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{Special Issue: Neutrosophic Advancements And Their Impact on Research in Latin America}

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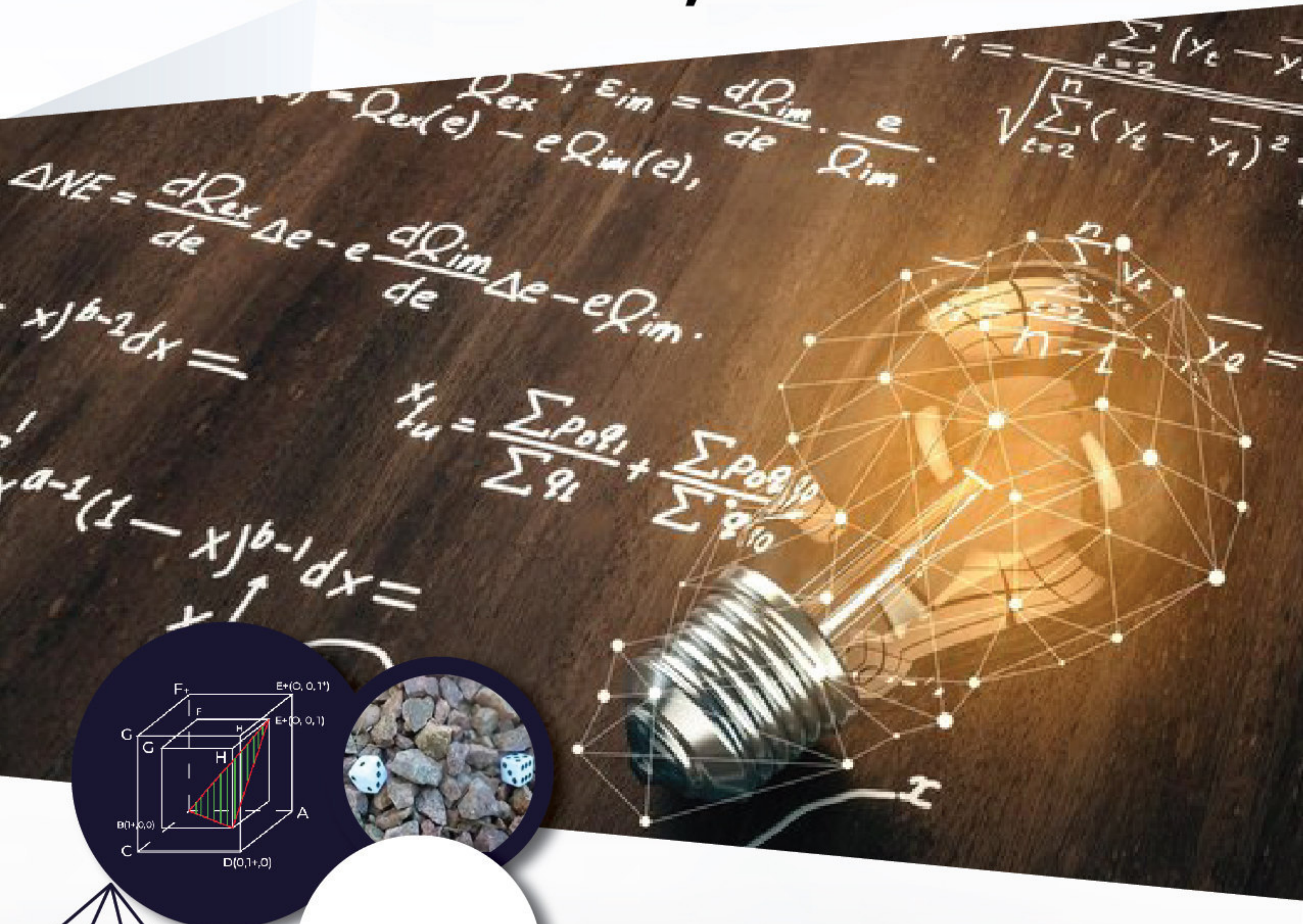

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FLORENTIN SMARANDACHE
MOHAMED ABDEL-BASSET
MAIKEL LEYVA VAZQUEZ
SAID BROUMI

EDITORS-IN-CHIEF

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Information for Authors and Suscribers

"Neutrosophic Sets and Systems" has been created for publications on advanced studies in neutrosophy, neutrosophic set, neutrosophic logic, neutrosophic probability, neutrosophic statistics that started in 1995 and their applications in any field, such as the neutrosophic structures developed in algebra, geometry, topology, etc.

The submitted papers should be professional, in good English, containing a brief review of a problem and obtained results. Neutrosophy is a new branch of philosophy that studies the origin, nature, and scope of neutralities, as well as their inter actions with different ideational spectra.

This theory considers every notion or idea <A> together with its opposite or negation <antiA> and with their spectrum of neutralities <neutA> in between them (i.e. notions or ideas supporting neither <A> nor <antiA>). The <neutA> and <antiA> ideas together are referred to as <nonA>.

Neutrosophy is a generalization of Hegel's dialectics (the last one is based on <A> and <antiA> only).
According to this theory every idea <A> tends to be neutralized and balanced by <antiA> and <nonA> ideas - as a state of equilibrium.

In a classical way <A>, <neutA>, <antiA> are disjoint two by two. But, since in many cases the borders between notions are vague, imprecise, Sorites, it is possible that <A>, <neutA>, <antiA> (and <nonA> of course) have common parts two by two, or even all three of them as well.

Neutrosophic Set and Neutrosophic Logic are generalizations of the fuzzy set and respectively fuzzy logic (especially of intuitionistic fuzzy set and respectively intuitionistic fuzzy logic). In neutrosophic logic a proposition has a degree of truth (T), a degree of indeterminacy (I), and a degree of falsity (F), where T, I, F are standard or non-standard subsets of]-0, 1+[.

Neutrosophic Probability is a generalization of the classical probability and imprecise probability.
Neutrosophic Statistics is a generalization of the classical statistics.
What distinguishes the neutrosophics from other fields is the <neutA>, which means neither <A> nor <antiA>.

<neutA>, which of course depends on <A>, can be indeterminacy, neutrality, tie game, unknown, contradiction, igno- rance, imprecision, etc.

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Preface: Neutrosophic Advancements and Their Impact on Research in Latin America.

In the ever-evolving landscape of contemporary research, the utilization of neutrosophic methods has burgeoned into an innovative and multidisciplinary approach, offering profound insights and solutions to intricate issues spanning education, law, and healthcare. This expanded preface not only introduces a unique collection of articles authored by experts from Mexico, Peru, Cuba, Spain, Chile, Brazil, República Dominicana, Colombia, Estados Unidos, Uruguay, Panamá, Canada, Paraguay and Ecuador but also underscores the transformative impact of neutrosophic research on the fabric of Latin American society.

The growth of research in neutrosophy has been particularly pronounced, manifesting its influence across diverse domains. In the realm of education, researchers are exploring novel ways to integrate neutrosophic principles into pedagogical strategies, fostering a nuanced understanding of complex subjects and encouraging critical thinking among students. Neutrosophy has thus become a cornerstone in shaping the educational landscape, challenging traditional paradigms and encouraging a more comprehensive approach to learning.

Furthermore, the legal arena has witnessed a paradigm shift with the incorporation of neutrosophic decision-making. The nuanced and balanced perspectives offered by neutrosophy have proven instrumental in addressing legal complexities, contributing to a more equitable and just legal system. The articles in this collection delve into the application of neutrosophic models in legal frameworks, highlighting their potential to revolutionize the practice of law in the region.

In the healthcare sector, the adoption of neutrosophic modeling for resource allocation signifies a departure from conventional approaches. By incorporating the inherent uncertainty and indeterminacy of healthcare decision-making, researchers are paving the way for more adaptive and responsive healthcare systems. This collection explores the potential of neutrosophic methods to optimize healthcare resource allocation, thereby enhancing the quality of care provided to diverse communities.

A noteworthy development accompanying this surge in neutrosophic research is the establishment and growth of the Latin American Association of Neutrosophic Clinics. This association serves as a nexus for collaboration, fostering interdisciplinary exchanges and providing a platform for researchers and practitioners to share their advancements and challenges. The association's commitment to promoting neutrosophic research across Latin America is exemplified by its flagship publication, the "Neutrosophic Computing and Machine Learning" journal.

Undoubtedly, the pioneering efforts of Dr. Florentin Smarandache and Dr. Mohamed Abdel-Baset have played a pivotal role in nurturing the growth of neutrosophy in the region. Their unwavering support, both in terms of advocacy and research contributions, has catalyzed the expansion of neutrosophic studies in Latin America. This collection, in many ways, stands as a testament to their enduring commitment and the collaborative spirit that propels the field forward.

This collection of articles represents not only a snapshot of the current state of neutrosophic research in Latin America but also a testament to its transformative potential. As readers delve into these contributions, they are invited to witness the ongoing evolution of neutrosophy and its profound implications for education, law, healthcare, and beyond.

Maikel Y. Leyva Ph.D.

President of the Latin American Association of Neutrosophic Sciences

University of New Mexico

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Balancing Act: A Neutrosophic Approach to Human Rights and Values in Varied Societal Contexts

Fernando Castro Sánchez [1], Kleber Eduardo Carrión León [2], Paul Orlando Piray Rodríguez [3] and José Sergio Puig Espinosa[4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.fernandocastro@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.klebercarrion@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Riobamba. Ecuador. E-mail: ur.paulpr13@uniandes.edu.ec
[4] Centro de Estudios para la Calidad Educativa y la Investigación Científica. México. E-mail: puigespinosa@gmail.com

Abstract. This article explores the challenges that arise when human rights come into conflict with cultural, political, and ethical values in diverse societies. Eight areas of discord related to human rights are identified, and four criteria are proposed to assess how human rights relate to these values. These criteria include universality and cultural relativism, contextualization, ethical pluralism, and equity and social justice. The evaluation is based on neutrosophic selection criteria, employing the COPRAS multicriteria method. This analytical and decision-making approach is applied to eight specific cases of conflicts between human rights and values, such as women's rights, freedom of expression, and others. The results obtained provide a solid foundation for understanding how human rights relate to cultural, political, and ethical values in diverse societies. The article highlights the importance of finding a balance between protecting fundamental rights and respecting cultural and ethical diversity in resolving these conflicts. The promotion and protection of human rights remain a fundamental goal of the international community, regardless of cultural, political, or ethical differences.

Keywords: COPRAS, neutrosophic selection criteria, human rights, values, conflict.

1. Introduction

Human rights are universal principles that protect the dignity and freedom of all human beings, regardless of race, religion, sex, nationality or any other status. Cultural, political, and ethical values are the beliefs and principles that guide the behavior of people and societies [1].

In some cases, human rights may conflict with cultural, political, and ethical values. This can occur for several reasons, such as:

- Differences in conceptions of human dignity: In some cultures, human dignity is grounded in adherence to traditional social norms, whereas in others, it is based on individual autonomy and freedom of choice.
- Differences in political priorities: Governments may prioritize economic development or national security over human rights.
- Differences in religious or moral beliefs: Certain religions or moral systems may deem specific behaviors acceptable, while human rights prohibit them.

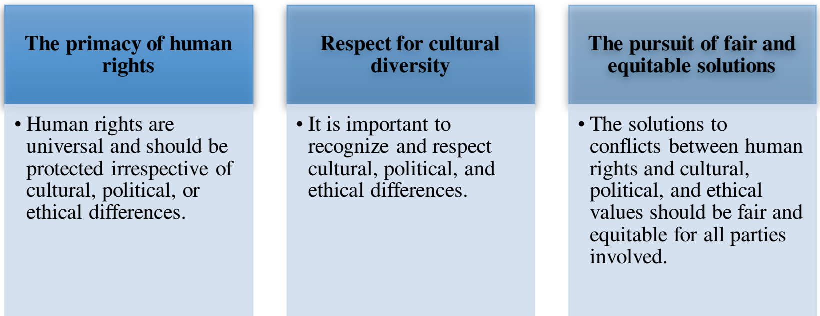
Some examples of cases in which human rights have come into conflict with cultural, political, and ethical values are [2]:

Figure 1: Cases. Source: Own elaboration based on [2].

Case 1: Rights of women	• In some countries, women have fewer rights than men. This may include the prohibition of education or employment, discrimination in accessing public services, or domestic violence. These rights may come into conflict with cultural values that view women as inferior to men.
Case 2: Rights of homosexuals	• In some countries, homosexuality is illegal or penalized. This may come into conflict with cultural values that consider homosexuality as a sin or a deviation.
Case 3: Rights of children	• In some countries, children are compelled to work in hazardous or unhealthy conditions. This may come into conflict with cultural values that emphasize the need to protect children.
Case 4: Rights of refugees	• Refugees are individuals who have fled their countries of origin due to war, persecution, or violence. In some countries, refugees are treated with hostility, and they may even be denied access to protection. This may come into conflict with ethical values that assert that all human beings deserve to be treated with dignity.
Case 5: Rights of animals	• In some countries, animals are treated cruelly in agriculture, industry, or scientific research. This may come into conflict with ethical values that assert animals deserve to be treated with respect.

The resolution of conflicts between human rights and cultural, political, and ethical values is a complex challenge. There is no single solution for all cases. However, it is important to consider the following factors (Figure 2):

Figure 2: Factors to consider when resolving conflicts between human rights and values. Source: own elaboration.



The promotion and protection of human rights is a fundamental objective of the international community. Conflicts between human rights and cultural, political, and ethical values put this objective to the test [3]. However, it is important to remember that human rights are universal and must be protected regardless of cultural, political, or ethical differences [4].

Some examples of conflicts between human rights and cultural, political, and ethical values due to differences in perceptions and norms in different societies and contexts are:

1. Women's Rights vs. Cultural Practices: In some societies, cultural practices such as female genital mutilation or forced marriages conflict with women's rights to equality, physical integrity, and autonomy. The struggle to ensure women's rights often clashes with deeply rooted cultural norms.
2. Freedom of Expression vs. Moral Protection: in some countries, laws of defamation, blasphemy, or insult to the State can limit freedom of expression. This poses a conflict between the right to freedom of expression and the perceived need to protect morality or political stability.
3. Right to Privacy vs. National Security: National security concerns often clash with individuals' right to privacy. Mass surveillance measures, such as online data collection, raise questions about balancing security with respect for individual privacy.
4. Right to Non-discrimination vs. Religious Practices: In some cases, religious beliefs may conflict with the principle of non-discrimination. For example, the refusal of some religious institutions to marry or provide services to same-sex couples may clash with the equality and non-discrimination rights of these couples.
5. Right to Life vs. Death Penalty: The death penalty is a controversial issue in many countries. Some argue that the death penalty is necessary for justice and security, while others consider it inhumane and a violation of the right to life.
6. Rights of Refugees vs. State Sovereignty: When refugees flee conflicts or persecution in their home countries, they often seek refuge in other countries. This may conflict with state sovereignty, as governments may disagree on whether or not to admit refugees.
7. Right to Freedom of Religion vs. Secular State: In societies with a strict separation between church and state, conflicts arise when religious practices clash with laws or public policies. This may involve issues such as wearing the Islamic veil in public schools or the objection of some religious institutions to provide specific health services, such as contraception.
8. Intellectual Property Rights vs. Access to Medicines and Technology: Protecting intellectual property rights can hinder access to affordable medicines and medical technology in developing countries. This raises an ethical dilemma between protecting investment and ensuring access to basic needs.

In these cases, it is important to find a balance between respect for universal human rights and recognition of cultural, political, and ethical differences [5-15]. The challenges lie in how to reconcile these conflicts. In many cases, international courts, governments, and human rights organizations play an important role in resolving these dilemmas [6-13-16-17].

The objective of this research is to evaluate how human rights are related to cultural, political, and ethical values and their influence on societies.

2 Preliminaries

2.1 COPRAS method

The multicriteria decision-making technique proposed can be expressed in a general manner as described next. A decision-making problem is evaluated, consisting of m alternatives that must be assessed considering n criteria, and x_{ij} can be expressed as the value of the i-th alternative according to the j-th criterion [7], [8]. The main concept of the COPRAS technique consists of the steps described below:

Step1. Select the appropriate set of criteria that describes the chosen alternatives.

Step2. Prepare decision-making matrix *X*:

$$X = \begin{bmatrix} x_{11} & x_{12} \cdots & x_{1n} \\ x_{22} & x_{22} \cdots & x_{2n} \\ \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & x_{mn} \end{bmatrix} \quad (1)$$

Step 3. Determine the weights of the criteria w_j.

Step 4. Normalize the decision-making matrix $\bar{X}$. The values of the normalized matrix are determined as:

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}; i = 1,2, \dots, m; j = 1,2, \dots, n \quad (2)$$

Step 5. Compute the weighted normalized decision-making matrix *D,* which components are calculated as

$$d_{ij} = \bar{x}_{ij} \cdot w_j; i = 1,2, \dots, m; j = 1,2, \dots, n \quad (3)$$

Step 6. Calculate the sum of the criterion values with respect to optimization direction for each alternative

$$P_{+i} = \sum_{j=1}^{L_{max}} d_{+ij};\ P_{-i} = \sum_{j=1}^{L_{min}} d_{-ij} \quad (4)$$

where d_{+ij} values correspond to the criteria to be maximized and values d_{-ij} correspond to the criteria to be minimized.

Step 7. Determine the minimal component of the P_{-i}:

$$P_{-min} = min_i P_{-i}; i = 1,2, \dots, L_{min} \quad (5)$$

Step 8. Determine the score value of each alternative Q_i:

$$Q_i = P_{+i} + \frac{P_{-min} \sum_{j=1}^{L_{min}} P_{-j}}{P_{-i} \sum_{j=1}^{L_{min}} \frac{P_{-min}}{P_{-j}}}; j = 1, \dots, L_{min} \quad (6)$$

Step 9. Determine optimality criterion *K* for the alternatives:

$$K = max_i Q_i ; i = 1,2, \dots, m \quad (7)$$

Step 10. Determine the priority of the alternatives. The greater score value Q_i for the alternative corresponds to the higher priority (rank) of the alternative.

2.2 Neutrosophic Sets

Definition 1. Let X be a space of the objects and $x \in X$. A neutrosophic set A in X is defined by three functions: truth-membership function $T_A(x)$, an indeterminacy- membership function $I_A(x)$ and falsity-membership function $F_A(x)$. These functions are defined on real standard or real non-standard subsets of $]0^-, 1^+[$. That is $T_A(x): X \rightarrow]0^-, 1^+[, I_A(x): X \rightarrow]0^-, 1^+[$ and $F_A(x): X \rightarrow]0^-, 1^+[$. There is not any restriction on the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$, so $0^- \le supT_A(x) + supI_A(x) + supF_A(x) \le 3^+$.

2.2.1 Single-valued Neutrosophic Set

A single-valued neutrosophic set (SVNS) has been defined as described in [9].

Definition 2. Let X be a universal space of the objects and $x \in X$. A single valued neutrosophic set (SVNS) $\tilde{N} \subset X$ can be expressed as:

$$\tilde{N} = \{\langle x, T_{\tilde{N}}(x), I_{\tilde{N}}(x), F_{\tilde{N}}(x)\rangle : x \in X\} \quad (8)$$

where $T_{\tilde{N}}(x): X \rightarrow][0,1], I_{\tilde{N}}(x): X \rightarrow][0,1]$ and $F_{\tilde{N}}(x): X \rightarrow][0,1]$

with $0 \le T_{\tilde{N}}(x) + I_{\tilde{N}}(x) + F_{\tilde{N}}(x) \le 3$ or all $x \in X$. The values $T_{\tilde{N}}(x)$, $I_{\tilde{N}}(x)$, and $F_{\tilde{N}}(x)$ represent the degrees of truth-membership, indeterminacy-membership, and falsity-membership of x with respect to Ñ, respectively [10]. When the set X contains only a single element, Ñ is referred to as a single-valued neutrosophic number [11]. To simplify matters, a single-valued neutrosophic number is denoted as $\tilde{N}_A=(t_A, i_A, f_A)$, where t_A, i_A, and f_A are all within the range [0,1], and their sum satisfies the condition $0 \le t_A + i_A + f_A \le 3$.

Definition 3. Let $\tilde{N}_1 = (t_1, i_1, f_1)$ and $\tilde{N}_2 = (t_2, i_2, f_2)$ be two SVN numbers, then the sum of $\tilde{N}_1$ and $\tilde{N}_2$ is defined as follows:

$$\tilde{N}_1 + \tilde{N}_2 = (t_1 + t_2 - t_1 t_2, i_1 i_2, f_1 f_2) \quad (9)$$

Definition 4. Let $\tilde{N}_1 = (t_1, i_1, f_1)$ and $\tilde{N}_2 = (t_2, i_2, f_2)$ be two SVN numbers, then multiplication between $\tilde{N}_1$

and $\tilde{N}_2$ is defined as follows:

$\tilde{N}_1 * \tilde{N}_2 = (t_1 t_2, i_1 + i_2 - i_1 i_2, f_1 + f_2 - f_1 f_2)$ (10)

Definition 5. Let $\tilde{N} = (t, i, f)$ be an SVN number and $\lambda \in \mathbb{R}$ an arbitrary positive real number, then:

$\lambda\tilde{N} = \left(1 - (1 - t)^{\lambda}, i^{\lambda}, f^{\lambda}\right), \lambda > 0$ (11)

Definition 6. If A= $\{A_1, A_2, \dots, A_n\}$, and B= $\{B_1, B_2, \dots, B_n\}$ (i= 1,2,…,m) are two single-valued neutrosophic sets, then the separation measure between A and B applying the normalized Euclidian distance can be expressed as follows:

$$q_n(A,B) = \sqrt{\frac{1}{3n}\sum_{j=1}^{n}\left(\left(t_A(x_i) - t_B(x_i)\right)\right)^2 + \left(\left(i_A(x_i) - i_B(x_i)\right)\right)^2 + \left(\left(f_A(x_i) - f_B(x_i)\right)\right)^2}$$

$(i = 1,2, \dots, n)$ (12)

Definition 7. Let A = (a, b, c) be a single-valued neutrosophic number, a score function is mapped $\tilde{N}_A$ into the single crisp output $S(\tilde{N}_A)$ as follows

$S(\tilde{N}_A) = \frac{3 + t_A - 2i_A - f_A}{4}$ (13)

where $S(\tilde{N}_A) \in [0,1]$. This score function allows to have the results in the same interval since single-valued neutrosophic numbers are used.

The notion of a linguistic variable proves to be highly valuable in addressing decision-making challenges of an intricate nature. A linguistic variable's magnitude is denoted as a component within its set of terms. These linguistic magnitudes can be effectively represented using single-valued neutrosophic numbers.

Within this approach, we involve k decision-makers, m alternatives, and n criteria. The k decision-makers assess the significance of m alternatives across n criteria and establish rankings for the performance of the n criteria based on linguistic statements that have been transformed into single-valued neutrosophic numbers. The weights of importance, derived from single-valued neutrosophic values of linguistic expressions, are presented in Table 1.

Table 1: Linguistic variable and SVNSs. Source: [12].

Linguistic terms	SVNNs
Extremely good (EG)/ 10 points	(1.00, 0.00, 0.00)
Very very good (VVG)/ 9 points	(0.90, 0.10, 0.10)
Very good (VG)/ 8 points	(0.80, 0.15, 0.20)
Good (G) / 7 points	(0.70, 0.25, 0.30)
Moderately good (MG) / 6 points	(0.60, 0.35, 0.40)
Medium (M) / 5 points	(0.50, 0.50, 0.50)
Moderately bad (MB) / 4 points	(0.40, 0.65, 0.60)
Bad (B) / 3 points	(0.30, 0.75, 0.70)
Very bad (VB) / 2 points	(0.20, 0.85, 0.80)
Very very bad (VVB) / 1 point	(0.10, 0.90, 0.90)
Extremely bad (EB) / 0 points	(0.00, 1.00, 1.00)

The performance of the group decision-making applying the COPRAS-SVNS approach can be described by the following steps.

- Step 1. Determine the importance of the experts. In the case when the decision is made by a group of experts (decision-makers), firstly the importance of the final decision of each expert is determined. If a vector $\lambda = (\lambda_1, \lambda_2, \dots, \lambda_k)$ is the vector describing the importance of each expert, where $\lambda_k \geq 0$ and $\sum_{k=1}^{K} \lambda_k = 1$.
- Step 2. At this point, each decision-maker performs his evaluations concerning the ratings of the alternatives with respect to the attributes and the weights of the attributes. If the k^{th} expert's evaluation of the i^{th} alternative by the j^{th} criterion is denoted by x_{ij}^k , $i = 1,2, \dots, m; j = 1,2, \dots, n$. This evaluation is expressed in linguistic terms presented in Table 1. So, the decision matrix for any particular expert can be constructed

$$X^k = \begin{bmatrix} {x^k}_{11} & {x^k}_{12} \cdots & {x^k}_{1n} \\ {x^k}_{22} & {x^k}_{22} \cdots & {x^k}_{2n} \\ \vdots & \vdots & \vdots \\ {x^k}_{m1} & {x^k}_{m2} \cdots & {x^k}_{mn} \end{bmatrix} \quad (14)$$

- Step 3. Calculate the weights of the criteria. The aggregated weights of the criteria are determined by

$$w_j = \lambda_1 w_j^{(1)} \cup \lambda_2 w_j^{(2)} \cup \dots \cup \lambda_k w_j^{(k)} = \left(1 - \prod_{k=1}^{K}\left(1 - t_j^{(w_k)}\right)^{\lambda_k}, \prod_{k=1}^{K}\left(i_j^{(w_k)}\right)^{\lambda_k}, \prod_{k=1}^{K}\left(f_j^{(w_k)}\right)^{\lambda_k}\right) \quad (15)$$

- Step 4. Construction of the aggregated weighted single-valued decision matrix

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} \cdots & \tilde{x}_{1n} \\ \tilde{x}_{22} & \tilde{x}_{22} \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} \cdots & \tilde{x}_{mn} \end{bmatrix} \quad (16)$$

where any particular element $\tilde{x}_{ij} = (\tilde{t}_{ij}, \tilde{\iota}_{ij}, \tilde{f}_{ij})$ represents the rating of the alternative A_i with respect to the j criterion and is determined as follows

$$\tilde{x}_{ij} = \lambda_1 x_{ij}^{(1)} \cup \lambda_2 x_{ij}^{(2)} \cup \dots \cup \lambda_k x_{ij}^{(k)} = \left(1 - \prod_{k=1}^{K}\left(1 - t_j^{(x_k)}\right)^{\lambda_k}, \prod_{k=1}^{K}\left(i_j^{(x_k)}\right)^{\lambda_k}, \prod_{k=1}^{K}\left(f_j^{(x_k)}\right)^{\lambda_k}\right) \quad (17)$$

- Step 5. Determine the weighted decision matrix. Following Equation (3), the weighted decision matrix can be expressed as $D = \lfloor d_{ij} \rfloor, d = 1,2,\dots,m; j = 1,2,\dots,n,$ where $d_{ij} = \tilde{x}_{ij} * w_j$. Applying Equation (10), a single element of the weighted decision matrix can be calculated

$$d_{ij} = t_{ij}^{\tilde{x}} t_j^{w}, i_{ij}^{\tilde{x}} + i_j^{w} - i_{ij}^{\tilde{x}} i_j^{w}, f_{ij}^{\tilde{x}} + f_j^{w} - f_{ij}^{\tilde{x}} f_j^{w} \quad (18)$$

- Step 6. Calculate the summation of the values for the benefit. Let $L_+ = \{1,2,\dots,L_{max}\}$ be a set of the criteria to be maximized. Then the index of the benefit for each alternative can be determined

$$P_{+i} = \sum_{j=1}^{L_{max}} d_{+ij} \quad (19)$$

where the sum of the single value neutrosophic numbers is calculated by applying Equation (9).

- Step 7. Calculate the summation of the values for cost. Let be $L_- = \{1,2,\dots,L_{min}\}$ a set of criteria to be minimized. Then the index of the cost of each alternative can be determined

$$P_{-i} = \sum_{j=1}^{L_{min}} d_{-ij} \quad (20)$$

- Step 8. Determine the minimal value of the P_{-i}.
- Step 9. Determine the score value of each alternative Q_i. In the beginning, the score values are calculated from the aggregated values for benefit and cost $S(P_{+i})$ and $S(P_{-i})$ applying Equation (13). The score values of the alternatives can be expressed as

$$Q_i = S(P_{+i}) + \frac{S(P_{-min}) \sum_{i=1}^{L_{min}} S(P_{-i})}{S(P_{-min}) \sum_{i=1}^{L_{min}} \frac{S(P_{-min})}{S(P_{-i})}} \quad (21)$$

- Step 10. Determine the optimality criterion K for the alternatives:

$$K = max_i Q_i; i = 1,2,\dots,m \quad (22)$$

Step 11. Determine the priority of the alternatives. The greater score value Q_i for the alternative corresponds to the highest priority (rank) of the alternative.

3 Results and Discussion

The exploration of the document base led to the identification of a series of controversies related to human rights that must be considered for the desired analysis. In total, eight areas of discord have been detected and proposed as options to be evaluated in the context of this study. To assess how human rights relate to cultural, political, and ethical values, four criteria are taken into account, which have been generated through a brainstorming process and then endorsed by expert consensus:

1. Universality and cultural relativism: It is necessary to consider whether human rights are perceived as universal, i.e., applicable in all cultures, or if there are cultural differences that can influence the interpretation and implementation of certain rights. Balancing the universality of rights with respect for cultural diversity is important.
2. Contextualization: It evaluates whether human rights can be adapted to the cultural, political, and ethical circumstances of a particular society without compromising their essence. Contextualization involves finding a balance between universal values and cultural specificities.
3. Ethical pluralism: It considers whether ethical pluralism is respected and protected, i.e., if the coexistence of different ethical value systems in a society is allowed without violating fundamental rights.
4. Equity and social justice: It verifies whether cultural and political policies and practices contribute to the promotion of equity and social justice, which in turn can influence the realization of economic and social rights.

These criteria help assess how human rights relate to the cultural, political, and ethical values of a society and how potential conflicts in this context can be addressed. The evaluation should seek a balance between the protection of fundamental rights and respect for cultural and ethical diversity.

The evaluation involves the participation of 5 specialists in the relevant research field. The high relevance of all these experts is valued due to their extensive experience in the subject matter. The criteria are weighted based on the assessments of the specialists, taking into account the values presented in Table 1. As a result, Table 2 displays the set of weights obtained after implementing Equation (15).

Table 2: Vector of weights of the analyzed criteria. Source: own elaboration.

Criteria weights	SVNN
w_1	(0.87989;0.12011;0.11487)
w_2	(0.83428;0.16572;0.15849)
w_3	(0.82671;0.17329;0.15157)
w_4	(0.85573;0.14427;0.13195)

Specialists analyze the choice options considering how the criteria influence them, according to the values presented in Table 1. Subsequently, the acquired data are transformed into sets of neutral information for application in analysis, as shown in the following tables:

Table 3: Evaluation of decision alternatives with respect to Criterion 1: Universality and cultural relativism. Source: own elaboration.

Alternatives	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Rights of women	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.75,0.25,0.2)
Freedom of expression	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)
Right to privacy	(0.9,0.1,0.1)	(0.9,0.1,0.1)	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.9,0.1,0.1)
Right to non-discrimination	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)
Right to life	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
Rights of refugees	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)
Right to religious freedom	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.75,0.25,0.2)	(0.75,0.25,0.2)	(0.5,0.5,0.5)
Intellectual property rights	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)

Table 4: Evaluation of the decision alternatives with respect to Criterion 2: Contextualization. Source: own elaboration.

Alternatives	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Rights of women	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.9,0.1,0.1)
Freedom of expression	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
Right to privacy	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)
Right to non-discrimination	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)
Right to life	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
Rights of refugees	(0.75,0.25,0.2)	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)
Right to religious freedom	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.75,0.25,0.2)	(0.35,0.75,0.8)	(0.5,0.5,0.5)
Intellectual property rights	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)

Table 5: Evaluation of decision alternatives with respect to Criterion 3: Ethical pluralism. Source: own elaboration.

Alternatives	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Rights of women	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)
Freedom of expression	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)
Right to privacy	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)
Right to non-discrimination	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)
Right to life	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
Rights of refugees	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)
Right to religious freedom	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.35,0.75,0.8)	(0.75,0.25,0.2)	(0.5,0.5,0.5)
Intellectual property rights	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.5,0.5,0.5)

Table 6: Evaluation of the decision alternatives with respect to Criterion 4: Equity and social justice. Source: own elaboration.

Alternatives	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Rights of women	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.9,0.1,0.1)
Freedom of expression	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
Right to privacy	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)
Right to non-discrimination	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)
Right to life	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
Rights of refugees	(0.75,0.25,0.2)	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.35,0.75,0.8)
Right to religious freedom	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.75,0.25,0.2)	(0.75,0.25,0.2)	(0.35,0.75,0.8)
Intellectual property rights	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)

The analyses carried out by professionals serve as the foundation on which the operations mentioned in the process intended to create the decision matrix are executed. Once formula (17) is applied, the initial decision matrix is generated (Table 7), in which the results obtained after carrying out the indicated method are presented.

Table 7: Initial decision matrix. Source: own elaboration.

Alternatives/Criteria	Universality and cultural relativism	Contextualization	Ethical pluralism	Equity and social justice
Rights of women	(0.67,0.33,0.289)	(0.725,0.275,0.251)	(0.35,0.75,0.8)	(0.725,0.275,0.251)
Freedom of expression	(0.81,0.19,0.19)	(0.5,0.5,0.5)	(0.383,0.692,0.728)	(0.5,0.5,0.5)
Right to privacy	(0.88,0.12,0.115)	(0.81,0.19,0.19)	(0.621,0.379,0.347)	(0.81,0.19,0.19)
Right to non-discrimination	(0.725,0.275,0.251)	(0.725,0.275,0.251)	(0.685,0.315,0.302)	(0.725,0.275,0.251)
Right to life	(0.685,0.315,0.302)	(0.618,0.393,0.398)	(0.685,0.315,0.302)	(0.445,0.588,0.603)
Rights of refugees	(0.621,0.379,0.347)	(0.601,0.411,0.381)	(0.541,0.472,0.457)	(0.491,0.555,0.552)
Right to religious freedom	(0.67,0.33,0.289)	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.652,0.358,0.317)
Intellectual property rights	(0.621,0.379,0.347)	(0.565,0.435,0.416)	(0.445,0.588,0.603)	(0.541,0.472,0.457)

Starting from the initial decision matrix acquired, the implementation of the required modifications continues according to the approach of the method used to solve the problem and obtain the desired results. By using equation (19), the weighted decision matrix is generated, the results of which are presented in Table 8.

Table 8: Weighted decision matrix. Source: own elaboration.

Alternatives	Risk of Recidivism	Social reintegration capacity	Family reintegration capacity	Repair of the prejudice caused
Rights of women	(0.59;0.41;0.371)	(0.605;0.395;0.37)	(0.289;0.793;0.83)	(0.62;0.38;0.35)
Freedom of expression	(0.713;0.287;0.283)	(0.417;0.583;0.579)	(0.317;0.745;0.769)	(0.428;0.572;0.566)
Right to privacy	(0.774;0.226;0.217)	(0.676;0.324;0.318)	(0.513;0.487;0.446)	(0.693;0.307;0.297)
Right to non-discrimination	(0.638;0.362;0.337)	(0.605;0.395;0.37)	(0.566;0.434;0.408)	(0.62;0.38;0.35)
Right to life	(0.603;0.397;0.382)	(0.516;0.494;0.493)	(0.566;0.434;0.408)	(0.381;0.647;0.655)
Rights of refugees	(0.546;0.454;0.422)	(0.501;0.509;0.479)	(0.447;0.563;0.539)	(0.42;0.619;0.611)
Right to religious freedom	(0.59;0.41;0.371)	(0.501;0.509;0.479)	(0.497;0.513;0.475)	(0.558;0.451;0.407)
Intellectual property rights	(0.546;0.454;0.422)	(0.471;0.529;0.509)	(0.368;0.659;0.663)	(0.463;0.548;0.529)

This examination makes it possible to identify the factors proposed by the method under consideration to choose between the available options. Table 9 shows the results achieved after carrying out the appropriate procedures.

Table 9: Pi, S(P) values, and Q score values for each alternative. Source: own elaboration.

Measures	Pi+	Pi-	S(P+)	S(P-)	Q
Rights of women	(0.893; 0.119; 0.107)	(0.59; 0.41; 0.371)	0.89	0.6000	1.54
Freedom of expression	(0.772; 0.248; 0.252)	(0.713; 0.287; 0.283)	0.76	0.7140	1.31
Right to privacy	(0.951; 0.049; 0.042)	(0.774; 0.226; 0.217)	0.95	0.7760	1.46
Right to non-discrimination	(0.935; 0.065; 0.053)	(0.638; 0.362; 0.337)	0.94	0.6440	1.55
Right to life	(0.87; 0.138; 0.132)	(0.603; 0.397; 0.382)	0.87	0.6070	1.51
Rights of refugees	(0.84; 0.178; 0.158)	(0.546; 0.454; 0.422)	0.83	0.5540	1.54
Right to religious freedom	(0.889; 0.118; 0.093)	(0.59; 0.41; 0.371)	0.89	0.6000	1.55
Intellectual property rights	(0.821; 0.191; 0.178)	(0.546; 0.454; 0.422)	0.82	0.5540	1.53

Table 9 shows the values of Pi, S(P), and the score Q for each alternative. According to these results, the human rights that experts have considered of greatest importance in the context of cultural, political, and ethical values are the right to non-discrimination and the right to religious freedom. These findings provide a solid foundation for the discussion and analysis of the interaction of human rights with cultural and ethical values in the society under study.

In terms of specific results, it is observed that experts have different perceptions and evaluations of the options. This underscores the complexity of issues related to human rights and their relationship with cultural, political, and ethical values. For example, in the case of women's rights, some experts valued the importance of contextualization and ethical pluralism, while others emphasized universality and cultural relativism. These differences reflect the diversity of opinions and approaches in interpreting human rights.

It is crucial to recognize that resolving conflicts between human rights and cultural, political, and ethical values is a complex challenge, and there is no one-size-fits-all solution. However, international courts, governments, and human rights organizations play a significant role in resolving these dilemmas. The promotion and protection of human rights remain a fundamental goal of the international community, and it is essential to remember that these rights are universal and should be protected irrespective of cultural, political, or ethical differences.

This study contributes to understanding how human rights relate to cultural, political, and ethical values, and how these conflicts can be addressed. As societies evolve and change, ongoing reflection on these issues is crucial to ensure that human rights continue to be a cornerstone of justice and equity worldwide.

Conclusions

This scientific article has explored the relationship between human rights and cultural, political, and ethical values in different contexts. Eight areas of controversy were identified and evaluated through four criteria: universality and cultural relativism, contextualization, ethical pluralism, and equity and social justice. These criteria allowed for the assessment of how human rights relate to cultural, political, and ethical values and how potential conflicts in this context can be addressed.

The results demonstrate that the perception of the universality of human rights varies depending on the case and the influence of cultural, political, and ethical values. The contextualization of human rights is considered essential to balance universal values with cultural specificities. Ethical pluralism and the protection of different ethical value systems are important for maintaining cultural diversity. Additionally, the importance of policies and practices contributing to equity and social justice for the realization of economic and social rights is highlighted.

Resolving conflicts between human rights and cultural, political, and ethical values is a complex challenge that requires delicate balance. The involvement of experts and the weighting of criteria are useful tools for addressing these challenges and finding solutions that protect fundamental rights while respecting cultural and ethical diversity. Ultimately, the promotion and protection of human rights must remain a fundamental goal of the international community, regardless of cultural, political, or ethical differences.

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Automation and Optimization of Industrial Scale Essential Oil Extraction from Citrus Peel Using a Neutrosophic Control System Model

Manuel Michael Beraún-Espíritu[1], Ketty Marilú Moscoso-Paucarchuco[2], Luis Enrique Espinoza-Quispe[3], Fabricio Miguel Moreno-Menéndez[4], Jesús César Sandoval-Trigos[5], Edson Hilmer Julca-Marcelo[6], Bheny Janett Tuya-Cerna[7] and Edgar Gutiérrez-Gómez[8]

[1] School of Mechatronic Engineering, Universidad Continental, Huancayo, Perú. E-mail: mberaun@continental.edu.pe
[2] Universidad Nacional Autónoma de Huanta, Ayacucho, Perú. E-mail: kmoscoso@unah.edu.pe
[3] Universidad Peruana Los Andes, Huancayo, Perú. E-mail: d.lespinoza@upla.edu.pe
[4] Universidad Peruana Los Andes, Huancayo, Perú. E-mail: d.fmoreno@upla.edu.pe
[5] Universidad Peruana Los Andes, Huancayo, Perú. E-mail: d.jsandoval@upla.edu.pe
[6] Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: edsonjm@uncp.edu.pe
[7] Universidad Nacional Santiago Antúnez de Mayolo, Ancash, Perú. E-mail: btuyac@unasam.edu.pe
[8] Universidad Nacional Autónoma de Huanta, Ayacucho, Perú. E-mail: egutierrez@unah.edu.pe

Abstract. The extraction of essential oils in the world is widely used to combat various diseases, and also helps for giving a good taste to food (flavoring condiments) and cosmetics that do not pollute the environment or generate chemicals. Peru is in the top 10 countries with the greatest biological diversity in the world, having an approximate 10% of world flora and endless endemic species, also valuing the citrus fruits having productive of orange, lime, grapefruit, tangerine, and tangelo. Therefore, processes are analyzed and a model for the extraction of essential oil from citrus fruits is developed, through the design of an industrial-scale steam extractor, which establishes the automation of the filling and emptying of the distiller to obtain better results and also automates a closed-loop control for refrigeration, to help the operator to control and supervise the process of refrigeration and water filling using a control panel. The distillation process was analyzed where an average of 1% to 5% of essential oil of citrus fruits was obtained and the development of a control for the supervision of the filling and emptying of the water was analyzed. In this paper we introduce a Neutrosophic (Indeterminate) Control System model based on the well-known Fuzzy Control Systems models, especially Mamdani's. It is applied in the process of automating the extraction of essential oil from citrus fruits. An Indeterminate Control System, like its similar Fuzzy Control System, makes it possible to control the oil production process with the help of natural language. The advantage of the Indeterminate Control System is that it explicitly considers indeterminacy due to the non-homogeneity of the parameters within the system, thus it is more accurate.

Keywords: Steam Traction, Essential oils, Automation, Essential oil distillation machine, Programmable Logic Control (PLC), Indeterminate Control System, Mamdani`s Control System, Neutrosophic Number.

1 Introduction

Essential oils were first used in the home over 1000 years ago in the civilizations of India, Greece, Rome, and Mesopotamia. Essential oils contain a homogeneous mixture of organic compounds. All compounds have the effect of producing aromas that the human olfactory can smell, they are complex alloys of volatile organic compounds with a pleasant aroma and can be found in different families of plants, fruits, stems, etc. Naturally, they are substances that provide a characteristic odour and are present in different parts of the plant, such as valerian root, leaves (mint, eucalyptus), fruits (fennel, cumin), flowers (chamomile, roses) or the skin of fruits (orange, mandarin, grapefruit, and tangelo).

Generally, to obtain oil, plants must contain an average of 0.5% - 5% oil about the mass of the plant. A brief exploration of essential oils tells us that the consistency groups are low molecular weight aliphatic compounds consisting of phenylpropanoids, terpenes, monoterpenes, sesquiterpenes, etc. Industrial-scale extraction methods for essential oils are based on steam extraction [1]. There are different extraction methods such as pressing, supercritical, enfleurage, expression, microwave liquid extraction, volatile solvent extraction, and vapour extraction, which have excellent product quality, but in most cases are extremely expensive to implement and operate. Steam entrainment distillation is based on the fact that the aroma of the plants can be entrained by the steam generated from the water, then cooled, and finally separated. The vapour produced from the water will be cooled, causing it to condense and form two immiscible states, the mother liquor (hydrolyzed) and the essential oil. This type of distillation focuses on equal amounts of immiscible liquids used to separate organic substances that are insoluble in water.

In this work an approximate amount of essential oil is extracted from the peel of mandarin, tangelo, grapefruit, and orange, the citrus fruit will be extracted to use the peel. The essential oil of citrus fruits is used in the pharmaceutical industry as a flavouring agent to mask unpleasant odours in medicines, as well as in perfumes, cleaning products, and citrus fruit essential oil is in high commercial demand. An essential oil extraction pilot plant allows us to see the productivity that can be achieved with an extraction machine, and then having a pilot extraction plant allows us to evaluate the performance that can be achieved and learn from practice. An industrial-scale essential oil extractor was designed focusing on the control of the machine, automation through a Programmable Logic Control (PLC), looking for the correct operation of the extraction plant in case of possible failures, having a result of automation in the part of filling and emptying of the tanks, it will also help to cool in an average of 8 to 13°C. The automation has a PLC, which is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon a custom program to control the state of output devices; a Human Machine Interface (HMI) screen (it can be programmed to display important status and control information to the operator), which seeks to automate industrial plants to regulate process parameters through automatic control systems, taking into account steam, temperature and pressure. This system will allow us to program and monitor the essential oil extractor. The extractor will have a manual control that can be operated from the plant through a control panel, allowing better management of the extractor machine, which will increase productivity and reduce operation time, which will benefit the user and operator.

However, this automation process can be considered ambitious in the sense that different types of citrus peels are distilled, which means that the results will not always have the same quality when processing two different types of citrus. It is known that some of them perform more efficiently than others. Also, part of the process depends on manual work, which can lead to human errors, while other components depend on code, which can sometimes fail. That is, there are several factors in which automation can fail.

Traditional automation methods try to minimize errors as much as possible, including staff training. The way to understand this problem by the authors of this article is that within the same system, we deal with elements of natural language and with IF-THEN rules that allow operators and software the most appropriate treatment of the processes that they proposed [2].

There is a similar theory of Fuzzy Inference Systems (FIS) models such as the Sugeno's, Mamdani's, and Tsukamoto's models, which are the most popular, where the characteristics of Fuzzy Sets are combined with Artificial Neural Networks [2]. There are also Fuzzy Control Systems (FCS) that are applied in the control of industrial processes that require automation with certain characteristics of approximate reasoning [2-9-18-19]. For their part, Neutrosophic Systems, coined by F. Smarandache, have a distant relationship with what we are dealing with in this article since Smarandache uses a definition more in line with Systems Theory and Dynamic Systems [10]. On the other hand, there are approaches to define Neutrosophic Control Systems that respond to linear control models used in electrical circuits, for example [11], and others like in [12, 13, 17].

The article is divided into sections, the first of which is Materials and Methods, where the fundamental concepts of Fuzzy Systems are explained, as well as the basic notions of citrus oil extraction. In the Results section, we expose the designed model and its application in the essential oil extraction plant of citrus fruits. Conclusions are given at the end of the paper.

2. Materials and Methods

2.1 The Essential Oil Extraction from Citrus Peel

The use of the VDI 2221 methodology will help us to show detailed known levels, and the evaluation of components and types of materials in the calculation memory for its adequate final design, the purpose of this method is to find the appropriate solution among multiple proposed alternatives, as shown in Figure 1.

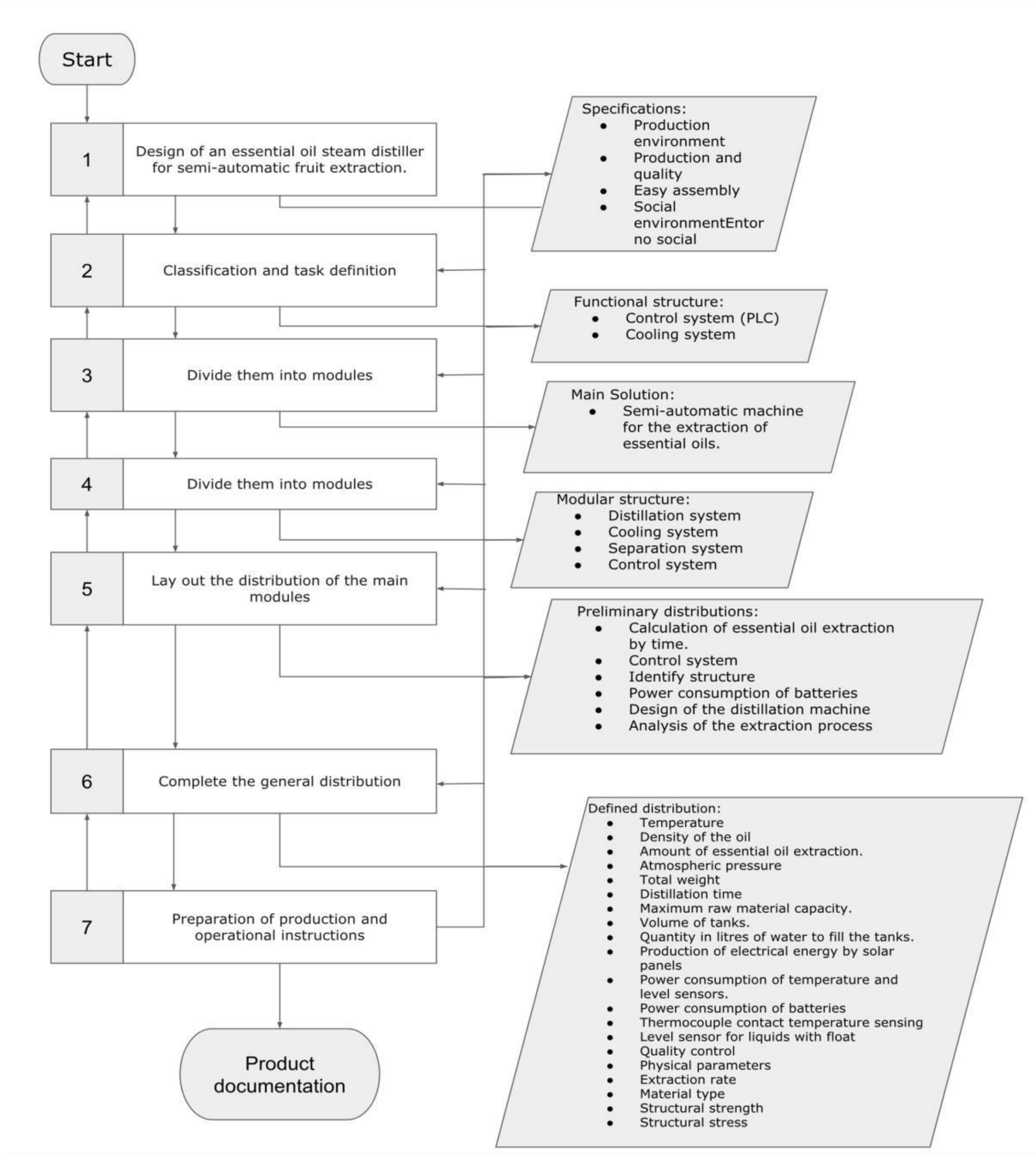
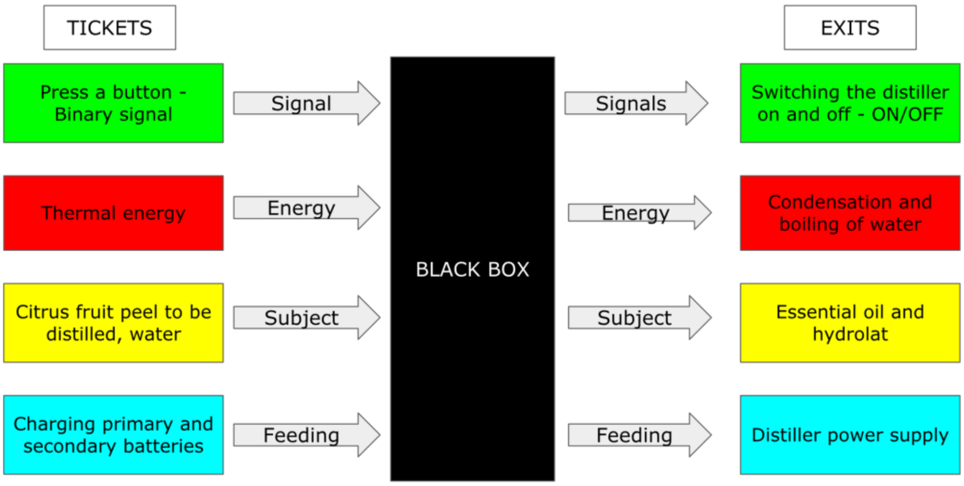


Figure 1: Mechanical Design Standard VDI 2221.

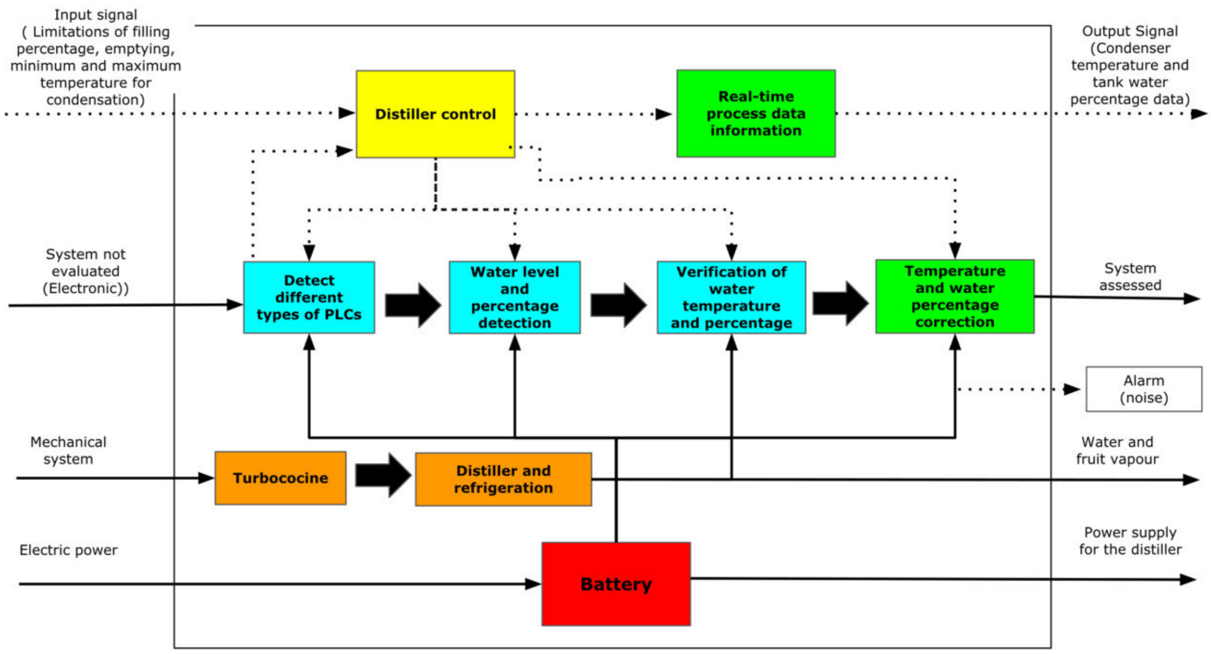
During the analysis, we will seek to determine the functions that must be satisfied to achieve the project objective. Starting with the elaboration of the black box to find the inputs and outputs of the essential oil distiller as shown in Figure 2.

Figure 2: Scheme of the Black Box.



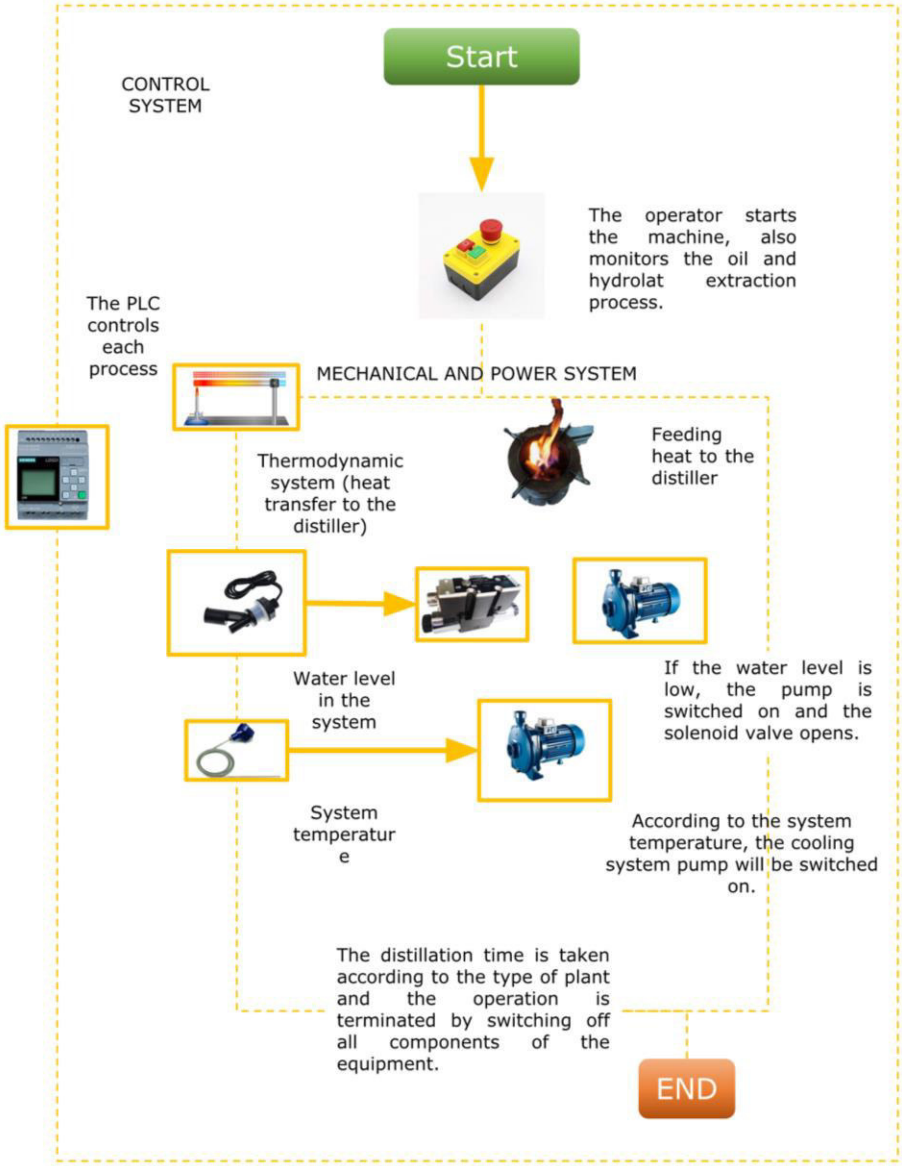
The next step was to define the functions to be performed based on the processes to be fulfilled by the system, in addition to other factors related to the distiller. To do so, a sequence of functions was made to better detail the idea of this section, as shown in Figure 3.

Figure 3: Function structure.



The figure shows the operating diagram of the mechatronic system for the distillation of essential oils according to the type of material, thus automatically shutting down for optimal operation of the machine, as shown in Figure 4.

Figure 4: Mechatronic system diagram.



2.2 Fuzzy Control System

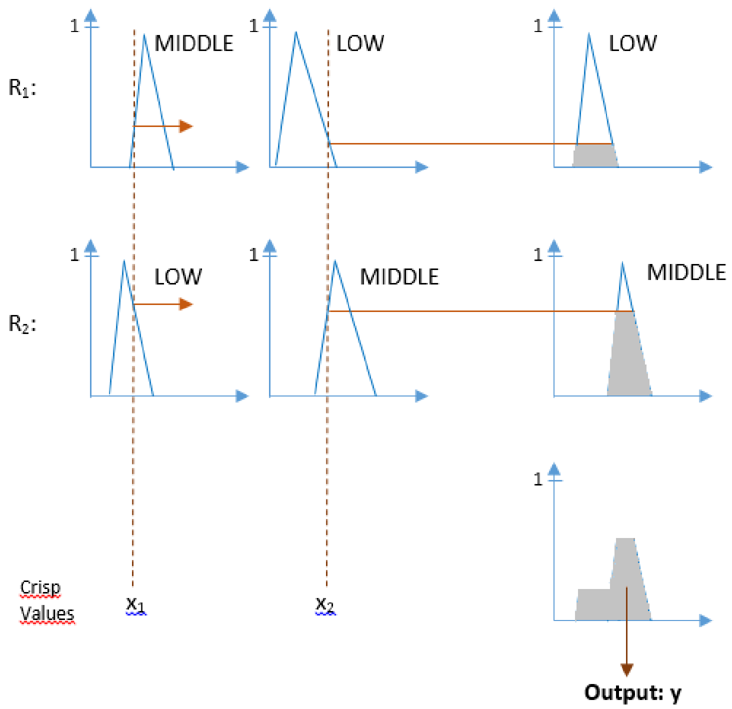
A Fuzzy Control System is a control system where some fuzzy IF-THEN rules are defined by experts [6]. Thus, the system responds to these rules dynamically. When the system is referred to as multi-input-multi-output (MIMO), there are two or more rules in the following form:

R_1: IF x is A_1 AND y is B_1 THEN z is C_1,
R_2: IF x is A_2 AND y is B_2 THEN z is C_2,
⋮
R_n: IF x is A_n AND y is B_n THEN z is C_n.

An example of a Fuzzy Controller is Mamdani's model, see Figure 5, where the represented rules in the figure are the following:

R_1: IF x_1 is MIDDLE AND x_2 is LOW THEN y is LOW,
R_2: IF x_1 is LOW AND x_2 is MIDDLE THEN y is MIDDLE.

Figure 5: Scheme of a Mamdani's fuzzy control.



3 Results

In this section, we describe the Neutrosophic Model we designed and the results. First, we recall the following definition in Neutrosophic Theory [14-16]:

A Neutrosophic Number can be represented in the form of $N = a + bI$, where $a, b \in \mathbb{R}$, and I is a constant such that $I^2 = I$, $0 \cdot I = 0$, $\underbrace{I + I + \cdots + I}_{n\ times} = nI$. a is called the *determinate part* and b is the *indeterminate part*.

Given $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$ two neutrosophic numbers, some operations between them are defined as follows:

$N_1 + N_2 = a_1 + a_2 + (b_1 + b_2)I$ (Addition),

$N_1 - N_2 = a_1 - a_2 + (b_1 - b_2)I$ (Difference),

$N_1 \times N_2 = a_1 a_2 + (a_1 b_2 + b_1 a_2 + b_1 b_2)I$ (Product),

$\frac{N_1}{N_2} = \frac{a_1 + b_1 I}{a_2 + b_2 I} = \frac{a_1}{a_2} + \frac{a_2 b_1 - a_1 b_2}{a_2(a_2 + b_2)} I$ (Division).

Undoubtedly, the temperature, pressure, and other parameters are not constant in time or space. So, we want to take into account the indeterminacy of them in the space during a certain time. Thus, we use neutrosophic numbers in the form of $N = a + bI$ to model the value measured for this parameter by the sensor and also the estimation of other values not directly captured by the sensor. E.g., when the sensor takes temperature is 20°C, maybe at a farther point we have 18°, then $N = 20 + 2I = [18, 22]$ when $I = [-1, 1]$.

In this model it is necessary to control mainly two variables, *Distillation Temperature* (*T*) and *Water Level* used in cooling (*W*). The rules are simple but effective:

R_1: IF T is $High$ AND W is Low THEN S is Hot,

R_2: IF T is Low AND W is $High$ THEN S is $Cold$.

Here, S is the variable *Temperature of the System*. If S is *Hot*, the pump is operated, while if S is *Cold*, the temperature T is increased and the solenoid valve is closed.

The solenoid valve is one of the most important actuators for our distiller as they will be in charge of transporting the water to the highest points of the machine. This actuator will allow us to control the water flow to the condenser and distiller as well as the filling of the water storage tanks.

At the same time, these rules must be adapted to the species of citrus to distill.

Figure 6 is the depiction of the membership functions used to model the variable High Temperature (in red lines), Low Temperature (in blue lines), and Normal Temperature (in cyan lines).

Figure 6: Membership functions of the linguistic values of T. High is represented in red line, Low is in blue line, and Normal is in cyan lines.

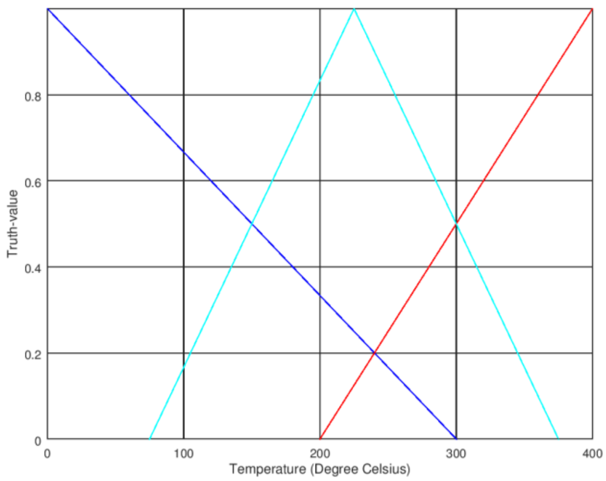
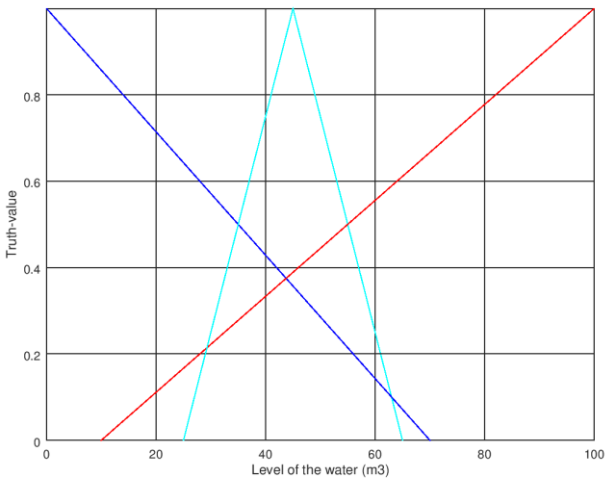


Figure 7 contains the plots of the membership functions for Low Levels of Water (in blue lines), High Levels of Water (in red lines), and Normal Levels of Water (in cyan lines).

Figure 7: Membership functions of the linguistic values of W. High is represented in red line, Low in blue line, and Normal is in cyan lines.



For modeling the Temperature of the System we use again the membership functions of Figure 6, with the labels “Cold” for “Low Temperature”, “Hot” for “High Temperature” and “Adequate” for “Normal Temperature”.

The indeterminacy constant is $I_T = [-5, 5]$ºC for T and S; whereas, $I_W = [-5, 5]\ m^3$ for W.

For processing the input data in the form of $N_T = T_d + T_i I_T$, $N_W = W_d + W_i I_W$, and $N_S = S_d + S_i I_S$ we use the Indeterminate Mamdani’s Fuzzy Control which we introduce in this paper. See Figure 8:

Figure 8: Scheme of the Indeterminate Mamdani's Control System.

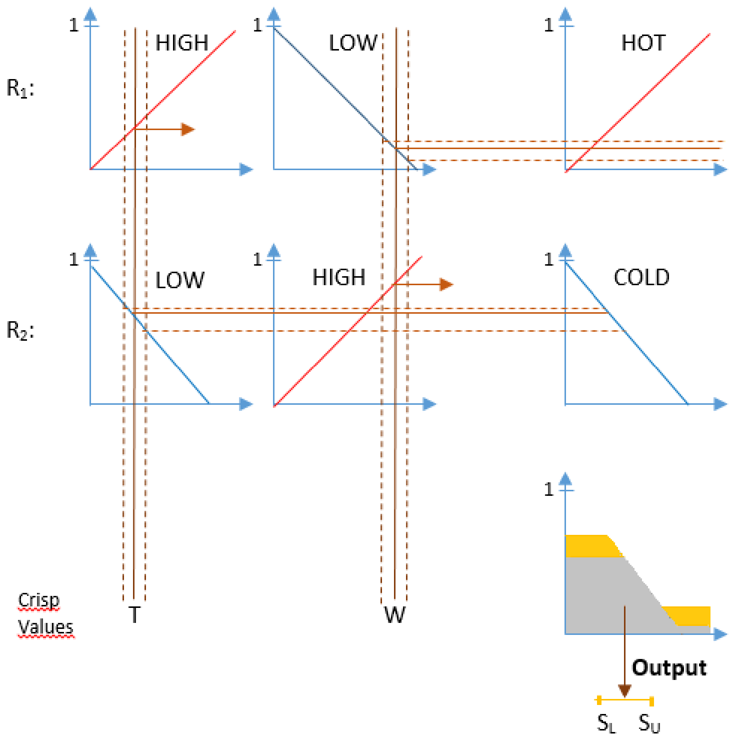
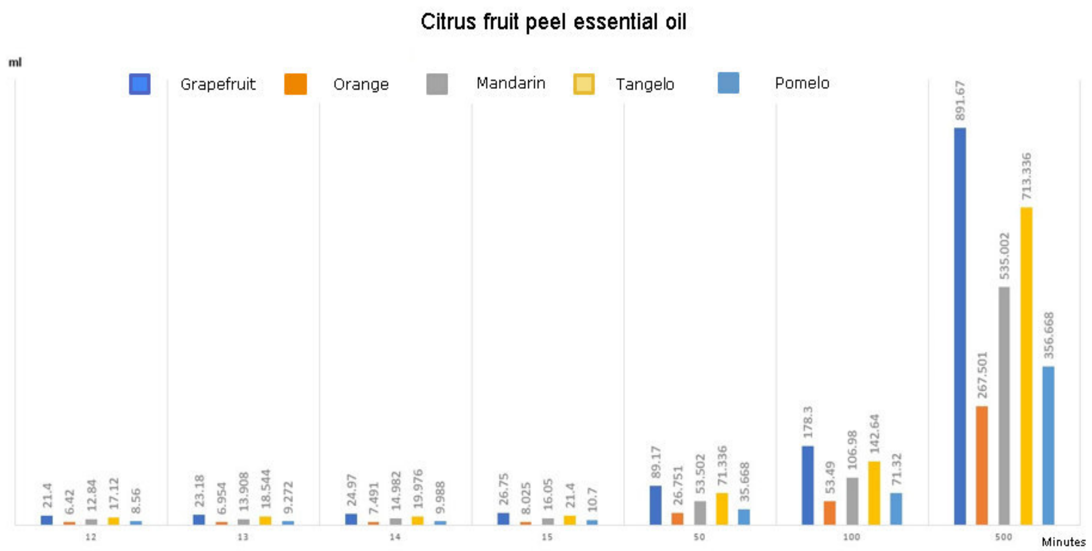


Figure 8 represents graphically the Indeterminate Mandani's Control System used in this problem. Here, instead of inputting crisp values, we input neutrosophic numbers. In the defuzzification process, we defuzzify the region in grey, and also the region colored (including the zones in yellow). So, we obtain an interval as the output of the temperature of the system $S = [S_L, S_U]$.

When, $S_L < 150\ ^oC$ the system has to be heated, while if $S_U > 300\ ^oC$ the system has to be cooled.

The results obtained were that within 8 hours approximately 40 to 50 liters of hydrolase and essential oil would be obtained, of which only 1.338% is citrus fruit essential oil. We also obtained the fixed and manipulable parameters of the distiller, as shown in Figure 9.

Figure 9: Hydrolat and essential oils obtained during 8 hours.



Conclusion

The steam distiller designed to obtain essential oils from citrus fruits contains a semi-automatic control system, which allows the extraction of essential oils with a percentage between 1% and 5% of the total. The results obtained show that, on average, 2.3% of essential oils were extracted from every 10,000 kilograms of citrus fruit used in the process. In addition, an average density of 96.7 kg/l was determined for the oils of the five types of citrus fruit used. Through experimental and theoretical calculations, a quantity of approximately 2.3 liters of essential oil per 10,000 kilograms of citrus fruit was obtained, which represents an error of 3.2999% concerning the theoretical value. The distiller's control system includes a closed loop that automates the filling and emptying of the storage tanks, as well as temperature control during cooling. Also, maybe for the first time, a Plant uses an Indeterminate Control System. The advantage is that the non-homogeneity in the distribution of heat and water for cooling is included in the modeling, having adequate results.

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A hybrid of ARAS and neutrosophic 2-tuple linguistic model to evaluate gender equitable policies from the perspective of Latin American professor's

Katia Ninozca Flores-Ledesma[1], María Eugenia Navas Rios[2], Carlos Oswaldo Venturo Orbegoso[3] Myriam Griselda Lora Loza[4], Claudia Milena Gómez-Zuluaga[5], Mónica Elisa Meneses-La Riva [6], Ana María Vallina-Hernández [7], and Willian Sebastián Flores-Sotelo[8]

[1] Universidad César Vallejo, Lima, Perú. E-mail: kfloresl1@ucvvirtual.edu.pe, kfloresl@unicartagena.edu.co
[2] Universidad de Cartagena, Cartagena, Colombia. E-mail: mnavasr@unicartagena.edu.co.
[3] Universidad César Vallejo, Lima, Perú. E-mail: cventuro@ucv.edu.pe
[4] Universidad César Vallejo, Lima, Perú E-mail: mlora@ucv.edu.pe
[5] Unidad Central del Valle del Cauca, El Cauca, Colombia. E-mail: cmgomez@uceva.edu.co
[6] Universidad César Vallejo, Lima, Perú. E-mail: mmenesesl@ucv.edu.pe
[7] Pontifica Universidad Católica de Valparaíso, Valparaíso, Chile, E-mail: ana.vallina@pucv.cl.
[8] Universidad Nacional Federico Villarreal, Lima, Perú E-mail: wfloress@unfv.edu.pe

Abstract. This paper aims to introduce a hybrid model between the Additive Ratio Assessment System (ARAS) method and the neutrosophic 2-tuples linguistic model. ARAS is used to make complex decisions by comparing the collected data with optimal values. The neutrosophic 2-tuple linguistic model allows the inclusion of indeterminacy in addition to uncertainty for computation with words. The hybridization of both models allows us to make decision with evaluations based on linguistic scales, which is a natural way of deciding by human beings. This new model is applied to measure the implementation of gender-equitable policies in Latin America. The results of the analysis of public gender equity policies are presented from the perception of university professors from Peru, Colombia, Costa Rica, Argentina, Chile, El Salvador, Mexico, and Ecuador. The discoveries reveal that in all age groups until adulthood, there has always been gender discrimination in various aspects such as health, education, work, family, and mainly socially. Latin American countries have sexist roots, however they also seek to guarantee the implementation of effective public policies for gender equality in all sectors of society.

Keywords: Gender equality, equal opportunities, equal rights, public policies, Additive Ratio Assessment System (ARAS), neutrosophic linguistic 2-tuple model.

1 Introduction

The linguistic 2-tuple method has enjoyed acceptance and popularity within the Soft Computing scientific community [1]. It is a special case of Computing with Words championed by L. Zadeh who promoted calculations with words rather than with numbers [2, 3]. It is known that human beings ordinarily make decisions without the need to perform calculations based on numerical scales. So, linguistic terms also help us to calculate effectively.

The neutrosophic linguistic 2-tuple method has served to generalize the original technique, where a triad of elements is incorporated to determine the truthfulness, indeterminacy, and falsity of a proposition [4-6]. The idea is to achieve greater accuracy at the cost of greater indeterminacy in the evaluations. Both the original fuzzy method and its neutrosophic pair preserve information during processing, due to the concept of "symbolic translation."

Additionally, we use the method known as Additive Ratio Assessment System (ARAS) [7]. This is used to make complex decisions for comparing the assessment with ideal values of the criteria. In this article we apply the method to evaluate the policies of equality gender by Latin American countries, in addition to ordering these aspects in a way that highlights which countries in the region are the ones that need the most attention from the authorities. A contribution of this paper is that it combines the ARAS decision-making method with the neutrosophic linguistic 2-tuples for the first time, to the best of the authors' knowledge. The hybrids of ARAS with other models can be read in [8-14], especially ARAS has been hybridized with fuzzy 2-tuples linguistic model [15, 16-20].

Gender equality is a key issue on the international sustainable development agenda and is recognized as a fundamental human right of people in the social and economic spheres, food, health, housing, education, right to work and equal opportunities. The gender perspective is crucial to identify and challenge discrimination against women and seek equal opportunities and resources for men and women. In addition, the perspective of women's empowerment and the importance of promoting their participation in processes of social change are analyzed. International and regional organizations that have promoted the gender perspective in Latin America stand out. Although progress has been made in public policies that promote gender equality, it is still not enough.

If we analyze this phenomenon by country, El Salvador continues to face challenges such as the lack of acceptance of gender theory in academia and the persistence of gender roles and stereotypes in society. Studies in Colombia examined government policy regarding women and gender equality in the municipality of Chinavita, Boyacá. It was concluded that in recent decades, national governments have done much to improve policies for women.

Continuing with the analysis we find the progress made by academia in Costa Rica in promoting gender equality, but they also recognize the ongoing issues and controversies surrounding these initiatives. They highlight the need to continue efforts to increase gender equality in higher education, particularly in science and technology. The prohibition of *in vitro* fertilization in Costa Rica also draws attention due to the Catholic influence in the country's legislation.

Likewise in Chile, we can see that gender colonialism and public policies cause the imposition of a dominant vision of the masculine over the other. In this specific case we find the discriminatory gender perspective of the mestizo society in Chile on the Native Americans. We consider that this gender colonialism has existed since the relationship between indigenous peoples with European and Chilean societies, which has been expressed specifically through the implementation of public policies since the period after the dictatorship (1990 hereinafter) in the context of government action directed by a neoliberal development model.

In Peru, despite the efforts made by the government and civil society, gender inequalities persist in different areas, including access to education, health, employment, and women's political participation. In this context, it is necessary to evaluate the public policies implemented to promote gender equity and determine their effectiveness in reducing gender gaps in the country.

According to the 2021 World Bank report, Peru has made progress in promoting gender equality in recent years, but there are still significant gaps in access to economic and political opportunities for women. In this context, it is necessary to evaluate the public policies implemented to promote gender equity and determine their effectiveness in reducing gender gaps.

In summary, in this paper, we also analyze the implementation of public policies against gender violence in several Latin American countries, and point out deficiencies in their compliance.

To evaluate the situation of equal opportunities in Latin American countries, we consulted women academics and researchers from universities in this region of the planet. We determined that this is a qualitative rather than a quantitative issue, where a value cannot be established exactly, since discrimination contains many subtle ways of manifesting itself, which is why there is uncertainty and indeterminacy when we have to determine the degree of discrimination within Latin American societies, in addition to the fact that we want to give a general vision of the region, where there are also differences by country. For all these reasons we used measurements based on linguistic scales, and we processed data using the neutrosophic linguistic 2-tuple method. We carry out the rankings using the ARAS method, which also provides a similarity index for each country comparing with ideal values.

This paper consists of a materials and methods section where the basic notions of the neutrosophic linguistic 2-tuple and ARAS methods are recalled. The new model and results section exposes the model we propose here and its application to the case study. We finished the paper with the Conclusions section.

2 Materials and Methods

This section contains the basic notions of the neutrosophic linguistic 2-tuple model in subsection 2.1 and the ARAS decision-making method in subsection 2.2.

2.1. Neutrosophic linguistic 2-tuple model

Definition 1 ([4-6]). Let $S = \{s_0, s_1, \dots, s_g\}$ be a set of linguistic terms and $\beta \in [0, g]$ a value that represents the result of a symbolic operation, then the linguistic 2-tuple that expresses the information equivalent to β is obtained using the following function:

$$\Delta: [0, g] \to S \times [-0.5, 0.5)$$
$$\Delta(\beta) = (s_i, \alpha) \tag{1}$$

Where s_i is such that $i = \text{round}(\beta)$ and $\alpha = \beta - i$, $\alpha \in [-0.5, 0.5)$ and "round" is the usual rounding operator, s_i is the index label closest to β and α is the value of the *symbolic translation*.

It should be noted that $\Delta^{-1}: \langle S \rangle \rightarrow [0, g]$ is defined as $\Delta^{-1}(s_i, \alpha) = i + \alpha$. Thus, a *linguistic 2-tuple* $\langle S \rangle$ is identified with its numerical value in $[0, g]$.

Suppose that $S = \{s_0, \dots, s_g\}$ is a *2-Tuple Linguistic Set* (2TLS) with odd cardinality g+1. It is defined for $(s_T, a), (s_I, b), (s_F, c) \in L$ and a, b, c $\in [0, g]$, where $(s_T, a), (s_I, b), (s_F, c) \in L$ independently express the degree of truthfulness, indeterminacy, and falsehood by 2TLS. The *2-Tuple Linguistic Neutrosophic Number* (2TLNN) is defined as follows:

$$l_j = \left\{(s_{T_j}, a), (s_{I_j}, b), (s_{F_j}, c)\right\} \quad (2)$$

Where $0 \leq \Delta^{-1}(s_{T_j}, a) \leq g$, $0 \leq \Delta^{-1}(s_{I_j}, b) \leq g$, $0 \leq \Delta^{-1}(s_{F_j}, c) \leq g$, and $0 \leq \Delta^{-1}\left(s_{T_j}, a\right) + \Delta^{-1}\left(s_{I_j}, b\right) + \Delta^{-1}(s_{F_j}, c) \leq 3g$.

The scoring and accuracy functions allow us to rank 2TLNN.

Let $l_1 = \left\{(s_{T_1}, a), (s_{I_1}, b), (s_{F_1}, c)\right\}$ be a 2TLNN in L, the scoring and accuracy functions in l_1 are defined as follows, respectively:

$$S(l_1) = \Delta\left\{\frac{2g + \Delta^{-1}(s_{T_1}, a) - \Delta^{-1}(s_{I_1}, b) - \Delta^{-1}(s_{F_1}, c)}{3}\right\},\ \Delta^{-1}(S(l_1)) \in [0, g] \quad (3)$$

$$H(l_1) = \Delta\left\{\frac{g + \Delta^{-1}(s_{T_1}, a) - \Delta^{-1}(s_{F_1}, c)}{2}\right\},\ \Delta^{-1}(H(l_1)) \in [0, g] \quad (4)$$

2.2. Notions on Additive Ratio Assessment System (ARAS)

The first step in solving the multi-criteria decision-making problem with the support of the ARAS method is to form the following $m \times n$ matrix with m rows and n columns ([7-18-19]).

$$X = \begin{bmatrix} x_{01} & \cdots & x_{0j} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix} i = 1,2,\dots,m; j = 1,2,\dots,n. \quad (5)$$

Where m is the number of alternatives, n is the number of criteria that describe each alternative, x_{ij} represents the evaluation of the i alternative according to the j criterion, whereas x_{0j} is the optimal value of the j criterion.

When x_{0j} is unknown then it is taken as:

$$x_{0j} = max_i\, x_{ij}, \text{ if } max_i\, x_{ij}\ is\ preferable$$
$$x_{0j} = min_i\, x_{ij}^{*}, \text{ if } min_i\, x_{ij}^{*}\ is\ preferable \quad (6)$$

The criteria whose values are maximum are normalized with the following Equation:

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \quad (7)$$

The criteria whose values are minimum are normalized with the following Equations:

$$x_{ij} = \frac{1}{x_{ij}^{*}}, \bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \quad (8)$$

In the other stage, the weights w_j are defined for the criteria, which satisfy $w_j \in (0,1)$:

$$\sum_{j=1}^{n} w_j = 1 \quad (9)$$

Thus, the following matrix is formed:

$$\hat{X} = \begin{bmatrix} \hat{x}_{01} & \cdots & \hat{x}_{0j} & \cdots & \hat{x}_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{i1} & \cdots & \hat{x}_{ij} & \cdots & \hat{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{m1} & \cdots & \hat{x}_{mj} & \cdots & \hat{x}_{mn} \end{bmatrix} i = 1,2,\dots,m; j = 1,2,\dots,n. \quad (10)$$

This is the matrix whose its elements are normalized by Equation 11:

$$\hat{x}_{ij} = \bar{x}_{ij} w_j; j = 1,2,\dots,n. \quad (11)$$

Later, numerical values are calculated with Equation 12:

$$O_i = \sum_{j=1}^{n} \hat{x}_{ij}; i = 1,2,\dots,m. \quad (12)$$

Where O_i is the value of the optimality function of the i alternative.

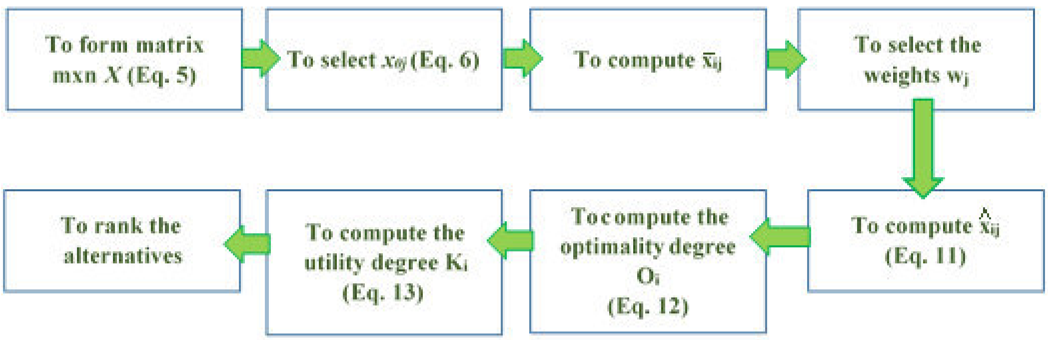
The highest value for O_i is the best and the lowest value is the worst.

The degree of usefulness of the i alternative is obtained by comparing it with the ideal degree O_0, which is calculated with Equation 13:

$$K_i = \frac{O_i}{O_0};\ i = 1,2, \dots, m. \tag{13}$$

Figure 1 contains a diagram of the algorithm to follow in the ARAS method.

Figure 1: Scheme of the ARAS algorithm for multi-criteria decision-making.



3 New Model and Results

This section consists of two subsections, the first one where we present the details of the new model and the second one contains the results of applying the model to the case study of gender parity in Latin America.

3.1. The New Model

This subsection contains the details of the new model that hybridizes neutrosophic linguistic 2-tuple model with the ARAS multicriteria decision-making method. We explain this in the following steps:

1. We start from a set $E = \{e_1, e_2, \dots, e_k\}$ of $k \geq 1$ experts, and $C = \{c_1, c_2, \dots, c_n\}$ of n criteria to measure m feasible alternatives $A = \{a_1, a_2, \dots, a_m\}$, as in the original ARAS method.
   For each criterion there is a linguistic measurement scale consisting of a set $S_i = \{s_1^i, s_2^i, \dots, s_{l_i}^i\}$ with l_i which is an odd number.
2. Each expert e_p evaluates each alternative a_j according to the criterion c_i, giving a triad $\left(s_{jpq_T}^i, s_{jpq_I}^i, s_{jpq_F}^i\right)$ where $s_{jpq_T}^i \in S_i$ means the linguistic evaluation given by the p expert that the alternative meets the given criterion, see that q_T is the index of the linguistic term within the set S_i. In a similar way, $s_{jpq_I}^i$ indicates the linguistic label for indeterminacy and likewise, $s_{jpq_F}^i$ is used for falsehood.
   This includes the evaluation of an ideal alternative a_0 for each of the criteria. The evaluations of this ideal alternative are obtained from experts or either as the maximum of the values given when the maximum is preferable, or the minimum when this is preferable.
3. The triads $\left(s_{jpq_T}^i, s_{jpq_I}^i, s_{jpq_F}^i\right)$ are aggregated for each criterion and each alternative for all experts. To do this, the arithmetic mean is used by all the experts of the given evaluations. In this way values are obtained, see Equation 14:

$$\left(\bar{s}_{jq_T}^i, \bar{s}_{jq_I}^i, \bar{s}_{jq_F}^i\right) \text{ with } \beta_T = \frac{\sum_{p=1}^k q_T}{k},\ \beta_I = \frac{\sum_{p=1}^k q_I}{k},\ \text{and } \beta_F = \frac{\sum_{p=1}^k q_F}{k} \tag{14}$$

   To simplify the notations, there are $r_j^i = \left(\beta_{T_j}^{\ i}, \beta_{I_j}^{\ i}, \beta_{F_j}^{\ i}\right) \in [0, l_i]^3$ triples of beta values obtained for each of the evaluations for truthfulness, falsity, and indeterminacy, respectively.
   This is how the matrix that appears in Equation 15 is formed.

$$X_\beta = \begin{bmatrix} r_0^1 & \cdots & r_o^j & \cdots & r_0^n \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_i^1 & \cdots & r_i^j & \cdots & r_i^n \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_m^1 & \cdots & r_m^j & \cdots & r_m^n \end{bmatrix} i = 1,2, \dots, m;\ j = 1,2, \dots, n. \tag{15}$$

4. Now the values of the matrix X_β are normalized as follows:
   The criteria whose ideal values are maximum are normalized with Equation 16.

$$\bar{r}_i^j = \frac{r_i^j}{\sum_{i=0}^m r_i^j} \tag{16}$$

Where $\bar{r}_j^i = \left(\frac{\beta_{T_j}^i}{\sum_{t=0}^m \beta_{T_j}^t}, \frac{\beta_{I_j}^i}{\sum_{t=0}^m \beta_{I_j}^t}, \frac{\beta_{F_j}^i}{\sum_{t=0}^m \beta_{F_j}^t}\right)$.

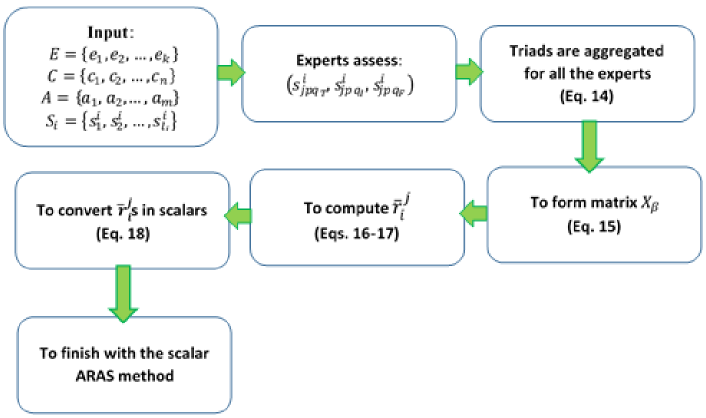
The criteria whose values are minimum are normalized with Equation 17:

$$r_i^j = \frac{1}{r_i^{j*}}, \bar{r}_i^j = \frac{r_i^j}{\sum_{i=0}^m r_i^j} \tag{17}$$

5. To convert $\bar{r}_i^j = (\gamma_T, \gamma_I, \gamma_F) \in [0,1]^3$ into a scalar in $[0,1]$, so we use Equation 18 ([17]).
$$\lambda(\bar{r}_i^j) = \frac{2+\gamma_T-\gamma_I-\gamma_F}{3} \tag{18}$$
Let us call $\bar{x}_{ij} = \lambda(\bar{r}_i^j)$.
6. The original ARAS method is applied to the above results, utilizing Equations 7, 9-13 for the values $\bar{x}_{ij}$s.

Figure 2 contains a schematic of the proposed algorithm.

Figure 2: Scheme of the ARAS algorithm hybridized with the neutrosophic linguistic 2-tuple model for multi-criteria decision-making



3.2. The Case Study

A total of 240 female academics from Latin American universities in Peru, Colombia, Costa Rica, Argentina, Chile, El Salvador, Mexico, and Ecuador who have been surveyed online about the implementation of gender parity policies in their countries. 30 academics were selected from each country, especially those whose research topic is related to the study of gender parity.

It was decided to ask them their impressions on the following aspects:

C_1 - **Political participation**: refers to the degree of representation and influence of women in public decision-making spaces. It is measured on the scale $S_1 = \{s_1^1, s_2^1, s_3^1\}$ with s_1^1= "Poor", s_2^1= "More or less", and s_3^1= "Adequate".

C_2 - **Presence of gender violence**: refers to the forms of physical, sexual, psychological or economic violence that women suffer due to their condition of being women. It is measured on a scale $S_2 = \{s_1^2, s_2^2, s_3^2\}$ with s_1^2= "Little or none", s_2^2= "Medium", and s_3^2= "High".

C_3 - **Presence of wage gap**: refers to the difference between the average earnings of men and women for the same job or for equivalent jobs. It is measured on a scale $S_3 = \{s_1^3, s_2^3, s_3^3\}$ with s_1^3= "Little or none", s_2^3= "Medium", and s_3^3= "High".

C_4 - **Labor considerations towards women**: refers to the fact that the particularities of women are taken into account in terms of their work performance beyond salary parity, such as the granting of paid maternity leave for workers with advanced pregnancies or recently given birth; the employment consideration of women with small children, etc. It is measured on a scale $S_4 = \{s_1^4, s_2^4, s_3^4\}$ with s_1^4= "Little or none", s_2^4= "Medium", and s_3^4= "High".

C_5 - **Access to public life**: refers to the access that women have to study, to work in a decent job, and to receive quality care in health centers. It is measured on a scale $S_5 = \{s_1^5, s_2^5, s_3^5\}$ with s_1^5= "Little or none", s_2^5= "Medium", and s_3^5= "High".

The respondents were asked to give their opinion on each of these criteria, according to the scales specified in a triad of linguistic values, the first to express certainty, the second indeterminacy, and the third to mean falsehood. It was explained to them that this way greater accuracy in their answers is guaranteed.

The alternatives to measure are the eight countries mentioned above, which are: a_1 =Peru, a_2 =Colombia, a_3 = Costa Rica, a_4 =Argentina, a_5 =Chile, a_6 =El Salvador, a_7 =Mexico, and a_8 =Ecuador.

Each alternative (country) was evaluated by the women of this country, not by all, which is why Formula 14 was restricted to the corresponding respondents.

a_0 was defined with the following values for the criteria:

(s_3^1, s_3^1, s_1^1), (s_1^2, s_1^2, s_3^2), (s_1^3, s_1^3, s_3^3), (s_3^4, s_3^4, s_1^4), and (s_3^5, s_3^5, s_1^5), where the first two terms are equal because it means that there is no indeterminacy.

Table 1 contains the data requested in Equation 15 about the triads that appear in Equation 14.

Table 1: Matrix of evaluations with the triple betas aggregated for all experts for each country.

Country/Criteria	C_1	C_2	C_3	C_4	C_5
a_0 = Optimal	(3,3,1)	(1,1,3)	(1,1,3)	(3,3,1)	(3,3,1)
Peru	(2.53, 2.54, 1.21)	(1.42,1.41,2.63)	(1.40,1.42,2.59)	(2.43,2.42,1.52)	(2.62,2.60,1.32)
Colombia	(1.54, 1.49, 1.21)	(1.55,1.49,2.59)	(1.45,1.42,2.58)	(2.44,2.39,1.49)	(2.65,2.63,1.36)
Costa Rica	(2.98, 2.93, 1.07)	(1.03,1.04,2.97)	(1.14,1.13,2.89)	(2.90,2.89,1.02)	(2.98,2.99,1.01)
Argentina	(2.82, 2.79, 1.12)	(1.65,1.62,2.42)	(1.35,1.36,2.66)	(2.89,2.90,1.03)	(2.68,2.62,1.26)
Chile	(2.89, 2.88, 1.09)	(1.05,1.05,2.91)	(1.33,1.33,2.69)	(2.91,2.93,1.01)	(2.77,2.74,1.12)
El Salvador	(2.42, 2.36, 1.23)	(1.89,1.73,2.00)	(1.61,1.65,2.09)	(2.01,2.00,1.80)	(2.23,2.20,1.78)
Mexico	(2.82, 2.76, 1.16)	(1.77,1.78,2.05)	(1.34,1.35,2.60)	(2.78,2.76,1.24)	(2.67,2.64,1.40)
Ecuador	(2.54, 2.50, 1.22)	(1.40,1.37,2.62)	(1.37,1.38,2.61)	(2.46,2.47,1.43)	(2.66,2.63,1.39)

Table 2 contains the normalized values for each criterion, according to Equations 16 and 17.

Table 2: Matrix of evaluations with the normalized triple betas from Table 1.

Country/Criteria	C_1	C_2	C_3	C_4	C_5
a_0 = Optimal	(0.13,0.13,0.10)	(0.15,0.15,0.09)	(0.15,0.15,0.10)	(0.13,0.13,0.09)	(0.12,0.12,0.09)
Peru	(0.11, 0.11, 0.12)	(0.11,0.10,0.11)	(0.10,0.10,0.11)	(0.10,0.10,0.13)	(0.11,0.11,0.11)
Colombia	(0.07, 0.06, 0.12)	(0.11,0.10,0.11)	(0.10,0.11,0.11)	(0.10,0.10,0.13)	(0.11,0.11,0.12)
Costa Rica	(0.13,0.13,0.10)	(0.15,0.14,0.09)	(0.13,0.13,0.10)	(0.12,0.12,0.09)	(0.12,0.12,0.09)
Argentina	(0.12, 0.12, 0.11)	(0.09,0.09,0.12)	(0.11,0.11,0.11)	(0.12,0.12,0.09)	(0.11,0.11,0.11)
Chile	(0.12, 0.12, 0.11)	(0.14,0.14,0.10)	(0.11,0.11,0.11)	(0.12,0.12,0.09)	(0.11,0.11,0.10)
El Salvador	(0.10, 0.10, 0.12)	(0.08,0.09,0.14)	(0.09,0.09,0.14)	(0.08,0.08,0.16)	(0.09,0.09,0.15)
Mexico	(0.12, 0.12, 0.11)	(0.08,0.08,0.14)	(0.11,0.11,0.11)	(0.12,0.12,0.11)	(0.11, 0.11, 0.12)
Ecuador	(0.11, 0.11, 0.12)	(0.11,0.11,0.11)	(0.11,0.11,0.11)	(0.10,0.10,0.12)	(0.11, 0.11, 0.12)

Table 3 reflects the results of converting the values in Table 2 to scalars after applying Equation 18.

Table 3: Matrix of evaluations with the results of Table 2 converted into numerical values.

Country/Criteria	C_1	C_2	C_3	C_4	C_5
a_0 = Optimal	0.63333	0.63667	0.63333	0.63667	0.63667
Peru	0.62667	0.63333	0.63000	0.62333	0.63000
Colombia	0.63000	0.63000	0.63000	0.62333	0.62667
Costa Rica	0.63333	0.63333	0.63333	0.63667	0.63667
Argentina	0.63000	0.62667	0.63000	0.63667	0.63000
Chile	0.63000	0.63333	0.63000	0.63667	0.63333
El Salvador	0.62667	0.61667	0.62000	0.61333	0.61667
Mexico	0.63000	0.62000	0.63000	0.63000	0.62667
Ecuador	0.62667	0.63000	0.63000	0.62667	0.62667

Equation 7 is applied to the elements in Table 3 to normalize them. These results are shown in Table 4.

Table 4: Matrix of the normalized elements of Table 3.

Country/Criteria	C_1	C_2	C_3	C_4	C_5
a_0 = Optimal	0.11176	0.11249	0.11176	0.11242	0.11242
Peru	0.11059	0.11190	0.11118	0.11006	0.11124
Colombia	0.11118	0.11131	0.11118	0.11006	0.11065
Costa Rica	0.11176	0.11190	0.11176	0.11242	0.11242
Argentina	0.11118	0.11072	0.11118	0.11242	0.11124
Chile	0.11118	0.11190	0.11118	0.11242	0.11183
The Savior	0.11059	0.10895	0.10941	0.10830	0.10889
Mexico	0.11118	0.10954	0.11118	0.11124	0.11065
Ecuador	0.11059	0.11131	0.11118	0.11065	0.11065

Table 5 contains a summary of the optimality and utility values applying the ARAS crisp method. The weights $w_j = \frac{1}{5}$ were applied.

Table 5: Optimality and utility values of the ARAS crisp method for the results of Table 4.

Country/Criteria	Optimality	Utility	Ranking
a_0 = Optimal	0.11217	1.00000	-
Peru	0.11099	0.98950	4
Colombia	0.11088	0.98846	5
Costa Rica	0.11205	0.99895	1
Argentina	0.11135	0.99265	3
Chile	0.11170	0.99580	2
El Salvador	0.10923	0.97377	8
Mexico	0.11076	0.98740	7
Ecuador	0.11088	0.98846	5

Thus, the country with the greatest parity among those studied is Costa Rica, followed by Chile, and in that order are Argentina, Peru, Colombia and Ecuador in the same position, Mexico, and ending with El Salvador.

Conclusion

This paper was dedicated to introducing a model where the ARAS decision-making method is hybridized with the neutrosophic linguistic 2-tuple model. The new model presents several advantages, such as the possibility of evaluating and calculating with words, which is a natural way for human beings to carry out evaluations in daily life. Additionally, the neutrosophic component allows us to include not only uncertainty but also indeterminacy. As for the ARAS method, it helps make complex decisions and is computationally inexpensive, due to its simplicity and effectiveness.

We successfully tested this new model to determine the degree to which gender parity policies are applied in eight Latin American countries, from the perspective of 240 female academics from universities in these countries. It was concluded that the order in which the countries are, from the one in the best conditions to the one with the worst conditions, is as follows: Costa Rica, Chile, Argentina, Peru, Colombia and Ecuador are in the same position, Mexico, and El Salvador.

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Characterization of social skills and emotion management of students in a public Peruvian university based on Plithogenic Statistics and Indeterminate Likert Scale

Camayo-Lapa, Becquer Frauberth[1], Flores Ledesma Katia Ninozca[2] Landa-Guadalupe, Liz Evelyn [3], Quispe-Solano, Miguel Angel [4], De La Cruz Porta, Erika Amelia[5], López Bulnes Jorge Luis[6], Carlos Francisco Cabrera Carranza [7], and Agueda Saturnina Choque Mandamiento [8]

[1]Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: bcamayo@uncp.edu.pe

[2] Universidad César Vallejo, Lima, Perú. E-mail: kfloresl1@ucvvirtual.edu.pe, kfloresl@unicartagena.edu.co

[3]Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: 2014101478I@uncp.edu.pe

[4]Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: mquispe@uncp.edu.pe

[5]Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: edelacruz@uncp.edu.pe

[6] Universidad Nacional Mayor de San Marcos, Perú. E-mail: jlopezb@unmsm.edu.pe

[7] Universidad Nacional Mayor de San Marcos, Perú. E-mail: ccabrerac@unmsm.edu.pe

[8] Escuela de Educación Superior Pedagógica Pública Emilia Barcia Boniffatti, Lima, Perú. E-mail: achoque@eesppemiliabarcia.edu.pe

Abstract. This paper aims to investigate whether social skills are a factor related to emotion management since inadequate emotion management is causing mental illnesses in this century, such as stress and depression. The objective was to determine the relationship between social skills and emotional management in students at the National University of Central Peru. To estimate social skills, the scales proposed by the Technical Team of the Department of Mental Health Promotion and Prevention of Psychosocial Problems of Peru were applied to a random sample of 184 from a population of 352 students. The variable of adequate management of emotions was measured using an Indeterminate Likert Scale since we consider that emotion has multiple components and therefore it is more precise to measure it when all the components are taken into account at the same time. To process the collected data, plithogenic statistics were applied that allow the study of events of a multivariate nature in an indeterminate framework.

Keywords: Social skills, emotion management, refined neutrosophic sets, Indeterminate Likert Scale, plithogenic statistics, $\boldsymbol{\tau}$ test of Kendall.

1 Introduction

Globalization, which means the internationalization of social, economic, and cultural relations, is nothing more than the internationalization of capitalism where people from different parts of the world can interact, requiring greater work and emotional skills from people to be able to function professionally in a manner appropriate and assertive in this society. Likewise, companies in the world need professionals who have social skills and, most importantly, management of their emotions since these companies work in uncertainty and are in constant crisis.

It has been shown that there is a relationship between social skills and teaching performance in educational institutes at the university level. Social skills are also related to entrepreneurship and learning achievements. Emotional intelligence and social skills gain greater influence concerning behavioral changes in secondary school students.

The Ministry of Health, as an institutional policy, proposes training professionals and promoters of education for the development of their abilities and skills; for the prevention of risk behaviors in adolescents, and the early detection of inappropriate behavior in schools. If we do not study and intervene so that students have social skills and emotional control, school conflicts and mental illnesses of students will increase, thereby lowering their academic level and good professional training, which leads us to study the relationship that exists between abilities and emotion management in educational centers. To do this, we formulate the main objective as follows: Determine the relationship that exists between social skills and emotion management in students of the National University of Central Peru.

In the educational aspect, the research is carried out to benefit students, teachers, and families, to prevent serious consequences of mental health, with a multisector intervention in students in the control of their emotions about their abilities.

To carry out this study, 184 undergraduate students from the National University of Central Peru were investigated. It is known that emotions are not defined by a single component; e.g., there can be joy with a small component of sadness, anger, or dissatisfaction. Therefore, to more accurately reflect this human element, we resort to the Indeterminate Likert Scales ([1]), where students do not express only the degree of management of their emotions on a scale to choose a single value, but they have to precise the degrees for all types of emotion management, even though these emotion management can be contradictory to each other, including neutrality or indifference. This measurement scale is based on the refined neutrosophic sets, where each component of the neutrosophic sets, which are truthfulness (T), indeterminacy (I), and falseness (F), are refined into types of Ts, Is, or Fs, for more accurately specifying what people want to measure ([2-4]).

To process the data we use plithogenic statistics ([5]). Plithogenic sets represent the dynamics between variables of different nature ([6-9]). Especially plithogenic probabilities and statistics study events where multivariate phenomena exist that include indeterminacy ([8]). This is the case, where the degree of different management of emotions is measured, including both the degree of good management and bad management, in addition to neutrality and indifference. For statistical processing, Kendall's Tau Correlation Test is applied, which is adapted as a plithogenic statistics test ([10, 11]).

Let us remark that plithogeny theory was introduced by Prof. F. Smarandache and it has been applied in some real-life situations, mainly for Multicriteria Decision Making Problems ([12-15]).

The structure of this article is as follows, we continue with a preliminaries section that is dedicated to exposing the theories and concepts that are used throughout the paper, such as the Indeterminate Likert Scale, plithogenic theory, and plithogenic probabilities and statistics. The results section summarizes the results obtained from the applied calculations. The article has a last conclusions section.

2 Preliminaries

This section is dedicated to recalling the concepts that are used for the study we carried out, these are the Indeterminate Likert Scale and plithogenic statistics. Below we present the formal definitions:

2.1. Indeterminate Likert Scale

Definition 1 ([12, 16]): The *Single-Valued Neutrosophic Set* (SVNS) N over U is $A = \{< x;\ T_A(x), I_A(x), F_A(x) > : x \in U\}$, where $T_A: U \rightarrow [0,1]$, $I_A: U \rightarrow [0,1]$, and $F_A: U \rightarrow [0,1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

Definition 2 ([12, 16]): The *refined neutrosophic logic* is defined such that: a truth T is divided into several types of truths: $T_1, T_2, \dots, T_p$, I into various indeterminacies: $I_1, I_2, \dots, I_r$ and F into various falsities: $F_1, F_2, \dots, F_s$, where all $p, r, s \geq 1$ are integers, and $p + r + s = n$.

Definition 3 ([12, 16]) A *triple refined indeterminate neutrosophic set* (TRINS) A in X is characterized by positive $P_A(x)$, indeterminacy $I_A(x)$, negative $N_A(x)$, positive indeterminacy $I_{P_A}(x)$ and negative indeterminacy $I_{N_A}(x)$ membership functions. Each of them has a weight $w_m \in [0,1]$ associated with it. For each $x \in X$, there are $P_A(x), I_{P_A}(x), I_A(x), I_{N_A}(x), N_A(x) \in [0,1]$, $w_P^m(P_A(x)), w_{IP}^m(I_{P_A}(x)), w_I^m(I_A(x)), w_{IN}^m(I_{N_A}(x)), w_N^m(N_A(x)) \in [0,1]$ and $0 \leq P_A(x) + I_{P_A}(x) + I_A(x) + I_{N_A}(x)(x) + N_A(x) \leq 5$. Therefore, a TRINS A can be represented by $A = \{\langle x;\ P_A(x), I_{P_A}(x), I_A(x), I_{N_A}(x), N_A(x)\rangle | x \in X\}$.

Let A and B be two TRINS in a finite universe of discourse, $X = \{x_1, x_2, \dots, x_n\}$, which are denoted by: $A = \{\langle x;\ P_A(x), I_{P_A}(x), I_A(x), I_{N_A}(x), N_A(x)\rangle | x \in X\}$ and $B = \{\langle x;\ P_B(x), I_{P_B}(x), I_B(x), I_{N_B}(x), N_B(x)\rangle | x \in X\}$,

Where $P_A(x_i), I_{P_A}(x_i), I_A(x_i), I_{N_A}(x_i), N_A(x_i), P_B(x_i), I_{P_B}(x_i), I_B(x_i), I_{N_B}(x_i), N_B(x_i) \in [0,1]$, for every $x_i \in X$. Let w_i (i = 1,2,...,n) be the weight of an element x_i(i = 1,2,...,n), with $w_i \geq 0$ (i = 1,2,...,n) and $\sum_{i=1}^{n} w_i = 1$.

The generalized TRINS weighted distance is ([12]):

$$d_\lambda(A,B) = \left\{\frac{1}{5}\sum_{i=1}^{n} w_i \left[|P_A(x_i) - P_B(x_i)|^\lambda + |I_{P_A}(x_i) - I_{P_B}(x_i)|^\lambda + |I_A(x_i) - I_B(x_i)|^\lambda + |I_{N_A}(x_i) - I_{N_B}(x_i)|^\lambda + |N_A(x_i) - N_B(x_i)|^\lambda\right]\right\}^{1/\lambda} \quad (1)$$

Where $\lambda > 0$.

The Indeterminate Likert Scale is formed by the following five elements:
– Negative membership,
– Indeterminacy leaning towards negative membership,
– Indeterminate membership,
– Indeterminacy leaning towards positive membership,
– Positive membership.
These values substitute the classical Likert scale with values:
–Strongly disagree,
– Disagree,
–Neither agree or disagree,
– Agree,
–Strongly agree.

2.2. On Plithogenic Statistics

Regarding plithogenic sets, we have the following concepts ([5]):

Let U be a universe of discourse, and P a non-empty set of elements, $P \subseteq U$. let A be a non-empty set of *one -dimensional attributes* $A = \{\alpha_1, \alpha_2, \dots, \alpha_m\}$, $m \geq 1$; and $\alpha \in A$ let be a given attribute whose spectrum of all possible values (or states) is the non-empty set S, where S can be a discrete finite set $S = \{s_1, s_2, \dots, s_l\}$, $1 \leq l < \infty$, or infinitely countable set $S = \{s_1, s_2, \dots, s_\infty\}$, or infinitely uncountable (continuous) set $S =]a, b[$, $a < b$ where] ... [is any open, semi-open, or closed interval of the set of real numbers or another general set.

Let V be a non-empty subset of S, where V is the range of all attribute values needed by experts for their application. Each element $x \in P$ is characterized by the values of all attributes in $V = \{v_1, v_2, \dots, v_n\}$, for $n \geq 1$.

In the set of attribute values V, in general, there is a dominant attribute value, which is determined by experts in its application. The dominant attribute value means the most important attribute value that experts are interested in.

Each attribute value $v \in V$ has a corresponding *degree of appurtenance* $d(x, v)$ of element x, to the set P, for some given criteria.

The degree of appurtenance can be a *fuzzy degree of appurtenance*, an *intuitionistic degree of appurtenance*, or a *neutrosophic degree of appurtenance* to the plithogenic set.

Therefore, the *degree of appurtenance function is:*

$$\forall x \in P, d: P \times V \rightarrow P\left([0,1]^z\right) \quad (2)$$

So $d(x, v)$ is a subset of $[0,1]^z$, where $\mathcal{P}([0,1]^z)$ is the power set of $[0,1]^z$, where z = 1 (fuzzy degree of appurtenance), z = 2 (for the intuitionistic degree of appurtenance), or z = 3 (for the neutrosophic degree of appurtenance).

Given the cardinal $|V| \geq 1$. Let be $c: V \times V \rightarrow [0,1]$ the *fuzzy attribute value contradiction degree function* between any two attribute values v_1 and v_2, denoted by $c(v_1, v_2)$, and satisfying the following axioms:

1. $c(v_1, v_1) = 0$, the degree of contradiction between the same attribute value is zero;
2. $c(v_1, v_2) = c(v_2, v_1)$, commutativity.

One can define a *fuzzy attribute value contradiction degree function* (c as before, which we can denoted by c_D to distinguish it from the next two), an *intuitionistic attribute value contradiction degree function* ($c_{ID}: V \times V \rightarrow [0,1]^2$), or more generally, a *neutrosophic attribute value contradiction degree function* ($c_N: V \times V \rightarrow [0,1]^3$) can be used increasing the complexity of the calculation, but also increasing the precision.

We mainly calculate the degree of contradiction between the values of uni-dimensional attributes. For multi-dimensional attribute values, we divide them into corresponding one-dimensional attribute values.

The *attribute value contradiction degree function* helps the plithogenic aggregation operators and the plithogenic inclusion relation (partial order) to obtain a more accurate result.

The attribute value contradiction degree function is designed in each field where a plithogenic set is used according to the application to be solved. If ignored, aggregations still work, but the result may lose precision.

Then (P, a, V, d, c) is called a *plithogenic set*, ([5]):

1. Where "P" is a set, "a" is an attribute (multidimensional in general), "V" is the range of the attribute values, "d" is the degree of appurtenance of the attribute value of each element x to the set P to some given criteria ($x \in P$), and "d" means "d_D" or "d_{ID}" or "d_N", when it is a fuzzy degree of appurtenance, an intuitionistic degree of appurtenance, or a neutrosophic degree of appurtenance respectively of an element x to the plithogenic set P;
2. "c" means either "c_D" or "c_{ID}" or "c_N", when it comes to the fuzzy degree of contradiction, intuitionistic degree of contradiction, or neutrosophic degree of contradiction between the attribute values respectively.

The functions $d(\cdot,\cdot)$ and $c(\cdot,\cdot)$ are defined according to the applications that the experts need to solve.
The notation below is used:
$x(d(x,V)),\ d(x,V) = \{d(x,v), \text{for all } v \in V\}, \forall x \in P.$
The attribute value contradiction degree function is calculated between each attribute value concerning the dominant attribute value (denoted by v_D) in particular, and with concerning attribute values as well.
The attribute value contradiction degree function c between the attribute values is used in the definition of plithogenic aggregation operators (intersection (AND), union (OR), implication ($\Longrightarrow$), equivalence ($\Longleftrightarrow$), inclusion relation (partial order), and other plithogenic aggregation operators that combine two or more degrees of attribute value acting on the t-norm and the t-conorm, ([5, 9]).
Most plithogenic aggregation operators are linear combinations of the fuzzy t-norm (denoted by $\wedge_D$), and the fuzzy t-conorm (denoted by $\vee_D$), but nonlinear combinations can also be constructed.
If the t-norm is applied on the dominant attribute value denoted by v_D, and the contradiction between v_D and v_2 is $c(v_D, v_2)$, then on the attribute value v_2 it is applied:

$$[1 - c(v_D, v_2)] \cdot t_{norm}(v_D, v_2) + c(v_D, v_2) \cdot t_{conorm}(v_D, v_2) \quad (3)$$

Or, by using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \wedge_D v_2) + c(v_D, v_2) \cdot (v_D \vee_D v_2) \quad (4)$$

Similarly, if the t- conorm is applied on the dominant attribute value denoted by v_D, and the contradiction between v_D and v_2 is $c(v_D, v_2)$, then on the attribute value v_2 it is applied:

$$[1 - c(v_D, v_2)] \cdot t_{conorm}(v_D, v_2) + c(v_D, v_2) \cdot t_{norm}(v_D, v_2) \quad (5)$$

Or, by using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \vee_D v_2) + c(v_D, v_2) \cdot (v_D \wedge_D v_2) \quad (6)$$

The *Plithogenic Intersection* is defined as:

$$(a_1, a_2, a_3) \wedge_P (b_1, b_2, b_3) = \left(a_1 \wedge_D b_1, \frac{1}{2}[(a_2 \wedge_D b_2) + (a_2 \vee_D b_2)], a_3 \vee_D b_3\right) \quad (7)$$

The *Plithogenic Union* is defined as:

$$(a_1, a_2, a_3) \vee_P (b_1, b_2, b_3) = \left(a_1 \vee_D b_1, \frac{1}{2}[(a_2 \wedge_D b_2) + (a_2 \vee_D b_2)], a_3 \wedge_D b_3\right) \quad (8)$$

In other words, for what applies to the appurtenance, the opposite applies to the non-appurtenance, while in indeterminacy the average between them applies.
Regarding the Plithogenic Statistics we have the following:
Plithogenic Statistics has as its aim to study the analysis and observation of events as in classical statistics. It is a generalization of the classical Multivariate Statistics, where multivariate results of neutrosophic or indeterminate variables are analyzed.
For example, according to the example in Smarandache ([7]) about Plithogenic Neutrosophic Probability (PNP), $PNP(Jenifer) = \{(0.5, 0.9, 0.2), (0.6, 0.7, 0.4), (0.8, 0.2, 0.1), (0.4, 0.3, 0.5)\}$ which consists of the neutrosophic probabilities that Jenifer will pass each of the 4 subjects corresponding to the semester. For example, to pass Differential Equations she has 50% of success rate, 20% of failure rate, and 90% of indeterminacy rate. That is why the neutrosophic probability of passing the semester is $(min\{0.5, 0.6, 0.8, 0.4\}, max\{0.9, 0.7, 0.2, 0.3\}, max\{0.2, 0.4, 0.1, 0.5\}) = (0.4, 0.9, 0.5)$.
Regarding Plithogenic Refined Probability (PRP), probabilities are generalized to the case where there is more than one value of truthfulness of probabilities, more than one value of indeterminacy, or more than one value of falsity. The illustrative example used by Smarandache is the following:
Suppose that for each subject Jenifer has to be evaluated in two tests, one oral and the other written. Then the set of probabilities is refined as: $T_1(\text{oral test})$, $T_2(\text{written test})$; $I_1(\text{oral test})$, $I_2(\text{written test})$; and $F_1(\text{oral test})$, $F_2(\text{written test})$.

So, $PRP(Jenifer) =$

$$\{\big((0.5, 0.6), (0.4, 0.7), (0.1, 0.2)\big), \big((0.6, 0.8), (0.0, 0.7), (0.3, 0.4)\big), \big((0.8, 0.8), (0.1, 0.2), (0.1, 0.0)\big), \\ ((0.3, 0.7), (0.2, 0.3), (0.5, 0.4))\}$$

For example, $\big((0.5, 0.6), (0.4, 0.7), (0.1, 0.2)\big)$ means that concerning the first subject, Jenifer has a 50% probability of passing the oral test and a 60% probability of passing the written test; 40% indeterminacy whether she will pass the oral test and 70% of indeterminacy whether she will pass the written test; while there is 10% of chance of not passing the oral exam and 20% of chance of not passing the written exam.

3 Results

The population is made up of 352 students from the careers of the National University of Central Peru. The sample is made up of 184 undergraduate students. The students were selected with simple random sampling. The sample size is representative of the size of the population with the parameters e = 0.05 and k = 0.95, according to Formula 9 ([17]).

$$n = \frac{k^2 Npq}{e^2(N-1)+k^2pq} \quad (9)$$

Where:
n is the sample size,
N is the population size,
k is a constant depending on the level of confidence,
e is the sampling error,
p: is the proportion of elements of the population satisfying the characteristic measured,
q: is 1-p. We use p = 0.5.

For the social skills variable, the psychometric technique adapted by the Specialized Institute of Mental Health of the Ministry of Health of Peru was used. Each studied student was classified according to their social skills and as a result of the psychometric tests on a measurement scale {Very High, High, High Average, Average, Low Average, Low, Very Low}, moreover, according to the results of the test, the specialists were asked to rank the respondents on their social skills, which is why if Y is the variable that indicates social skills, each of the students has an associated number from 1 to 184, where 1 means the student with the highest social skill and 184 is the worst.

On the other hand, the variable X is used to measure the ability to manage emotions; for this end, students were asked to self-evaluate according to the following visual scale shown in Figure 1:

Figure 1. Visual scale for measuring the degree of ability to manage emotions by students.

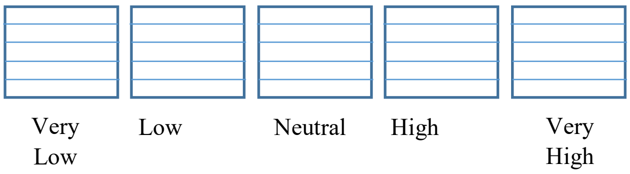

Figure 1 is a visual aid for students to evaluate themselves on how they perceive they manage their emotions. There were given examples so that they understood how to carry out this evaluation, such as the one shown in Figure 2.

Figure 2. Example of the use of the visual scale for measuring the degree of ability to manage emotions by students.

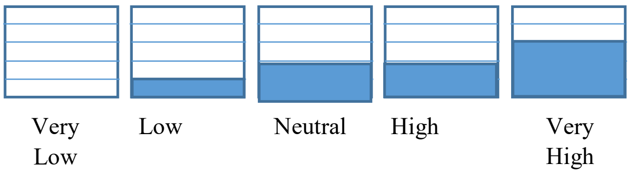

Figure 2 illustrates how to use the proposed scale, where the respondent assesses himself/herself managing emotions (from 0-5), 0 for "Very low", 1 for "Low ", 2 for "Neutral" and "High", and 3 for " Very High". The meaning of this type of Likert scale is that the management of emotions changes over time and in this way greater fidelity is obtained to measure like this the behavior of each individual.

This scale of 0-5 for each component can be converted into a scale of 0-1, only by dividing each of these components by 5.

The next step is to define an ordering operator between the elements of this measurement scale. To do this, given $V = (v_1, v_2, v_3, v_4, v_5) \in [0,1]^5$ a vector that represents the evaluation of each student where v_1 represents the evaluation of "Very High", v_2 that of "High" and so on, the following function is used:

$$\gamma(V) = 2v_1 + v_2 + 0.5v_3 - v_4 - 2v_5 \quad (10)$$

Thus, given V_1 and V_2 it is preferred V_1 over V_2 if and only if $\gamma(V_2) < \gamma(V_1)$ and is denoted by $V_2 \prec V_1$.

Thus, the conditions are given to order the elements of both X and Y. Below we present the details of the calculation for the τ Kendall test.

τ of Kendall is a nonparametric measure of association for ordinal variables that ignores ties [11-18-19-20]. The sign of the coefficient indicates the direction of the relationship and its absolute value indicates the strength. Higher values indicate that the relationship is closer. Generally, Kendall coefficients of 0.9 or greater are considered very good. It is used when studying the relationship between qualitative ordinal variables. The steps to follow are the following:

1. Order the observations in the variable X from 1 to n. Order the observations Y from 1 to n.
2. Arrange the list of n subjects so that the subjects' ranks in the variable X are in their natural order; this is 1, 2, 3,…, n.
3. Reorder the ranges Y in the order in which they occurred when the ranges X are in the natural order. Determine the values of S, the number of agreements in the order minus the number of disagreements in the order, for the observed orders in the ranges of Y.
4. If there are no ties between the observations X or Y, use Equation 11 to calculate the value of T.

$$T = \frac{2S}{n(n-1)} \tag{11}$$

If there are ties, use Equation 12.

$$T = \frac{2S}{\sqrt{n(n-1)-T_x}\sqrt{n(n-1)-T_y}} \tag{12}$$

Where $T_x = \sum t(t-1)$ is the number of tied observations in each group of ties in the variable X.

$T_y = \sum t(t-1)$ is the number of tied observations in each group of ties in the variable Y.

5. If the n subjects constitute a random sample from some population, the hypothesis that the variables are independent in that population can be tested, so calculate the value z associated with T using Equation 13.

$$z = \frac{T-\mu_T}{\sigma_T} = \frac{3T\sqrt{n(n-1)}}{\sqrt{2(2n+5)}} \tag{13}$$

Table 1 summarizes the results of the evaluations regarding students' social skills:

Table 1. Results obtained from the psychometric tests on the Social Skills variable on the ordinal qualitative scale.

	Frequency	Percentage (%)
Very high	22	12.0
High	35	19.0
High average	52	28.3
Average	36	19.6
Average low	35	19.0
Low	4	2.2
Total	184	100.0

Additionally, according to the results of the function γ of Equation 10, those who obtained scores greater than or equal to 2 were classified as “Very High”, “High” are those who obtained scores greater than or equal to 1, “Average” group within those that fall from -1 to 1, “Low” between -2 and -1, and “Very Low” less than -2.

This is how Table 2 was obtained:

Table 2. Results obtained on the Emotion Management variable on the ordinal qualitative scale.

	Frequency	Percentage (%)
Very low	19	10.3
Low	62	33.7
Average	60	32.6
High	29	15.8
Very high	14	7.6
Total	184	100.0

As mentioned above, to apply the τ of Kendall test it is necessary to order the elements of the populations for the variables X and Y. The result of this test is shown in Table 3.

Table 3. Relationships between the social skills variable and the emotion management variable.

Proof statistics	Coefficient	p-value
Kendall Tau	0.315	<0.001
Cases valid	184	

The contrast of hypotheses with a significance level of 0.05 and applying the statistical test of Kendall's Tau by counting final values of different levels, leads to the conclusion that there is a direct significant relationship between social skills and emotion management in students due to having a p-value <0.001 for a low degree of correlation of 0.315. That is to say, the greater the social skills, the greater the management of emotions and vice versa.

It is also possible to predict the probability that each student has adequate management emotions using the following equations:

If $V = (v_1, v_2, v_3, v_4, v_5)$ is the vector that indicates the normalized values of the Indeterminate Likert Scale for the student M, then we have:

$$PNP(M) = (v_1 + v_2 - v_1 v_2, v_3, v_4 + v_5 - v_4 v_5) \tag{14}$$

That is, the plithogenic neutrosophic probability that M will manage his/her emotions correctly in the future is calculated with Equation 14. For example, from Figure 2 we have $E = (3,2,2,1,0)$, therefore $V = \left(\frac{3}{5}, \frac{2}{5}, \frac{2}{5}, \frac{1}{5}, 0\right)$, and then $PNP(M) = \left(1 - \frac{6}{25}, \frac{2}{5}, \frac{1}{5}\right) = \left(\frac{19}{25}, \frac{2}{5}, \frac{1}{5}\right)$. This information can be combined with others, for example, if it is known that the PNP probability of M will have assertive behavior is $\left(\frac{8}{25}, \frac{1}{5}, \frac{3}{25}\right)$, then the PNP probability of M having assertive behavior in the future and at the same time managing their emotions well is equal to $\left(\frac{8}{25}, \frac{2}{5}, \frac{1}{5}\right) = \left(min\left(\frac{19}{25}, \frac{8}{25}\right), max\left(\frac{2}{5}, \frac{1}{5}\right), max\left(\frac{1}{5}, \frac{3}{25}\right)\right)$.

Conclusion

The most recent neutrosophic theories were used in this paper to study if there is a significant correlation between the variables of emotion management and social skills in university students at a public university in Peru. To do this we use Kendall's tau test, however, we consider it is important to take into account the complexity of measuring emotions that is insufficient to capture through a single value or term. That is why an Indeterminate Likert Scale was used. The statistical test was also carried out with data expressed in plithogenic refined form, which constitutes an example of the use of classical statistical tests in problems where there is an indeterminacy of multivariate variables.

We conclude that there is a direct significant relationship between social skills and emotion management in students with a low degree of correlation. That is to say, the greater the social skills, the greater the management of emotions and vice versa. Therefore, it is recommended to introduce class exercises that contribute to improving social skills in students, such as solving practical exercises by forming work teams or promoting the creation of teams to bring collective solutions to extra-class homework to the classroom.

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A comparative study based on neutrosophic numbers and the Indeterminate VIKOR method for the selection of three types of vertical axis wind turbines adapted to the conditions of Peru

David Elvis Condezo Hurtado [1], Becquer Frauberth Camayo-Lapa [2], José Eduardo Galarza-Linares [3], Brecio Daniel Lazo-Baltazar [4], Armando Felipe Calcina Sotelo [5], Adrián Becquer Camayo-Vivas[6] Bartolomé Sáenz Loayza [7], and Miguel Ángel Quispe Solano [8]

[1]Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: dcondezo@uncp.edu.pe
[2] Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: bcamayo@uncp.edu.pe
[3]Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: jgalarza@uncp.edu.pe
[4]Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: blazo@uncp.edu.pe
[5]Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: acalcina@uncp.edu.pe
[6] Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: vivaadrian9@hotmail.com
[7] Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: bsaenz@uncp.edu.pe
[8] Universidad Nacional del Centro del Perú, Huancayo, Perú. E-mail: mquispe@uncp.edu.pe

Abstract. The use of vertical axis wind turbines to electrify homes without electricity in the Peruvian region of Junín is essential to address the challenges of climate change and move towards a more sustainable and environmentally friendly future. The objective was set to compare three types of wind turbines, these are Darrieus H, Savonius, and Windside concerning to the wind speeds that occur in the Junín region. This is because the operation of these wind turbines in this region is not yet known. The following procedure was tracked: first, the design was made and then it was experimented in the wind tunnel laboratory of the Faculty of Electrical and Electronic Engineering of the National University of Central Peru. In the study, we took into account that there is indeterminacy in the variable wind speed among others, which is why we adapted the traditional variables to the use of neutrosophic numbers. Additionally, we carried out a comprehensive study that includes other variables for decision-making. To select the best complete option we asked a group of 3 experts for their evaluations according to several criteria and we used the VIKOR method for intervals adapted to neutrosophic numbers.

Keywords: Wind turbines, electrification, winds, electrical power, neutrosophic numbers, Indeterminate VIKOR method.

1 Introduction

The possibility of increasing electricity production without polluting the environment can be achieved using wind fields. This is one of the techniques that has had the greatest advancement and research over the last decades.

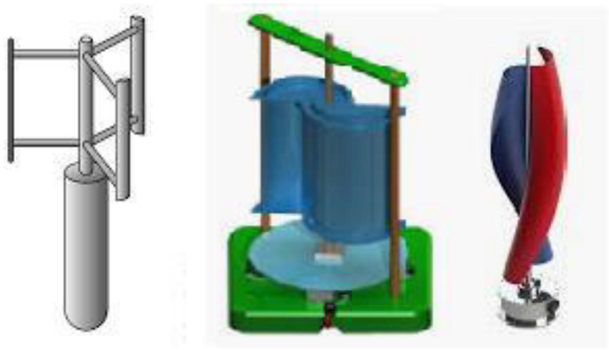
Vertical axis wind turbines have low performance due to the shape of the blades, which is the reason for carrying out several studies so that these elements can capture a greater amount of air mass, taking into account that the transformation of air into kinetic energy must be carried out on the rotor, which is made up of the blades and the hub.

The theory that governs this study is based on the conversion of kinetic energy into mechanical. But obtaining a super wind generator is almost impossible because according to Betz's law, it is not possible to capture the entire mass of air or otherwise the wind turbine would not be able to rotate. The airfoil is obtained through a genetic algorithm optimization of an objective function that maximizes the aerodynamic performance of the airfoils, providing better structural rigidity compared to a NACA design that is thinner.

The most used vertical axis wind turbines are Darrieus, Savonius, and Windside due to their easy construction and assembly. They are currently used in urban homes in Europe, but in Peru this technology is only recently known. That is why it is important to determine which of these three types of wind turbines best adapt to the climatic and physical conditions of the Junín region. The present investigation consists of studying which of the three wind turbine models has the best performance at high speeds and low speeds in isolated homes in the region.

Figure 1 contains schematic representations of the Darrieus H, Savonius, and Windside wind turbines.

Figure 1. Schemes of the three types of wind turbines studied, from left to right: Darrieus H, Savonius, and Windside type.



To meet this purpose, we carried out experiments on models of wind turbines built to scale to be tested in wind tunnels of the Faculty of Electrical and Electronic Engineering of the National University of Central Peru. When studying this type of phenomenon, it is not enough to determine the operation of the devices at a constant speed, because the wind has speed variations that can be abrupt. That is why, instead of working with precise values of the variables to be studied, we prefer to use neutrosophic numbers that allow us to include the indeterminacy that exists in this type of studies ([1,2]). Neutrosophic numbers are defined in the form of $a + bI$, where $a, b \in \mathbb{R}$, a is the determined part and bI is the indeterminate part, I is a symbolic element that represents indeterminacy, although it can also be equated to a numerical interval so that the calculations are replaced with values in the form of intervals instead of values in the form of scalars.

On the other hand, we have 3 experts to determine which of the three types of generators is optimal. This is a decision-making problem that is not simple because in addition to the technological component that consists of obtaining the greatest energy gain, there are also other variables to take into account for the selection, such as the durability of the equipment, and its efficiency, maintenance cost, among others. All of these variables are also indeterminate.

For decision-making, we use the Indeterminate VIKOR method, which is a variation of VIKOR for intervals [3]. The VIKOR originally emerged as a model for multi-criteria decision-making where experts evaluate alternatives for certain criteria, comparing them with ideal values, both positive and negative [4]. A ranking is formed of the alternatives that best satisfy these conditions. On the other hand, the interval-valued VIKOR generalizes the classical method to an indeterminacy framework, where uncertainty and indeterminacy are considered in decision-making, and we adapt this method to the case of data in the form of neutrosophic numbers. In scientific literature we can read other generalizations of VIKOR technique [5-10].

In this paper a materials and methods section where the basic notions of neutrosophic numbers are recalled, and also the VIKOR method for data in the form of interval numbers. Next, we present a section called The Study where the theoretical details of the study carried out and the obtained results appear, particularly the equations used in the experiment. We end the article with the conclusions.

2 Materials and Methods

A *neutrosophic number* N has the following form:

$\mathrm{N} = \mathrm{a} + \mathrm{bI}$, where a is the *determinate* (sure) part of N, and bI is the *indeterminate* (unsure) part of N.

The arithmetic operations between these numbers are summarized below:

Given $\mathrm{N}_1 = \mathrm{a}_1 + \mathrm{b}_1\mathrm{I}$ and $\mathrm{N}_2 = \mathrm{a}_2 + \mathrm{b}_2\mathrm{I}$, which are two neutrosophic numbers, some operations between them are defined as follows, [1, 2, 11, 12]:

$N_1 + N_2 = a_1 + a_2 + (b_1 + b_2)I$ (Addition)

$N_1 - N_2 = a_1 - a_2 + (b_1 - b_2)I$ (Difference)

$N_1 \times N_2 = a_1a_2 + (a_1b_2 + b_1a_2 + b_1b_2)I$ (Product)

$\frac{N_1}{N_2} = \frac{a_1+b_1I}{a_2+b_2I} = \frac{a_1}{a_2} + \frac{a_2b_1-a_1b_2}{a_2(a_2+b_2)}I$ (Division)

We have I is a constant such that $I^2 = I$, $0 \cdot I = 0$, $\underbrace{I + I + \cdots + I}_{n\ times} = nI$, and $I^{-1}$is undefined

In general, we have the following definition:

Definition 1: ([13-15]) Let R be a ring. The *neutrosophic ring* ⟨R ∪ I⟩ is also a ring, generated by R and I under the operation of R, where I is a neutrosophic element that satisfies the property $I^2 = I$. Given an integer n, then, n+I and nI are neutrosophic elements of ⟨R ∪ I⟩ and in addition $0 \cdot I = 0$. Also, I^{-1}, the inverse of I is not defined.

E.g., a neutrosophic ring is ⟨ℤ ∪ I⟩ generated by ℤ, which is the set of integers.

We use the following interval-valued arithmetic when we convert I in the interval:

Given $I_1 = [a_1, b_1]$ and $I_2 = [a_2, b_2]$ we have the following operations between them (see [16, 17-18-19-20]):

1. $I_1 \le I_2$ if and only if $a_1 \le a_2$ and $b_1 \le b_2$.
2. $I_1 + I_2 = [a_1 + a_2, b_1 + b_2]$ (Addition);
3. $I_1 - I_2 = [a_1 - b_2, b_1 - a_2]$ (Subtraction),
4. $I_1 \cdot I_2 = [\min\{a_1 \cdot b_1, a_1 \cdot b_2, a_2 \cdot b_1, a_2 \cdot b_2\}, \max\{a_1 \cdot b_1, a_1 \cdot b_2, a_2 \cdot b_1, a_2 \cdot b_2\}]$ (Product),
5. $I_1/I_2 = I_1 \cdot (1/I_2) = \{a/b: a \in I_1, b \in I_2\}$, always that $0 \notin I_2$ (Division).
6. $\sqrt{I} = [\sqrt{a}, \sqrt{b}]$, always that $a \ge 0$ (Square root).
7. $I^n = \underbrace{I \cdot I \cdots I \cdot I}_{\text{n times}}$

The de-neutrosophication process was introduced by Salmeron and Smarandache [1], which converts a neutrosophic number into one numerical value. This process provides a range of numbers for centrality using as a base the maximum and minimum values of $I = [a_1, a_2]$, based on Equation 1:

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \tag{1}$$

The VIKOR method is specified below for data in the form of intervals, which can be treated as data in the form of neutrosophic numbers [3]:

We have to input the Table shown below:

	C_1	C_2	⋯	C_n
A_1	$[f_{11}^L, f_{11}^U]$	$[f_{12}^L, f_{12}^U]$	⋯	$[f_{1n}^L, f_{1n}^U]$
A_2	$[f_{21}^L, f_{21}^U]$	$[f_{22}^L, f_{22}^U]$	⋯	$[f_{2n}^L, f_{2n}^U]$
⋯	⋯	⋯	⋯	⋯
A_m	$[f_{m1}^L, f_{m1}^U]$	$[f_{m2}^L, f_{m2}^U]$	⋯	$[f_{mn}^L, f_{mn}^U]$

Where $A_1, A_2, \dots, A_m$ are the alternatives to choose one of them, $C_1, C_2, \dots, C_n$ are the criteria by which to evaluate the alternatives, $f_{ij} \in [f_{ij}^L, f_{ij}^U]$ is the evaluation of the alternative A_i with respect to the criterion C_j that is not known exactly what it is except that it belongs to the given interval. This interval can be expressed in the form of neutrosophic numbers such as $[f_{ij}^L, f_{ij}^U] = f_{ij}^L + (f_{ij}^U - f_{ij}^L)I$, where $I = [0, 1]$.

In addition, there is a vector of weights $W = [w_1, w_2, \dots, w_n]$ for each of the criteria. The steps to track are the following:

A) Determine the positive ideal solution (PIS) in Equation 2 and the negative ideal solution (NIS) in Equation 3.

$$A^* = \{f_1^*, \dots, f_n^*\} = \{(max_i\, f_{ij}^U | j \in K) \text{ or } (min_i\, f_{ij}^L | j \in J)\}, j = 1,2,\dots,n. \tag{2}$$

$$A^- = \{f_1^-, \dots, f_n^-\} = \{(min_i\, f_{ij}^L | j \in K) \text{ or } (max_i\, f_{ij}^U | j \in J)\}, j = 1,2,\dots,n. \tag{3}$$

Where K is associated with the benefit criteria and J is associated with the cost criteria.

B) The intervals $[S_i^L, S_i^U]$ and $[R_i^L, R_i^U]$ are calculated as shown below:

$$S_i^L = \sum_{j \in K} w_j \left(\frac{f_j^* - f_{ij}^U}{f_j^* - f_j^-}\right) + \sum_{j \in K} w_j \left(\frac{f_{ij}^L - f_j^*}{f_j^- - f_j^*}\right) \; i = 1, \dots, m \tag{4}$$

$$S_i^U = \sum_{j \in K} w_j \left(\frac{f_j^* - f_{ij}^L}{f_j^* - f_j^-}\right) + \sum_{j \in K} w_j \left(\frac{f_{ij}^U - f_j^*}{f_j^- - f_j^*}\right) \; i = 1, \dots, m \tag{5}$$

$$R_i^L = max\left\{w_j \left(\frac{f_j^* - f_{ij}^U}{f_j^* - f_j^-}\right) | j \in K, w_j \left(\frac{f_{ij}^L - f_j^*}{f_j^- - f_j^*}\right) | j \in J\right\} \; i = 1, \dots, m \tag{6}$$

$$R_i^U = max\left\{w_j \left(\frac{f_j^* - f_{ij}^L}{f_j^* - f_j^-}\right) | j \in K, w_j \left(\frac{f_{ij}^U - f_j^*}{f_j^- - f_j^*}\right) | j \in J\right\} \; i = 1, \dots, m \tag{7}$$

C) Calculate the interval $Q_i = [Q_i^L, Q_i^U]$; i = 1,2,…, m; such that:

$$Q_i^L = v\left(\frac{S_i^L - S^*}{S^- - S^*}\right) + (1-v)\left(\frac{R_i^L - R^*}{R^- - R^*}\right) \quad (8)$$

$$Q_i^U = v\left(\frac{S_i^U - S^*}{S^- - S^*}\right) + (1-v)\left(\frac{R_i^U - R^*}{R^- - R^*}\right) \quad (9)$$

Where:

$$S^* = min_i\, S_i^L,\ S^- = max_i\, S_i^U \quad (10)$$

$$R^* = min_i\, R_i^L,\ R^- = max_i\, R_i^U \quad (11)$$

v means the strategy weight of the majority of the criteria or the maximum of the group utility. It is assumed $v = 0.5$.

D) According to the classical VIKOR method, an alternative that has a minimum Q_i is the best alternative and is taken as a trade-off solution. However, in this method Q_i is an interval. Therefore, an order relation between intervals is used as indicated in the next step:

E) Suppose we have two intervals $[a^L, a^U]$ and $[b^L, b^U]$, to determine the minimum between them we have the following cases:
   (1) If the two intervals do not have intersections, the minimum of them is the one with the lowest values. That is, when $a^U \le b^L$, then the minimum is taken as $[a^L, a^U]$.
   (2) If both intervals are the same, then both are taken with equal importance.
   (3) When $a^L \le b^L < b^U \le a^U$, the minimum interval is taken as: if $\alpha(b^L - a^L) \ge (1-\alpha)(a^U - b^U)$ then $[a^L, a^U]$ is the minimum, otherwise $[b^L, b^U]$ is the minimum.
   (4) When $a^L < b^L < a^U < b^U$, if $\alpha(b^L - a^L) \ge (1-\alpha)(b^U - a^U)$, then $[a^L, a^U]$ is the minimum, otherwise $[b^L, b^U]$ is the minimum.

Here α is introduced as an optimistic level of the decision-maker with $\alpha \in (0,1]$, a decision-maker with a higher alpha value is considered more optimistic than a decision-maker with a lower one. A rational decision maker has an $\alpha = 0.5$.

3 The study

We worked with speeds ranging from 4 m/s to 7 m/s. It is important to indicate that the simulation was carried out with wind turbines of 53cm high and 20cm wide. This reference dimension was taken due to the size of the wind tunnel. The maximum speeds of the region were also considered as reference. It is the province of Junín located at more than 3000 meters above sea level, with average wind speeds of 7 m/s and air mass densities of 909 $Kg.m^{-3}$.

From the point of view of modeling the physics of wind turbines, the following equations are used:

Betz's law is taken into account, which indicates that it is not possible to capture the entire air mass or otherwise the wind turbine would not be able to rotate. This law is modeled by the equation:

$$P = 0.20 D_I^2 v_e^3 \quad (12)$$

Where:

D_I is the Diameter [meters] of the wind turbine,

V_e is the undisturbed wind speed [meters/seconds],

The axial intromission factor (a_{xi}) measures the reduction in the undisturbed speed of the wind when passing through the actuator disc and is expressed by the following equation:

$$a_{xi} = \frac{v_e - v_{avg}}{v_e} \quad (13)$$

Where:

v_e is the undisturbed wind speed [meters/seconds],

v_{avg} is the speed of the air through the actuator disc [meters/seconds].

The vertical axis wind turbine is a machine that is installed very close to the ground, consequently the expense in assembly and maintenance is minimal, and it does not even have an orientation system because it is omnidirectional. The disadvantage of this type of wind turbine is efficiency.

In the Savonius type wind turbine the rotor is simple and is made up of split hollow cylinders that rotate in the direction of least resistance. The Darrieus wind turbine is the most successful machine on the market. It has more efficiency than the Savonius but is not better than the horizontal axis wind turbine. It is shaped like a jump rope that has greater centrifugal force. The problem with this type of machine is starting, so it needs an initial impulse, but if it manages to start, it begins to provide power. The Windside type wind turbine is similar to the Savonius rotor, the difference is the use of the aerodynamic concept, which allows the efficiency of a horizontal axis to be approximated, see Figure 1.

For the experiment, the simulation of prototypes of three vertical axis technologies was carried out, based on the DL WIND-B wind tunnel. An instrument was created to collect data on electricity generation, wind speeds and others. The torque and speed of the wind turbine were analyzed.

The results are shown in the Figures that follow, starting with the comparison of speeds of the different wind turbines.

Figure 2. Comparison of power in the axis for different wind speeds.

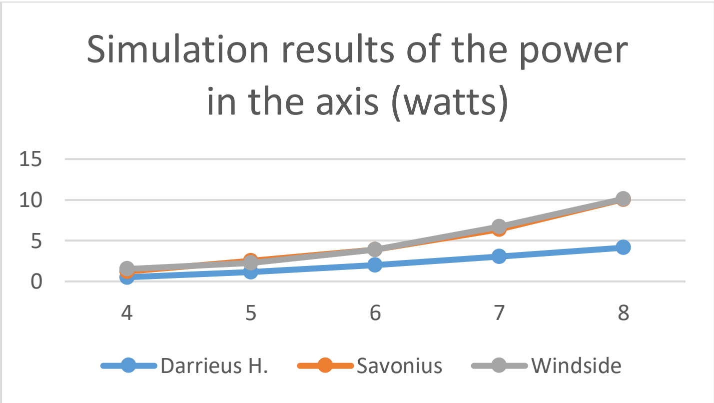


Figure 3. Neutrosophic histogram of power in the axis simulation results. The determined part appears in blue and the indeterminate part in orange.

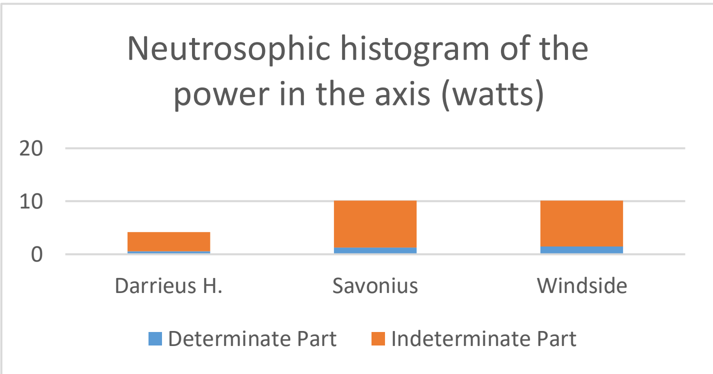


Figure 2 represents the measured axis power for wind speeds between 4m/s and 8m/s for the three types of wind turbines. Figure 3 represents the neutrosophic histogram of the on-axis power of the wind turbines. Recall that a neutrosophic histogram like the neutrosophic numbers contains a determinate part (represented in blue in Figure 3) and an indeterminate part (represented in orange).

Table 1 contains more details of the experiment results.

Table 1. Comparison of power generation of the three wind turbines.

Wind turbine model	**Aerodynamic coefficient**	**Air density (kg.m $^{-3}$)**	**Area (m ^{2})**	**Relative air speed (m/s)**	**Theoretical power in the axis (watts)**	**Power in the axis with simulation (watts)**
Darrieus H.	1.33	0.909	0.106	4	0.61	0.52
				5	1.19	1.13
				6	2.05	1.98
				7	3.26	3.05
				8	4.86	4.14

Wind turbine model	Aerodynamic coefficient	Air density (kg.m $^{-3}$)	Area (m^2)	Relative air speed (m/s)	Theoretical power in the axis (watts)	Power in the axis with simulation (watts)
Savonius	23	0.909	0.14045	4	1.39	1.22
				5	2.72	2.53
				6	4.70	3.89
				7	7.46	6.41
				8	11.14	10.08
Windside	2.35	0.909	0.11	4	1.11	1.52
				5	2.18	2.25
				6	3.76	3.89
				7	5.97	6.72
				8	8.91	10.12

From the previous results we have that for the Darrieus H. the power generated is $[0.52, 4.14] = 0.52 + 3.62I$; for the Savonius it is $[1.22, 10.08] = 1.22 + 8.86I$ and for the Windside it is $[1.52, 10.12] = 1.52 + 8.6I$. Therefore it is evidently preferred the Windside concerning the power, closely followed by Savonius. As for speeds of wind of 5m/s Savonius generated more power than Windside we compared the averages of the powers in both and the results were 4.826 Watts for the Savonius and 4.9 Watts for the Windside, so it confirms the decision made that the latter is the one that generates the most current electric.

However, this is only one factor, there are others like the efficiency of each of the models, the maintenance cost, in addition to the current power it generates and the durability.

We evaluate the three types of wind turbines $A_1 =$ Darrieus H., $A_2 =$ Savonius, and $A_3 =$ Windside for $C_1 =$ Power, $C_2 =$ Efficiency, $C_3 =$ Maintinance cost, $C_4 =$ Durability. The evaluations are shown in Table 2.

Table 2. Evaluation of the three types of wind turbines with respect to four criteria, namely: Power, Efficiency, Maintenance cost, and Durability.

Wind turbine	C_1(Watts)	C_2(%)	C_3(% initial cost)	C_4(Years)
Darrieus H.	$0.52 + 3.62I$	$30 + 10I$	$1 + I$	$20 + I$
Savonius	$1.22 + 8.86I$	$10 + 7I$	$1 + I$	$25 + 5I$
Windside	$1.52 + 8.6I$	$11 + 7I$	$1 + I$	$25 + 4I$

3 experts were hired, who were asked to determine the weights of each of the 4 criteria for decision making. $W = [w_1, w_2, w_3, w_4]$. Among them, they reached a consensus such that $w_1 = 0.2$, $w_2 = 0.3$, $w_3 = 0.2$, $w_4 = 0.3$. Note that the values of the weights are in the interval $[0, 1]$ and satisfy the condition $\sum_{j=1}^{4} w_j = 1$.

From Equations 2 and 3 we have:

$A^* = \{f_1^*, f_2^*, f_3^*, f_4^*\} = \{10.12, 40,1,30\}$, $A^- = \{f_1^-, f_2^-, f_3^-, f_4^-\} = \{0.52,10,2,20\}$.

Then, the intervals $[S_i^L, S_i^U]$ and $[R_i^L, R_i^U]$ are calculated with the help of Equations 4-7:

$S_1 = [0.39458, 0.8]$, $R_1 = [0.39458, 0.8]$; $S_2 = [0.23083,0.83542\ ]$, $R_2 = [0.23083,0.83542]$; $S_3 = [0.25, 0.81917]$, $R_3 = [0.25,0.81917]$.

From Equations 8-11 it is calculated:

$Q_1 = [0.27084, 0.94141] = 0.27084 + 0.67057I$, $Q_2 = [0, 1] = I$, and $Q_3 = [0.031707, 0.973122] = 0.031707 + 0.94142I$.

According to the order defined in the algorithm for $\alpha = 0.5$, there is, Q_2 is the minimum, followed by Q_3, and ends Q_1.

That is, according to a more complete analysis, the Savonius model is preferred, then Windside, and finally Darrieus H.

Conclusion

Neutrosophic tools, such as neutrosophic numbers were used to model the indeterminacy that exists in the ranges of variation in wind speeds, which implies changes in the watts of electrical energy generation. A simulation of three types of wind turbines was carried out in a wind tunnel, these are: Darrieus H., Savonius and Windside. As a result, the Windside vertical axis wind turbine is the one that has the best performance and generates greater power compared to the other wind turbines that were studied.

On the other hand, we use the VIKOR Indeterminate decision-making method, which basically consists of the VIKOR algorithm for interval numbers, adapted to neutrosophic numbers. The 3 types of wind turbines were compared with respect to 4 criteria, which are: Power, Efficiency, Maintinance cost, and Durability. Three experts served as support to assign weights to each of the criteria. The result is that the Savonius type is preferred over the others.

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University of New Mexico

Preserving Freedom in the Digital Age: A Neutrosophic Exploration of Online Privacy and Security Measures

María Elena Infante Miranda[1], Nelson Francisco Freire Sánchez[2], Rene Estalin Portilla Paguay[3], and Erick González Caballero[4]

[1] Universidad Regional Autónoma de los Andes, Ibarra. Ecuador. E-mail: ui.mariainfante@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Riobamba. Ecuador. E-mail: ur.nelsonfreire@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Tulcán, Ecuador. E-mail: ut.renepp25@uniandes.edu.ec
[4] Member, Asociación Latinoamericana de Ciencias Neutrosóficas, La Habana, Cuba. E-mail: erickgc@yandex.com

Abstract. Online privacy is a topic that directly impacts individual freedom, and its protection is crucial to ensure security and individual liberties. It affects the safeguarding of personal information, freedom of expression, access to information, protection against surveillance, and protection against online manipulation. This work aims to address issues of online privacy and the balance between security and individual liberties. To achieve this, the neutrosophic COPRAS method was employed to evaluate strategies that involve the creation of specific regulations and policies to protect the online privacy of citizens. The study concluded that public-private collaboration and ongoing dialogue are essential for developing fair and effective solutions that benefit society as a whole.

Keywords: Online privacy, individual freedom, personal information, Neutrosophy.

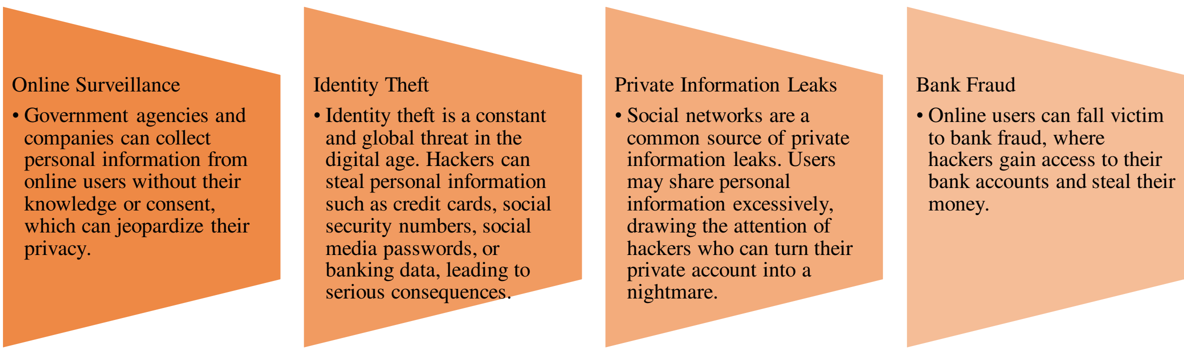
1 Introduction

Online privacy and the balance between security and individual liberties have become increasingly important issues in the digital age. As technology advances rapidly, daily life is becoming more intertwined with the online world, raising critical issues related to the protection of personal data, privacy, and cybersecurity. In this context, the need to ensure people's privacy online without compromising security has become a fundamental challenge for governments, businesses, and citizens alike.

On one hand, cybersecurity has become an urgent priority, as cyberattacks and online threats are becoming more sophisticated and frequent. Protecting online systems and infrastructure is crucial to maintaining the integrity of business operations, critical infrastructure, and ultimately, national security. However, these security measures should not jeopardize individual freedoms or undermine people's privacy. In the case of Ecuador, the Constitution of the Republic, in Article 66, paragraphs 19 and 20, establishes the right to the protection of personal data and the right to personal and family privacy [1].

On the other hand, online privacy is a fundamental right that is in constant tension with the need to protect oneself from cyber threats. Companies and organizations collect large amounts of personal data, raising questions about how this data is used and shared and whether individuals have real control over their information. Regulation and transparency are crucial to ensuring that people can make informed decisions about their online privacy.

Figure 1. Main threats to privacy. Source: own elaboration.



In this context, the conversation about balancing cybersecurity with privacy protection has become increasingly relevant. Regulation, cybersecurity education, sector collaboration, and the promotion of privacy technologies are just a few strategies used to address this challenge. Achieving an appropriate balance between online security and individual freedoms is essential to ensure that people can enjoy the benefits of the digital age without compromising their fundamental rights. This is a complex but essential task that requires a multi-disciplinary approach and active participation from society as a whole.

The Ecuadorian state has sanctioning laws that are restrictive for society; however, when society presents illicit acts, it adapts with the criminal type to obtain not only the execution of the act itself but also a proportionate sanction. Thus, the Comprehensive Organic Criminal Code sanctions the crime of Invasion of Privacy, in its Article 178a, stating that a person who, without consent or legal authorization, accesses, intercepts, examines, retains, records, reproduces, disseminates, or publishes personal data, data messages, voice, audio and video, postal objects, information contained in computer media, private or reserved communications of another person by any means, is subject to penalties [2].

Today, within social networks, the violation of personal privacy through the publication or dissemination of intimate content is increasingly common. It is asserted that the Ecuadorian state does not guarantee the protection of personal data, and those who engage in these actions do not receive the sanctions established by law. In the Ecuadorian state, neither the legal nor the technological security and privacy of personal information leaked on social networks are guaranteed.

In the digital age, privacy has become a matter of great importance due to the vast amount of personal information shared online. Privacy on the internet has always been a controversial issue. This is a fundamental right that must be protected both outside and inside the internet, as many users are unaware of who accesses their personal information and how it is used.

The use of the internet has popularized a series of rights such as freedom of information and freedom of expression. At the same time, it has posed serious risks to the integrity of other fundamental rights, no less important, such as the right to the protection of personal data and the right to privacy, i.e., those that affect the sphere of people's privacy [3]. Social networks, like almost all phenomena of great relevance to human groups, act as double-edged swords.

One constant threat of internet use is identity theft, but some measures can be taken to prevent it. Here are some ways to prevent identity theft:

1. Protect Personal Information: Keep your financial records, Social Security and Medicare cards, and any other documents with personal information in a secure place. When you decide to discard these documents, shred them before throwing them away. If you receive account statements with personal information by mail, retrieve your mail from the mailbox as soon as possible.
2. Monitor Your Bank and Credit Accounts: Regularly review your bank and credit accounts for suspicious activity. If you notice anything unusual, contact your bank or credit card company immediately.
3. Change Your Passwords Regularly: It's important to change your passwords regularly and use secure and unique passwords for each account.
4. Download Apps from Official Sites: Make sure to download apps only from official sites and avoid using computers in cybercafés or connecting to public networks.
5. Enable Facial Recognition or Fingerprint: Use these tools to unlock your mobile device, as only you will be able to activate it.

To identify if you have been a victim of identity theft, you should be vigilant for warning signs. These may include charges or purchases you didn't make, bills or collection notices for services you didn't sign up for, calls or emails from companies you haven't contacted, notifications of credit or debt you didn't request, inability to access online accounts, and notifications of address changes you didn't initiate. If you suspect you've been a victim of identity theft, it's important to take immediate steps to protect yourself and recover the stolen information.

Once you suspect you have fallen victim to identity theft, it's crucial to take immediate action to minimize the damage. Some of these actions include:

- Contact the fraud department of the companies, banks, or credit unions where compromised accounts exist. Explain that you have been a victim of identity theft and request them to close or freeze the compromised account.
- Reach out to the police department to report the crime and obtain a police report.
- Visit the website of the Federal Trade Commission where you can report identity theft and create a plan for recovery after identity theft.
- Decide whether to freeze the credit report for security.
- Place a fraud alert or freeze the credit report.
- Change passwords for all online accounts.
- Review bank and credit card statements for any suspicious activity.
- Notify major credit bureaus to place fraud alerts and freeze credit.

- Document all unauthorized transactions and be patient, as the process may take several months.

To identify if a website is secure before sharing personal information, you can check the SSL certificate. You should analyze if the site looks trustworthy, use only trusted websites, read the privacy policy, verify the contact information, look for reviews and comments, and use antivirus software and a firewall.

The protection of privacy is generally recognized in Article 12 of the Universal Declaration of Human Rights. Two decades later, the Covenant on Civil and Political Rights was signed in New York, and Article 17 determines that no one shall be subjected to arbitrary or unlawful interference with their privacy, family, home, or correspondence, nor illegal attacks on their honor and reputation. (...) Everyone has the right to the protection of the law against such interference or attacks. The privacy of children and adolescents [4].

Scammers use a range of methods, from traditional ones like stealing your mail to high-tech approaches such as cyberattacks on banks, retailers, and other companies storing consumer data. They may pretend to be from utility companies, banks, or major tech firms to obtain personal information or send phishing emails with links that can infect your device with data-collecting malware.

Online education is crucial to teach users about online privacy and how to protect their personal information. Online users must be aware of the risks and know how to safeguard themselves. They should be familiar with online rights to protect individual freedom, express themselves without fear of censorship or persecution, and access the internet without discrimination based on race, gender, religion, or any other factor.

On the other hand, the digitization of education has brought many benefits but has also raised concerns about student privacy. Children and adolescents are particularly vulnerable to privacy violations. Current education styles set expectations where students must be more actively involved and engage in flexible communication scenarios that allow them to learn independently regardless of place and time.

Given recent privacy breaches involving mobile apps and geolocation services, privacy advocates have intensified their message, warning citizens about the dangers associated with apps designed to combat COVID-19. These warnings, combined with the widespread desire for privacy among mobile device users, jeopardize the effectiveness of these apps. Convincing people to participate and install these apps poses a challenge for public health authorities and technology providers [5].

Identity theft is a growing crime that affects millions of people each year. It is important to take measures to protect personal information and minimize the impact of this crime. The protection of personal data in the field of information and telecommunications services is a topic that requires attention. Therefore, it is necessary to identify regulations, techniques, and tools that safeguard and effectively ensure the protection of the personal data of users of convergent services.

Online privacy and the balance between security and individual freedoms are issues of critical importance in today's society. With the continuous advancement of technology, the way information is shared, communicated, and transactions are conducted has undergone a radical change. Digitization has led to an exponential growth in the amount of personal data generated and stored online, raising concerns about how this data is handled and protected.

Therefore, the general objective of this research is to address issues of online privacy and the balance between security and individual freedoms.

Specific objectives:

- Develop clear and equitable online privacy policies.
- Promote public awareness of the importance of online privacy.

2 Materials and methods

2.1Neutrosophic COPRAS Method

The Neutrosophic COPRAS (Classificatory and Ordinal Positional Ranking Algorithm by Similarity) [6, 7] is a mathematical method used in multicriteria decision-making, where different criteria are combined, and neutrosophic weights are assigned to classify and rank alternatives [8-13]. It is applied in complex situations where multiple factors, criteria, and the inclusion of indeterminacy must be considered to evaluate and select options.

Before delving into the Neutrosophic COPRAS method, it is essential to define the neutrosophic set under analysis. This set is characterized by the elements: true υ, indeterminate φ, and false ϕ of x in h, respectively, and their images constitute standard or non-standard subsets within the range (0;1). For X in the universe of discourse, the neutrosophic set of a unique value h on X is defined as an object in the representation $h = \{\langle x, \upsilon_h(x), \varphi_h(x), \phi_h(x)\rangle : x \in X\}$ [9-14]. Where $\upsilon_h(x), \varphi_h(x), \phi_h(x)$ satisfy the following condition $0 \leq \upsilon_h(x) + \varphi_h(x) + \phi_h(x) \leq 3$ for all $x \in X$. For modeling the neutrosophic COPRAS method, each neutrosophic number is expressed in the form (*c, d, e*). Therefore, it is defined as follows:

- c= $\upsilon_h(x)$ for the true membership functions.
- $d = \varphi_h(x)$ for the indeterminate membership functions.

- $e = \phi_h(x)$ for the false membership functions.

The neutrosophic number defined for the study is determined as $h = (c, d, e)$, where c, d, e, ∈ $\{0,1\}$, and it satisfies the following condition: $0 \leq c + d + e \leq 3$. Thus, the scoring function Y of a neutrosophic number is defined by the following equation [10]:

$$Y(h) = \frac{1 + c - 2d - e}{2} \quad (1)$$

The Neutrosophic COPRAS method involves the following mathematical methodology:

- Criteria and alternatives are defined: The relevant criteria and alternatives to evaluate and compare are identified.
- Assignment of weights to the criteria: The relative weights of each criterion are determined to reflect their importance in decision-making (Table 1).

Table 1. Neutrosophic linguistic terms used to evaluate the criteria. Source: own elaboration.

Linguistic term	SVNN
Very Important (VI)	(0.95,0.15,0.14)
Important (I)	(0.7,0.2,0.25)
Medium (M)	(0.50,0.55,0.5)
Not Important (NI)	(0.3,0.8,0.80)
Not Very Important (VNI)	(0.10,0.90,0.95)

- Evaluation of alternatives: The alternatives are evaluated for each criterion and a score is assigned (see Table 2).

Table 2. Linguistic terms used to determine and evaluate the proposed alternatives. Source: own elaboration.

Criterion	SVNN
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9,0.1,0.1)
Very good (VG)	(0.8,0.15,0.2)
Good (G)	(0.7,0.25,0.3)
Moderately good (MDG)	(0.6,0.35,0.4)
Medium (M)	(0.5,0.5,0.5)
Moderately bad (MDB)	(0.4,0.65,0.6)
Bad (B)	(0.3,0.75,0.7)
Very bad (VB)	(0.2,0.85,0.8)
Very very bad (VVB)	(0.1,0.9,0.9)
Extremely bad (EB)	(0,1,1)

- Normalization of scores: Scores are normalized to ensure that all alternatives are comparable.
- Calculation of the association rules matrix: The association rules matrix is used to combine normalized scores and criteria weights to calculate a final score for each alternative.
- Ordering of alternatives: The alternatives are ordered based on their final score to determine the best option.

Furthermore, the COPRAS Neutrosophic method is capable of simultaneously delineating ratios between the ideal and the worst solutions, in a step-by-step classification and evaluation of the alternatives in terms of their neutrosophic importance and degree of usefulness [11-15]. The COPRAS Neutrosophic method algorithm consists of the following steps:

Step 1: Calculation of the normalized decision matrix x^*_{hij}, using equation (1).

$$x^*_{hij} = \frac{x_{hij}}{\sum_{i=1}^{m} x_{hij}} \quad (2)$$

Step 2: Determine the weighted normalized decision matrix D_{hij}, according to equation (2).

$$D_{hij} = x^*_{hij} \cdot w_{hj} = \begin{bmatrix} w_{h1}\, x_{h11} & w_{h2}\, x_{h12} & \cdots & w_{h1}\, x_{h1n} \\ w_{1h}\, x_{h21} & w_{h2} x_{h22} & \cdots & w_{h1}\, x_{h2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_{h1}\, x_{hm1} & w_{h2} x_{hm2} & \cdots & w_{hn}\, x_{hmn} \end{bmatrix} \quad (3)$$

Where x^*_{hij} is the value of the normalized performance of i_{th} alternatives in j_{th} criteria and w_{hj} is the weight associated with the j_{th} criteria.

Step 3: The sums S_{i+} and S_{i-} of the weighted normalized values are calculated for both the beneficial (B) and non-beneficial (NB) criteria respectively. These sums S_{i+} and $S_{i-}$are calculated by equations (1), (4) and (5) respectively.

$$S_{i_+} = \sum_{k=1}^{k} D_{ij} \quad (4)$$

$$S_{i_-} = \sum_{k=1}^{k} D_{ij} \quad (5)$$

Step 4: Determine the relative importance of the alternatives Q_i using Equation (6).

$$Q_i = S_i + \frac{\sum_{j=1}^{m} s_{i-}}{s_{i-} \sum_{j=1}^{m} \frac{1}{s_{i-}}} \quad (6)$$

The relative importance Q_i of an alternative shows the degree of satisfaction achieved by this alternative.

Step 5: Calculation of the performance index P_i of each alternative, using Equation (7):

$$P_i = \frac{Q_i}{Q_{max}} \cdot 100 \quad (7)$$

Where Q_{max} is the maximum value of relative importance. The performance index value P_i is used to obtain a complete ranking of the candidate alternatives.

Finally, the neutrosophic COPRAS method allows combining different criteria and weights to evaluate and select alternatives in complex multi-criteria decision-making situations with the inclusion of the indeterminacy of the solution [12-16-17].

3 Results

Method Development

To choose the best alternative, there are 5 important criteria to consider:

Cybersecurity - C1
Right to online privacy - C2
Protection of personal data - C3
Access to public information - C4
Governmental oversight - C5

Alternatives

1. Cybersecurity education: Promote education and awareness about cybersecurity to empower individuals to better protect themselves online.
2. Online privacy laws: Establish regulations and laws that safeguard the right to online privacy, limiting the collection and use of personal data without consent.
3. Data protection regulation: Implement robust regulations to ensure the protection of personal data, including measures to prevent data breaches and misuse.
4. Public information access portal: Create an online portal that facilitates access to public information to promote government transparency and empower citizens.
5. Independent oversight: Establish an independent government oversight body to ensure compliance with cybersecurity, data protection, and online privacy standards, holding the government accountable for adhering to these standards.

This section explores the general causes affecting online privacy and presents the results of the conducted study.

Table 3. Alternatives.

Alternatives	Cyber security	Right to privacy online	Personal data protection	Access to public information	Government oversight
	C1	**C2**	**C3**	**C4**	**C5**
A1	(0.6,0.35,0.4)	(0.4,0.65,0.6)	(0.3,0.75,0.7)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
A2	(0.4,0.65,0.6)	(0.5,0.5,0.5)	(0.6,0.35,0.4)	(0.6,0.35,0.4)	(0.5,0.5,0.5)
A3	(0.5,0.5,0.5)	(0.7,0.25,0.3)	(0.3,0.75,0.7)	(0.4,0.65,0.6)	(0.3,0.75,0.7)
A4	(0.4,0.65,0.6)	(0.3,0.75,0.7)	(0.4,0.65,0.6)	(0.3,0.75,0.7)	(0.4,0.65,0.6)
A5	(0.4,0.65,0.6)	(0.7,0.25,0.3)	(0,1,1)	(0.4,0.65,0.6)	(0.7,0.25,0.3)

Table 4. Calculation of the normalized decision matrix x_{ij}^{*}.

Alternatives	C1	C2	C3	C4	C5
A1	(0.2,0.85,0.8)	(0,1,1)	(0,1,1)	(0.2,0.85,0.8)	(0.2,0.85,0.8)
A2	(0,1,1)	(0.2,0.85,0.8)	(0.3,0.75,0.7)	(0.3,0.75,0.7)	(0.2,0.85,0.8)
A3	(0.2,0.85,0.8)	(0.2,0.85,0.8)	(0,1,1)	(0.2,0.85,0.8)	(0,1,1)
A4	(0,1,1)	(0,1,1)	(0.2,0.85,0.8)	(0,1,1)	(0,1,1)
A5	(0,1,1)	(0.2,0.85,0.8)	(0,1,1)	(0,1,1)	(0.3,0.75,0.7)

Table 5. Weighted normalized decision matrix D_{ij}.

	C1	C2	C3	C4	C5
Weight	**(0.3,0.8,0.80)**	**(0.10,0.90,0.95)**	**(0.3,0.8,0.80)**	**(0.10,0.90,0.95)**	**(0.10,0.90,0.95)**
A1	(0.6,0.35,0.4)	(0.2,0.85,0.8)	(0.4,0.65,0.6)	(0.3,0.75,0.7)	(0.3,0.75,0.7)
A2	(0.4,0.65,0.6)	(0.3,0.75,0.7)	(1,0,0)	(0.4,0.65,0.6)	(0.3,0.75,0.7)
A3	(0.5,0.5,0.5)	(0.4,0.65,0.6)	(0.5,0.5,0.5)	(0.3,0.75,0.7)	(0.2,0.85,0.8)
A4	(0.4,0.65,0.6)	(0,1,1)	(0.7,0.25,0.3)	(0.2,0.85,0.8)	(0.2,0.85,0.8)
A5	(0.4,0.65,0.6)	(0.4,0.65,0.6)	(0,1,1)	(0.2,0.85,0.8)	(0.4,0.65,0.6)
Classification	**B**	**B**	**B**	**NB**	**B**

Table 6. Determine S_{i-}, S_{i+}, Q_i and P_i.

	S_{i+}	S_{i-}	$1/S_{i-}$	Q_i	P_i	Ranking
Maximum				2,239		
A1	1,736	0.327	3.058103976	1995	89.1%	**4**
A2	2,042	0.429	2.331002331	2,239	100.0%	**1**
A3	1,702	0.288	3.472222222	1996	89.2%	**3**
A4	1,597	0.2055	4.866180049	2009	89.7%	**2**
A5	1.4215	0.2505	3.992015968	1,759	78.6%	**5**
Total		**1,500**	**17,720**			

After applying the Neutrosophic COPRAS method, it has been determined that alternative A2 is the one that best fits the established criteria, as it has the highest weighted score. This weighted score is obtained from a combination of the scores assigned to each alternative for each criterion and the previously established weights for the criteria.

Recommendations are proposed that can contribute to effectively addressing online privacy issues and balance security with individual freedoms.

- Develop robust regulations: Implement strong laws and regulations that protect online privacy and balance cybersecurity with individual freedoms. These regulations should address the collection and use of personal data, as well as required security measures.
- Promote cybersecurity education: Encourage cybersecurity education from an early age so that people are aware of online threats and know how to protect their personal information.
- Foster transparency: Organizations and companies should be transparent about how they collect, use, and share individuals' data. This includes providing clear consent options and allowing users to control their data.
- Promote the adoption of privacy technologies: Encourage the adoption of technologies that protect privacy, such as the use of virtual private networks (VPNs), privacy-focused browsers, and encrypted email services.
- Drive research in cybersecurity and privacy: Invest in research and development in the field of online cybersecurity and privacy to proactively address emerging threats and develop effective solutions.
- Foster public-private collaboration: Encourage cooperation between the government, businesses, and civil society to effectively address online privacy and cybersecurity challenges.
- Protect individual rights: Ensure that any cybersecurity measure does not violate individual rights, such as freedom of expression and privacy.
- Audits and supervision: Conduct regular audits and supervision of organizations' data collection and usage practices to ensure compliance with privacy regulations.
- Incentives for compliance: Establish appropriate incentives and sanctions to encourage organizations to comply with online privacy regulations.
- Promotion of user responsibility: Educate users about the importance of being aware of their online security and taking steps to protect their data.

Conclusion

Online privacy is crucial to protect the freedom of expression of online users and to ensure that they can access the Internet without being discriminated against based on their race, gender, religion, or any other factor. Protecting online privacy is crucial to guarantee individual freedom and the integrity of democracy. It is essential to create laws and regulations that safeguard the privacy and online rights of users and to educate them about online privacy and how to protect their personal information. Privacy is a fundamental right that must be protected to ensure individual freedom and online security.

The use of single-valued neutrosophic numbers for analysis certified the practical use and application of neutrosophic set logic. It allowed for the inclusion of uncertainty, indeterminacy, and the use of linguistic terms. The conclusion drawn was that the alternative "Online Privacy Laws (A2)" has the highest score. Therefore, it is necessary to establish regulations and laws that protect the right to online privacy.

Balancing security and privacy is a constant challenge. In an increasingly interconnected and digitized world, balancing cybersecurity with privacy protection is an ongoing challenge. Policies and regulations must be flexible and adaptable to address constantly evolving threats without excessively compromising individual freedoms.

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Neutrosophic Assessment of Corporate Responsibility in Ecuador's Environmental Context

Carlos Gilberto Rosero Martínez [1], Ingrid Joselyne Díaz Basurto [2], Francisco Alejo Guanoluisa Almache [3] and Jean Pierre Ramos Carpio [4]

[1] Universidad Regional Autónoma de Los Andes, Tulcán. Ecuador. E-mail: ut.carlosrosero@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Quevedo. Ecuador. E-mail: uq.ingrdidiaz@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Ibarra. Ecuador. E-mail: ui.franciscog@uniandes.edu.ec
[4] Centro de Estudios para la Calidad Educativa y la Investigación Científica, México. E-mail: jeanpierrer88@gmail.com

Abstract. Currently, the environmental situation in Ecuador faces significant challenges due to the interaction of companies with the surroundings. The need to mitigate environmental damage in a context of indeterminacy and complexity becomes a priority. Under a neutrosophic approach, this study aimed to evaluate the responsibility of companies in cases of environmental damage in Ecuador. The results obtained from the neutrosophic Entropy method reveal a balance between certainty and indeterminacy in the assessment of criteria such as the severity of environmental damage and regulatory compliance. Collaboration and effective regulation emerge as essential, as well as the importance of ongoing assessment. Additionally, the neutrosophic Aras method addresses and highlights the indeterminacy of the issue and emphasizes the need for fair and consistent environmental management to promote corporate responsibility in protecting Ecuador's environment.

Keywords: environmental damages, regulatory compliance, community impact, corporate responsibility.

1 Introduction

In recent decades, the debate regarding corporate responsibility in the event of environmental damage has gained significant prominence in both society and the academic sphere [1]. The escalating concern for environmental conservation has prompted scrutiny of the role of businesses and their responsibility in safeguarding natural resources. Of particular note is that in Ecuador, instances of environmental damage caused by companies have been documented across various sectors and geographic regions. These include:

- The oil sector in the Amazon: Ecuador has experienced significant environmental damage in the Amazon region due to oil extraction. Oil spills and resulting pollution have affected indigenous communities and the region's biodiversity [2].
- Mining in Zamora-Chinchipe: Mining, particularly gold mining, has been a source of concern in the province of Zamora-Chinchipe. Although environmental damage has been reported, its exact magnitude and extent may be uncertain due to a lack of complete data and variability in the application of environmental regulations (indeterminacy).
- Agriculture and pesticide use: The use of pesticides and fertilizers in agriculture has resulted in soil and water contamination in various regions of Ecuador [3]. These cases have been documented and steps have been taken to address the problem.
- Pollution in the Guayas River Basin: The Guayas River basin, which includes the city of Guayaquil, has experienced high levels of pollution, primarily due to industrial activity and urban growth. This contamination is a well-established concern within the analysis.
- Mineral extraction in El Cobre: The mineral extraction project in El Cobre, in the province of Azuay, has generated controversy. Some claim it has caused significant environmental damage, while others argue that steps have been taken to minimize its impact. The situation is the subject of debate that presents levels of indetermination existing in the variability of the criteria (indeterminacy).
- Industrial fishing in Galapagos: Industrial fishing around the Galapagos Islands has raised concerns about sustainability and potential damage to the marine ecosystem [4] [5]. The exact assessment of these damages may be uncertain in the results presented to the study (indeterminacy).
- Deforestation in the coastal region: Deforestation in the coastal region of Ecuador has been a well-documented problem, with the conversion of forests to agricultural and urban land [6]. The evidence supports the existence of environmental damage.

These examples illustrate the impact of environmental damage in different regions of Ecuador. The information reveals levels of indeterminacy regarding the quantification of damages, the obtained information, and contradictions in possible impacts. Therefore, it should be analyzed through the application of neutrosophy to assess certainty or indeterminacy in data related to environmental damages caused by Ecuadorian companies. The variety of neutrosophic degrees reflects the complexity and diversity of the situation in the country in recent years.

Another point to analyze is focused on the regulations governing responsibility for environmental damage in Ecuador. In general, these regulations establish the obligation of companies to repair environmental damages. Additionally, they set forth the sanctions and measures that can be applied in case of non-compliance with these obligations. The following regulations are outlined:

- The Constitution of the Republic of Ecuador of 2008 recognizes the rights of nature and establishes the obligation of the State and individuals to protect the environment and restore affected ecosystems.
- The Environmental Management Law establishes standards for environmental management in the country and defines environmental damage as any significant loss, decrease, detriment, or impairment of pre-existing conditions in the environment or one of its components.
- The Mining Law establishes the obligations and responsibilities of mining companies concerning the environment.
- The Prevention and Environmental Control Law sets standards for the prevention and control of environmental pollution [7].
- The Water Law establishes standards for the management and use of water in the country.
- The Forest Law establishes standards for the conservation and sustainable use of forests.

In Ecuador, various legal actions can be taken to establish responsibility for environmental damage. Some of these actions include:

- Civil actions: Civil actions aim to repair environmental damage caused by the company. These actions can be filed by any person or entity that has suffered environmental damage and may include claims for compensation for the damages incurred.
- Criminal actions: Criminal actions seek to sanction the company for the environmental crime committed. These actions can be brought by the Ministry of the Environment or by any person who is aware of the commission of the crime.
- Administrative actions: Administrative actions seek to sanction the company for the violation of environmental regulations. These actions can be filed by the Ministry of the Environment or by any entity responsible for environmental monitoring and control.
- Protective actions: Protective actions aim to protect the environmental rights of individuals and nature. These actions can be brought by any person or entity that believes their environmental rights are being violated.

In general, these actions seek to establish corporate responsibility for environmental damage and pursue their remediation. Moreover, these actions may include sanctions and measures to prevent the recurrence of such damage in the future. This highlights the need for ongoing assessment and strengthened efforts to ensure increased effectiveness in promoting corporate environmental responsibility in Ecuador [8-19-20]. Therefore, the main objective of this study is to:

- Evaluate corporate responsibility in cases of environmental damage through a neutrosophic analysis approach.

2 Methods

2.1 Neutrosophic analysis

The neutrosophic set is defined by the following elements: true α, indeterminate β, and false γ of x in G, respectively and their images constitute standard or non-standard subsets within the range $\{0,1\}$. For X of the universe of discourse, it is defined from the single-valued neutrosophic set G over X as an object in the representation $G = \{\langle x, \alpha_G(x), \beta_G(x), \gamma_G(x)\rangle : x \epsilon X\}$.

Where $\alpha_G(x), \beta_G(x), \gamma_G(x)$ satisfy the following condition for all $x \in X$. So, to define each Single Valued Neutrosophic Number (SVNN), it is expressed as follows: $G = (o, i, z)$ for the modeling of the study.

Therefore, $o = \vartheta_G(x)$, $i = \beta_G(x)$, and $z = \gamma_G(x)$ correspond to the true, indeterminate, and false membership functions, respectively.

To determine a point within the neutrosophic set Y(G) from a number (G), we proceed to use the formula proposed by Smarandache or the formula proposed by Basset, according to equations (1) and (2).

$$Y(G) = o + z - i \tag{1}$$

$$Y(G) = \frac{o + z - i}{2} \tag{2}$$

For the modeling of the methods and evaluation of the criteria, they are defined according to the scales shown in Table 1.

Table 1: Linguistic terms that represent the weight of the importance of the criteria. Source: own elaboration.

Linguistic scale	SVNN (o, i, z)
Very High (VH)	(0.95,0.15,0.14)
High (H)	(0.7,0.2,0.25)
Medium (M)	(0.50,0.55,0.5)
Low (L)	(0.3,0.8,0.80)
Very Low (VL)	(0.10,0.90,0.95)

For the evaluations concerning the alternatives and criteria, an importance scale is defined for each SVNN according to the scales shown in Table 2.

Table 2: Linguistic terms that represent the neutrosophic weight of the alternatives and criteria obtained. Source: own elaboration.

Linguistic term	SVNN
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.95,0.05,0.15)
Very good (VG)	(0.85,0.15,0.25)
Good (G)	(0.75,0.25,0.35)
Moderately good (MDG)	(0.65,0.35,0.45)
Medium (M)	(0.55,0.45,0.55)
Moderately bad (MDB)	(0.45,0.55,0.65)
Bad (B)	(0.35,0.65,0.75)
Very bad (VB)	(0.25,0.75,0.85)
Very very bad (VVB)	(0.15,0.85,0.95)
Extremely bad (EB)	(0,0.95,1)

2.2 Neutrosophic entropy

This method was proposed by Zeleny in 1982. It assumes that the neutrosophic importance of a criterion should be proportional to the amount of information inherently provided by the set of alternatives regarding that criterion [9]. Neutrosophic entropy measures uncertainty and indeterminacy in the information formulated using probability theory. It indicates that a broad distribution represents more indeterminacy than one with pronounced peaks.

The greater the diversity in evaluations (values) of alternatives, the more importance that criterion should have in the final decision, as it has greater discrimination power among alternatives [10]. The method measures the diversity and indeterminacy of a criterion through entropy. The calculated entropy is higher when the evaluations of the considered alternatives are more similar. For the development of the neutrosophic entropy method, it is calculated in the following steps:

Step 1. Construction of the decision matrix (see Figure 1).

Figure 1: Neutrosophic entropy decision matrix. Source: own elaboration.

$$\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

Step 2. Calculation of the normalized decision matrix P_{ij}, the objective of normalization is to obtain dimensionless values of different criteria to make comparisons between them. It is calculated using Equation (3).

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{3}$$

Step 3. Calculation of entropy E_j, using Equation (4)

$$E_j = -k\left(\sum_{i=1}^{m} P_{ij} ln(p_{ij})\right), donde\ t = 1, 2, 3, \ldots, n. \tag{4}$$

Where $k = \frac{1}{\ln m}$ is a constant that guarantees $0 \leq E_j \leq 1$ and m is the number of alternatives.

Step 4. Calculation of criterion diversity D_j, Equation (5) allows this parameter to be calculated.

$$D_j = 1 - E_j \tag{5}$$

Step 5. Calculation of the normalized weight W_j of each criterion, using Equation (6).

$$W_j = \frac{D_j}{\sum_{i=1}^{m} D_j} \tag{6}$$

2.3 Aras neutrosophic

The neutrosophic ARAS method determines the complex relative efficiency of a feasible alternative is directly proportional to the relative effect of the values and weights of the main criteria considered [11]. By relying on the theory of utility and the analysis of the neutrosophic Aras [12], the steps of this method are described below:

Step 1: Formation of the decision matrix L_{ij} (see Figure 2).

Figure 2: Decision matrix L_{ij} of the neutrosophic Aras method. Source: own elaboration.

$$\begin{bmatrix} l_{11} & l_{12} & \cdots & l_{1j} & \cdots & l_{1n} \\ l_{21} & l_{22} & \cdots & l_{2j} & \cdots & l_{2n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ l_{i1} & l_{i2} & \cdots & l_{ij} & \cdots & l_{in} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ l_{m1} & l_{m2} & \cdots & l_{mj} & \cdots & l_{mn} \end{bmatrix}$$

Step 2: Calculation of the normalized decision matrix $\bar{L}_{ij}$, taking into account the beneficial (B) and non-beneficial (NB) values, it is calculated using Equation (7) and (8):

$$\bar{L}_{ij} = \frac{l_{ij}}{\sum_{i=0}^{m} l_{ij}} \tag{7}$$

$$L_{ij} = \frac{1}{l_{ij}^{*}} \tag{8}$$

Step 3: Calculation of the weighted normalized decision matrix is calculated with Equation (9) and in Figure 3.

$$\hat{L}_{ij} = \bar{L}_{ij} \cdot W_j \tag{9}$$

Figure 3: Normalized decision matrix. Source: own elaboration.

$$\begin{bmatrix} \hat{l}_{11} & \hat{l}_{12} & \cdots & \hat{l}_{1j} & \cdots & \hat{l}_{1n} \\ \hat{l}_{21} & \hat{l}_{22} & \cdots & \hat{l}_{2j} & \cdots & \hat{l}_{2n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{l}_{i1} & \hat{l}_{i2} & \cdots & \hat{l}_{ij} & \cdots & \hat{l}_{in} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{l}_{m1} & \hat{l}_{m2} & \cdots & \hat{l}_{mj} & \cdots & \hat{l}_{mn} \end{bmatrix}$$

Weight values W_j are determined using the Entropy method. Where W_j is the weight of criterion j and $\bar{L}_{ij}$ is the normalized classification of each criterion.

Step 4: Calculation of the optimization function S_i by using Equation (10).

$$S_i = \sum_{j=1}^{n} \hat{L}_{ij} \tag{10}$$

Where S_i is the value of the optimization function of the alternative i. This calculation has a directly proportional relationship with the process of the values $\hat{L}_{ij}$ and weights W_j of the investigated criteria and their relative influence on the final result.

Step 5: Calculation of the degree of utility. This grade is determined by comparing the variant that is being analyzed with the best S_o, according to Equation (11).

$$K_i = \frac{S_i}{S_o} \tag{11}$$

Where S_i and S_o are the values of the optimization function. These values range from 0 to 100%, therefore, the alternative with the highest K_i is the best of the analyzed alternatives [13-17].

3 Results

The preliminary neutrosophic analysis establishes indeterminacies when assessing the effectiveness of corporate environmental responsibility in Ecuador. These government regulations and policies are not applied to their full extent and scope in the country regarding corporate environmental responsibility in cases of environmental damage. The neutrosophic analysis of regulations and the analyzed information defines the inherent indeterminacies in this matter:

- Regulatory Compliance: In terms of the existence of environmental regulations, there is a degree of truth in Ecuador. The country has laws and regulations aimed at protecting the environment and promoting corporate responsibility in this area. This reflects a solid foundation for regulation.
- Implementation of Regulations: The actual effectiveness of the implementation of regulations and government policies is an area of indeterminacy. Although there are regulations on paper, their effective implementation can vary depending on factors such as supervisory capacity, corruption, and industry pressure.
- Imposed Sanctions: Sanctions imposed for environmental damage show a degree of truth in Ecuador. There have been documented cases where companies have faced legal and financial consequences for violating environmental regulations. This reflects a degree of compliance and enforcement.
- Effectiveness in Prevention: The ability of regulations and government policies to prevent environmental damage is an area of indeterminacy. While sanctions have been applied in response to damage, the ability to prevent damage in the first place is variable and, in some cases, questionable.
- Corporate Involvement: The active involvement of companies in promoting environmental responsibility is an uncertain aspect. Some companies may voluntarily engage in responsible practices, while others may resist or minimize their responsibility.

The evaluation of the effectiveness of regulations and government policies regarding environmental responsibility presents levels of existing indeterminacy. This emphasizes the need to promote and enhance actions and best practices to mitigate environmental damage in Ecuador. For this purpose, the following actions and best practices are proposed based on the findings of the preliminary neutrosophic analysis:

I. Strengthening the enforcement of regulations: Existing environmental regulations should be enforced more effectively. This includes stricter supervision, harsher penalties for non-compliance, and a legal framework ensuring that companies comply with regulations.

II. Promoting transparency and citizen participation: Promote transparency in the disclosure of environmental information by companies. This encourages citizen participation in environmental decision-making, improving accountability and responsibility.

III. Incentives for environmental responsibility (Indeterminacy): Fiscal and financial incentives can be established for companies that demonstrate effective commitment to environmental responsibility. The effectiveness of these incentives may vary depending on implementation.

IV. Strengthening education and awareness: Environmental education and public awareness are essential to foster a culture of environmental respect. Awareness campaigns and educational programs can help improve understanding and attitudes toward the environment.

V. Promotion of Corporate Social Responsibility (CSR) (Indeterminacy): Encourage the incorporation of CSR practices into business strategies to mitigate environmental damage in Ecuador.

To select the action or best practice to enhance, criteria for evaluation must be established. In the following neutrosophic method, the entropy values (E_j) for each variable, the diversity of the criterion (D_j), and the normalized weights of each criterion (W_j) are determined at the time of evaluation (see Table 3 to 5).

Development of the Neutrosophic Entropy method

Table 3: Neutrosophic entropy evaluation matrix. Source: own elaboration.

Alternatives	Regulatory compliance	Environmental damage	Moral responsibility	Impact on the community	Economic benefits
	SVNN	SVNN	SVNN	SVNN	SVNN
	C1	**C2**	**C3**	**C4**	**C5**
A1	(0.85,0.15,0.2)	(0.45,0.65,0.6)	(0.55,0.5,0.5)	(0.45,0.65,0.6)	(0.75,0.25,0.3)
A2	(0.25,0.85,0.8)	(0.35,0.75,0.7)	(0.35,0.75,0.7)	(0.35,0.75,0.7)	(0.55,0.5,0.5)
A3	(0.45,0.65,0.6)	(0,0.95,1)	(0.45,0.65,0.6)	(0.25,0.85,0.8)	(0.55,0.5,0.5)
A4	(0.55,0.5,0.5)	(0.25,0.85,0.8)	(0.45,0.65,0.6)	(0.65,0.35,0.4)	(0.25,0.85,0.8)
A5	(0.55,0.5,0.5)	(0.25,0.85,0.8)	(0.45,0.65,0.6)	(0.45,0.65,0.6)	(0.25,0.85,0.8)

Table 4: Normalized decision matrix. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5
A1	(0.35,0.75,0.7)	(0.35,0.75,0.7)	(0.25,0.85,0.8)	(0.25,0.85,0.8)	(0.35,0.75,0.7)
A2	(0,0.95,1)	(0.25,0.85,0.8)	(0,0.95,1)	(0,0.95,1)	(0.25,0.85,0.8)
A3	(0,0.95,1)	(0,0.95,1)	(0.25,0.85,0.8)	(0,0.95,1)	(0.25,0.85,0.8)
A4	(0.25,0.85,0.8)	(0,0.95,1)	(0,0.95,1)	(0.35,0.75,0.7)	(0,0.95,1)
A5	(0.25,0.85,0.8)	(0,0.95,1)	(0.25,0.85,0.8)	(0.25,0.85,0.8)	(0,0.95,1)

Table 5: Calculation according to the entropy method.

Criteria	E_j	D_j	W_j	Order
Normative compliance	0.942	0.058	(0.3,0.8,0.80)	2
Environmental damage	0.859	0.141	(0.95,0.15,0.14)	1
Economic benefits	0.994	0.006	(0.10,0.90,0.95)	4
Impact on the community	0.964	0.036	(0.10,0.90,0.95)	3
Moral responsibility	0.942	0.058	(0.3,0.8,0.80)	2

Criteria weighting: The neutrosophic multicriteria analysis has provided weights for different evaluation criteria, allowing for a balanced consideration of the importance of each criterion in assessing the environmental responsibility of companies.

Relative importance: Based on the calculated weights, the relative importance of criteria has been determined. This has highlighted the relevance of certain aspects, such as the severity of damage and normative compliance, in comparison to others.

Improvement in evaluation: Criteria weighting enhances the quality of the evaluation by considering variability and indeterminacy in the data. This allows for a more precise and fair assessment of companies' performance in terms of environmental responsibility.

Development of the neutrosophic Aras method

Once the weights are defined, the evaluation of each action and best practice is carried out to mitigate environmental damage in Ecuador. To achieve this, the neutrosophic ARAS method is modeled to determine the best action or practice to enhance the ranking of alternatives for the application under study (see Tables 6 to 8).

Table 6: Decision matrix. Source: own elaboration.

Alternatives	Regulatory compliance	Environmental damage	Moral responsibility	Impact on the community	Economic benefits
	SVNN	SVNN	SVNN	SVNN	SVNN
	C1	**C2**	**C3**	**C4**	**C5**
R1	(0.65,0.35,0.4)	(0.45,0.65,0.6)	(0.35,0.75,0.7)	(0.45,0.65,0.6)	(0.55,0.5,0.5)
R2	(0.45,0.65,0.6)	(0.55,0.5,0.5)	(0.55,0.5,0.5)	(0.55,0.5,0.5)	(0.45,0.65,0.6)
R3	(0.55,0.5,0.5)	(0.75,0.25,0.3)	(0.35,0.75,0.7)	(0.45,0.65,0.6)	(0.35,0.75,0.7)
R4	(0.35,0.75,0.7)	(0.35,0.75,0.7)	(0.45,0.65,0.6)	(0.35,0.75,0.7)	(0.45,0.65,0.6)
R5	(0.45,0.65,0.6)	(0.75,0.25,0.3)	(0,0.95,1)	(0.35,0.75,0.7)	(0.65,0.35,0.4)

Table 7: Normalized decision matrix. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5
R1	(0.25,0.85,0.8)	(0,0.95,1)	(1,0.05,0)	(0.25,0.85,0.8)	(0.25,0.85,0.8)
R2	(0,0.95,1)	(0.25,0.85,0.8)	(1,0.05,0)	(0.25,0.85,0.8)	(0,0.95,1)
R3	(0.25,0.85,0.8)	(0.25,0.85,0.8)	(1,0.05,0)	(0,0.95,1)	(0,0.95,1)
R4	(0,0.95,1)	(0,0.95,1)	(1,0.05,0)	(0,0.95,1)	(0,0.95,1)
R5	(0,0.95,1)	(0.25,0.85,0.8)	(1,0.05,0)	(0,0.95,1)	(0.25,0.85,0.8)
Classification	**B**	**B**	**NB**	**B**	**B**
w_j	(0.3,0.8,0.80)	(0.95,0.15,0.14)	(0.10,0.90,0.95)	(0.10,0.90,0.95)	(0.3,0.8,0.80)

Table 8: Optimization function S_i based on weight W_j assignment. Source: own elaboration.

Alternatives / Weight	C1	C2	C3	C4	C5	S_i	K_i	
R1	0.0544	0.0672	0.0000	0.0262	0.0428	0.1906	80.61%	
R2	0.0307	0.0953	0.0000	0.0344	0.0369	0.1973	83.43%	$S_0 = 0.2510$
R3	0.0445	0.1266	0.0000	0.0231	0.0266	0.2207	93.35%	
R4	0.0299	0.0563	0.0000	0.0164	0.0325	0.1350	57.12%	
R5	0.0345	0.1266	0.0000	0.0200	0.0553	0.2364	100.00%	

The results of the neutrosophic ARAS method evaluate the promotion of corporate social responsibility and incentives for environmental responsibility as the action and best practice to enhance. To enhance these actions, regulatory bodies should work on policies focused on promoting measures aimed at repairing environmental damage caused in Ecuador. Some of these measures are directed at the:

- Compensation or indemnification: Companies can compensate or indemnify individuals or communities affected by the environmental impacts caused by their activities. This may include payment of a sum of money covering damages and losses, as well as the recovery of degraded ecosystems.
- Environmental restoration: Companies can take measures to restore the environment affected by their activities. This may include reforestation of degraded areas, recovery of contaminated water bodies, and disposal of toxic waste, among other measures.
- • Prevention of future damages: Companies can take measures to prevent future environmental damage. This may include the implementation of cleaner technologies [14], adoption of more sustainable practices [15], and conducting environmental impact assessments, among other measures.

- Compliance with environmental standards: Companies can take measures to comply with the environmental standards established in Ecuador. This may include the implementation of environmental management systems [16-18-21], conducting environmental audits, and training workers on environmental issues, among other measures.

Strengthening measures with an impact focused on environmental protection:

Promoting investment in environmental protection and natural resource management: Companies must invest in environmental protection and natural resource management to reduce their environmental impact and promote more sustainable business practices. To achieve this, fiscal and financial incentives can be established for companies that implement environmental protection and natural resource management measures.

Promoting the hiring of environmental insurance: Although there is currently no specific environmental damage insurance in Ecuador, the hiring of civil liability insurance and bonds can be promoted to cover environmental damages caused by companies.

Enhancing citizen participation: It is significant for civil society to actively participate in decision-making related to the environment and corporate responsibility. For this purpose, mechanisms for citizen participation can be established in the evaluation of projects with a high environmental impact and in reporting violations of environmental regulations.

The results indicate the need for a balanced approach to assess corporate responsibility in cases of environmental damage in Ecuador. The severity of environmental damage and regulatory compliance are areas of certainty, while the impact on the community and the complex interactions between economic benefits and environmental damage present indeterminate challenges. The application of regulations and collaboration among stakeholders is fundamental to addressing these challenges and promoting more effective environmental responsibility.

Conclusion

The assessment of corporate responsibility in cases of environmental damage in Ecuador involves a complex balance between certainty and indeterminacy. The results obtained from the neutrosophic entropy method define the severity of environmental damage and regulatory compliance as the criteria with the highest weight. Meanwhile, other factors, such as the impact on the community and the relationship between economic benefits and environmental damage, constitute areas of indeterminacy in the analyzed study. This underscores the need for a balanced approach that recognizes neutrosophic complexity when selecting actions and practices in favor of environmental protection.

The results of the neutrosophic Aras method highlight the action and best practices for promoting corporate social responsibility and incentives for environmental responsibility. Therefore, effective collaboration among companies, government authorities, civil society, and other stakeholders is crucial. Rigorous enforcement of environmental regulations, continuous monitoring, and the imposition of sanctions are essential to ensure that companies assume their environmental responsibility effectively. Furthermore, promoting a culture of corporate social responsibility is essential to align economic interests with environmental protection.

The assessment of corporate responsibility in cases of environmental damage is not a static process. It must be continuous and adapt as circumstances change and new information is obtained. Constant measurement of environmental impact, regulatory compliance, and community well-being is crucial for evaluating the effectiveness of implemented measures and strategies. Environmental responsibility should be a constant concern in both corporate and government decision-making.

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Neutrosophic Modeling of Healthcare Resource Allocation

Olivia Elizabeth Altamirano Guerrero [1], Neyda De Las Mercedes Hernández Bandera [2], Lexter Iván Mihalache Bernal [3] and José Sergio Puig Espinosa [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.oliviaaltamirano@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.neydahernandez@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.lextermb48@uniandes.edu.ec
[4] University for Scientific Research, 5201 Blue Lagoon Drive, Suite 921. 33126. Miami, Florida. USA. Email: puigespinosa@gmail.com

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 $T_A: U \to [0, 1]$, $I_A: U \to [0, 1]$, and $F_A: U \to [0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

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:

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

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

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

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:

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

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.

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

[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.

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

The matrix must satisfy the condition $\widetilde{A}\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, 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≤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	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{5}$	$\tilde{5}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	1/5	$\tilde{1}$	**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.

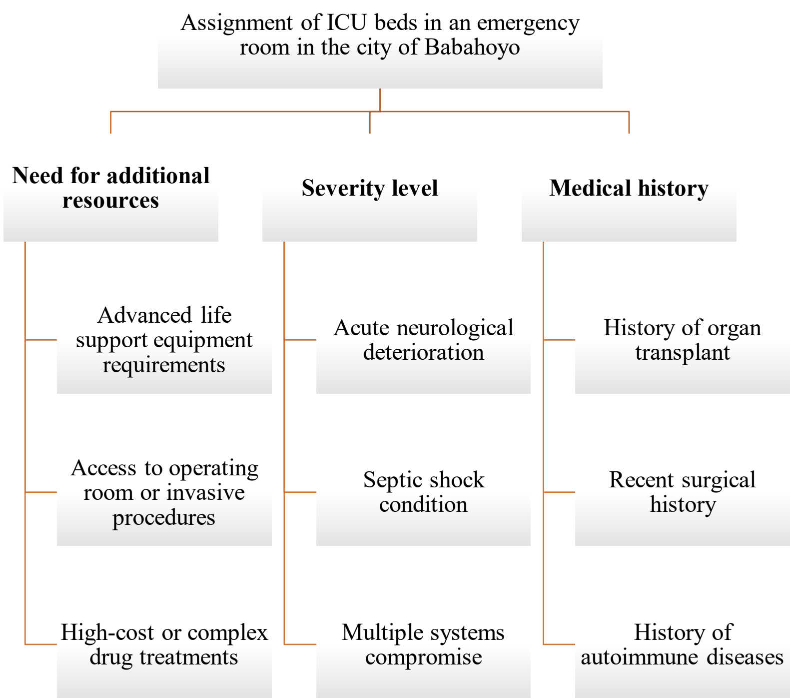
Table 8. Summary of the global evaluations of the criteria and sub-criteria

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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University of New Mexico

Neutrosophic Analysis of Nursing Education and Training

Roberto Enrique Alvarado Chacón [1], Adisnay Rodríguez Plasencia [2], Olga Mireya Alonzo Pico [3] and Maura De La Caridad Salabarría Roig [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. E-mail: ua.robertoac58@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ambato. E-mail: ua.adisnayrodriguez@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Tulcán. E-mail: ut.olgaalonzo@uniandes.edu.ec
[4] Centro de Estudios para la Calidad Educativa y la Investigación Científica, Toluca, México. E-mail: maura1059@gmail.com

Abstract. Nursing education and training in Ecuador presents a complex and multifaceted situation, marked by ambiguities, inconsistencies, and contradictions in pedagogical and curricular approaches. In this context, the general objective of this neutrosophic analysis was to identify and understand these ambiguities, inconsistencies, and contradictions, while seeking solutions and improvements from a neutrosophic perspective. The results of this research revealed that the variable "relevance of curricular updating" is fundamental and that factors such as updating, relevance, implementation, and continuous evaluation interact in a complex way. Neutrosophic statistics provided precise data on their relative influence. In summary, it is concluded that addressing ambiguities and contradictions in nursing education and training in Ecuador requires continuous evaluation, collaboration between institutions, curricular flexibility, and feedback from multiple stakeholders. This neutrosophic approach is essential to make informed decisions and improve the quality of nursing education in the country.

Keywords: Nursing education, pedagogical approaches, neutrosophy, neutrosophic statistics.

1 Introduction

In Ecuador, the governing bodies of professional education, together with the universities, are responsible for the training of future professionals. Therefore, with the support of the government, vocational-technical training is a priority, and the institutions must be provided with a series of tools to support the development and training of health professionals.

Therefore, as a result of the COVID-19 emergency, there is a need to keep up to date and train each health specialty. However, this study focuses on nursing education and training as the first line of action in the event of a health emergency. Although the curricula and training plans have indeed presented ambiguities, inconsistencies, and contradictions regarding nursing education and training in the different educational institutions [1]. In the context of nursing education programs in Ecuador, it is possible to identify various sources of ambiguity in learning objectives, such as:

- Vagueness in the formulation of objectives: Some learning objectives may be formulated in a vague or general way, making it difficult to accurately understand what students are expected to achieve. For example, an objective such as "develop communication skills" is ambiguous, as it does not specify which communication skills should be developed or in what context.
- Lack of clear evaluation criteria: In some cases, objectives may lack concrete evaluation criteria that indicate how the achievement of the objective will be measured. This can lead to multiple interpretations of what students are expected to demonstrate.[2]
- Overlapping or Duplicate Objectives: Programs may sometimes have objectives that overlap or are duplicated in scope, leading to confusion about educational priorities.
- Use of undefined technical language: In the field of nursing, it is common to use technical terminology. However, if not defined precisely, it can lead to misunderstandings and multiple interpretations.
- Ambiguous objectives in terms of competencies: Ambiguity can also arise when objectives are related to the development of professional competencies [3]. If it is not clearly specified what each competency entails, students may have difficulty understanding how they should acquire them.

Inconsistencies can arise from various sources and can hinder the learning process. Here are some possible areas of inconsistency:

- Outdated content: Nursing is a constantly evolving field due to advances in healthcare and technology. If curriculum content is not updated regularly, there may be inconsistencies between what is taught and current nursing practices.[4]
- Divergence between theory and practice: If there is a lack of alignment between the theory taught in the classroom and the practical skills required in clinical practice, students may face difficulties in

applying what they have learned in real situations.

- Inconsistencies in course sequence: If courses in the curriculum do not follow a logical sequence or if there are gaps in coverage of the concepts and skills necessary for nursing [5], this can lead to inconsistencies in knowledge acquisition.
- Lack of interdisciplinary integration: Nursing often involves collaboration with other health professionals. If the curriculum does not encourage the integration of interdisciplinary knowledge [6], there may be inconsistencies in how students work in healthcare teams [7-17-18].

Inconsistencies in assessment can have a significant impact on the quality of education and the training of competent nursing professionals. Here are some possible areas of contradiction:

- Divergence between assessment methods: There may be contradictions if different assessment methods are used (e.g., written exams, clinical assessments, peer assessment) that measure competencies and skills inconsistently.[8-14]
- Inconsistency in assessment criteria: If there is no clear alignment between the criteria used to assess student performance and the learning objectives, this can lead to contradictions in the way students are graded.
- Contradictions in feedback: If teachers offer inconsistent or contradictory feedback to students about their performance, this can lead to confusion and difficulties in improving.
- Inequity in assessment: If assessment methods are not equitable or if there are biases in the assessment of certain groups of students, contradictions in the equity and fairness of the assessment process may occur.

Based on the deficiencies detected, it is necessary to apply a neutrosophic analysis due to the level of indetermination existing in the study. Determining the ambiguities, inconsistencies, and contradictions at a neutrosophic level allows to visualize the impact on nursing education and training in Ecuador. Therefore, this study's main objective is:

- Analyze nursing education and training to identify ambiguities, inconsistencies, and contradictions in pedagogical and curricular approaches, as well as explore possible solutions and improvements from a neutrosophic perspective.

Specific objectives:

- Determine the neutrosophic variable that affects nursing education and training in Ecuador.
- Determine the neutrosophic factors that intervene in the states of the neutrosophic variable that affect nursing education and training in Ecuador.
- Propose solutions that influence the ambiguities, inconsistencies, and contradictions identified in nursing education and training.

2 Materials and methods

2.1 Neutrosophic Statistics

Neutrosophic probabilities and statistics are a generalization of classical and imprecise probabilities and statistics. The Neutrosophic Probability of an event E is the probability that event E occurs, the probability that event E does not occur, and the probability of indeterminacy (not knowing whether event E occurs or not) [9-15]. In classical probability nsup≤1, while in neutrosophic probability nsup≤3+. The function that models the neutrosophic probability of a random variable x is called the neutrosophic distribution:

$$NP(x) = (T(x), I(x), F(x))$$

Where T(x) represents the probability that the value x occurs, F (x) represents the probability that the value x does not occur, and I (x) represents the indeterminate or unknown probability of the value x. Neutrosophic Statistics is the analysis of neutrosophic events and deals with neutrosophic numbers, neutrosophic probability distribution, neutrosophic estimation, neutrosophic regression [10], etc.

It refers to a set of data, which is made up totally or partially of data with some degree of indeterminacy, and to the methods to analyze them. Neutrosophic statistical methods allow to interpret and organize neutrosophic data (data that may be ambiguous, vague, imprecise, incomplete, or even unknown) to reveal underlying patterns.

In short, Neutrosophic Logic, Neutrosophic Sets, and Neutrosophic Probabilities and Statistics have a wide application in various research fields and constitute a new study reference in full development. Neutrosophic Descriptive Statistics comprises all techniques for summarizing and describing the characteristics of neutrosophic numerical data.

Neutrosophic Numbers are numbers of the form $N= a + bI$ where a and b are real or complex numbers, while "I" is the indeterminacy part of the neutrosophic number N. The study of neutrosophic statistics refers to a neutrosophic random variable where X_l and $X_u I_N$ represent the correspondingly lower and upper level that the variable under study can reach, in an indeterminate interval. The neutrosophic mean of the variable $(\bar{x}_N)$ is calculated with the following expression:

$$X_N = X_l + X_u I_N;\ I_N \in [I_l, I_u] \quad (1)$$

$$\text{Where, } \bar{x}_a = \frac{1}{n_N}\sum_{i=1}^{n_N} X_{il},\quad \bar{x}_b = \frac{1}{n_N}\sum_{i=1}^{n_N} X_{iu},\quad n_N \in [n_l, n_u], \quad (2)$$

It is a neutrosophic random sample. However, for the calculation of neutral frames (NNS), it can be calculated as follows

$$\sum_{i=1}^{n} N(X_i - \bar{X}_{iN})^2 = \sum_{i=1}^{n} N\begin{bmatrix} \min\begin{pmatrix} (a_i + b_i I_L)(\bar{a} + \bar{b} I_L), (a_i + b_i I_L)(\bar{a} + \bar{b} I_U) \\ (a_i + b_i I_U)(\bar{a} + \bar{b} I_L), (a_i + b_i I_U)(\bar{a} + \bar{b} I_U) \end{pmatrix} \\ \max\begin{pmatrix} (a_i + b_i I_L)(\bar{a} + \bar{b} I_L), (a_i + b_i I_L)(\bar{a} + \bar{b} I_U) \\ (a_i + b_i I_U)(\bar{a} + \bar{b} I_L), (a_i + b_i I_U)(\bar{a} + \bar{b} I_U) \end{pmatrix} \end{bmatrix}, I \in [I_L, I_U] \quad (3)$$

Where $a_i = X_l b_i = X_u$. The variance of the neutrosophic sample can be calculated by

$$S_N^2 = \frac{\sum_{i=1}^{n_N}(X_i - \bar{X}_{iN})^2}{n_N};\ S_N^2 \in [S_L^2, S_U^2] \quad (4)$$

The neutrosophic coefficient (NCV) measures the consistency of the variable. The lower the NCV value, the more consistent the factor's performance is with respect to the other factors. The NCV can be calculated as follows.

$$CV_N = \frac{\sqrt{S_N^2}}{\bar{X}_N} \times 100;\ CV_N \in [CV_L, CV_U] \quad (5)$$

The Neutrosophic Argumentation coefficient evaluates the criteria through Linguistic Terms with SVNN of consensus for the justification of the experts' opinion, (see Table 1)[11-13-16].

Table 1: Linguistic terms that represent the weight of the factors.

Linguistic term	SVNN
Extremely Relevant (ER)	(1,0,0)
Very Very Relevant (VVR)	(0.95,0.12,0.15)
Very Relevant (VR)	(0.85,0.15,0.25)
Relevant (R)	(0.75,0.3,0.35)
Moderately Relevant (MDR)	(0.65,0.35,0.4)
Medium (M)	(0.5,0.5,0)
Moderately Irrelevant (MDI)	(0.4,0.5,0.55)
Irrelevant (I)	(0.3,0.75,0.8)
Very Irrelevant (VI)	(0.25,0.8,0.85)
Very Very Irrelevant (VVI)	(0.15,0.9,0.95)
Extremely Irrelevant (EI)	(0,0,1)

2.2 Data collection

The sample size of respondents is calculated using equation 6, which takes the probabilities as 50% or 0.05, according to the following results:

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

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

$$n = \frac{ZNpq}{E^2(N-1) + Z^2pq} \quad (6)$$

Where: n: Sample size, Z: Value of the normal distribution with the assigned confidence level, E: Desired sampling error, N: Population size.

The variability of the data and criteria obtained conditions the use of neutrosophic statistics. The level of instability of democracy characterized by experts denotes indeterminate random components. The existence of the variability of similar responses, but with representative neutrosophic degrees, makes the use of classical statistics impossible.

3 Results

Data collection: Statistics allows to analyze situations in which random components contribute significantly to the variability of the data obtained. To measure the levels of ambiguities, inconsistencies, and contradictions in the pedagogical and curricular approaches, it was decided to work with 95% confidence, so surveys were applied to determine the *level of relevance of the curricular update in the variable* (see Table 2).

To do this, the criteria of 80 respondents from Universidad de los Andes are evaluated by a group of experts in higher education, training and curricula, and health. The impossibility of measuring some determinants of the states of the *relevance of the curricular update* is defined in the variability of similar responses.

Table 2: Characteristics of the variable. Source: own elaboration.

Variable	Coding	Sample	Scale $[0\ ;\ 1], \forall\, F_n$
Levels of Relevance of the curricular update	RCU	[45;203]	**[1,0,0]:** On this scale, the variable indicates that the curricular update in nursing education and training in Ecuador is highly relevant and is completely aligned with the latest trends and advances in nursing. There are no uncertainties, meaning there is high confidence that the curriculum is up-to-date and relevant. **[0.75,0.3,0]:** On this scale, the variable indicates that the curricular update is mostly relevant, but with some indeterminations. This could mean that, while efforts are made to keep the curriculum up to date, there are still areas where alignment with the latest trends is uncertain or where further improvements are needed. **[0.5,0.5,0]:** In this scale, the variable reflects a balance between the relevance and lack of relevance of the curricular update. There is significant indeterminacy, suggesting that it is unclear to what extent the curriculum is kept up-to-date and relevant. There may be a mix of updated and outdated items. **[0.3,0.75,0.8]:** On this scale, the variable indicates that curricular updating is mostly irrelevant, but with some indeterminations. This could reflect a situation where substantial revision of the curriculum is needed to bring it in line with current nursing practices. **[0,0,1]:** On this scale, the variable indicates that the curricular update is completely irrelevant and does not adjust at all to the latest trends and advances in nursing. There are no indeterminacies, meaning there is high confidence that an urgent review of the curriculum is required.

Development of the method: For neutrosophic statistical modeling, experts select five factors that prevail in the neutrosophic sets (factors that intervene in the states of the variable), starting from defining the variable to be studied (Table 3). It should be considered that the proposed solutions are subject to constant updates motivated by advances in research, technologies, and contributions of statistical information on nursing education and training in Ecuador.

Table 3: Development of the method. Source: own elaboration.

Factor	Source elements	Relationship between factor and set	Acceptance range	Observations
F1	Scope factors	Subsets: • Comprehensive update • Limited update	Subsets: • [0 ; 0; 0.5] • [0.5 ; 0; 1]	These factors indicate the extent and depth of the update. They can vary from [0 ; 0; 1] (thorough and complete update) to [1; 0; 0] (limited or superficial update)
F2	Upgrade factors	Subsets: • Fully updated. • Partially updated.	Subsets: • [0 ; 0; 0.5] • [0.25 ; 0; 0.75]	These factors represent the degree to which the curriculum is updated to reflect the latest trends and advances in the field of nursing in Ecuador. Neutrosophic values can vary from [0; 0; 1] (fully updated) to [1 ; 0;

Factor	Source elements	Relationship between factor and set	Acceptance range	Observations
		• Completely outdated.	• [0.5 ; 0; 1]	0] (completely outdated).
F3	Relevance factors	Subsets: • Highly relevant • Partially relevant • Not relevant	Subsets: • [0 ; 0; 0.5] • [0.25 ; 0; 0.75] • [0.5 ; 0; 1]	These factors evaluate whether the curricular update adapts to the specific needs and challenges of nursing in Ecuador. The neutrosophic values could range from [0; 0; 1] (highly relevant) to [1 ; 0; 0] (not relevant at all).
F4	Implementation factors	Subsets: • Successful implementation • Implementation failure	Subsets: • [0 ; 0; 0.5] • [0.5 ; 0; 1]	These factors reflect the extent to which the proposed updates are effectively carried out in practice, including their integration into curricula and adoption by educational institutions. They can vary from [0 ; 0; 1] (successful implementation) to [1 ; 0; 0] (implementation failure).
F5	Continuous evaluation factors	Subsets: • Effective continuous evaluation • Lack of continuous evaluation	Subsets: • [0 ; 0; 0.5] • [0.5 ; 0; 1]	These factors consider whether there is a systematic evaluation and feedback process to ensure that the curriculum update remains relevant over time. Neutrosophic values can range from [0; 0; 1] (effective continuous evaluation) to [1; 0; 0] (lack of continuous evaluation).

For the development of the neutrosophic statistical study, it is recommended by experts to analyze the levels of relevance of curricular updating in Ecuador. Studies under conditions of indeterminacy are associated, based on the results of the statistical bases and the surveys carried out (Table 4). To obtain the frequency of the interval for RCU, a score referring to Table 1 (Linguistic terms for each factor) is applied to each survey. The respondent (belonging to the group of experts) determines from the analyzed sample which factors are affected and under what level of relevance.

Table 4: Neutrosophic frequency of the RCU. Source: own elaboration.

No	F1	F2	F3	F4	F5
1	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]
2	[(0.4,0.5,0.55);(1,0,0)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]	[(0.15,0.9,0.95);(0.25,0.8,0.85)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]
3	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.95,0.12,0.15)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
4	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]
5	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.95,0.12,0.15)]
6	[(0,0,1);(0.3,0.75,0.8)]	[(0,0,1);(0.3,0.75,0.8)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.25,0.8,0.85)]	[(0,0,1);(0,0,1)]
7	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]
8	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0,0,1);(0,0,1)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]
9	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0,0,1);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]
10	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(1,0,0)]
11	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0,0,1);(0.25,0.8,0.85)]	[(0.3,0.75,0.8);(0.95,0.12,0.15)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]
12	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]
13	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0,0,1);(0.15,0.9,0.95)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]
14	[(0,0,1);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]
15	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0,0,1);(0.25,0.8,0.85)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
16	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
17	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.95,0.12,0.15)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]
18	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]
19	[(0.4,0.5,0.55);(0.95,0.12,0.15)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]
20	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.25,0.8,0.85)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]
21	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0,0,1);(0.15,0.9,0.95)]	[(0.4,0.5,0.55);(0.95,0.12,0.15)]
22	[(0,0,1);(0,0,1)]	[(0,0,1);(0,0,1)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.25,0.8,0.85)]
23	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.95,0.12,0.15)]
24	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0,0,1);(0.3,0.75,0.8)]
25	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.95,0.12,0.15)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.95,0.12,0.15)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]
26	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0,0,1);(0.3,0.75,0.8)]	[(0,0,1);(0,0,1)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
27	[(0,0,1);(0.4,0.5,0.55)]	[(0,0,1);(0.15,0.9,0.95)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]
28	[(0,0,1);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.15,0.9,0.95);(0.15,0.9,0.95)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]
29	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.95,0.12,0.15)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0,0,1);(0.3,0.75,0.8)]
30	[(0.25,0.8,0.85);(0.25,0.8,0.85)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]
31	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]
32	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]	[(0,0,1);(0.15,0.9,0.95)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]
33	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.95,0.12,0.15)]	[(0,0,1);(0.25,0.8,0.85)]	[(0.3,0.75,0.8);(0.95,0.12,0.15)]	[(0.4,0.5,0.55);(0.95,0.12,0.15)]
34	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0,0,1);(0.25,0.8,0.85)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]

No	F1	F2	F3	F4	F5
35	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]
36	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0,0,1);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]
37	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.15,0.9,0.95)]
38	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
39	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]
40	[(0.25,0.8,0.85);(0.25,0.8,0.85)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0,0,1);(0,0,1)]	[(0,0,1);(0.25,0.8,0.85)]
41	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]
42	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0,0,1);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]
43	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0,0,1);(0,0,1)]	[(0.4,0.5,0.55);(1,0,0)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]
44	[(0,0,1);(0.25,0.8,0.85)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0,0,1);(0.25,0.8,0.85)]
45	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.15,0.9,0.95)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]
46	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.15,0.9,0.95)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0,0,1);(0.15,0.9,0.95)]	[(0,0,1);(0,0,1)]
47	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.95,0.12,0.15)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
48	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0,0,1);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]
49	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0,0,1);(0.25,0.8,0.85)]	[(0.4,0.5,0.55);(1,0,0)]
50	[(0.15,0.9,0.95);(0.25,0.8,0.85)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]
51	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0,0,1);(0,0,1)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]
52	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]
53	[(0.3,0.75,0.8);(0.95,0.12,0.15)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0,0,1);(0.4,0.5,0.55)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
54	[(0.25,0.8,0.85);(0.25,0.8,0.85)]	[(0,0,1);(0,0,1)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]
55	[(0,0,1);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.25,0.8,0.85)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0,0,1);(0.15,0.9,0.95)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]
56	[(0,0,1);(0.25,0.8,0.85)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]
57	[(0.4,0.5,0.55);(1,0,0)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0,0,1);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.15,0.9,0.95)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]
58	[(0.4,0.5,0.55);(0.95,0.12,0.15)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0,0,1);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]
59	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]
60	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]
61	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]
62	[(0,0,1);(0.15,0.9,0.95)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.25,0.8,0.85)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
63	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
64	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.25,0.8,0.85)]	[(0,0,1);(0.3,0.75,0.8)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]
65	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0,0,1);(0.15,0.9,0.95)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0,0,1);(0.15,0.9,0.95)]
66	[(0.15,0.9,0.95);(0.15,0.9,0.95)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0,0,1);(0.25,0.8,0.85)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]
67	[(0,0,1);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0,0,1);(0.25,0.8,0.85)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0,0,1);(0.15,0.9,0.95)]
68	[(0,0,1);(0.3,0.75,0.8)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
69	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]
70	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]
71	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0,0,1);(0.15,0.9,0.95)]	[(0.25,0.8,0.85);(0.25,0.8,0.85)]	[(0.25,0.8,0.85);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
72	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.15,0.9,0.95)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]
73	[(0.15,0.9,0.95);(0.15,0.9,0.95)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.3,0.75,0.8);(0.95,0.12,0.15)]
74	[(0,0,1);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(1,0,0)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]
75	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0,0,1);(0.4,0.5,0.55)]
76	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0,0,1);(0.3,0.75,0.8)]	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]
77	[(0,0,1);(0,0,1)]	[(0.4,0.5,0.55);(1,0,0)]	[(0,0,1);(0,0,1)]	[(0.3,0.75,0.8);(0.75,0.3,0.35)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]
78	[(0,0,1);(0.15,0.9,0.95)]	[(0.3,0.75,0.8);(0.4,0.5,0.55)]	[(0,0,1);(0.25,0.8,0.85)]	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0,0,1);(0.3,0.75,0.8)]
79	[(0.3,0.75,0.8);(0.3,0.75,0.8)]	[(0,0,1);(0.15,0.9,0.95)]	[(0.15,0.9,0.95);(0.25,0.8,0.85)]	[(0.15,0.9,0.95);(0.3,0.75,0.8)]	[(0.15,0.9,0.95);(0.4,0.5,0.55)]
80	[(0.4,0.5,0.55);(0.75,0.3,0.35)]	[(0.25,0.8,0.85);(0.3,0.75,0.8)]	[(0.4,0.5,0.55);(1,0,0)]	[(0,0,1);(0,0,1)]	[(0.4,0.5,0.55);(1,0,0)]
1-80	**[(0.3,0.75,0.8);(0.4,0.5,0.55)]**	**[(0.25,0.8,0.85);(0.4,0.5,0.55)]**	**[(0.25,0.8,0.85);(0.4,0.5,0.55)]**	**[(0.25,0.8,0.85);(0.3,0.75,0.8)]**	**[(0.3,0.75,0.8);(0.4,0.5,0.55)]**

For the development of the statistical study, the neutrosophic frequencies of the factors are analyzed to determine the level of relevance that affects nursing education and training in Ecuador. For each factor, a sample of the elements associated with the surrounding environment of the curricula for nursing education and training by specialists is analyzed. The analysis of the sample that makes up the analyzed groups with respect to determining the relationship between updating, scope, relevance, implementation, and continuous evaluation of nursing training plans (Table 3).

The preliminary tracking results have an average indeterminacy level close to (0.4,0.5,0.55) per factor analyzed, except for F4. The result diagnoses the deterioration of each factor that affects nursing education and training in Ecuador according to the sample analyzed:

I. For the scope factors of education and training plans, it is between irrelevant and moderately irrelevant. Therefore, they present a tendency towards limited updating in reference to the advancement of the health field in the world.
II. For the updating factors of education and training plans, it is between very irrelevant and moderately irrelevant. Therefore, they tend to be partially updated to reflect the latest trends and advances in the field of nursing in Ecuador.
III. For the relevance factors of education and training plans, it is between very irrelevant and irrelevant. Therefore, they tend to be partially relevant when evaluating whether the curricular update adapts to the specific needs and challenges of nursing in Ecuador.
IV. For the implementation factors of the proposed updates, it is between very irrelevant and irrelevant. Therefore, they present a tendency towards failure in implementation, in the proposed updates with the objective of including their integration in the study plans and adoption by educational institutions. So not all institutions manage to integrate it into nursing training.
V. For the continuous evaluation factors of curricular updating, whether it remains relevant over time is

between irrelevant and moderately irrelevant. Therefore, they have a tendency towards a lack of continuous evaluation to ensure that there is a systematic process of evaluation and feedback of curricular updating, which remains relevant over time in Ecuador.

From the results obtained, it can be seen that the existing levels of indeterminacy require the use of neutrosophic statistics for a greater understanding of the interrelated neutrosophic sets.

Neutrosophic statistical analysis: Modeling the data on the level of deterioration existing in the factors associated with nursing education and training in Ecuador shows that factors 2, 3, and 4 require studies with a level of depth. To determine the level of incidence between the causes and conditions that affect the levels of RCU, it is necessary to analyze the means (Table 5). To understand which factor implies a representative mean, $\bar{x} = \in [\bar{x}_L; \bar{x}_U]$, the values of the neutrosophic means are calculated to study the variations of the effects and the values of the neutrosophic standard deviation $S_N \in [S_L; S_U]$. To determine which factor requires a higher level of accuracy when diagnosing each subset, therefore the values $CV_N \in [CV_L ; CV_U]$ are calculated.

Table 5: Neutrosophic statistical analysis of the RCU level. Source: own elaboration.

Factors	$\bar{x}_N$	S_N	CV_N
Scope factors	0.275 + 0.496 I	0.017 + 0.322 I	0.062 + 0.649 I
Upgrade factors	0.249 + 0.473 I	0.016 + 0.322 I	0.064 + 0.681 I
Relevance factors	0.226 + 0.49 I	0.017 + 0.301 I	0.075 + 0.614 I
Implementation factors	0.216 + 0.449 I	0.016 + 0.328 I	0.074 + 0.731 I
Continuous evaluation factors	0.276 + 0.521 I	0.015 + 0.329 I	0.054 + 0.631 I

The relevance of curricular updating in nursing education and training in Ecuador is a multidimensional concept that involves several neutrosophic factors. The neutrosophic variable "*relevance of curricular updating*" depends on the interaction and balance of these factors. From the analysis of Table 5, the factors that affect the levels of RCU and the associated level of indeterminacy are observed. Some factors having average evaluations $\bar{x} = \in [\bar{x}_L; \bar{x}_U]$ close to the lower evaluation values stand out, for example:

- Updating Factors: Constantly updating the curriculum to reflect advances in nursing is essential to maintain relevance. If this factor is at or near the lower end of the neutrosophic scale, it indicates that the curriculum is not updated regularly and could have a very negative impact on relevance.
- Relevance factors: The relevance of the curricular update to the specific needs of nursing in Ecuador is also crucial. If the curriculum is not adapted to the real needs and challenges of the local health system, this could make the update less relevant.
- Implementation factors: Even if updates are made, if they are not implemented effectively in practice, relevance may be compromised. Lack of successful implementation could result in a curriculum that is out of date in practice, negatively affecting relevance.

These neutrosophic factors may have a particularly significant impact on the relevance of curricular updating in nursing education and training in Ecuador. Therefore, the neutrosophic variable "*relevance of curricular updating*" depends on the interaction and balance of these factors. Therefore, to determine which of these neutrosophic factors is the most influential, it is necessary to analyze other neutrosophic statistical elements.

Therefore, it is necessary to analyze the current state of nursing education and training in Ecuador to mitigate the impact of the imbalance observed between the analyzed factors. This means that the level of affectation of the variable due to these three factors depends on defining the weight in the levels of indeterminacy at the scale of the factor analyzed. To do this, it is necessary to resort to the CV_{ND} analysis of these factors and determine the one that most affects the variable to determine the planned solutions.

Comparative analysis: To determine the measure of referent indeterminacy for $\bar{x} = \in [\bar{x}_L; \bar{x}_U], S_N \in [S_L; S_U]$ y $CV_N \in [CV_L ; CV_U]$ associated with the form of neutrosophic numbers (Table 6). In the results obtained, it is observed that the values range from 0.054 to 0.075 with the indeterminacy measure of [0.878;0.914] generated by a sample of [100;203] questionnaires and statistical information, obtained from the analyzed sample.

Table 6: Neutrosophic forms with a measure of indeterminacy. Source: own elaboration.

Factors	$\bar{x}_N$	S_N	CV_N
F1	0.275 + 0.496 I;I ∈ [0,0.446,0]	0.017 + 0.322 I;I ∈ [0,0.947,0]	0.062 + 0.649 I;I ∈ [0,0.904,0]
F2	0.249 + 0.473 I;I ∈ [0,0.474,0]	0.016 + 0.322 I;I ∈ [0,0.95,0]	0.064 + 0.681 I;I ∈ [0,0.906,0]
F3	0.226 + 0.490 I;I ∈ [0,0.539,0]	0.017 + 0.301 I;I ∈ [0,0.944,0]	0.075 + 0.614 I;I ∈ [0,0.878,0]
F4	0.216 + 0.449 I;I ∈ [0,0.519,0]	0.016 + 0.334 I;I ∈ [0,0.951,0]	0.074 + 0.731 I;I ∈ [0,0.899,0]
F5	0.276 + 0.521 I;I ∈ [0,0.47,0]	0.015 + 0.329 I;I ∈ [0,0.954,0]	0.054 + 0.631 I;I ∈ [0,0.914,0]

From the results expected by the neutrosophic statistical study, from the three factors analyzed, there is a greater prevalence in the *updating factors*, with a frequency of $0.249 + 0.473$ I, for a 90.6% CV_N. Therefore, it is necessary to mitigate the negative effects coming from the predominant factor "*updating factors*" that most influence the neutrosophic variable "*relevance of curricular updating*" in nursing education and training in Ecuador. To this end, neutrosophic solutions are proposed aimed at treating the ambiguities, inconsistencies, and contradictions identified. Among the proposed solutions are:

- Ongoing Needs Assessment: Conduct a periodic and systematic needs assessment involving practicing nurses, employers, and other stakeholders to identify areas requiring updating. This helps remove ambiguity about which updates are necessary and relevant.
- Interinstitutional collaboration: Promote collaboration between different nursing educational institutions in Ecuador to share resources and experience in curricular updating. This can help reduce inconsistencies in how updating is approached across different programs.
- Continuing education for teachers: Provide continuing education and professional development opportunities for nursing teachers. This allows them to stay up to date and facilitate the effective implementation of new curricular updates.
- Rigorous impact evaluation: Implement a rigorous evaluation process to measure the impact of curricular updates on nursing practice and graduate performance. This helps remove ambiguity about whether the updates are having a positive effect.
- Curriculum Flexibility: Introduce flexibility into the curriculum to allow for more agile updates and adjustments as needed. This can help address the inconsistency between the rapidity of changes in practice and the ability of the curriculum to adapt.
- Permanent review committees: Establish permanent curriculum review committees that include teachers, students, nursing professionals, and external experts. These committees can review and adjust the curriculum on an ongoing basis, thereby eliminating contradictions and ensuring ongoing relevance.
- Clinical Practice Integration: Integrate more up-to-date clinical practice opportunities into the curriculum, where students can directly apply what they have learned in real-world healthcare settings.
- Resources for updating: Provide adequate resources, such as access to up-to-date literature and technology, to support ongoing updating of the curriculum.
- Feedback from employers: Collect regular feedback from employers on graduate performance and use this information to guide curriculum updates.
- External review mechanisms: Implement external review mechanisms, such as accreditations and peer reviews, to ensure the quality and relevance of the curriculum.

Conclusion

The relevance of curricular updating in nursing education in Ecuador is a complex variable that involves multiple neutrosophic factors, including *updating, relevance, implementation, and continuous evaluation* factors. The results obtained through neutrosophic statistics have highlighted how these factors interact interdependently, and how their values influence the perception of curricular relevance.

The results of neutrosophic statistics have shown that periodic and systematic evaluation is essential to understand the evolution of the relevance of curricular updating. This assessment must involve all stakeholders and address ambiguities, inconsistencies, and contradictions identified through concrete data and precise measurements.

Collaboration between nursing educational institutions and curricular flexibility are effective strategies that have been statistically validated through neutrosophic research. The data have shown how these strategies can contribute to reducing ambiguities and improving the adaptation of training programs to the changing needs of nursing and society in Ecuador.

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Plithogenic Iadov model to study university teaching practices in the complexity of the educational process of comprehensive training by competencies

Pedro Barrientos Gutiérrez [1], Katia Ninozca Flores-Ledesma [2], Santos Lucio Guanilo Gómez [3], Jorge Luis López Bulnes [4], Jorge Leonardo Jave Nakayo [5], Carlos Francisco Cabrera Carranza [6], Abrahan Cesar Neri Ayala [7], and Santiago Ernesto Ramos Yovera [8]

[1] Universidad Nacional del Centro. Huancayo, Perú. E-mail: pbarrientos@uncp.edu.pe
[2] Universidad César Vallejo, Lima. Perú. E-mail: kfloresl1@ucvvirtual.edu.pe, kfloresl@unicartagena.edu.co
[3] Universidad Nacional Jorge Basadre Grohgman. Tacna, Perú. E-mail: lguanilog@unjbg.edu.pe
[4] Universidad Nacional Mayor de san Marcos, Perú. E-mail: jlopéz@unfv.edu.pe
[5] Universidad Nacional Mayor de san Marcos, Perú. E-mail: Jorge.jave@unmsm.edu.pe
[6] Universidad Nacional Mayor de san Marcos, Perú. E-mail: ccabrerac@unmsm.edu.pe
[7] Universidad Nacional José Faustino Sánchez Carrión, Huacho. Perú. E-mail: aneri@unjfsc.edu.pe
[8] Universidad Nacional José Faustino Sánchez Carrión, Huacho. Perú. E-mail: sramos@unjfsc.edu.pe

Abstract. Teaching practices constitute a dynamic performance with the capacity for transformation, the evolution of human consciousness, autonomy, leadership and conscious commitment to strategic intervention with a holistic vision in the process of teaching and educating that generates emotionally healthy spaces to "learn to learn", to do, to coexist, to be and to undertake the student. In this context, the article reports research that had the purpose of measuring and modeling the meanings of university teaching practices in the complexity of the educational process of comprehensive competency training. To do this, 25 professors from Latin American universities were surveyed regarding the impact of today's university graduates in the region on social life, technology, and entrepreneurship. The plithogenic Iadov technique was introduced to process the data, where the Iadov logic chart becomes mainly Plithogenic Inconsistent Picture Fuzzy Numbers. We consider that the theory of plithogeny makes a formal approach to complex phenomena because it generalizes dynamic systems.

Keywords: University teaching, educational process, training by competencies, Iadov technique, plithogenic Iadov technique, plithogenic inconsistent picture fuzzy set.

1 Introduction

University teaching practices as a conscious dynamic performance are fundamental in the comprehensive training of students. In this sense, the complexity of the educational process in achieving the professional and human profile of students in university training requires demanding preparation with a holistic vision of education, under a multilevel-multidimensional perspective.

Holistic education in vocational training is a challenge that must consider humanistic, scientific, and technological aspects, while also adapting to the context, future challenges, trends, and new educational perspectives. This approach combines integrity and quality in education; harmonizing their work on the principles of knowing how to learn, knowing how to do, knowing how to live together, knowing how to be, and knowing how to undertake with the permanent implementation of pedagogy by example.

Despite the diversity and complexity of the context in which the educational process moves, universities continue to be transmitters, consumers, and reproducers of knowledge on a large scale, but today they need to change their own academic and administrative structures to respond to the demands and requirements of a society in permanent evolution.

The educational process on the competency-based training curricular approach is encouraged to educate in diversity and complexity, learn in contexts of knowledge application, and tend towards human and professional training that allows combining other branches of knowledge, in such a way that it ensures the development of a consistent platform for understanding the problems that the future professional will have to solve. In this context, the epistemology of complexity as a reform for thought implies supporting an integrative vision that avoids the reduction, disjunction, and separation of knowledge.

From this perspective, the competency-based approach represents important challenges, since it implies a break with practices, ways of being, thinking, and feeling from rationality in which it is conceived that the function of the university is to teach, reproduce forms of life, culture, and ideology of content-laden studies and the teaching of theory without practice. Education must promote the training of people whose interaction with social reality leads them to build knowledge for a healthy lifestyle.

University teaching practices are a great responsibility that will allow students to have skills and abilities for research, development, innovation, and entrepreneurship (R+D+i+e). In this context, the meaning of university teaching practices is summarized as professionalism, which carries a particularly relevant meaning, on the one hand, effectiveness, and on the other hand, efficiency in the exercise of good teaching. That is why teaching requires a combination of skills, challenges, and knowledge; mainly, it requires curiosity and motivation, to be more competitive every day.

This paper aims to offer a logical-mathematical model to measure and model the complexity involved in university teaching practice by competencies in the Latin American context. To this end, we turn to Plithogeny, which is a theory that emerged from Neutrosophy, and which generalizes it. What is more, it is the theory that generalizes the dynamics of a phenomenon <A> against <AntiA> and includes in the dynamics <NeutA> of what is neither <A> nor <AntiA>. In addition to its interaction with other elements <B>, <NeutB>, and <AntiB>, among others that are necessary ([1]). That is, this is a new formal approach to modeling complex phenomena.

In this sense, 25 university professors were chosen, taking as criteria the experience in the practice of university teaching with two or more years in Latin American public universities. For the first time, it is used the Iadov logic table technique hybridized with the Plithogeny, although the neutrosophic Iadov technique already exists ([2]).

Iadov's technique constitutes an indirect way to study satisfaction when performing certain activities ([3]). It is based on the analysis of a questionnaire that has a specific internal structure that is unknown to the interviewee. The internal structure of the questionnaire follows a relationship between three closed questions and the subsequent analysis of other open questions. The relationship between closed questions is established through the so-called "Iadov Logical Chart". This technique and its generalizations have been used in studies carried out in the field of pedagogy [3-7].

The Neutrosophic Iadov converts the scalar numerical elements of the Iadov Logic Chart into neutrosophic numbers ([8-12]). Therefore, with the plithogenic Iadov technique we convert these elements into plithogenic neutrosophic numbers, especially the Plithogenic Inconsistent Picture Fuzzy Numbers (PIPFN) ([13]). PIPFN are types of Refined Neutrosphic Numbers where the indeterminacy I is split into I_1 as indeterminacy in general and I_2, as indeterminacy due to refusal [14-15]. We specifically use these numbers because they have applications in voting where there is abstention. The closed questions consist of determining the opinion of the respondents regarding how they perceive the impact of teaching by competencies through the imprint of graduates from Latin American universities today, in social life, in their levels of entrepreneurship, and technology.

The advantage offered by a plithogenic Iadov logic chart is that it can be studied with a tool designed to generalize the dynamics, about the behavior of the impact of Latin American pedagogy on important aspects of the societies of the region. In addition, it allows us to measure the current situation.

The article has a Materials and Methods section where the Iadov technique and basic notions of the Plithogeny theory are presented. The Results section contains the details of the plithogenic Iadov model and the results of the survey. The last section is dedicated to conclusions.

2 Materials and Methods

We begin this section by explaining the basic notions of plithogeny, to end it with the details of the Iadov technique.

Let U be a universe of discourse, and P a non-empty set of elements $P \subseteq U$ ([16-20]). Let A be a non-empty set of *one- dimensional attributes* $A = \{\alpha_1, \alpha_2, \dots, \alpha_m\}$, $m \geq 1$; and $\alpha \in A$ let be a given attribute whose spectrum of all possible values (or states) is the non-empty set S, where S can be a discrete finite set, $S = \{s_1, s_2, \dots, s_l\}$ $1 \leq l < \infty$, or infinitely countable set $S = \{s_1, s_2, \dots, s_\infty\}$, or infinitely uncountable (continuous) set $S =]a, b[$, $a < b$ where] ... [is an open, semi-open, or closed interval of the set of real numbers or another general set.

Let V be a non-empty subset of S, where V is the range of all attribute values needed by experts for their application. Each element $x \in P$ is characterized by the values of all attributes in $V = \{v_1, v_2, \dots, v_n\}$, for $n \geq 1$.

In the set of attribute values V, in general, there is a dominant attribute value, which is determined by experts in its application. The dominant attribute value means the most important attribute value that experts are interested in.

Each attribute value $v \in V$ has a corresponding *degree of appurtenance* $d(x, v)$ of element x, to the set P, concerning some given criteria.

The degree of membership can be a *fuzzy degree of appurtenance*, an *intuitionistic degree of appurtenance*, or a *neutrosophic degree of appurtenance* to the plithogenic set:

Therefore, the *degree of appurtenance function* is:

$$\forall x \in P, d: P \times V \rightarrow P([0,1]^z) \quad (1)$$

So $d(x, v)$ is a subset of $[0,1]^z$, where $\mathcal{P}([0,1]^z)$ is the power set of $[0,1]^z$, where z = 1 (fuzzy degree of appurtenance), z = 2 (for the intuitionistic degree of appurtenance), or z = 3 (for the neutrosophic degree of appurtenance).

Be the cardinal $|V| \geq 1$. Let be $c: V \times V \rightarrow [0,1]$ the *fuzzy attribute value contradiction degree function* between any two attribute values v_1 and v_2, denoted by $c(v_1, v_2)$, and satisfying the following axioms:

1. $c(v_1, v_1) = 0$, the degree of contradiction between the same attribute values is zero;
2. $c(v_1, v_2) = c(v_2, v_1)$, commutativity.

One can define a fuzzy attribute value contradiction degree function (c as before, which we can denote by c_F to distinguish it from the next two), an intuitionistic attribute value contradiction degree function ($c_{IF}: V \times V \rightarrow [0,1]^2$), or more generally, a function of neutrosophic attribute value contradiction degree function ($c_N: V \times V \rightarrow [0,1]^3$) can be used increasing the complexity of the calculation, but also increasing the precision.

We mainly calculate the degree of contradiction between the values of uni-dimensional attributes. For multi-dimensional attribute values, we divide them into corresponding one-dimensional attribute values.

The degree of attribute value contradiction degree function helps the plithogenic aggregation operators and the plithogenic inclusion relation (partial order) to obtain a more accurate result.

The attribute value contradiction degree function is designed in each field where a plithogenic set is used according to the application to be solved. If ignored, aggregations still work, but the result may lose precision.

Then (P, a, V, d, c) is called a *plithogenic set*, [16]:

1. Where "P" is a set, "a" is an attribute (multidimensional in general), "V" is the range of the attribute values, "d" is the degree of appurtenance of the attribute value of each element x to the set P for some given criteria ($x \in P$), and "d" means "d_F" or "d_{IF}" or "d_N", when it is a fuzzy degree of appurtenance, an intuitionistic degree of appurtenance, or a neutrosophic degree of appurtenance, respectively of an element x to the plithogenic set P;
2. "c" means " c_F" or " c_{IF}" or " c_N", when it comes to fuzzy degree of contradiction, intuitionistic degree of contradiction, or neutrosophic degree of contradiction between the attribute values, respectively.

The functions $d(\cdot,\cdot)$ and $c(\cdot,\cdot)$ are defined according to the applications that the experts need to solve.

The following notation is used:

$x(d(x,V)),\ d(x,V) = \{d(x,v), \text{for all } v \in V\}, \forall x \in P$ where:

The attribute value contradiction degree function is calculated between each attribute value concerning the dominant attribute value (denoted by v_D) in particular, and concerning other attribute values as well.

The degree of contradiction function of the attribute value c between the attribute values is used in the definition of plithogenic aggregation operators (intersection (AND), union (OR), implication ($\Rightarrow$), equivalence ($\Leftrightarrow$), inclusion relation (order partial), and other plithogenic aggregation operators that combine two or more degrees of attribute values acting on the t-norm and the t-conorm).

Most plithogenic aggregation operators are linear combinations of the fuzzy t-norm (denoted by $\wedge_F$), and the fuzzy t-conorm (denoted by $\vee_F$), but nonlinear combinations can also be constructed.

If the t-norm is applied on the dominant attribute value denoted by v_D, and the contradiction between v_D and v_2 is $c(v_D, v_2)$, then on the attribute value v_2 it is applied:

$$[1 - c(v_D, v_2)] \cdot t_{norm}(v_D, v_2) + c(v_D, v_2) \cdot t_{conorm}(v_D, v_2) \quad (2)$$

Or, by using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \wedge_D v_2) + c(v_D, v_2) \cdot (v_D \vee_D v_2) \quad (3)$$

Similarly, if the t- conorm is applied on the dominant attribute value denoted by v_D, and the contradiction between v_D and v_2 is $c(v_D, v_2)$, then on the attribute value v_2 it is applied:

$$[1 - c(v_D, v_2)] \cdot t_{conorm}(v_D, v_2) + c(v_D, v_2) \cdot t_{norm}(v_D, v_2) \quad (4)$$

Or, by using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \vee_D v_2) + c(v_D, v_2) \cdot (v_D \wedge_D v_2) \quad (5)$$

The *Plithogenic Neutrosophic Intersection* is defined as:

$$(a_1, a_2, a_3) \wedge_P (b_1, b_2, b_3) = \left(a_1 \wedge_D b_1, \frac{1}{2}[(a_2 \wedge_D b_2) + (a_2 \vee_D b_2)], a_3 \vee_D b_3\right) \quad (6)$$

The *Plithogenic Neutrosophic Union* is defined as:

$$(a_1, a_2, a_3) \vee_P (b_1, b_2, b_3) = \left(a_1 \vee_D b_1, \frac{1}{2}[(a_2 \wedge_D b_2) + (a_2 \vee_D b_2)], a_3 \wedge_D b_3\right) \quad (7)$$

In other words, concerning what applies to appurtenance, the opposite applies to non-appurtenance, while in indeterminacy the average between them applies.

Next, we follow this section with the details of Iadov's modeling.

Let us begin with Iadov's logical chart as can be seen in Table 1.

Table 1: Generic Iadov logic chart with three closed questions. Source: [4].

	1. Closed question								
	No			I don't know			Yes		
2. Closed question	3.Closed question								
	Yes	I don't know	No	Yes	I don't know	No	Yes	I don't know	No
Very satisfied.	1	2	6	2	2	6	6	6	6
Partially satisfied.	2	2	3	2	3	3	6	3	6
I don't care.	3	3	3	3	3	3	3	3	3
More unsatisfied than satisfied.	6	3	6	3	4	4	3	4	4
Not at all satisfied.	6	6	6	6	4	4	6	4	5
I don't know what to say.	2	3	6	3	3	3	6	3	4

The personal and individual satisfaction scale for these activities responds to the following structure based on the score obtained:

1. Clear satisfaction with the activities,
2. More satisfied than dissatisfied,
3. Satisfaction not defined,
4. More dissatisfied than satisfied,
5. Clear dissatisfaction,
6. Contradictory.

The results are then coded according to the numbering using Table 2.

Table 2: Individual satisfaction scale. Source: [4].

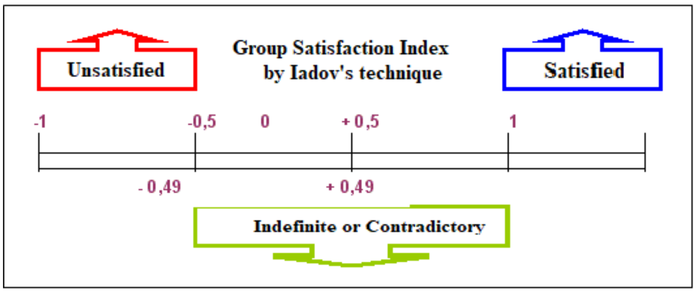
Expression	**Score**
Clear Satisfaction	1
More satisfied than dissatisfied	0.5
Not defined or Contradictory	0
More dissatisfied than satisfied	-0.5
Clear dissatisfaction	-1

To calculate the ISG (*Group Satisfaction Index*), a numerical scale is established with Equation 8 ([4]).

$$GSI = \frac{A(+1)+B(+0.5)+C(0)+D(-0.5)+E(-1)}{N} \tag{8}$$

In this formula, A, B, C, D, and E, represent the number of respondents with individual indexes 1, 2, 3 or 6, 4, 5, and where N represents the total number of respondents that the group has. The group satisfaction index fluctuates between -1 and +1. Values between -1 and -0.5 indicate dissatisfaction; those between -0.49 and +0.49 show contradiction and those that fall between 0.5 and 1 indicate that there is satisfaction. See Figure 1.

Figure 1: Linguistic interpretation of the Group Satisfaction Index. Source: [4].



3 Results

To process the data collected, the Iadov's logical chart is used, which appears in Table 1, with three closed questions:

1. Do you consider that as a result of the pedagogical models, university graduates in your country are entrepreneurs?
2. How do you perceive the influence of university graduates in your country on their social environment, as a result of pedagogical models?
3. Do you consider that as a result of the pedagogical models, university graduates in your country positively influence the technological development of your country?

Additionally, they were asked to respond to open questions that substantiated each of their answers in the closed questions in as much detail as possible.

Table 2 is replaced by Neutrosophic Numbers, most of which are Plithogenic Inconsistent Picture Fuzzy Numbers (PIPFNs) as shown in Table 3.

Table 3: Individual satisfaction scale mainly based on Plithogenic Inconsistent Picture Fuzzy Numbers.

Expression	Neutrosophic Numbers
Clear Satisfaction	(0.9, 0, 0, 0.1)
More satisfied than dissatisfied	(0.6, 0.1, 0.1,0.2)
Not Defined	(0,0,1,0)
Contradictory	(1,0,0,1)
More dissatisfied than satisfied	(0.2, 0.1,0.1, 0.6)
Clear dissatisfaction	(0.9,0,0,0.1)

PIPFNs generalize Picture Fuzzy Numbers as a special case of Refined Neutrosophic Numbers because the indeterminate component of the Neutrosophic numbers (T, I, F) is split into two elements I_1, which is indetermination as itself and I_2 which is indeterminacy due to refusal, therefore the PIPFN are of the form (T, I_1, I_2, F) that F. Smarandache defines so that they comply with the condition $T + I_1 + I_2 + F = 1$, however, we consider the condition $T + I_2 + F = 1$ such that of the Picture Fuzzy Numbers, and in addition $I_1 \in [0,1]$ ([13, 21-23-24-25-26]). The idea of using these numbers is in their application in voting situations where abstention is included. The model we are proposing is a kind of vote of the 25 specialists surveyed on the effectiveness of the pedagogy according to its impact on the country.

Of the numbers that appear in Table 2, see that all of them satisfy the condition $T + I_1 + I_2 + F = 1$, excluding (1,0,0,1) which is not a PIPFN, we use this exception to represent the contradiction in the best possible way, which is allowed in the field of Neutrosophic Numbers.

We are based on the Refined Neutrosophic Norm (Equation 8) and Conorm (Equation 9) which are defined as below:

Given, $x = (T_A, I_{1_A}, I_{2_A}, F_A)$ and $y = (T_B, I_{1_B}, I_{2_B}, F_B)$, then:

$$x \wedge_{RN} y = \left(min(T_A, T_B), max\left(I_{1_A}, I_{1_B}\right), max\left(I_{2_A}, I_{2_B}\right), max(F_A, F_B)\right) \quad (8)$$

$$x \vee_{RN} y = \left(max(T_A, T_B), min\left(I_{1_A}, I_{1_B}\right), min\left(I_{2_A}, I_{2_B}\right), min(F_A, F_B)\right) \quad (9)$$

We use these operators conveniently combined as explained below:

1. All results with the same value on the scale in Table 2 are aggregated using the operator $\wedge_{RN}$ of Equation 8.
2. These five results are aggregated. Let us call w_1 the weight corresponding to “Clear satisfaction”, w_2 those corresponding to “More satisfied than dissatisfied”, w_3 those corresponding to “Not defined” along with the “Contradictory”, w_4 those corresponding to “More dissatisfied than satisfied”, and w_5 corresponds to “Clear dissatisfaction”.
   These weights are obtained from the survey, as the proportion among those who gave their opinion for one of those values that appears in Table 2 divided by 25. That is $w_1 = \frac{A}{N}$, $w_2 = \frac{B}{N}$, $w_4 = \frac{D}{N}$, and $w_5 = \frac{E}{N}$, in addition to $w_3 = 0$, according to the classical Iadov’s technique for N = 25.
   We start by aggregating with Equation 10:

$$Agg_1 = [w_1(0.9, 0, 0, 0.1) \wedge_{RN} w_2(0.6, 0.1, 0.1, 0.2)] + [w_1(0.9, 0, 0, 0.1) \vee_{RN} w_2(0.6, 0.1, 0.1, 0.2)] \quad (10)$$

Then with Equation 11.

$$Agg_2 = [w_4(0.1, 0, 0, 0.9) \wedge_{RN} w_5(0.2, 0.1, 0.1, 0.6)] + [w_4(0.1, 0, 0, 0.9) \vee_{RN} w_5(0.2, 0.1, 0.1, 0.6)] \quad (11)$$

The last aggregation is obtained as:

$$Agg = (Agg_1 \wedge_{RN} Agg_2) + (Agg_1 \vee_{RN} Agg_2) \quad (12)$$

Let us remark what we consider $\alpha(T, I_1, I_2, F) = (\alpha T, \alpha I_1, \alpha I_2, \alpha F)$ for $\alpha \in [0, 1]$.

In practice the details of the survey are as follows: The information collection process was carried out through in-depth interviews with the subjects through guiding questions sent in a Google form using instant messaging resources such as WhatsApp; while others were sent through phone calls, audio recording, then these interviews were taken to Excel form and in the case of audio it was converted to mp3 with the online-audio-with-pour tool.

The results are shown in Table 4:

Table 4: Plithogenic Iadov logic chart with the results of the survey. The number of professionals who voted according to each cell appears in parentheses.

	1. Do you consider that as a result of the pedagogical models, university graduates in your country are entrepreneurs?								
	No			I don't know			Yes		
2. How do you perceive the influence of graduates from universities in your country on their social environment, as a result of pedagogical models?	3. Do you consider that as a result of the pedagogical models, university graduates in your country positively influence the technological development of your country?								
	Yes	I don't know	No	Yes	I don't know	No	Yes	I don't know	No
Very satisfied.	1**(2)**	2	6	2	2	6	6	6	6
Partially satisfied.	2**(2)**	2**(10)**	3	2	3	3	6	3	6
I don't care.	3	3	3	3	3	3	3	3	3
More unsatisfied than satisfied.	6	3	6	3	4	4	3	4	4**(4)**
Not at all satisfied.	6	6	6	6	4	4	6	4	5**(7)**
I don't know what to say.	2	3	6	3	3	3	6	3	4

From Table 4 we have $w_1 = \frac{2}{25}$, $w_2 = \frac{12}{25}$, $w_4 = \frac{4}{25}$, $w_5 = \frac{7}{25}$ in addition to $w_3 = 0$.
From Equations 10-12 we have:
$Agg_1 = (0.36, 0.048, 0.048, 0.104)$,
$Agg_2 = (0.072, 0.028, 0.028, 0.312)$,
$Agg = (0.432, 0.076, 0.076, 0.416)$.

This means that there is a 43.2% certainty that the pedagogical methods are adequate and therefore the graduates are useful to society, contributing with technology, and are entrepreneurs. There is a total indetermination of 15.2%, with 7.6% indetermination in general and the same percentage of refusal. Finally, there is a 41.6% certainty that this is not true.

Conclusion

Being a university teacher in the 21st century and the complexity of the educational process of comprehensive training by competencies, in Latin American university spaces, means understanding the great responsibility, commitment, and human and professional competence of dynamic action in the transformation, evolution of consciousness of human, autonomy, leadership and strategic intervention with a holistic vision in the comprehensive training process to "learn to learn", learn to do, learn to live together, learn to be and learn to undertake.

This article proposes a logical-mathematical model to determine the degree of satisfaction with the objectives of university education in terms of entrepreneurship of graduates, the influence of graduates in society, and technology. To this end, we introduced the Plithogenic Iadov technique, where the logical chart of the classical Iadov technique is interpreted according to plithogenic neutrosophic numbers, most of them on a Plithogenic Inconsistent Picture Fuzzy Numbers scale, which allows the results to be interpreted as a vote.

We applied the model to a real-life case, where 25 Latin American professors were surveyed and the conclusion was reached that 43.2% think that graduates are influential in the aforementioned aspects, against 41.6% who do not, plus 15.2% of indeterminacy. That is why we recommend delving deeper into the teaching methods in force in the region to improve them and make them more effective.

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Neutrosophic Methods in Corporate Social Responsibility

Gustavo Adolfo Alvarez Gómez [1], Corona Gómez Armijos [2], Ariel Romero Fernandez [3], and Karina Pérez Teruel [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: rectorado@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: vicerrectorado@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: dir.investigacion@uniandes.edu.ec
[4] Universidad Abierta para Adultos (UAPA), Santiago de los Caballeros, República Dominicana.
E-mail: karinaperez@uapa.edu.do

Abstract. The purpose of this study was to implement the neutrosophic logic in order to identify the most favorable corporate social responsibility strategies to be applied in the short and medium term in a small and medium-sized food company located in the city of Santo Domingo. To achieve this objective, the COPRAS method approach was expanded by incorporating single-valued neutrosophic sets as an essential part of the decision-making process related to the aforementioned area of study. The adoption of the neutrosophic COPRAS method provided an effective framework for evaluating and prioritizing the various facets of corporate social responsibility, empowering the organization to make more informed and ethical decisions. As a result, it was confirmed that the application of neutrosophic logic proved to be a valuable tool for addressing the inherent uncertainty present in decision-making focused on corporate social responsibility.

Keywords: corporate social responsibility, neutrosophic logic, decision-making, COPRAS, SVNN.

1 Introduction

The decision-making process is an essential element in the dynamics of human beings, both in their personal and professional dimensions. Although each choice that is made is guided by initially defined objectives, in many circumstances, these objectives may conflict [1]. The imperative need to simultaneously address criteria and options in decision dilemmas becomes even more crucial, particularly when faced with data sets characterized by uncertainty.[2]

In recent years, there has been a remarkable increase in the amount of research directed towards the inclusion of the vagueness inherent in the initial information, to address problems of a complex nature. In this context, multi-criteria decision-making methods (MCDM) are widely used [3]. Thus, decision-makers employ subjective evaluation techniques as a response to this challenge.

In the study carried out by [4], the theory of fuzzy sets (FS) was presented to address the problems related to data characterized by its uncertainty and imprecision. Afterward, other variants of fuzzy sets were introduced to expand the scope of this theory [5]. However, despite the efforts made in the application of fuzzy sets to solve multi-criteria decision-making (MCDM) problems, it has been identified that they fail to cover all the forms of uncertainty that arise in the resolution of practical dilemmas in various areas of real life.[6]

To address this challenge, [7] proposed the theory of neutrosophic sets as a generalization of "fuzzy" sets and "intuitionistic fuzzy" sets. Within the framework of neutrosophy, truth membership, indeterminacy membership, and false membership are considered completely independent and fall into the non-standard unitary interval $]0^-, 1^+[$ [8]. To simplify the practical applicability of neutrosophic ensembles, [9] introduced the notion of a Single-Valued Neutrosophic Set (SVNS) and proposed set-theoretic operations as well as some specific properties of SVNSs.[9]

The applicability of neutrosophic logic in solving complex decisional dilemmas extends to various areas, ranging from industry [10] to business [11] and even the sciences [12]. This is due to their ability to deal with situations in which uncertainty, ambiguity, and contradictory information challenge conventional methodologies. Within the business context, decision-making is critically important, as it can have a substantial impact on the success and sustainability of a company. Each business choice must be based on a thorough analysis that considers a multiplicity of criteria and alternatives. Furthermore, in a business environment characterized by its constant dynamism, the ability to adapt and make decisions based on accurate information become imperative.[13-18]

In the contemporary business context, a growing awareness of companies has been observed in relation to their actions, which are now oriented not only towards obtaining economic resources but also towards the generation of social and environmental well-being. Corporate Social Responsibility (CSR) represents a business perspective that implies that organizations assume ethical and social responsibilities that go beyond their legal and economic obligations. In essence, CSR encompasses the voluntary adoption of business practices and decisions that not only seek to generate economic benefits but also seek to produce a positive impact on society, the environmental environment, and the stakeholders involved in the company.

Small and medium-sized businesses (SMEs) operating in the food sector in Ecuador make up one of the most prominent and predominant sectors in the country. In this sense, the adoption of appropriate CSR practices can represent a beneficial factor for the gradual growth and consolidation of these small companies in the market. Therefore, the present study aims to apply neutrosophic logic to determine the CSR strategies that are considered most preferable to implement in the short and medium term by an SME in the food sector in the city of Santo Domingo.

To carry out this task, it is suggested to expand the approach of the COPRAS method by incorporating single-valued neutrosophic sets as an integral part of the decision-making process in the context of the aforementioned object of study. For this purpose, the method called COPRAS-SVNS is used, which was proposed by [14-19-21-22] to address this specific problem. To provide a more detailed understanding of the research, a complete description of the COPRAS method is provided in section 2. Then, in section 3, the essential principles related to single-valued neutrosophic sets are set out, along with the underlying logic that guides the application of the method. Finally, in the subsequent sections, the findings and conclusions derived from this study are detailed.

2 The COPRAS method

A decision-making problem consists of *m* alternatives that must be evaluated considering *n* criteria and x_{ij} can be expressed as the value of the i^{th} alternative by the criterion. The main idea of the COPRAS technique consists of the steps described below:

Step1. Select the appropriate set of criteria that describes the chosen alternatives.

Step2. Prepare decision-making matrix *X*:

$$X = \begin{bmatrix} x_{11} & x_{12} \cdots & x_{1n} \\ x_{22} & x_{22} \cdots & x_{2n} \\ \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & x_{mn} \end{bmatrix} \quad (1)$$

Step 3. Determine the weights of the criteria w_j.

Step 4. Normalize decision-making matrix $\bar{X}$. The values of the normalized matrix are determined as

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}; i = 1,2,\dots,m; j = 1,2,\dots,n \quad (2)$$

Step 5. Compute weighted normalized decision-making matrix D, which components are calculated as

$$d_{ij} = \bar{x}_{ij} \cdot w_j; i = 1,2,\dots,m; j = 1,2,\dots,n \quad (3)$$

Step 6. Compute summation of the criterion values with respect to optimization direction for each alternative

$$P_{+i} = \sum_{j=1}^{L_{max}} d_{+ij};\ P_{-i} = \sum_{j=1}^{L_{min}} d_{-ij} \quad (4)$$

where d_{+ij} values correspond to the criteria to be maximized and d_{-ij} values correspond to the criteria to be minimized.

Step 7. Determine the minimum component of the P_{-i}:

$$P_{-min} = min_i P_{-i}; i = 1,2,\dots,L_{min} \quad (5)$$

Step 8. Determine the score value of each alternative Q_i:

$$Q_i = P_{+i} + \frac{P_{-min}\sum_{j=1}^{L_{min}} P_{-j}}{P_{-i}\sum_{j=1}^{L_{min}} \frac{P_{-min}}{P_{-j}}}; j = 1,\dots,L_{min} \quad (6)$$

Step 9. Determine optimality criterion K for the alternatives:

$$K = max_i Q_i\ ; i = 1,2,\dots,m \quad (7)$$

Step 10. Determine the priority of the alternatives. The greater score value for the alternative corresponds to the higher priority (rank) of the alternative.Q_i

3 Neutrosophic Sets

Definition 1. Let X be a space of the objects and $x \in X$. A neutrosophic set A in X is defined by three functions: truth-membership function $T_A(x)$, an indeterminacy- membership function $I_A(x)$ and falsity-membership function $F_A(x)$. These functions are defined on real standard or real non-standard subsets of $]0^-, 1^+[$. That is

$T_A(x): X \to]0^-, 1^+[, I_A(x): X \to]0^-, 1^+[$ and $F_A(x): X \to]0^-, 1^+[$. There is no restriction on the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$, so $0^- \leq supT_A(x) + supI_A(x) + supF_A(x) \leq 3^+$.

3.1 Single valued neutrosophic set.

A single-valued neutrosophic set (SVNS) has been defined as described in [9].

Definition 2. Let X be a universal space of the objects and $x \in X$. A single valued neutrosophic set (SVNS) $\tilde{N} \subset X$ can be expressed as

$$\tilde{N} = \{\langle x, T_{\tilde{N}}(x), I_{\tilde{N}}(x), F_{\tilde{N}}(x)\rangle : x \in X\} \tag{8}$$

where $T_{\tilde{N}}(x): X \to][0,1], I_{\tilde{N}}(x): X \to][0,1]$ and $F_{\tilde{N}}(x): X \to][0,1]$

with $0 \leq T_{\tilde{N}}(x) + I_{\tilde{N}}(x) + F_{\tilde{N}}(x) \leq 3$ or all $x \in X$. The values $T_{\tilde{N}}(x)$, $I_{\tilde{N}}(x)$ and $F_{\tilde{N}}(x)$ correspond to the truth-membership degree, the indeterminacy-membership degree, and the falsity-membership degree of x to Ñ, respectively. For the case when X consists of a single element, Ñ is called a single-valued neutrosophic number [15][16]. For the sake of simplicity, a single-valued neutrosophic number is expressed by $\tilde{N}_A = (t_A, i_A, f_A)$ where $t_A, i_A, f_A \in [0,1]$ and $0 \leq t_A + i_A + f_A \leq 3$.

Definition 3. Let $\tilde{N}_1 = (t_1, i_1, f_1)$ and $\tilde{N}_2 = (t_2, i_2, f_2)$ be two SVN numbers, then summation between $\tilde{N}_1$ and $\tilde{N}_2$ is defined as follows:

$$\tilde{N}_1 + \tilde{N}_2 = (t_1 + t_2 - t_1 t_2, i_1 i_2, f_1 f_2) \tag{9}$$

Definition 4. Let $\tilde{N}_1 = (t_1, i_1, f_1)$ and $\tilde{N}_2 = (t_2, i_2, f_2)$ be two SVN numbers, then multiplication between $\tilde{N}_1$ and $\tilde{N}_2$ is defined as follows:

$$\tilde{N}_1 * \tilde{N}_2 = (t_1 t_2, i_1 + i_2 - i_1 i_2, f_1 + f_2 - f_1 f_2) \tag{10}$$

Definition 5. Let $\tilde{N} = (t, i, f)$ be an SVN number and $\lambda \in \mathbb{R}$ an arbitrary positive real number, then

$$\lambda\tilde{N} = \left(1 - (1 - \mathrm{t})^{\lambda}, i^{\lambda}, f^{\lambda}\right), \lambda > 0 \tag{11}$$

Definition 6. If A= $\{A_1, A_2, \ldots, A_n\}$, and B= $\{B_1, B_2, \ldots, B_n\}$ (i= 1,2,…,m) are two single-valued neutrosophic sets, then the separation measure between *A* and *B* applying the normalized Euclidian distance can be expressed as follows:

$$q_n(A, B) = \sqrt{\frac{1}{3n}\sum_{j=1}^{n}\left(\left(t_A(x_i) - t_B(x_i)\right)\right)^2 + \left(\left(i_A(x_i) - i_B(x_i)\right)\right)^2 + \left(\left(f_A(x_i) - f_B(x_i)\right)\right)^2}$$

$$(i = 1,2, \ldots, n) \tag{12}$$

Definition 7. Let A = (a,b,c) be a single-valued neutrosophic number, a score function is mapped $\tilde{N}_A$ into the single crisp output $S(\tilde{N}_A)$ as follows:

$$S(\tilde{N}_A) = \frac{3 + t_A - 2i_A - f_A}{4} \tag{13}$$

where $S(\tilde{N}_A) \in [0,1]$. This score function is the modification of the score function proposed by [17-20] and allows to have the results in the same interval since single-valued neutrosophic numbers are being used.

The concept of linguistic variables is very useful for solving decision-making problems with complex content. The value of a linguistic variable is expressed as an element of its term set. Such linguistic values can be represented using single-valued neutrosophic numbers.

In the method, there are k-decision makers, m-alternatives and n-criteria. k-decision makers evaluate the importance of the m-alternatives under n-criteria and rank the performance of the n-criteria with respect to linguistic statements converted into single valued neutrosophic numbers. The importance weights based on single-valued neutrosophic values of the linguistic terms are given in Table 1.

Table 1: Linguistic variables and SVNSs. Source: [14]

Linguistic terms	SVNNs
Extremely good (EG)/ 10 points	(1.00, 0.00, 0.00)
Very very good (VVG)/ 9 points	(0.90, 0.10, 0.10)
Very good (VG)/ 8 points	(0.80, 0.15, 0.20)

Linguistic terms	SVNNs
Good (G) / 7 points	(0.70, 0.25, 0.30)
Medium Good (MG) / 6 points	(0.60, 0.35, 0.40)
Medium (M) / 5 points	(0.50, 0.50, 0.50)
Medium Bad (MB) / 4 points	(0.40, 0.65, 0.60)
Bad (B) / 3 points	(0.30, 0.75, 0.70)
Very Bad (VB) / 2 points	(0.20, 0.85, 0.80)
Very Very Bad (VVB) / 1 point	(0.10, 0.90, 0.90)
Extremely Bad (EB) / 0 points	(0.00, 1.00, 1.00)

The performance of the group decision-making applying COPRAS-SVNS approach can be described by the following steps.

- Step 1. Determine the importance of the experts. In the case when the decision is made by a group of experts (decision makers), firstly the importance or share of the final decision of each expert is determined. If a vector $\lambda = (\lambda_1, \lambda_2, \dots, \lambda_k)$ is the vector describing the importance of each expert, where $\lambda_k \geq 0$ and $\sum_{k=1}^{K} \lambda_k = 1$.
- Step 2. In the framework of this step, each decision maker performs his evaluations concerning the ratings of the alternatives with respect to the attributes and the attribute weights. It is denoted by $x_{ij}^{k}, i = 1,2,\dots,m; j = 1,2,\dots,n$ the k^{th} expert's evaluation of the i^{th} alternative by the j^{th} criterion. This evaluation is expressed in linguistic terms presented in Table 1. So, the decision matrix for any particular expert can be constructed.

$$X^k = \begin{bmatrix} x^k{}_{11} & x^k{}_{12} \cdots & x^k{}_{1n} \\ x^k{}_{22} & x^k{}_{22} \cdots & x^k{}_{2n} \\ \vdots & \vdots & \vdots \\ x^k{}_{m1} & x^k{}_{m2} \cdots & x^k{}_{mn} \end{bmatrix} \tag{14}$$

- Step 3. Calculate the weights of the criteria. The aggregated weights of the criteria are determined by:

$$\mathrm{w}_j = \lambda_1 \mathrm{w}_j^{(1)} \cup \lambda_2 \mathrm{w}_j^{(2)} \cup \dots \cup \lambda_k \mathrm{w}_j^{(k)} = \left(1 - \prod_{k=1}^{K} \left(1 - t_j{}^{(w_k)}\right)^{\lambda_k}, \prod_{k=1}^{K} \left(i_j{}^{(w_k)}\right)^{\lambda_k}, \prod_{k=1}^{K} \left(f_j{}^{(w_k)}\right)^{\lambda_k}\right) \tag{15}$$

- Step 4. Construction of the aggregated weighted single-valued decision matrix

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} \cdots & \tilde{x}_{1n} \\ \tilde{x}_{22} & \tilde{x}_{22} \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} \cdots & \tilde{x}_{mn} \end{bmatrix} \tag{16}$$

where any particular element $\tilde{x}_{ij} = (\tilde{t}_{ij}, \tilde{\imath}_{ij}, \tilde{f}_{ij})$ represents the rating of the alternative A_i with respect to j criterion and is determined as follows:

$$\tilde{x}_{ij} = \lambda_1 \mathrm{x}_{ij}^{(1)} \cup \lambda_2 \mathrm{x}_{ij}^{(2)} \cup \dots \cup \lambda_k \mathrm{x}_{ij}^{(k)} = \left(1 - \prod_{k=1}^{K} \left(1 - t_j{}^{(x_k)}\right)^{\lambda_k}, \prod_{k=1}^{K} \left(i_j{}^{(x_k)}\right)^{\lambda_k}, \prod_{k=1}^{K} \left(f_j{}^{(x_k)}\right)^{\lambda_k}\right) \tag{17}$$

- Step 5. Determine the weighted decision matrix. Following Eq. (3), the weighted decision matrix can be expressed as $D = \lfloor d_{ij} \rfloor, d = 1,2,\dots,m; j = 1,2,\dots,n$, where $d_{ij} = \tilde{x}_{ij} * w_j$. Applying Eq. (10), a single element of the weighted decision matrix can be calculated.

$$d_{ij} = t_{ij}^{\tilde{x}} t_j^{w}, i_{ij}^{\tilde{x}} + i_j^{w} - i_{ij}^{\tilde{x}} i_j^{w}, f_{ij}^{\tilde{x}} + f_j^{w} - f_{ij}^{\tilde{x}} f_j^{w} \tag{18}$$

- Step 6. Perform a summation of the values for the benefit. Let $L_+ = \{1,2,\dots,L_{max}\}$ be a set of the criteria to be maximized. Then the index of the benefit for each alternative can be determined

$$P_{+i} = \sum_{j=1}^{L_{max}} d_{+ij} \tag{19}$$

where this summation of the single value neutrosophic numbers is performed applying Eq. (9).

- Step 7. Perform a summation of the values for cost. Let be $L_- = \{1,2,\dots,L_{min}\}$ a set of criteria to be minimized. Then the index of the cost of each alternative can be determined

$$P_{-i} = \sum_{j=1}^{L_{min}} d_{-ij} \tag{20}$$

- Step 8. Determine the minimum value of the P_{-i}.
- Determine the score value of each alternative Q_i. At the beginning, the score values are calculated from the aggregated values for benefit and the cost $S(P_{+i})$ and $S(P_{-i})$ applying Eq.(13). The score values of the alternatives can be expressed as:

$$Q_i = S(P_{+i}) + \frac{S(P_{-min})\sum_{i=1}^{L_{min}} S(P_{-i})}{S(P_{-min})\sum_{i=1}^{L_{min}} \frac{S(P_{-min})}{S(P_{-i})}} \tag{21}$$

- Step 10. Determine optimality criterion K for the alternatives:

$$K = max_i Q_i ; i = 1,2, \dots , m \tag{22}$$

Step 11. Determine the priority of the alternatives. The greater score value Q_i for the alternative corresponds to the highest priority (rank) of the alternative.

4 Results

The influence of CSR on the image and reputation of a company implies that the implementation of strategies oriented to different levels of CSR can represent a relevant source of competitive advantages for the organization. In this context, the company under study is immersed in the phase of designing and executing strategies focused on the levels of CSR that are most attractive for effective implementation in the medium term. To carry out this process, a panel of five experts will be used and evaluation criteria will be applied to select an appropriate number of strategies on which to focus gradually.

The CSR levels that will be decided on are contemplated below:

Social Dimension:

1. History of evolution, transformation, or merger of business activities.
2. Revelation of mission, vision, and policies.
3. National and international quality, environment, and occupational safety certifications.
4. Administrative, strategic measures and plans aimed at the community.
5. Training and education measures for the workforce.
6. Relations with the competition.
7. Programs aimed at the community and society.

Ethical Dimension:

1. Existence of a Code of Ethics related to interest groups.
2. Evidence of behavioral foundations based on values of honesty, fairness, and integrity.
3. Organizational ethical commitments.
4. Quality and safety of the product offered to the market.
5. It does not offend the competition or discredit it.

Environmental Dimension:

1. Action plan for environmental care.
2. Proactive and purposeful action towards the environment in products and services.
3. Differentiating environmental innovative products and processes.
4. Innovation of business image in improving reputation.

Collaborative Dimension:

1. Implementation of Corporate Governance systems and timely and transparent reporting.
2. Maintenance of good health and occupational safety conditions.
3. Promotion of equal opportunities without discrimination in the workforce.
4. Promotion of the expression of new ideas.

Network Dimension:

1. Availability of an internet portal related to business activity.
2. Offering options in different languages.
3. Use of a slogan related to responsible practices.
4. Use of effective communication channels.
5. Availability of a news section that reports on activities carried out.
6. Publication of financial reports exposed to the public.

For analysis and selection, the application of 4 criteria focused on:

C1. Immediate Impact: Evaluate the potential to generate a short-term positive impact on key stakeholders.

C2. Feasibility and available resources: Analyze whether the company has the necessary resources to implement the strategy effectively in the short term.

C3. Risk Assessment: Evaluate the risks associated with the strategy and determine whether they can be managed effectively in the short term.

C4. Brand awareness: Evaluate whether the strategy can improve the company's brand image and reputation immediately, which can translate into tangible business benefits.

These data are analyzed by the experts selected for the study, who assess the selection alternatives based on the analyzed criteria. Experts are considered to have an equal degree of importance. The weight vector of the criteria is obtained through the evaluations carried out by the experts considering the values provided in Table 1. In this way, Table 2 shows the weight vector obtained after applying equation (15).

Table 2: Vector of weights of the analyzed criteria. Source: own elaboration.

Weights vector	SVNN
Immediate Impact (w_1)	(0.82671;0.17329;0.15157)
Feasibility and available resources (w_2)	(0.83428;0.16572;0.15849)
Risk assessment (w_3)	(0.79186;0.20814;0.17411)
Brand recognition (w_4)	(0.82671;0.17329;0.15157)

The evaluation of the options is carried out considering the values recorded in Table 1, and all the starting data are converted into neutrosophic sets. Based on the evaluations carried out by the experts, the transformations required to build the decision matrix are carried out. This process is carried out using equation (17). The results derived from this procedure are presented in Table 3.

Table 3: Initial decision matrix. Source: own elaboration.

Alternatives	Immediate Impact	Feasibility and available resources	Risk assessment	Brand recognition
History of evolution, transformation, or merger of business activities.	(0.67,0.33,0.289)	(0.725,0.275,0.251)	(0.35,0.75,0.8)	(0.725,0.275,0.251)
Revelation of mission, vision, and policies.	(0.81,0.19,0.19)	(0.5,0.5,0.5)	(0.383,0.692,0.728)	(0.5,0.5,0.5)
National and international quality, environment, and occupational safety certifications.	(0.88,0.12,0.115)	(0.81,0.19,0.19)	(0.88,0.12,0.115)	(0.81,0.19,0.19)
Administrative, strategic measures and plans aimed at the community.	(0.725,0.275,0.251)	(0.725,0.275,0.251)	(0.88,0.12,0.115)	(0.725,0.275,0.251)
Training and education measures for the workforce.	(0.685,0.315,0.302)	(0.618,0.393,0.398)	(0.685,0.315,0.302)	(0.445,0.588,0.603)
Relations with the competition.	(0.621,0.379,0.347)	(0.601,0.411,0.381)	(0.541,0.472,0.457)	(0.491,0.555,0.552)
Programs aimed at the community and society.	(0.88,0.12,0.115)	(0.88,0.12,0.115)	(0.88,0.12,0.115)	(0.88,0.12,0.115)
Existence of a Code of Ethics related to interest groups.	(0.621,0.379,0.347)	(0.565,0.435,0.416)	(0.445,0.588,0.603)	(0.541,0.472,0.457)
Evidence of behavioral foundations based on values of honesty, fairness, and integrity.	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)
Organizational ethical commitments.	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)
Quality and safety of the product offered to the market.	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)
It does not offend the competition or discredit	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)
Action plan for environmental care.	(0.88,0.12,0.115)	(0.88,0.12,0.115)	(0.88,0.12,0.115)	(0.88,0.12,0.115)
Proactive and purposeful action towards the environment in products and services.	(0.725,0.275,0.251)	(0.725,0.275,0.251)	(0.725,0.275,0.251)	(0.725,0.275,0.251)
Differentiating environmental innovative products and processes.	(0.88,0.12,0.115)	(0.88,0.12,0.115)	(0.88,0.12,0.115)	(0.88,0.12,0.115)

Alternatives	Immediate Impact	Feasibility and available resources	Risk assessment	Brand recognition
Innovation of business image in improving reputation	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)
Implementation of Corporate Governance systems and timely and transparent reporting.	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)
Maintenance of good health and occupational safety conditions.	(0.88,0.12,0.115)	(0.88,0.12,0.115)	(0.88,0.12,0.115)	(0.88,0.12,0.115)
Promotion of equal opportunities without discrimination in the workforce.	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)
Encouraging the expression of new ideas	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)
Availability of an internet portal related to business activity.	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)
Offering options in different languages.	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)
Use of a slogan related to responsible practices.	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)
Use of effective communication channels.	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)
Availability of a news section that reports on activities carried out	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)	(0.618,0.393,0.398)
Publication of financial reports exposed to the public.	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)	(0.601,0.411,0.381)

The initial decision matrix allows obtaining the weighted decision matrix, which is constructed by applying equation (19). At this point, it is necessary to clarify that criteria 1,2 and 4 are considered profit criteria, so their maximization is sought. On the contrary, criterion 3 is considered a cost criterion, so its minimization is considered a greater benefit. Taking this into account, the next step is to determine the coefficients proposed by the method analyzed to select among the alternatives.

Table 4: Values of Pi, S(P), and Q score value for each alternative. Source: own elaboration.

CSR dimensions	Pi+	Pi-	S(P+)	S(P-)	Q
History of evolution, transformation, or merger of business activities.	(0.946; 0.054; 0.042)	(0.289; 0.793; 0.83)	0.949	0.2180	1.1670
Revelation of mission, vision, and policies.	(0.91; 0.09; 0.088)	(0.317; 0.745; 0.769)	0.911	0.2650	1.0750
National and international quality, environment, and occupational safety certifications.	(0.977; 0.023; 0.021)	(0.511; 0.498; 0.489)	0.978	0.5070	1.2550
Administrative, strategic measures and plans aimed at the community.	(0.948; 0.052; 0.044)	(0.511; 0.498; 0.489)	0.95	0.5070	1.2280
Training and education measures for the workforce.	(0.89; 0.118; 0.116)	(0.566; 0.434; 0.408)	0.885	0.5730	1.0290
Relations with the competition.	(0.878; 0.133; 0.115)	(0.447; 0.563; 0.539)	0.874	0.4460	1.0460
Programs aimed at the community and society.	(0.986; 0.014; 0.012)	(0.511; 0.498; 0.489)	0.987	0.5070	1.2570
Existence of a Code of Ethics related to interest groups.	(0.881; 0.122; 0.106)	(0.497; 0.513; 0.475)	0.883	0.4990	1.0880
Evidence of behavioral foundations based on values of honesty, fairness, and integrity.	(0.905; 0.101; 0.102)	(0.511; 0.498; 0.489)	0.9	0.5070	1.2480
Organizational ethical commitments.	(0.895; 0.112; 0.092)	(0.497; 0.513; 0.475)	0.895	0.4990	1.0730
Quality and safety of the product offered to the market.	(0.905; 0.101; 0.102)	(0.511; 0.498; 0.489)	0.9	0.5070	1.2480
It does not offend the competition or discredit	(0.895; 0.112; 0.092)	(0.497; 0.513; 0.475)	0.895	0.4990	1.0730
Action plan for environmental care.	(0.986; 0.014; 0.012)	(0.511; 0.498; 0.489)	0.987	0.5070	1.2570
Proactive and purposeful action towards the environment in products and services.	(0.953; 0.047; 0.038)	(0.497; 0.513; 0.475)	0.955	0.4990	1.1010
Differentiating environmental innovative products and processes.	(0.986; 0.014; 0.012)	(0.511; 0.498; 0.489)	0.987	0.5070	1.2570

CSR dimensions	Pi+	Pi-	S(P+)	S(P-)	Q
Innovation of business image in improving reputation	(0.905; 0.101; 0.102)	(0.497; 0.513; 0.475)	0.9	0.4990	1.0880
Implementation of Corporate Governance systems and timely and transparent reporting.	(0.895; 0.112; 0.092)	(0.511; 0.498; 0.489)	0.895	0.5070	1.0730
Maintenance of good health and occupational safety conditions.	(0.905; 0.101; 0.102)	(0.497; 0.513; 0.475)	0.9	0.4990	1.0880
Promotion of equal opportunities without discrimination in the workforce.	(0.895; 0.112; 0.092)	(0.599; 0.401; 0.365)	0.895	0.6080	1.6080
Encouraging the expression of new ideas	(0.905; 0.101; 0.102)	(0.511; 0.498; 0.489)	0.9	0.5070	1.2480
Availability of an internet portal related to business activity.	(0.895; 0.112; 0.092)	(0.511; 0.498; 0.489)	0.895	0.5070	1.2480
Offering options in different languages.	(0.905; 0.101; 0.102)	(0.497; 0.513; 0.475)	0.9	0.4990	1.0880
Use of a slogan related to responsible practices.	(0.895; 0.112; 0.092)	(0.511; 0.498; 0.489)	0.895	0.5070	1.0730
Use of effective communication channels.	(0.905; 0.101; 0.102)	(0.497; 0.513; 0.475)	0.9	0.4990	1.0880
Availability of a news section that reports on activities carried out	(0.895; 0.112; 0.092)	(0.511; 0.498; 0.489)	0.895	0.5070	1.0730
Publication of financial reports exposed to the public.	(0.905; 0.101; 0.102)	(0.497; 0.513; 0.475)	0.9	0.4990	1.0880

The results obtained after applying the method indicate that the most preferred factors, considering both the opinions of the experts and the evaluation criteria selected for the analysis, include obtaining quality, environmental, and occupational safety certifications both nationally and internationally. In addition, programs aimed at the community and society, the implementation of action plans for the preservation of the environment, innovation in products and processes with a differentiating environmental focus, and the promotion of equal opportunities without discrimination in the workplace are also highlighted.

These results suggest that, according to the experts' assessment and the evaluation criteria applied, these areas represent the main areas of focus and priority for the company in its pursuit of Corporate Social Responsibility (CSR). It is important to note that these findings can serve as a valuable guide for the company in the planning and execution of CSR strategies that contribute to its sustainable development and the generation of competitive advantages in the market.

7 Discussion

The corporate image is linked to CSR, allowing the company to reach a good strategy towards society. Thus, one of the key factors to achieve a good corporate image and reputation is being socially responsible. The application of neutrosophic and neutrosophic multi-criteria methods in corporate social responsibility decision-making represents an innovative and highly relevant approach in the field of business management.

The main advantage of neutrosophy in CSR decision-making lies in its ability to handle information and data that may be ambiguous, incomplete, or contradictory. CSR is constantly evolving and requires careful evaluation of various aspects, from ethical and environmental issues to community and employee relations. Neutrosophic multi-criteria methods allow companies to evaluate these complex interactions more accurately and fairly, considering not only the quantitative aspects but also the qualitative and subjective ones that are crucial in making ethical and socially responsible decisions.

Moreover, the application of neutrosophy and neutrosophic multi-criteria methods in CSR promotes transparency and the participation of multiple stakeholders. By incorporating the diversity of opinions and perspectives, companies can make more equitable and democratic decisions regarding their social commitment. This is especially important in a context where CSR is not only about complying with regulations but also about building strong relationships with society and generating shared value.

Conclusion

Corporate Social Responsibility is a key factor in modern business management. Neutrosophic methods offer an efficient framework for assessing and prioritizing CSR dimensions, which, in turn, enables companies to make more ethical and informed decisions. This study applied neutrosophic logic to identify the most favorable CSR strategies for short-to-medium-term implementation by an SME operating in the food sector in the city of Santo Domingo. The neutrosophic variant of the COPRAS method provided a practical framework for evaluating and prioritizing different dimensions of CSR, allowing the company to make informed and ethical decisions. This applied neutrosophic logic, which proved to be useful in dealing with uncertainty in decision-making concerning CSR. Uncertainty and ambiguity, common factors in CSR, can be effectively addressed through this methodology, helping to promote more ethical and socially responsible business management.

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A neutrosophic SERVQUAL model approach to study the quality of teaching support services at a technological institute in Ecuador

Víctor Gustavo Gómez Rodríguez [1], Abel Stalin Flores Laaz [2], Noemí Barbara Delgado Álvarez [3], Alejandro Reigosa Lara [4] and Manuel Roberto Tolozano Benites [5]

[1] Universidad Bolivariana del Ecuador, Durán. Ecuador. E-mail: vgomez@ube.edu.ec
[2] Instituto Superior Tecnológico Bolivariano de Tecnología, Guayaquil. Ecuador. E-mail: aflores@bolivariano.edu.ec
[3] Universidad Bolivariana del Ecuador, Durán. Ecuador. E-mail: ndelgadoa@ube.edu.ec
[4] Universidad Bolivariana del Ecuador, Durán. Ecuador. E-mail: areigosal@ube.edu.ec
[5] Universidad Bolivariana del Ecuador, Durán, Ecuador. E-mail: rtolozano@ube.edu.ec

Abstract. In this paper we present the results of the determination of dissatisfactions based on the gaps detected in the students' expectations about the services offered by the different departments of the "Instituto Superior Tecnológico Bolivariano" (ITB) and what each of them perceives concerning those services, so, we delve into the root causes that provoke them. With this point of reference, in the future it is intended focusing on the management towards the continuous improvement of the involved processes, guaranteeing the satisfaction and fulfillment of the institutional strategic objectives. SERVQUAL model is used for allowing us to measure the quality of the service and determine the existing gaps between expectations and perceptions in each of the dimensions under study, namely: tangibility, reliability, response capacity, security, and empathy. SERVQUAL model is applied in a neutrosophic framework to deal with the indeterminacy and uncertainty of students' opinions. Thus, we convert a Likert-type scale into triple membership functions of single-valued triangular neutrosophic numbers per interviewed, to represent: agreement, indeterminacy, and disagreement. The comparison lead to in a decrease in the quality of the services perceived against expectations in the period evaluated. We provide a partial result that constitutes the continuity of the application of the approach within the institutional scheme started in 2017.

Keywords: Service quality, SERVQUAL, institutional management, single-valued triangular neutrosophic number.

1 Introduction

Improving quality standards in higher education has become a worldwide requirement. Those who are dedicated to quality assessment for accreditation purposes constantly refine their models and focus them on measuring management and results indicators that make it possible to obtain judgments on the effectiveness and efficiency of professional training. This new reality has boosted competitiveness among educational institutions.

The challenges faced by higher education institutions (HEIs) are increasingly growing and demanding as they are not only subjected to external and structured evaluation processes, but also to those internal and not so structured, but as demanding as the previous ones in which the students themselves play a very important role as clients of the educational services, and the third element and not least important is the competition.

Even though self-financed HEIs are by law non-profit institutions, performance in environments under pressure places them in the constant search for methods, approaches, or philosophies that guarantee the continuous entry and retention of students to maintain stability in the income and with this, strengthen learning environments, train professionals capable of responding to the demands imposed by society and be competitive in the market. Educational management that identifies and applies models and strategies focused on processes and continuous improvement, is therefore essential and aligned with the fulfillment of the strategic objectives and goals planned by the institution.

Institutional management focused on quality teaching processes breaks the traditional paradigms and places the student at the highest level of attention, just at the center, placing institutional strategies, established procedures, and systems at the extremes, and finally the students, teachers, and staff of the support processes, converging towards the center of attention that is the student.

Getting applicants for the higher education service to choose a certain institution requires a lot of resources and human efforts, but the most complicated matter is to manage keeping the students so that they fulfill all their academic processes satisfactorily. This is the point where the competitive advantage must go beyond the benefits that are offered, the quality of the services must be added, both academic and non-academic, which allows to generate confidence in the students.

According to the state of opinions, we have perceived a negative judgment about the teaching support services at an Ecuadorian higher educational institution, the "Instituto Superior Tecnológico Bolivariano" (ITB). Therefore, we propose to study how to qualify the student's general opinion on the teaching received at ITB. Thus, we applied a survey to measure the quality of teaching at this institute. We decided to apply the SERVQUAL model, which is classical to studying the quality of services ([1]). On the other hand, because we are dealing with uncertainty and indeterminacy, we used single-valued triangular neutrosophic numbers for approaching to the neutrosophic framework the crisp values obtained in a crisp Likert scale ([2]). Thus, we applied SERVQUAL model to the de-neutrosified results. In literature SERVQUAL has been extended in many uncertainty frameworks as can be read in ([3-10]).

The paper has the following structure, first, there is a materials and methods section concerning to SERVQUAL model and single-valued triangular neutrosophic numbers. Section 3 is dedicated to showing the results of our study. Finally, Section 4 concludes this paper.

2 Materials and Methods

2.1. On the SERVQUAL model

Two models are known that can be used to measure the quality of service. The first of them is the SERVPERF model, which only works under the results of perceptions, and the second one is the SERVQUAL model, which allows expectations to be compared with perceptions ([1, 11-13]).

The SERVQUAL model is one of the main tools for measuring service quality. This model attempts to answer three essential questions: When is a service perceived as being of quality? What dimensions make up quality? And, what questions should be included in the quality questionnaire? The model was illustrated so that consumers' perceptions of quality are influenced by five gaps that occur in organizations as described below.

The first gap is related to the expectations of the clients and the perceptions of the company, they are based on the fact that the managers or administrators of the organizations do not always recognize which of the client's needs they have to satisfy. This prevents the generation of actions that make it possible to meet expectations about the service offered.

The second one is defined by the managers' perceptions and the quality specifications of the service offered. Even if the administration is clear about the expectations of the clients, that could be useless, since they do not know the standards of quality or norms that allow them to increase the level of quality.

On the other hand, the third of the gaps which includes quality specifications and service delivery, emphasizes ensuring that the service provided complies with all quality specifications and standards.

The penultimate gap is identified with the delivery of the service and what is communicated about it to customers. In this sense, advertising allows to create expectations among consumers, but it will depend on the organization if it can deliver what it is communicating.

The fifth gap marks the difference between the expectation of the service and the quality perceived by the customer. This gap is considered for the measurement of quality because consumer perceptions will depend on the causes that generate the four previous gaps.

The quality assessment questionnaire is made up of five dimensions, which are: reliability, responsiveness, security, empathy, and tangibility. "Reliability" refers to providing the service carefully and reliably. Whereas, "response capacity" is the willingness of staff to help or quickly solve customer requirements. The "security" consists of the trust generated by the service received. "Empathy" focuses on identifying alternatives to provide personalized attention. Lastly, "tangibility" relates to the appearance and functionality of physical facilities, equipment, personnel, and materials, and communication channels.

The SERVQUAL model is made up of two questionnaires with 22 items each of them, and they are assessed using a Likert scale. The first questionnaire is focused on knowing what the clients' expectations are about the service and the second questionnaire focuses on the perceptions of the quality of the service received.

2.2. The single-valued triangular neutrosophic numbers

Definition 1: ([14-17]) The *Neutrosophic set* N is characterized by three membership functions, which are the truth-membership function T_A, indeterminacy-membership function I_A, and falsity-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 $^-0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+$.

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

Definition 2: ([14-17]) The *Single-Valued Neutrosophic Set* (SVNS) N over U is $A = \{< x;\ T_A(x), I_A(x), F_A(x) > : x \in U\}$, where $T_A: U \to [0,1]$, $I_A: U \to [0,1]$, and $F_A: U \to [0,1]$, $0 \le T_A(x) + I_A(x) + F_A(x) \le 3$.

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

Definition 3: ([14-17-21-22]) The *single-valued triangular neutrosophic number* $\tilde{a} = \langle (a_1, a_2. a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, whose truth, indeterminacy, and falsity membership functions are defined as follows, respectively:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \le x \le a_2 \\ \alpha_{\tilde{a}}, & x = a_2 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_2 < x \le a_3 \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \le x \le a_2 \\ \beta_{\tilde{a}}, & x = a_2 \\ \frac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \le a_3 \\ 1, & \text{otherwise} \end{cases} \quad (2)$$

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

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

Definition 4: ([14-17]) Given $\tilde{a} = \langle (a_1, a_2, a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued triangular neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
2. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_3, a_2 - b_2, a_3 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
3. Inversion: $\tilde{a}^{-1} = \langle (a_3^{-1}, a_2^{-1}, a_1^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, where $a_1, a_2, a_3 \neq 0$.
4. Multiplication by a scalar number:
$$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases}$$
5. Division of two triangular neutrosophic numbers:
$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle \left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 > 0 \textit{ and } b_3 > 0 \\ \langle \left(\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \textit{ and } b_3 > 0 \\ \langle \left(\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \textit{ and } b_3 < 0 \end{cases}$$
6. Multiplication of two triangular neutrosophic numbers:
$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1 b_1, a_2 b_2, a_3 b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 > 0 \textit{ and } b_3 > 0 \\ \langle (a_1 b_3, a_2 b_2, a_3 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 < 0 \textit{ and } b_3 > 0 \\ \langle (a_3 b_3, a_2 b_2, a_1 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 < 0 \textit{ and } b_3 < 0 \end{cases}$$

Where, $\wedge$ is a t-norm and $\vee$ is a t-conorm.

Let $\tilde{a} = \langle (a_1, a_2, a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ be a single-valued triangular neutrosophic number, then,

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (4)$$

$$\mathbf{A}(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (5)$$

They are called the score and accuracy degrees of ã, respectively.

Let $\{\widetilde{A}_1, \widetilde{A}_2, \cdots, \widetilde{A}_n\}$ be a set of n SVTNNs, where $\widetilde{A}_j = \langle (a_j, b_j, c_j); \alpha_{\tilde{a}_j}, \beta_{\tilde{a}_j}, \gamma_{\tilde{a}_j} \rangle$ (j = 1, 2, …, n), then the *weighted mean of the SVTNNs* is calculated with the following Equation:

$$\widetilde{A} = \sum_{j=1}^{n} \lambda_j \widetilde{A}_j \tag{6}$$

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

3 Results

The present work was carried out with a quantitative descriptive approach. The results obtained in the research will allow us for defining the existing gaps in the expectations and perception of the service that students receive during the second academic period that began in September 2019 and that lasted until February 2020, just before the beginning of the scourge of the pandemic caused by the COVID 19 virus.

The SERVQUAL model was used, specifically in the analysis of the fifth gap (expectations versus perception) where statistical indicators were obtained for each question and dimension, in turn, comparisons were made between the measurements.

The scope of the research is descriptive since this type of analysis is based on the description of the characteristics of the population under analysis concerning the variables under study. It is the non-experimental design of a transectional type since it analyzes the phenomenon in its natural context and the information is collected in a single moment.

Table 1 contains the questions asked in the SEVQUAL model.

Table 1. Questions asked in the SERVQUAL model, classified according to the corresponding dimensions.

	Dimension	Question
P1	Tangibility	Premises and facilities in good condition
P2	Tangibility	State-of-the-art classrooms and laboratories
P3	Tangibility	Properly uniformed and impeccable staff
P4	Tangibility	Enough attractive and explicit advertising
P5	Reliability	The staff shows interest in solving requirements
P6	Reliability	The staff undertakes to comply in the shortest time and does so
P7	Reliability	The staff offers good service at all times
P8	Reliability	The staff complies with the service in the established time
P9	Reliability	There are documents and student files in order and without failures
P10	Response Capacity	The solution/response time of the request is reported
P11	Response Capacity	Service is provided promptly
P12	Response Capacity	The staff is always ready to help
P13	Response Capacity	Staff always available to help with requirements
P14	Security	The staff transmits confidence
P15	Security	One feels secure when carrying out a procedure
P16	Security	Staff is friendly
P17	Security	Trained personnel to give reliable answers to requirements
P18	Empathy	The staff gives you personalized attention.
P19	Empathy	Adequate staff to offer personalized attention.
P20	Empathy	Customer service hours are appropriate.
P21	Empathy	The staff cares about offering well-being.
P22	Empathy	The staff understands the requirements.

The unit of analysis is made up of the ITB, and the target population is that of active students from the careers of Nursing, Administration, Accounting, Software Development, Land Transport, Trichology and Cosmetics, Older Adults, and Podiatry. Table 2 summarizes the number of surveyed students per career.

Table 2. Distribution of the sample by type of career and year.

Careers	September 2019 – February 2020
Nursing	157
Administration	102
Accounting	54
Software development	27
Land Transport	15
Trichology and Cosmetics	6
Elderly care	5
Podiatry	4
Total	370

The items that make up the SERVQUAL model questionnaire were measured on a Likert scale where the respondent had to indicate his/her agreement or disagreement with the statement presented to him/her. To this end, an orderly and one-dimensional scale from 1 to 7 is used. In the case of the expectations questionnaire, it is assumed that a score of 7 corresponds to "Extremely important" and 1 to "Extremely unimportant". For the questionnaire on perceptions, a score of 7 represents "that the evaluation is always fulfilled" and 1 that "it is never fulfilled".

The numerical results in the Likert scale were neutrosophied using the triangular neutrosophic numbers scale in Table 3.

Table 3. Importance weight as linguistic variables and their associated SVTNNs for expectations and perceptions. Source: [18].

Likert scale	Linguistic terms for expectations	Linguistic terms for perceptions	SVTNN
1	Extremely unimportant (EU)	Never fulfilled (NF)	$\langle(0,0,1); 0.00, 1.00, 1.00\rangle$
2	Not very important (NVI)	Few times fulfilled (FTF)	$\langle(0,1,3); 0.17, 0.85, 0.83\rangle$
3	Not important (NI)	Sometimes fulfilled (STF)	$\langle(1,3,5); 0.33, 0.75, 0.67\rangle$
4	Medium (M)	Medium (M)	$\langle(3,5,7); 0.50, 0.50, 0.50\rangle$
5	Important (I)	More fulfilled than not (MF)	$\langle(5,7,9); 0.67, 0.25, 0.33\rangle$
6	Very important (VI)	Most of times fulfilled (MTF)	$\langle(7,9,10); 0.83, 0.15, 0.17\rangle$
7	Extremely important (EI)	Always fulfilled (AF)	$\langle(9,10,10); 1.00, 0.00, 0.00\rangle$

To measure the reliability of the instrument, Cronbach's Alpha coefficient or internal consistency index was used, which is an indicator that assumes values between 0 and 1, [19, 20]. Below 0.7 is considered that the instrument is not reliable. Cronbach's Alpha values between 0.7 and 1 indicate that the construct is reliable. Table 4 presents the results obtained in both measurements.

Table 4. Cronbach's alpha coefficients for both questionnaires.

		Total sample (n= 370)
Expectations	Cronbach's Alpha	0.939
Perceptions	Cronbach's Alpha	0.944

From Table 4 it can be concluded that the instrument used is reliable since, for the total sample, in both questionnaires, the coefficient of Cronbach's Alpha is close to 1.

For processing the data we proceed with collecting the responses to the survey. Let us suppose for the dimension P_i (i =1,2, …, 22) in Table 1, we have both, $\upsilon_{ij} = \frac{\#\{Respondents\ having\ response\ Likert=j\}}{370}$ and $\omega_{ij} = \frac{\#\{Respondents\ having\ response\ Likert=j\}}{370}$, for j = 1,2,…,7 the answers in the Likert scale concerning i dimension, where υ_{ij} is expectation and ω_{ij} is perception.

Next, we calculate:

$$\Upsilon_i = (\upsilon_{i1}\langle(0,0,1); 0.00, 1.00, 1.00\rangle) + (\upsilon_{i2}\langle(0,1,3); 0.17, 0.85, 0.83\rangle) + (\upsilon_{i3}\langle(1,3,5); 0.33, 0.75, 0.67\rangle) + (\upsilon_{i4}\langle(3,5,7); 0.50, 0.50, 0.50\rangle) + (\upsilon_{i5}\langle(5,7,9); 0.67, 0.25, 0.33\rangle) + (\upsilon_{i6}\langle(7,9,10); 0.83, 0.15, 0.17\rangle) + (\upsilon_{i7}\langle(9,10,10); 1.00, 0.00, 0.00\rangle) \quad (7)$$

$$\Omega_i = (\omega_{i1}\langle(0,0,1); 0.00, 1.00, 1.00\rangle) + (\omega_{i2}\langle(0,1,3); 0.17, 0.85, 0.83\rangle) + (\omega_{i3}\langle(1,3,5); 0.33, 0.75, 0.67\rangle) + (\omega_{i4}\langle(3,5,7); 0.50, 0.50, 0.50\rangle) + (\omega_{i5}\langle(5,7,9); 0.67, 0.25, 0.33\rangle) + (\omega_{i6}\langle(7,9,10); 0.83, 0.15, 0.17\rangle) + (\omega_{i7}\langle(9,10,10); 1.00, 0.00, 0.00\rangle) \quad (8)$$

See that in Equations 7 and 8, we used the addition and the product by a scalar defined in Definition 4. They are the weighted mean of the survey results for SVTNNs for each dimension, so they are SVTNNs based on a 0-10 scale. Later we apply Formula 5 of accuracy for de-neutrosophication.

Table 5 shows the responses after the data were de-neutrosophied, according to the responses to each question of the expectations questionnaire and the one that mediates the perceptions, and a contrast is made between them to determine the gaps with what is expected and what is perceived about the services by the users, the students enrolled in the period September 2019 to February 2020 at the ITB.

Table 5. Results of processing the de-neutrosofied data from the survey in the period 2019-2020. We compare with the results obtained in 2017.

		Average of measurements sept. 2019–feb. 2020			Average of measurements 2017	Change in expectation
	Dimension	Expectative	Perception	Gap	Expectative	
P1	Tangibility	9.17	7.9	-1.29	8.3	0.87
P2	Tangibility	9.16	8.14	-1.01	8.51	0.64
P3	Tangibility	8.31	8.01	-0.3	8.3	0.01
P4	Tangibility	8.59	8.33	-0.26	7.96	0.63
P5	Reliability	9.03	8.23	-0.8	8.51	0.51
P6	Reliability	9.06	8.31	-0.74	8.3	0.76
P7	Reliability	9.37	8.66	-0.71	8.79	0.59
P8	Reliability	9.21	8.44	-0.76	8.76	0.46
P9	Reliability	9.21	8.8	-0.4	8.83	0.39
P10	Response Capacity	9.3	8.37	-0.93	8.61	0.69
P11	Response Capacity	9.27	8.31	-0.96	8.77	0.5
P12	Response Capacity	9.33	8.63	-0.7	8.64	0.69
P13	Response Capacity	9.29	8.27	-1	8.51	0.77
P14	Security	9.26	8.56	-0.7	8.8	0.46
P15	Security	9.5	8.61	-0.89	8.94	0.56
P16	Security	9.3	8.31	-0.99	8.8	0.5
P17	Security	9.37	8.5	-0.87	8.79	0.59
P18	Empathy	9.06	8.44	-0.61	8.61	0.44
P19	Empathy	9.16	8.27	-0.89	8.61	0.54
P20	Empathy	9.43	8.51	-0.91	8.9	0.53
P21	Empathy	9.33	8.4	-0.93	8.79	0.54
P22	Empathy	9.47	8.37	-1.1	8.51	0.96

The penultimate column in Table 5 contains the values of the students' expectations corresponding to the similar study carried out at the ITB in 2017. This preliminary study was exclusively dedicated to identifying the expectation about the support service for the training processes. The last column shows the change in students' expectation comparing the first period of 2017 with those enrolled two years later (late 2019 and early 2020).

The results show that the mean of the expectations is higher than the mean of the perception according to the responses given to the questionnaires by the students enrolled in the second academic period of 2019. This indicates that there are dissatisfactions in each of the observed dimensions or what is the same, that the level of satisfaction with the different services does not reach the expectations of the clients (students). The items that present the greatest gap are facilities (P1), the perception that the staff does not understand the requirements made by the students (P22), classrooms and equipment with state-of-the-art technology (P2), and the availability of staff in quantity necessary to expedite the procedures (P13).

Table 5 also shows that an analysis of the expectations declared by the students in 2017 and 2019 indicates that the dimensions which had more increments are those related to the "tangibility" dimension relative to physical facilities in good condition (P1), the one related to the dimension of "reliability" corresponding to the fact that the staff agrees to comply in the shortest time and does so (P6), the one related to the dimension of "response capacity" which refers to the availability of the staff to help with the requirements (P13), and the one corresponding to the dimension "empathy" about the understanding of the personnel about the nature and type of requirements (P22). The foregoing results lead to the need for further analysis of the results obtained for each of the dimensions to be deepened. Therefore, we can infer from our study that the gaps declared in 2017 have significantly been increased comparing with 2019-2020.

Conclusion

This paper combines the SERVQUAL model, which is used to measure the gaps between the expectation and the perception of 22 dimensions in teaching support services at the “Instituto Superior Tecnológico Bolivariano” (ITB) in Ecuador. 370 students of this institute were surveyed on 22 dimensions in the SERVQUAL model according to a Likert scale. The reliability of the survey was approved because it has obtained a Cronbach’s Alpha bigger than 0.9. The results were neutrosophied and aggregated utilizing Single-Valued Triangular Neutrosophic Numbers to incorporate the uncertainty and indetermination in classification. Later, they were de-neutrosophied to obtain a group assessment per dimension.

In the 2019 study, perceptions are lower than expectations, therefore, the ITB should focus on deepening the subject to implement improvements that can modify the perception of students about the teaching support services that they generally receive.

The general average of expectations in students enrolled in the first period of 2017 amounted to 8.61 and that of those enrolled in the second period of 2019 amounted to 9.19. This means that the expectations of students enrolled in the second semester of 2019 increased, on average, almost 7% compared to what students enrolled in early 2017 had on the same services, which is probably supported by the change in cohorts and in the influence of the different evaluation processes for accreditation purposes that have taken off in the country in recent years.

The general index of expectations for the year 2019 is 9.19 and the perception index is 8.37, which generates an average gap of -0.82 between them, together with the fact that for the 22 items the individuals gaps are negative, this is an indicator of the existence of problems in the level of complementary service to the training that the ITB offers to students.

It is recommended to accelerate the identification of the inputs and outputs of all the processes that occur in the institution to determine the control and management indicators and to be able to define the level of service that is given in each of them. The present study was carried out with a general approach and not related to the processes defined within the institutional management model, therefore it is recommended to carry out a broader study that includes all the processes.

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Neutrosophic Evaluation of Dental Implant Success Rates

Emma Arroyo Lalama [1], Dayanara Burbano Pijal [2], Marianela Buitrón Recalde [3], and Darvin Manuel Ramírez Guerra [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.emmaarroyo@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ibarra. Ecuador. E-mail: ui.dayanaraburbano@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.marielabr36@uniandes.edu.ec
[4] Universidad San Martín de Porres, Lima. Perú. E-mail: dramirezg1978@gmail.com

Abstract: This article introduces the concept of neutrosophy, a philosophy that promotes neutrality and balance in decision making and evaluation of situations within the medical field. Neutrosophy, while not yet widespread, may prove useful in ethically complex medical scenarios by encouraging balanced decisions and multiple perspective consideration. In implant dentistry, the success rates are influenced by factors including implant location, patient's general health, implant type, and surgical technique. The article employs a neutrosophic approach to assess the success rates of dental implants in a more comprehensive and unbiased manner. The approach considers both quantitative and qualitative aspects, along with uncertainties, to achieve a balanced evaluation. The findings indicate that the top priority criterion is the absence of pain or discomfort, followed by functionality and long-term maintenance, while the survival rate of the implant is less preferred. In summary, neutrosophy presents a valuable approach to appraise the success rates of dental implants in a well-rounded and ethical manner, incorporating diverse viewpoints that can benefit both dental practitioners and patients in decision-making.

Keywords: Neutrosophy, dental implants, success rates, dentistry, patients.

1 Introduction

Neutrosophy is a philosophy that focuses on the concept of neutrality and the pursuit of equilibrium in decision-making and situation assessment. Although not extensively acknowledged in scientific or medical circles, the term has some applicability in these fields in particular circumstances.[1], [2]

In medical decision making, neutrosophy can help physicians make unbiased and objective medical decisions by considering all aspects of a clinical case, including risks and benefits, as well as the patient's preferences and values. When dealing with complex ethical situations in medical care, such as making end-of-life decisions or allocating limited resources, health care professionals may benefit from implementing neutrosophy. This approach can aid in approaching ethical dilemmas in a more balanced manner and considering multiple perspectives.[3]

Neutrosophy can encourage more open and balanced communication between doctors and patients, allowing patients to actively participate in making decisions about their health care. In medical research, neutrosophy could help scientists fairly evaluate the results of clinical studies and consider the validity of different therapeutic approaches [4]. In healthcare settings, where differences of opinion and conflicts may arise, neutrosophy could be used as an approach to mediate and resolve disputes impartially.[5], [6]

It is important to note that neutrosophy is neither a standard medical practice nor a recognized tool in the field of medicine. Medicine is based on solid scientific evidence, established clinical practices, and well-defined ethical principles. However, some principles of neutrosophy, such as seeking balance and considering multiple perspectives [7], may be useful in certain aspects of healthcare to promote more informed and ethical decisions. [8]

The evaluation of dental implant success rates is essential to determine the effectiveness and quality of dental implantology procedures [9]. This is important for both dental professionals and patients [10]. The following describes some key aspects of evaluating dental implant success rates:

1. Clinical parameters: Dental professionals evaluate the success rate of a dental implant by observing clinical parameters, such as implant stability, lack of mobility, health of surrounding tissues, and proper occlusion. These aspects are evaluated during long-term follow-up after implant placement.
2. X-rays: Panoramic x-rays or CT images, are used to evaluate the integration of the implant with the bone, proper position, and the absence of complications such as infections or bone reabsorption.

3. Evaluation of periodontal health: The health of the surrounding gums and the absence of periodontal disease are critical factors in evaluating the success of a dental implant. Inflammation or infection of the gums can jeopardize the stability of the implant.
4. Patient Evaluation: Patients also play a key role in evaluating the success rates of dental implants. They should follow oral care recommendations and maintain good oral hygiene to ensure the long-term success of their implants.
5. Risk factors: Assessment of patient risk factors such as general health, smoking, and pre-existing medical conditions is also important as they can influence the success rate of dental implants.

The evaluation of dental implant success rates is based on a series of clinical and radiological criteria, as well as the patient's active cooperation in the care and maintenance of oral health. Neutrosophy, if referring to any specific approach or technique, could potentially play a role in the evaluation. It is important that dental professionals use established and widely accepted methods to evaluate the effectiveness of dental implants.[11], [12-16]

The main objective of this research is to apply the neutrosophic approach to evaluate and analyze the success rates of dental implants from a more complete and balanced perspective. This will allow the development of a neutrosophic evaluation framework that allows considering not only quantitative aspects (for example, implant survival rates), but also qualitative aspects and uncertainties associated with success rates. In this way, providing recommendations and conclusions that may be useful to dental professionals and patients when making informed decisions about dental implants.

2 Preliminaries

Definition 1. Let X be a space of points (objects) with generic elements in X denoted by x. A single-valued neutrosophic set (SVNS) A in X is characterized by truth-membership function T_A (x), indeterminacy-membership function I_A (x), and falsity membership function F_A (x). Then, an SVNS A can be denoted by A = {x, $T_A(x)$, $I_A(x)$, $F_A(x)$ x ∈ X}, where T_A (x), I_A (x), F_A (x) ∈ [0, 1] for each point x in X. Therefore, the sum of T_A (x), I_A (x) and F_A (x) satisfies the condition $0 \leq T_A (x) + I_A(x) + F_A(x) \leq 3$[13-17-20].

Decision-making normally involves human language or is commonly referred to as *linguistic variables*. A linguistic variable simply represents words or terms used in human language. Therefore, this linguistic variable approach is convenient for decision-makers to express their assessments. Ratings of criteria can be expressed by using linguistic variables. Linguistic variables can be transformed into SVNSs as shown in Table 1.

Table 1: Linguistic variable and Single Valued Neutrosophic Numbers (SVNNs). Source: [14]

Linguistic variable	SVNS
Extremely preferred (EXP)	(1,0,0)
Very very preferred (VVP)	(0.9, 0.1, 0.1)
Very preferred (VP)	(0.8,0,15,0.20)
Preferred (P)	(0.70,0.25,0.30)
Equally preferred (EP)	(0.50,0.50,0.50)
Not preferred (NP)	(0.35,0.75,0.80)
Very not preferred (VNP)	(0.20,0.85,0.80)
Very very not preferred (VVNP)	(0.10,0.90,0.90)
Extremely not preferred (ENP)	(0,1,1)

Definition2. Let Ek = (Tk, Ik, Fk) be a neutrosophic number defined for the rating of k-th decision-maker. Then, the weight of the kth decision-maker can be written as [15-18]:

$$\psi_k = \frac{1-\sqrt{[(1-T_k(x))^2+(I_k(x))^2+(\mathrm{F}(x))^2]/3}}{\sum_{k=1}^{p}\sqrt{[(1-T_k(x))^2+(I_k(x))^2+(\mathrm{F}(x))^2]/3}} \quad (1)$$

Further, in achieving a favorable solution, group decision-making is important in any decision-making process. All the individual decision-maker assessments need to be aggregated into a neutrosophic decision matrix in the group decision-making process. This can be done by using a single-valued neutrosophic weighted averaging (SVNWA) aggregation operator proposed by Ye [14-19].

Definition 3. Let D (k) = (dij (k)) mxn be the single-valued neutrosophic decision matrix of the k-th decision-maker and be the weight vector of decision-maker such that each where$\psi = (\psi_1 \psi_2, \ldots, \psi_p)^T \psi_k \in [0,1], D = (d_{ij})_{mxn}$

$$d_{ij} = \langle 1 - \prod_{k=1}^{p} \left(1 - T_{ij}^{(p)}\right)^{\psi_k}, \prod_{k=1}^{p} \left(I_{ij}^{(p)}\right)^{\psi_k}, \prod_{k=1}^{p} \left(F_{ij}^{(p)}\right)^{\psi_k} \rangle \quad (2)$$

Definition 4. Let A and B be two single-valued neutrosophic numbers (SVNNs), then the normalized Hamming distance between them is:

$$d(A, B) \frac{|TA - TB| + |IA - IB| + |FA - FB|}{3} \quad (3)$$

Definition 5. Let A= (T_A, I_A, F_A) be a SVNN, the complement of SVNN A is:

$$A.C.= (F_A, 1-I_A, T_A). \quad (4)$$

2.1 Method

Let $A = (A_1, \ldots, A_m)$ be the alternatives, and G = (G1, G2, …, Gn) be the attributes. Let W = (w1, w2, …, wn) be the weights of the attributes, where 0≤wj≤1, $\sum_{j=1}^{n} w_j = 1$. Let aij, i = 1, 2… m, j = 1, 2, .., n, be the attribute value of the alternative A_i with attribute G_j, the $A = (a_{ij})$ $m\times n = \langle (T_{ij}, I_{ij}, F_{ij}) \rangle_{mxn}$is a SVNNs matrix, where T_{ij}, I_{ij}, and F_{ij} are membership degree, indeterminacy-membership degree, and non-membership degree, respectively. The steps to perform the analysis are described below:

- **Step 1:** Identify the decision alternatives to evaluate.
- **Step 2:** Determine the weights of decision-makers. Due to the method's logic, each decision-maker can have a unique and different evaluation from the rest of the decision-makers since each evaluation is awarded according to the level of knowledge of each expert regarding the decision topic discussed. The relative weight of each decision-maker is considered as linguistic variable and is converted into SVNN to later be identified by equation (1).
- **Step 3:** Convert linguistic assessments into SVNN given by experts. From the individual integer matrices obtained from the expert evaluations, the individual neutrosophic matrices of the decision-makers are constructed, as indicated in Table 1.
- **Step 4:** Obtain the initial relation matrix of alternatives A = (A1, …, Am) and attributes G = (G1, G2, …, Gn), where each aij, i = 1, 2, …, m, j = 1, 2, ..., n, is the value of the attribute of the alternative Ai with the attribute G. The A = (aij) m × n = $\langle (T_{ij}, I_{ij}, F_{ij}) \rangle_{mxn}$ is an SVNNs matrix, where T_{ij}, I_{ij}, and F_{ij} are the degree of membership, degree of indeterminacy- membership, and degree of non-membership, using equation (2).
- **Step 5:** Standardize decision information. That is, normalize A = (aij) m × n into B = (bij) m × n. If the decision is a cost factor, the decision information should be changed to its complementary set using equation (3), while if it is an efficiency factor, it should not be changed.
- **Step 6:** Construct a preference function Pj (Bi, Br) of the alternative Bi relative to Br under the attribute Gj using (5).

$$P_j(B_i, B_r) = \begin{cases} 0, d \leq p \\ \frac{d-p}{q-p}, p < d < q \\ 1, d \geq q \end{cases} \quad (5)$$

- **Step 7**: Calculate the relative weight of the attributes w_{jr}, which is the relative weight of Gj to Gr, where

$$w_{jr} = \frac{w_j}{w_r} = (j, r = 1,2, \dots, n) \tag{6}$$

- **Step 8:** Define the priority index π (Bi, Br) of the Bi scheme relative to Br by

$$\pi(B_i, B_r) = \frac{\sum_{j=1}^{n} w_{jr} P_j(B_i, B_r)}{\sum_{j=1}^{n} w_{jr}} \tag{7}$$

- **Step 9:** Calculate inflow Φ^+ (Bi), the outflowΦ^- (Bi) and the net flow Φ (Bi) as follows.

$$\Phi^+(\mathrm{B}_i) = \frac{\sum_{r=1}^{m} \pi(B_i, B_r) - \min_{1 \le i \le m} \{\sum_{r=1}^{m} \pi(B_i, B_r)\}}{\max_{1 \le i \le m} \{\sum_{r=1}^{m} \pi(B_i, B_r)\} - \min_{1 \le i \le m} \{\sum_{r=1}^{m} \pi(B_i, B_r)\}} \tag{8}$$

$$\Phi^-(\mathrm{B}_i) = \frac{\sum_{r=1}^{m} \pi(B_r, B_i) - \min_{1 \le i \le m} \{\sum_{r=1}^{m} \pi(B_r, B_i)\}}{\max_{1 \le i \le m} \{\sum_{r=1}^{m} \pi(B_r, B_i)\} - \min_{1 \le i \le m} \{\sum_{r=1}^{m} \pi(B_r, B_i)\}} \tag{9}$$

$$\Phi(\mathrm{B}_i) = \Phi^+(\mathrm{B}_i) - \Phi^-(\mathrm{B}_i) \tag{10}$$

- **Step 10:** Classify all the alternatives according to the value of $\Phi(\mathrm{B}_i)$. The higher the value of $\Phi(\mathrm{B}_i)$the better the alternative.

2.2 Methodological process

To identify alternatives to evaluate, a comprehensive review of the scientific literature related to dental implant success rates was conducted. The review identified the key factors that have been investigated, as well as the traditional approaches used in their evaluation. The most frequent indicators used to determine the success of dental implants include:

- Implant survival rate: This is the main indicator and refers to whether the implant remains in place and functional. It is measured as the percentage of implants that have not failed or been lost over time.
- No pain or discomfort: The lack of persistent pain or discomfort around the implant is an important indicator of success.
- Functionality: The patient's ability to chew and speak without problems with the implant is considered an important indicator.
- Aesthetic appearance: In cases of implants in visible areas, the aesthetic appearance is evaluated, including the alignment and color of the artificial tooth.
- Long-term maintenance: The patient must maintain good oral hygiene and have regular check-ups with the dentist to ensure the long-term success of the implant.

It is important to note that standards of success may vary by study and dental health professional. In some cases, an implant can be considered successful even if it does not meet all these indicators, as long as it provides adequate function and does not cause significant problems. However, in general, a high success rate in all these aspects is sought to consider an implant successful in the long term.

When evaluating the variables that influence dental implant success rates, it is important to consider several key factors that can affect the outcome and durability of the implants. There are various criteria to evaluate regarding the success rates of dental implants, however, they are also considered depending on the particular interest on the objective to be achieved. This study was structured with four evaluation criteria presented and endorsed by the decision makers. For the analysis, each criterion was assigned equal weight (w = 0.25). The following criteria will be considered for analyzing these variables:

- (IL) Implant location: The location of the implant in the mouth can influence its success. Implants in the posterior area may be subjected to more chewing forces than those in the anterior area, which may affect the success rate.
- (PH) Patient's health status: Underlying medical conditions, such as diabetes, osteoporosis, smoking and other risk factors, can influence the success rate of dental implants.

- (TM) Type of implant and material: The type of implant and the material used are also influential factors. Titanium implants are common, but there are other options, such as zirconia implants. The choice of implant must be appropriate for the patient's needs.
- (SP) Surgical procedure: The surgical technique used to place the implant, including precision in drilling the site and initial stability, is essential for success.

3 Results and Discussion

Table 2 shows the evaluations given to decision-makers according to their relative importance in terms of the topic discussed.

Table 2: Evaluations granted to decision-makers according to their importance. Source: Own elaboration

Decision-makers	Linguistic assessment	SVNN	Numerical value
Decision-maker 1	Very important	(0.9; 0.1; 0.1)	0.21
Decision-maker 2	Moderately important	(0.5; 0.5; 0.5)	0.17
Decision-maker 3	Very important	(0.9; 0.1; 0.1)	0.21
Decision-maker 4	Very important	(0.9; 0.1; 0.1)	0.21
Decision-maker 5	Important	(0.75; 0.25; 0.20)	0.2

Once the decision-makers individually evaluate the indicated alternatives based on each of the chosen criteria or attributes for the evaluation, they are transformed through equation (2) to obtain the normal alternative decision matrix, which is shown in Table 3.

Table 3: Normal decision matrix of alternatives. Source: Own elaboration

	IL	PH	TM	SP
Implant survival rate	(0.61424; 0.38576; 0.35486)	(0.67429; 0.32571; 0.28374)	(0.7626; 0.2374; 0.2081)	(0.7257; 0.2743; 0.2519)
Absence of pain or discomfort	(0.55653; 0.44347; 0.42667)	(0.5; 0.5; 0.5)	(0.56731; 0.43269; 0.41301)	(0.5; 0.5; 0.5)
Functionality	(0.68696; 0.31304; 0.2988)	(0.54297; 0.47088; 0.45555)	(0.47187; 0.54413; 0.5515)	(0.6024; 0.4096; 0.3789)
Aesthetic appearance	(0.69071; 0.30929; 0.29523)	(0.61623; 0.38377; 0.35244)	(0.47187; 0.54413; 0.5515)	(0.5673; 0.4327; 0.413)
Long term maintenance	(0.5; 0.5; 0.5)	(0.55653; 0.44347; 0.42667)	(0.5; 0.5; 0.5)	(0.7445; 0.2555; 0.2555)

All selected criteria are considered benefit criteria; That is, they must be maximized, except for criterion 4, so that the normalized matrix obtained coincides with the normal matrix shown in Table 3. From it, the preference degree matrices Pj (Bi, Br) with respect to Gj are obtained. This calculation can be performed using the proposed linear function (4). For this case it is assumed that q = 1, p = 0 (see Figure 1).

Figure 1: Matrix of degrees of preference (Pn) for each criterion. Source: Own elaboration

$$P_1 = \left|\begin{array}{cccccc} & B_1 & B_2 & B_3 & B_4 & B_5 \\ B_1 & 0.0000 & 0.0000 & 0.0187 & 0.0199 & 0.0000 \\ B_2 & 0.0239 & 0.0000 & 0.0426 & 0.0438 & 0.0000 \\ B_3 & 0.0000 & 0.0000 & 0.0000 & 0.0012 & 0.0000 \\ B_4 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ B_5 & 0.0484 & 0.0245 & 0.0671 & 0.0683 & 0.0000 \end{array}\right|$$

$$P_2 = \begin{array}{c|ccccc|} & B_1 & B_2 & B_3 & B_4 & B_5 \\ B_1 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ B_2 & 0.0721 & 0.0000 & 0.0102 & 0.0492 & 0.0244 \\ B_3 & 0.0619 & 0.0000 & 0.0000 & 0.0390 & 0.0142 \\ B_4 & 0.0229 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ B_5 & 0.0476 & 0.0000 & 0.0000 & 0.0247 & 0.0000 \end{array}$$

$$\mathrm{P}_3 = \begin{array}{c|ccccc|} & \mathrm{B}_1 & \mathrm{B}_2 & \mathrm{B}_3 & \mathrm{B}_4 & \mathrm{B}_5 \\ \mathrm{B}_1 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ \mathrm{B}_2 & 0.0683 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ \mathrm{B}_3 & 0.1198 & 0.0515 & 0.0000 & 0.0000 & 0.0225 \\ \mathrm{B}_4 & 0.1198 & 0.0515 & 0.0000 & 0.0000 & 0.0225 \\ \mathrm{B}_5 & 0.0973 & 0.0290 & 0.0000 & 0.0000 & 0.0000 \end{array}$$

$$P_4 = \begin{array}{c|ccccc|} & B_1 & B_2 & B_3 & B_4 & B_5 \\ B_1 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\ B_2 & 0.0827 & 0.0000 & 0.0364 & 0.0290 & 0.0815 \\ B_3 & 0.0463 & 0.0000 & 0.0000 & 0.0000 & 0.0451 \\ B_4 & 0.0537 & 0.0000 & 0.0074 & 0.0000 & 0.0525 \\ B_5 & 0.0012 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \end{array}$$

Using equation (6), the integral priority index is obtained, as shown in figure 2, from which the inflow, outflow and net flows of each alternative are obtained, as shown in table 4.

Figure 2: Integral priority index of the Bi scheme relative to Br. Source: Own elaboration

$$\Pi = \begin{array}{c|ccccc|} & B_1 & B_2 & B_3 & B_4 & B_5 \\ B_1 & 0.000 & 0.000 & 0.005 & 0.005 & 0.000 \\ B_2 & 0.062 & 0.000 & 0.022 & 0.030 & 0.026 \\ B_3 & 0.057 & 0.013 & 0.000 & 0.010 & 0.020 \\ B_4 & 0.049 & 0.013 & 0.002 & 0.000 & 0.019 \\ B_5 & 0.049 & 0.013 & 0.017 & 0.023 & 0.000 \end{array}$$

Table 4. Input, output, and net flows of the alternatives. Source: Own elaboration

	Φ+	Φ−	Φ
Implant survival rate	0	1,000	-1,000
Absence of pain or discomfort	1	0.000	1,000
Functionality	0.691	0.036	0.654
Aesthetic appearance	0.555	0.167	0.388
Long term maintenance	0.703	0.150	0.553

The positive and negative values in this analysis denote the degrees of preference and non-preference with respect to other alternatives. It can be observed from the obtained results that the absence of pain or discomfort is the most preferred variable compared to the others. Its superiority over the other variables is undisputable. Functionality and long-term maintenance are prioritized, with the implant survival rate being the least preferred. However, the analysis of negative feedback shows that the implant survival rate is the most non-preferred among the other systems.

The net flows confirm the data provided by the negative and positive flows and show that the aspect of preference by analysts regarding the success rates of dental implants during decision making was the absence of pain or discomfort, placing functionality and long-term maintenance in second and third place, respectively.

Conclusion

Neutrosophy is a philosophy that promotes the search for balance and neutrality in decision-making and evaluation of situations, and although it is not widely recognized in the medical field, it can be useful in certain contexts of medical care, especially in ethically complex situations.

In the field of dental implantology, evaluation of success rates is essential to determine the effectiveness of procedures. This evaluation is based on clinical parameters, radiographs, periodontal health, patient evaluation, and patient risk factors. The location of the implant, the patient's overall health, the type of implant and material used, and the surgical technique are key factors that influence the success rates of dental implants.

In this study, a neutrosophic approach was applied to evaluate and analyze the success rates of dental implants from a more complete and balanced perspective. This allowed to consider both quantitative and qualitative aspects, as well as the associated uncertainties. The results of the neutrosophic analysis indicated that the absence of pain or discomfort was the most preferred criterion among the analysts, followed by functionality and long-term maintenance. The implant survival rate had the lowest level of preference.

The net preference flows confirmed that the absence of pain or discomfort is the most important aspect in dental implant decision making, highlighting its relevance in patient satisfaction and the long-term success of the procedure. The neutrosophic approach provides a useful tool to evaluate dental implant success rates in a more balanced manner and considering multiple perspectives, which can help dental professionals and patients make more informed and ethical decisions in this field. However, the importance of using established and widely accepted methods in evaluating the effectiveness of dental implants in clinical practice is highlighted.

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Neutrosophic Analysis of Supply Chain Resilience

Lyzbeth Alvarez Gómez [1], Raúl Comas Rodríguez [2], Jimena Montes De Oca Sánchez [3], and José Felipe Ramírez Pérez [4]

[1] Universidad Regional Autónoma de Los Andes, Quevedo. Ecuador. E-mail: uq.direcacademica@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.raulcomas@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.jimenamontesdeoca@uniandes.edu.ec
[4] Universidad Autónoma de Baja California, México. E-mail: jramirez14@uabc.edu.mx

Abstract. The objective of this research is to extend the TOPSIS method by including single-valued neutrosophic sets to evaluate the vulnerabilities present in the supply chain of a footwear manufacturing company in the city of Ambato. To achieve this goal, principles of neutrosophic logic and the theory of single-valued neutrosophic sets were used. As a result of the application of this methodology, it was found that the most serious weaknesses identified were insufficient investment in technology and innovation, followed closely by the presence of obsolete and deficient communication systems. This study has provided solid evidence of the effectiveness and versatility of the method in a variety of scientific contexts and fields. The use of single-valued neutrosophic numbers as a resource for carrying out the analysis has confirmed the concrete applicability of neutrosophic set logic in practical situations.

Keywords: supply chain, decision making, neutrosophic set, vulnerability.

1 Introduction

The importance of decision making in everyday life and in the business environment is undeniable. In both contexts, decisions have a significant impact on outcomes and quality of life. However, it is often common to encounter situations where the desired objectives are in conflict or the available information is vague and uncertain [1]. This poses a crucial challenge in the decision-making process, as decisions based solely on accurate data may not be appropriate when it comes to dealing with the complexity and uncertainty of the real world.[2]

The inclusion of vague and indeterminate elements in decision-making procedures has become vital for finding effective solutions to complicated problems. Vagueness implies imprecision and ambiguity in accessible data, whereas indeterminacy relates to the uncertainty of information [3]. These elements are inherent in many situations, such as those related to the business environment, where conditions are constantly changing and information may be limited or imprecise.[4]

To address these challenges, researchers have developed approaches based on multi-criteria decision-making methods (MCDM) that enable decision-makers to account for vagueness and indeterminacy in their analysis. Such methods incorporate subjective and flexible evaluations that better capture the imprecise nature of the provided information. The incorporation of vague and uncertain elements into the decision-making process not only enhances adaptability to changing circumstances, but also mitigates suboptimal decisions influenced by oversimplified assumptions.[5]

To overcome the problem presented by uncertain and imprecise data, Zadeh introduced the fuzzy set (FS) theory in 1996. This theory enabled the representation of uncertainty by assigning degrees of membership to elements in a set. In decision making, this approach allowed decision makers to express their preferences and evaluate alternatives in terms of degrees of membership to decision criteria [6]. However, while fuzzy sets have been presented and applied to solve MCDM problems, there are still limitations in their ability to handle certain types of uncertainty in real-world scenarios.[7]

To address these limitations, neutrosophic set theory was formulated as an expansion of fuzzy set theory. Florentin Smarandache proposed this theory in 1995, introducing an innovative approach that enhanced the flexibility of representing uncertainty. Neutrosophic sets function independently with the ability for truth membership, indeterminacy membership, and falsity membership to take values within a nonstandard unit interval of]0-, 1+[.[8]

The integration of neutrosophic set theory into decision making methods has unlocked novel opportunities to address problems characterized by a high degree of vagueness, ambiguity, and uncertainty [9]. This enables decision-makers to more precisely model and manage uncertain information in complex situations. Moreover, neutrosophic set theory has demonstrated its immense value in multi-criteria decision-making, where the consideration of various factors and a more adaptable presentation of preferences are necessary.[10]–[12]

In the business context, decision making is of critical importance, as it can have a significant impact on the success and viability of a company. Every business decision, from investment in new projects to supply chain management, must be based on rigorous analysis and consider multiple criteria and alternatives. Moreover, in an ever-changing business environment, the ability to adapt and make informed decisions is essential.[13-18-20]

Supply chain resilience refers to its ability to withstand and recover from unexpected disruptions, such as natural disasters or interruptions in the flow of supplies. In this context, decision making plays a critical role in ensuring the continuity of operations and minimizing the impact of these unforeseen disruptions. Incorporating uncertainty and indeterminacy more fully enables decision-makers to evaluate supply chain management alternatives and risks more accurately. This identification process leads to development and implementation of robust and adaptive strategies to ensure supply chain continuity even under adverse conditions.[14-19-21-22]

The aim of this paper is to extend the TOPSIS method by applying single-valued neutrosophic sets to assess the vulnerabilities of the supply chain of a footwear company in the city of Ambato. The investigation begins with a detailed explanation of the basic concepts of single-valued neutrosophic sets and the underlying logic in Section 2, followed by a description of the TOPSIS method. In Section 3, this study presents a practical example of applying the aforementioned concepts to evaluate the resiliency of a supply chain within the chosen entity. The results are subsequently presented, followed by relevant conclusions derived from the study.

2 Method

First, some basic concepts of the neutrosophic theory and its relationship with the multicriteria method used are defined.

Definition 1. Let X be a space of points (objects) with generic elements in X denoted by x. A single-valued neutrosophic set (SVNS) A in X is characterized by truth-membership function T_A (x), indeterminacy-membership function I_A (x), and falsity membership function F_A (x). Then, an SVNS A can be denoted by A = {x, T_A(x), I_A(x), F_A(x) x ∈ X}, where T_A (x), I_A (x), F_A (x) ∈ [0,1] for each point x in X. Therefore, the sum of T_A (x), I_A (x) and F_A (x) satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.[15]

For convenience, a SVN number is denoted by A = ($a\ b\ c$), where a, b, c ∈ [0,1] and a + b + c ≤ 3

Definition 2. Let A_1= A_1= (a_1, b_1, c_1) and A_2 = (a_2, b_2, c_2) be two SVN numbers, then summation between A_1 y A_2 is defined as follows:

$$A1 + A2 = (a1 + a2 - a1a2, b1b2, c1c2) \tag{1}$$

Definition 3. Let A_1= (a_1, b_1, c_1) and A_2 = (a_2, b_2, c_2) be two SVN numbers, then multiplication between A_1 y A_2 is defined as follows:

$$A1 * A2 = (a1a2, b1 + b2 - b1b2, c1 + c2 - c1c2) \tag{2}$$

Definition 4. Let A = (a, b, c) be a SVN number and λ∈ℝ anarbitrary positive real number, then:

$$\lambda A = \left(1-(1-a)^{\lambda}, b^{\lambda}, c^{\lambda}\right), \lambda > 0 \tag{3}$$

Definition 5. Let A = $\{A_1, A_2, \ldots, A_n\}$ be a set of n SVN numbers, where A_j = (a_j, b_j, c_j) (j= 1, 2, …, n). The single value neutrosophic weighted average operator on them is defined by

$$\sum_{j=1}^{n} \lambda_j A_j = \left(1-\prod_{j=1}^{n}(1-a_j)^{\lambda_j}, \prod_{j=1}^{n} b_j^{\lambda_j}, \prod_{j=1}^{n} c_j^{\lambda_j}\right) \tag{4}$$

Where λ_j is the weight of A_j (j= 1, 2, …, n), $\lambda_j \in [0,1]$ and $\sum_{j=1}^{n}\lambda_j = 1$

Definition 6. Let $A^* = \{A_1^*, A_2^*, \ldots, A_n^*\}$ be a vector of n SVN numbers, such that A_j^* = (a_j^*, b_j^*, c_j^*) (j= 1,2,…,n), and $B_i = \{B_{i1}, B_{i2}, \ldots, B_{im}\}$ (i= 1,2,…,m), (j= 1,2,…,n). Then the separation measure between B_i and A^* based on Euclidian distance is defined as follows:

$$s_i = \left(\frac{1}{3}\sum_{j=1}^{n}\left(|a_{ij}-a_j^*|\right)^2 + \left(|b_{ij}-b_j^*|\right)^2 + \left(|c_{ij}-c_j^*|\right)^2\right)^{\frac{1}{2}} \tag{5}$$

(i= 1, 2, …, m)

Next, a score function for ranking SVN numbers is proposed below:

Definition 7. Let A = (a, b, c) be a single valued neutrosophic number, a score function S of a single valued neutrosophic value, based on the truth-membership degree, indeterminacy-membership degree and falsity membership degree is defined by

$$S(A) = \frac{1+a-2b-c}{2} \tag{6}$$

where $S(A) \in [-1,1]$

The score function S is reduced the score function proposed by[16] if b = 0 and a + b ≤ 1.

The concept of a linguistic variable is very useful for solving decision making problems with complex content. The value of a linguistic variable is expressed as an element of its term set. Such linguistic values can be represented using single valued neutrosophic numbers.

In the method, there are k-decision makers, m-alternatives, and n-criteria. k-decision makers evaluate the importance of the m-alternatives under n-criteria and rank the performance of the n-criteria with respect to linguistic statements converted into single valued neutrosophic numbers. The importance weights based on single valued neutrosophic values of the linguistic terms is given as Table 1.

Table 1. Linguistic variable and SVNSs. Note: Source:[17]

Linguistic term	SVNSs
Very not influential / (VNI)	(0.9;0.1;0.1)
No influential / (NI)	(0.75;0.25;0.20)
Medium influential / (MI)	(0.50;0.5;0.50)
Influential / (I)	(0.35;0.75;0.80)
Very high influential / (VI)	(0.10;0.90;0.90)

2.1 The TOPSIS method for SVNS

Assuming that $A = \{\rho_1, \rho_2, \dots, \rho_m\}$ is a set of alternatives, and $G = \{\beta_1, \beta_2, \dots, \beta_n\}$ is a set of criteria, the following steps will be carried out:

Step 1: Determine the relative importance of the experts. For this purpose, the specialists evaluate according to the linguistic scale shown in Table 1, and the calculations are performed with their associated SVNN, let $A_t = (a_t, b_t, c_t)$ be the SVNS corresponding to the t-th decision-maker (t = 1, 2, ..., k). The weight is calculated by the following formula:

$$\delta_t = \frac{a_t + b_t\left(\frac{a_t}{a_t + c_t}\right)}{\sum_{t=1}^{k} a_t + b_t\left(\frac{a_t}{a_t + c_t}\right)} \tag{7}$$

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

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 $d_{ij} = (u_{ij}, r_{ij}, v_{ij})$ and is used to aggregate all individual evaluations. d_{ij} 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 4. In this way, a matrix $D = (d_{ij})_{ij}$, is obtained, where each d_{ij} 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 $W = (w_1, w_2, \dots, w_n)$, where w_j denotes the relative importance of the criterion $\lambda_t w_j^t = (a_j^t, b_j^t, c_j^t)$. S_i is the evaluation of the criterion λ_t by the t-th expert. Then Equation 4 is used to add w_j^t the weights λ_t.

Step 4: Construction of the neutrosophic decision matrix from the single-valued weighted average with respect to the criteria.

$$D^* = D * W, \tag{8}$$

$$where \; d_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

Step 5: Calculation of the ideal positive and negative SVNN solutions. The criteria can be classified as cost type or benefit type. Let G_1 be the set of benefit-type criteria and G_2 be the cost-type criteria. The ideal alternatives will be defined as follows:

The positive ideal solution, corresponding to G_1.

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

The negative ideal solution, corresponding to G_2.

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

Where:

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

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

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

Step 6: Calculation of the distances to the positive and negative SVNN ideal solutions. The following equations are calculated using Equation 5:

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

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

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, with the condition that $\widetilde{\rho_j} \rightarrow 1$ is the optimal solution.

3 Results

The analysis and literature review conducted by field specialists have identified several latent vulnerabilities that currently impact the integrity of the footwear company's supply chain. To evaluate these vulnerabilities, four criteria were generated through brainstorming and subsequently ratified by experts in the field.

The criteria selected for the development of data analysis imply:

1. Impact on Production: Evaluates how each vulnerability affects footwear production, from delays to complete shutdowns.
2. Mitigation capacity: Evaluates the real possibility of taking measures to mitigate each vulnerability.
3. Impact on Costs: Analyzes how each vulnerability affects operating costs and profitability.
4. Domino Effect: Evaluates how one vulnerability can cascade down the supply chain.

The analysis involved five experts in the field of study who are considered specialists in the matter. due to their extensive experience.

The criteria's weights were based on experts' evaluations, as presented in Table 1. Table 2 shows the vector of weights obtained in the study.

Table 2: Vector of weights of the analyzed criteria. Source: Own elaboration.

Criteria weights	SVNN
w_1	(0.87989;0.12011;0.11487)
w_2	(0.83428;0.16572;0.15849)
w_3	(0.82671;0.17329;0.15157)
w_4	(0.85573;0.14427;0.13195)

The experts assess detected vulnerabilities based on the criteria's impact, referencing the values in Table 1. The resultant data is translated into neutrosophic sets for future analyses. Table 3 displays the preliminary evaluations provided by each expert regarding the assessed criteria.

Table 3: Evaluation of decision alternatives with respect to the evaluation criteria. Source: own elaboration

Criterion 1: Impact on Production					
Vulnerabilities	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Supplier Dependence	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.75,0.25,0.2)

		Criterion 1: Impact on Production			
Inefficient Transportation and Logistics	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)
Fluctuations in Raw Material Costs	(0.9,0.1,0.1)	(0.9,0.1,0.1)	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.9,0.1,0.1)
Geographic location	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.5,0.5,0.5)
Government regulations	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.9,0.1,0.1)
Raw material with very variable quality standards	(0.75,0.25,0.2)	(0.75,0.25,0.2)	(0.1,0.9,0.9)	(0.75,0.25,0.2)	(0.1,0.9,0.9)
Lack of investment in technology and innovation capacity in the supply chain.	(0.9,0.1,0.1)	(0.1,0.9,0.9)	(0.5,0.5,0.5)	(0.1,0.9,0.9)	(0.1,0.9,0.9)
Poor and obsolete internal and external communication systems	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.9,0.1,0.1)	(0.5,0.5,0.5)
		Criterion 2: Mitigation capacity			
Supplier Dependence	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.9,0.1,0.1)
Inefficient Transportation and Logistics	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
Fluctuations in Raw Material Costs	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)
Geographic location	(0.75,0.25,0.2)	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.75,0.25,0.2)
Government regulations	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.75,0.25,0.2)
Raw material with very variable quality standards	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.75,0.25,0.2)
Lack of investment in technology and innovation capacity in the supply chain.	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.35,0.75,0.8)
Poor and obsolete internal and external communication systems	(0.9,0.1,0.1)	(0.35,0.75,0.8)	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.75,0.25,0.2)
		Criterion 3: Impact on Costs			
Supplier Dependence	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)
Inefficient Transportation and Logistics	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)
Fluctuations in Raw Material Costs	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)
Geographic location	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
Government regulations:	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.35,0.75,0.8)
Raw material with very variable quality standards	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)
Lack of investment in technology and innovation capacity in the supply chain.	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)
Poor and obsolete internal and external communication systems	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.5,0.5,0.5)
		Criterion 4: Domino Effect			
Supplier Dependence	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.75,0.25,0.2)	(0.75,0.25,0.2)
Inefficient Transportation and Logistics	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.1,0.9,0.9)	(0.75,0.25,0.2)	(0.75,0.25,0.2)
Fluctuations in Raw Material Costs	(0.9,0.1,0.1)	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.75,0.25,0.2)	(0.9,0.1,0.1)

Criterion 1: Impact on Production					
Geographic location	(0.9,0.1,0.1)	(0.9,0.1,0.1)	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.9,0.1,0.1)
Government regulations	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.5,0.5,0.5)
Raw material with very variable quality standards	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.9,0.1,0.1)
Lack of investment in technology and innovation capacity in the supply chain.	(0.75,0.25,0.2)	(0.75,0.25,0.2)	(0.1,0.9,0.9)	(0.75,0.25,0.2)	(0.1,0.9,0.9)
Poor and obsolete internal and external communication systems	(0.5,0.9,0.1)	(0.1,0.9,0.9)	(0.5,0.5,0.5)	(0.1,0.9,0.9)	(0.1,0.9,0.9)

The expert evaluations serve as the foundation for the method's operations performed to derive the decision matrix. Equation (8) is implemented to obtain the neutrosophic decision matrix of the single-valued weighted average with respect to the criteria. Table 4 shows the results obtained after applying the above procedure.

Table 4: Initial decision matrix. Source: own elaboration

Alternatives	Impact on Production	Mitigation capacity	Impact on Costs	Domino effect
Supplier Dependence	(0.573;0.427;0.383)	(0.62;0.38;0.35)	(0.266;0.81;0.842)	(0.573;0.427;0.383)
Inefficient Transportation and Logistics	(0.693;0.307;0.297)	(0.428;0.572;0.566)	(0.266;0.81;0.842)	(0.538;0.462;0.414)
Fluctuations in Raw Material Costs	(0.753;0.247;0.232)	(0.693;0.307;0.297)	(0.473;0.527;0.484)	(0.733;0.267;0.247)
Geographic location	(0.62;0.38;0.35)	(0.61;0.39;0.34)	(0.38;0.62;0.605)	(0.753;0.247;0.232)
Government regulations:	(0.714;0.286;0.269)	(0.442;0.582;0.568)	(0.316;0.725;0.733)	(0.62;0.38;0.35)
Raw material with very variable quality standards	(0.499;0.501;0.449)	(0.572;0.437;0.419)	(0.266;0.81;0.842)	(0.714;0.286;0.269)
Lack of investment in technology and innovation capacity in the supply chain.	(0.414;0.586;0.58)	(0.493;0.54;0.549)	(0.291;0.766;0.785)	(0.499;0.501;0.449)
Poor and obsolete internal and external communication systems	(0.631;0.369;0.36)	(0.676;0.329;0.306)	(0.316;0.725;0.733)	(0.247;0.829;0.58)

The results allow to obtain the ideal positive and negative values for each criterion. Subsequently, this allows to determine the ideal distances that are used to calculate the coefficient of proximity. Table 5 shows the distances to the positive and negative ideal values for each competence, according to the criteria, as well as the coefficients of proximity calculated.

Table 5: Distances to the positive and negative ideal values of each competence and coefficients of proximity

Alternatives	d+	d-	CP
Supplier Dependence	0.76	0.55	0.418
Inefficient Transportation and Logistics	0.82	0.57	0.41
Fluctuations in Raw Material Costs	0.72	0.45	0.386
Geographic location	0.72	0.43	0.375
Government regulations	0.79	0.52	0.398
Raw material with very variable quality standards	0.79	0.54	0.406
Lack of investment in technology and innovation capacity in the supply chain.	0.8	0.62	0.438
Poor and obsolete internal and external communication systems	0.78	0.69	0.468

The results obtained through the application of the method to identify the main vulnerabilities in the supply chain of the footwear company allowed several relevant conclusions to be determined. Firstly, it was observed that the dependence on certain suppliers, although significant, did not reach the level of maximum criticality compared to other alternatives evaluated. This finding suggests that while vendor lock-in represents a significant risk, there are other, even more concerning, vulnerabilities.

Inefficiency in transportation and logistics was highlighted as a relevant vulnerability. Although this vulnerability did not reach the category of the worst possible situation, the distances from the ideal values indicated that there was room for substantial improvements in this area. This underlines the need to optimize transportation and logistics processes in the supply chain.

On the other hand, the fluctuation in raw material costs presented a CP of 0.386, positioning itself as one of the least critical vulnerabilities according to the results obtained. Despite their relevance, other alternatives evaluated generated greater concern. This suggests that while it is important to manage and anticipate fluctuations in raw material costs, other vulnerabilities require more immediate attention.

Geographic location was identified as a significant vulnerability. The presence of vulnerability necessitates the consideration of strategies to reduce risks, particularly concerning the distance between the firm and its clients and suppliers. Government regulations have yielded a CP score of 0.398, positioning it at an intermediate level of criticality. These findings suggest that companies need to be ready to adjust to potential regulatory modifications, underscoring the significance of possessing regulatory flexibility in the supply chain.

The lack of investment in technology and innovation in the supply chain was positioned as one of the most critical vulnerabilities. This highlights the urgency of addressing the lack of investment in technology and innovation in the supply chain, as it represents a significant risk for the company. Likewise, poor and outdated communication systems emerged as the most critical vulnerability. This result emphasizes the essential priority of improving communication systems, both internal and external, to ensure supply chain efficiency and resilience.

4 Discussion

Neutrosophy, a philosophical and logical approach that addresses uncertainty and imprecision in decision making, has demonstrated its capability to produce results linked to the evaluation of vulnerabilities in the supply chain. Recognizing the complex nature of the system and enabling a more precise depiction of uncertainty (by considering three logical values instead of the conventional true or false) produces a better representation of the inherent indeterminacy present in supply chain vulnerabilities.

Furthermore, Neutrosophy serves as an effective tool in evaluating the significance of each vulnerability. Since supply chain vulnerabilities can vary in terms of their impact and probability, neutrosophy offers a framework for expressing the associated uncertainty. This is particularly crucial when allocating limited resources to address the most critical vulnerabilities.

Furthermore, the use of neutrosophic sets has promoted communication and consensus among various stakeholders. By acknowledging that evaluations cannot be reduced to simply true or false terms, but may present different levels of accuracy, inaccuracy, and uncertainty, a more comprehensive and subtle discourse about vulnerabilities and their consequences has emerged. Consequently, this development has permitted more knowledgeable judgments and the creation of more efficient tactics to reinforce the supply chain and guarantee the continuity of business operations.

Conclusion

In the field of business science, a wide range of processes constantly take place, leading to complex decisions influenced by multiple factors. Mathematical methods, specifically multicriteria problem-solving approaches, have proven to be immensely valuable in many scenarios.

The use of neutrosophy, as a tool for incorporating uncertainties inherent in complex decision-making processes in the business world, is essential in this dynamic context. In this study, the TOPSIS method was incorporated with neutrosophic logic to assess the supply chain vulnerabilities of a footwear manufacturing company located in Ambato, to improve its overall performance. As a result, it was discovered that the most critical vulnerabilities are the insufficient investment in technology and innovation, closely followed by outdated and deficient communication systems. This highlights the urgent need to allocate more resources and focus towards enhancing innovation and technology within the supply chain, as well as modernizing communication systems.

This study clearly demonstrates the effectiveness and versatility of the method in various scientific environments and fields. Using single-valued neutrosophic numbers to perform the analysis has confirmed the practical applicability of neutrosophic set logic. To broaden the scope of study and its relevance to real-life issues, it is recommended to explore and adopt other multi-criteria methods related to the multiple dimensions of neutrosophic logic.

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University of New Mexico

Neutrosophic Perspectives in Healthcare Decision-Making: Navigating Complexity with Ethics, Information, and Collaboration

Alex Gabriel Lara Jacome [1], Elizabeth Mayorga Aldaz [2], Miguel Ramos Argilagos [3], and Darvin Manuel Ramírez Guerra [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.alexlara@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.elizabethmayorga@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.miguelramos@uniandes.edu.ec
[4] Universidad San Martín de Porres, Lima. Perú. E-mail: dramirezg1978@gmail.com

Abstract. Decision-making in healthcare is a multifaceted process that involves multiple actors and factors. It is a crucial process that directly influences the quality of care provided to patients. To make appropriate clinical decisions, it is essential to have accurate clinical information, including medical histories and test results, in addition to considering ethical principles. Interdisciplinary consultation, proper documentation, and institutional policies play a vital role in ethical and clinical decision-making, especially in complex situations. Research utilizes methods such as COPRAS and neutrosophic correlation coefficients to guide decision-making in complex situations, but it is emphasized that results may vary depending on the method used and the subjectivity of experts. The results highlight the importance of ethical principles in clinical decision-making, including doing good, avoiding harm, treating all patients fairly, and respecting patient autonomy. The combination of clinical information, ethical principles, and active participation of patients and their families is essential for making informed and ethical decisions that promote the health and well-being of patients.

Keywords: Neutrosophic correlation coefficients, COPRAS method, medical care, clinical decisions, ethics.

1. Introduction

Decision-making in healthcare is a fundamental process that directly influences the quality of care provided to patients. To make appropriate clinical decisions, healthcare professionals must have complete and accurate clinical information about the patient, including their medical history, test results, and current health status. This information is essential for evaluating treatment options and weighing the possible risks and benefits associated with each decision.

In addition to clinical information, it is fundamental to consider the ethical principles that guide decision-making in patient care. The principles of beneficence (doing good) and non-maleficence (avoiding harm) are essential and should be at the core of any medical choice. Patient autonomy must also be respected by involving them in the decision-making process and respecting their preferences and personal values. Ethical decision-making is based on a delicate balance between these ethical principles, adapted to the clinical situation and the patient's needs.[1]

Interdisciplinary consultation plays a significant role in complex situations, allowing multiple experts to contribute their perspectives and knowledge to make informed decisions. Additionally, institutional policies and ethical committees can provide additional guidance in ethical and clinical decision-making. Proper documentation of decisions is essential to ensure transparency and accountability in healthcare and can be crucial in case of disputes or subsequent evaluations.

Decision-making in healthcare is a continuous and adaptable process, as the patient's circumstances may change over time. Formal ethical review through hospital ethics committees or ethical consultants may be necessary in particularly complex or controversial cases. Ultimately, decision-making in healthcare is a key aspect of medical practice that requires training and ethical education, as well as constant reflection on how to balance clinical imperatives with ethical values and patient autonomy [2].

It is also a complex process that involves patients, their families, healthcare providers, and sometimes healthcare systems. All involved parties need to understand their roles and responsibilities in this process to ensure that decisions are made in an informed and ethical manner.

Patients should be informed about their medical condition, available treatment options, and the risks and benefits of each option. They should have the opportunity to discuss these options with their healthcare providers and make a decision that is consistent with their values and preferences. [3]

Healthcare providers have the responsibility to provide information and guidance to patients. They should have a thorough knowledge of available treatment options and be able to communicate this information clearly and concisely. They should respond to patients' questions honestly and completely. Additionally, they should respect patients' decisions, even if they disagree with them.

Families can play a significant role in healthcare decision-making. They can provide emotional and practical support to patients and help them understand medical information to make informed decisions. However, families need to respect the autonomy of the patient and not make decisions on their behalf unless the patient is unable to do so [4].

Healthcare systems can facilitate the decision-making process by providing information and resources to patients and their families. They can also assist in coordinating care among different healthcare providers [5].

Some factors that can hinder healthcare decision-making include:

- The complexity of medical information.
- Emotional stress from illness or injury.
- Uncertainty about the prognosis.
- Healthcare costs.

To make informed decisions about their healthcare, patients can take the following steps:

- Ask their healthcare provider about their medical condition and available treatment options.
- Inquire about the risks and benefits of each option.
- Discuss their situation with family and friends.
- Research treatment options on their own.
- Take the necessary time to make a decision.

Decision-making in healthcare is an important process that can have a significant impact on the health and well-being of patients. By understanding their rights and responsibilities, patients can make decisions that are in the best interest of their health.

Taking into account the previous reasoning, this research will carry out an evaluation of clinical and ethical decisions in patient care. For its development, the expansion of the COPRAS-SVNS method approach is carried out, in addition to using neutrosophic correlation coefficients and carrying out a comparison between these coefficients.

2 Preliminaries

Definition 1. Consider X as a collection of points or objects, with a representative element denoted as x. A neutrosophic set A within X is defined by three key functions: the truth-membership function $T_A(x)$, the indeterminacy-membership function $I_A(x)$, and a falsity-membership function $F_A(x)$. These functions, $T_A(x)$, $I_A(x)$ and $F_A(x)$ represent real standard or nonstandard subsets within the interval $]0^-, 1^+[$, meaning that, $T_A(x): X \to]0^-, 1^+[$, $I_A(x): X \to]0^-, 1^+[$ and $F_A(x): X \to]0^-, 1^+[$. There are no constraints on the sum of $T_A(x)$ $I_A(x)$ and $F_A(x)$, so $0^- \leq supT_A(x) + supI_A(x) + supF_A(x) \leq 3^+$. Applying neutrosophic sets to practical problems can be challenging. Therefore, the concept of a single-valued neutrosophic set (SVNS) was introduced to facilitate its use in real-world scientific and engineering applications. Below, we present the definition of an SVNS [6].

Definition 2. Let X be a space of points or objects with each point denoted as 'x.' An SVNS A within X is defined by three membership functions: the truth-membership function $T_A(x)$, the indeterminacy-membership function $I_A(x)$, and the falsity-membership function $F_A(x)$, each of which ranges from 0 to 1. Consequently, an SVNS A can be described as $A = \{x, T_A(x), I_A(x), F_A(x) \mid x \in X\}$, then, the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$, satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

Definition 3. The complement of an SVNS A is denoted by Ac and is defined as $Ac = \{x, F_A(x), 1 - I_A(x), T_A(x) \mid x \in X\}$

Definition 4. An SVNS A is contained in the other SVNS $B, A \subseteq B$ if and only if $T_A(x) \leq T_B(x), I_A(x) \geq I_B(x)$, and $F_A(x) \geq F_B(x)$ for every x in X.

Definition 5. Two SVNSs A and B are equal, written as A = B, if and only if $A \subseteq B$ and $B \subseteq A$

Definition 6. For any two SVNSs A and B in the universe of discourse $X = \{x_1, x_2, \ldots, x_n\}$, the correlation coefficient between two SVNSs A and B is defined as follows: [7]

$$M(A,B) = \frac{1}{3n}\sum_{i=1}^{n}[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (1)$$

Where

$\phi_i = \frac{3-\Delta T_i - \Delta T_{max}}{3-\Delta T_{min} - \Delta T_{max}}$,

$\varphi_i = \frac{3-\Delta I_i - \Delta I_{max}}{3-\Delta I_{min} - \Delta I_{max}}$,

$\psi_i = \frac{3-\Delta F_i - \Delta F_{max}}{3-\Delta F_{min} - \Delta F_{max}}$,

$\Delta T_i = |T_A(x_i) - T_B(x_i)|$,

$\Delta I_i = |I_A(x_i) - I_B(x_i)|$,

$\Delta T_i = |T_A(x_i) - T_B(x_i)|$,

$\Delta T_{min} = min_i|T_A(x_i) - T_B(x_i)|$,

$\Delta I_{min} = min_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{min} = min_i|F_A(x_i) - F_B(x_i)|$,

$\Delta T_{max} = max_i|T_A(x_i) - T_B(x_i)|$,

$\Delta I_{max} = max_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{max} = max_i|F_A(x_i) - F_B(x_i)|$,

for any $x_i \in X$ and i = 1, 2, . . ., n

Nonetheless, significant variances are taken into account when considering the elements within the universe. As a result, it is essential to factor in the weight of element x_i (where i = 1, 2, ..., n). In the subsequent discussion, we present a correlation coefficient that is weighted for SVNSs.

Definition 7. Let w_i be the weight for each element x_i $(i = 1,2,\ldots,n), w_i \in [0,1]$, and $\sum_{i=1}^{n} w_i = 1$, then we have the following weighted correlation coefficient between the SVNSs A and B:

$$M_w(A,B) = \frac{1}{3}\sum_{i=1}^{n} w_i[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (2)$$

Definition 8. Let $A = (T_A, I_A, F_A)$ and $B = (T_B, I_B, F_B)$ be two SVN numbers, then the sum between A and B is defined as follows:

$$A + B = (T_A+T_B - T_A t_B, I_A I_B, F_A F_B) \quad (3)$$

Definition 9. Let $A = (T_A, I_A, F_A)$ and $B = (T_B, I_B, F_B)$ be two SVN numbers, then multiplication of A by B is defined as follows:

$$A * B = (T_A T_B, I_A+I_B - I_A I_B, F_A + F_B - F_A F_B) \quad (4)$$

Definition 10. Let $A = (T_A, I_A, F_A)$ be a SVN number and $\lambda \in \mathbb{R}$ an arbitrary positive real number, then:

$$\lambda A = \left(1-(1-T_A)^{\lambda}, I_A{}^{\lambda}, F_A{}^{\lambda}\right), \lambda > 0 \quad (5)$$

Definition 11. If A= $\{A_1, A_2, \ldots, A_n\}$, and B= $\{B_1, B_2, \ldots, B_n\}$ (i= 1,2,…,m) are two single-valued neutrosophic sets, the measure of separation between A and B using the normalized Euclidean distance can be articulated in the following manner:

$$q_n(A,B) = \sqrt{\frac{1}{3n}\sum_{j=1}^{n}\left(\left(T_A(x_i) - T_B(x_i)\right)\right)^2 + \left(\left(I_A(x_i) - I_B(x_i)\right)\right)^2 + \left(\left(F_A(x_i) - F_B(x_i)\right)\right)^2}$$

$(i = 1,2,\ldots,n)$ (6)

Definition 12. Let $A = (T_A, I_A, F_A)$ be a single-valued neutrosophic number, a score function is mapped $\tilde{N}_A$ into the single crisp output $S(\tilde{N}_A)$ as follows

$$S(\tilde{N}_A) = \frac{3+T_A-2I_A-F_A}{4} \quad (7)$$

where $S(\tilde{N}_A) \in [0,1]$. The score function has been adapted to yield results within the same range as we work with single-valued neutrosophic numbers.

2.1 Decision-making method using the correlation coefficient of SVNSs

In the multiple-attribute decision-making problem with single-valued neutrosophic information, the characteristic of an alternative A_i $(i = 1,2,\ldots,m)$ on an attribute C_j $(j = 1,2,\ldots,n)$ is represented by the following SVNS [7]:

$$A_i = \{C_j, T_{Ai}(C_j), I_{Ai}(C_j), F_{Ai}(C_j) | Cj \in C, j = 1,2,\ldots,n\}$$

Where $T_{Ai}(C_j)$, $I_{Ai}(C_j)$, $F_{Ai}(C_j)) \in [0,1]$ and $0 \le T_{Ai}(C_j)$, $I_{Ai}(C_j)$, $F_{Ai}(C_j) \le 3$ for $Cj \in C, j = 1,2,\ldots,n, and\ i = 1,2,\ldots,m.$

For the sake of simplicity, the values associated with the three functions $T_{Ai}(C_j)$, $I_{Ai}(C_j)$, $F_{Ai}(C_j)$ are represented by a single-valued neutrosophic value (SVNV) denoted as $d_{ij} = < t_{ij}, i_{ij}, f_{ij} >$ $(i = 1,2,\ldots,m;\ j = 1,2,\ldots,n)$. Typically, these SVNVs are determined through the evaluation of an alternative A_i in relation to a criterion C_j by an expert or decision-maker. As a result, we can construct a single-valued neutrosophic decision matrix $D = (d_{ij})_{mxn}$.

In the context of solving problems involving multiple attributes for decision-making, the notion of an ideal point has been employed to assist in determining the optimal choice within the set of decisions. While it's important to note that there is no actual ideal alternative in the real world, this concept serves as a valuable theoretical framework for assessing available alternatives [8-14-16-17].

In the decision-making method, an ideal SVNV can be defined by $d_j^* =< t_j^*, i_j^*, f_j^* >=< 1,0,0 >$ $(j = 1,2,\dots,n)$ in the ideal alternative A^*. Hence, by applying Equation (2) the weighted correlation coefficient between an alternative A_i $(i = 1,2,\dots,m)$ and the ideal alternative A^* is given by [9-18]:

$$M_w(A_i, A^*) = \frac{1}{3}\sum_{j=1}^{n} w_j\left[\phi_{ij}\left(1-\Delta t_{ij}\right) + \varphi_{ij}\left(1-\Delta i_{ij}\right) + \psi_{ij}\left(1-\Delta f_{ij}\right)\right] \quad (8)$$

Where

$$\phi_{ij} = \frac{3-\Delta t_{ij}-\Delta t_{i\,max}}{3-\Delta t_{i\,min}-\Delta t_{i\,max}},$$

$$\varphi_i = \frac{3-\Delta i_{ij}-\Delta i_{i\,max}}{3-\Delta i_{i\,min}-\Delta i_{i\,max}},$$

$$\psi_i = \frac{3-\Delta f_{ij}-\Delta f_{i\,max}}{3-\Delta f_{i\,min}-\Delta f_{i\,max}},$$

$$\Delta t_{ij} = \left|t_{ij}-t_j^*)\right|,$$

$$\Delta i_{ij} = \left|i_{ij}-i_j^*)\right|,$$

$$\Delta f_{ij} = \left|f_{ij}-f_j^*)\right|,$$

$$\Delta t_{i\,min} = min_j\left|t_{ij}-t_j^*\right|,$$

$$\Delta i_{i\,min} = min_j\left|i_{ij}-i_j^*\right|,$$

$$\Delta f_{i\,min} = min_j\left|f_{ij}-f_j^*\right|,$$

$$\Delta t_{i\,max} = max_j\left|t_{ij}-t_j^*\right|,$$

$$\Delta i_{i\,max} = max_j\left|i_{ij}-i_j^*\right|,$$

$$\Delta f_{i\,max} = max_j\left|f_{ij}-f_j^*\right|,$$

for $i = 1,2,\dots,m$ and $j = 1,2,\dots,n$. By the correlation coefficient $M_w(A_i, A^*)$ $(i = 1,2,\dots,m)$, the ranking order of all alternatives and the best one(s) can be obtained.

2.2 COPRAS-SVNS

The notion of a linguistic variable proves to be highly advantageous when addressing decision-making challenges with intricate content. A linguistic variable's value is articulated as a member of its term collection. These linguistic values can be depicted using single-valued neutrosophic numbers [10-15].

Within the COPRAS-SVNS approach, there are k-decision makers, m-options, and n-criteria. The k-decision makers assess the significance of the m-options under the n-criteria and establish a ranking for the n-criteria in relation to linguistic statements transformed into single-valued neutrosophic numbers. The significance weights, determined by the single-valued neutrosophic values of the linguistic terms, are presented in Table 1.

Table 1: Linguistic variable and SVNSs. Source: [11]

Linguistic terms	SVNNs
Extremely good (EG)/ 10 points	(1.00, 0.00, 0.00)
Very very good (VVG)/ 9 points	(0.90, 0.10, 0.10)
Very good (VG)/ 8 points	(0.80, 0.15, 0.20)
Good (G) / 7 points	(0.70, 0.25, 0.30)
Medium good (MG) / 6 points	(0.60, 0.35, 0.40)
Medium (M) / 5 points	(0.50, 0.50, 0.50)
Medium bad (MB) / 4 points	(0.40, 0.65, 0.60)
Bad (B) / 3 points	(0.30, 0.75, 0.70)
Very bad (VB) / 2 points	(0.20, 0.85, 0.80)
Very very bad (VVB) / 1 point	(0.10, 0.90, 0.90)
Extremely bad (EB) / 0 points	(0.00, 1.00, 1.00)

The performance of the group decision-making applying the COPRAS-SVNS approach can be described by the following steps [12], [13]:

- Step 1. Determine the importance of the experts. In the case when the decision is made by a group of experts (decision-makers), firstly the importance or sharing of the final decision of each expert is determined. If a vector $\lambda = (\lambda_1, \lambda_2, \dots, \lambda_k)$ is the vector describing the importance of each expert, where $\lambda_k \geq 0$ and $\sum_{k=1}^{K} \lambda_k = 1$.
- Step 2. In the framework of this step, each decision-maker performs his evaluations concerning the ratings of the alternatives with respect to the attributes and the attribute weights. If we denote by $x_{ij}^k, i = 1,2,\dots,m; j = 1,2,\dots,n$ the k^{th} expert's evaluation of the i^{th} alternative by the j^{th} criterion. This evaluation is expressed in linguistic terms presented in Table 1. So, the decision matrix for any particular expert can be constructed

$$X^k = \begin{bmatrix} x^k{}_{11} & x^k{}_{12} \cdots & x^k{}_{1n} \\ x^k{}_{22} & x^k{}_{22} \cdots & x^k{}_{2n} \\ \vdots & \vdots & \vdots \\ x^k{}_{m1} & x^k{}_{m2} \cdots & x^k{}_{mn} \end{bmatrix} \quad (9)$$

- Step 3. Calculate the weights of the criteria. The aggregated weights of the criteria are determined by

$$\mathrm{w}_j = \lambda_1 \mathrm{w}_j^{(1)} \cup \lambda_2 \mathrm{w}_j^{(2)} \cup \dots \cup \lambda_k \mathrm{w}_j^{(k)} = \left(1 - \prod_{k=1}^{K} \left(1 - T_j^{(w_k)}\right)^{\lambda_k}, \prod_{k=1}^{K} \left(I_j^{(w_k)}\right)^{\lambda_k}, \prod_{k=1}^{K} \left(F_j^{(w_k)}\right)^{\lambda_k}\right) \quad (10)$$

- Step 4. Construction of the aggregated weighted single-valued decision matrix

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} \cdots & \tilde{x}_{1n} \\ \tilde{x}_{22} & \tilde{x}_{22} \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} \cdots & \tilde{x}_{mn} \end{bmatrix} \quad (11)$$

where any particular element $\tilde{x}_{ij} = (\tilde{T}_{ij}, \tilde{I}_{ij}, \tilde{F}_{ij})$ represents the rating of the alternative A_i with respect to the j criterion and is determined as follows

$$\tilde{x}_{ij} = \lambda_1 \mathrm{x}_{ij}^{(1)} \cup \lambda_2 \mathrm{x}_{ij}^{(2)} \cup \dots \cup \lambda_k \mathrm{x}_{ij}^{(k)} = \left(1 - \prod_{k=1}^{K} \left(1 - T_j^{(x_k)}\right)^{\lambda_k}, \prod_{k=1}^{K} \left(I_j^{(x_k)}\right)^{\lambda_k}, \prod_{k=1}^{K} \left(F_j^{(x_k)}\right)^{\lambda_k}\right) \quad (12)$$

- Step 5. Determine the weighted decision matrix. The weighted decision matrix can be expressed as $D = \lfloor d_{ij} \rfloor, d = 1,2,\dots,m; j = 1,2,\dots,n$, where $d_{ij} = \tilde{x}_{ij} * w_j$. a single element of the weighted decision matrix can be calculated as

$$d_{ij} = T_{ij}^{\tilde{x}} T_j^w, I_{ij}^{\tilde{x}} + I_j^w - I_{ij}^{\tilde{x}} I_j^w, F_{ij}^{\tilde{x}} + F_j^w - F_{ij}^{\tilde{x}} F_j^w \quad (13)$$

- Step 6. Calculate the sum of the values for the benefit. Let $L_+ = \{1,2,\dots,L_{max}\}$ be a set of the criteria to be maximized. Then the index of the benefit for each alternative can be determined

$$P_{+i} = \sum_{j=1}^{L_{max}} d_{+ij} \quad (14)$$

- Step 7. Calculate the sum of the values for cost. Let be $L_- = \{1,2,\dots,L_{min}\}$ a set of criteria to be minimized. Then the index of the cost of each alternative can be determined

$$P_{-i} = \sum_{j=1}^{L_{min}} d_{-ij} \quad (15)$$

- Step 8. Determine the minimal value of the P_{-i}.
- Step 9. Determine the score value of each alternative Q_i. In the beginning, the score values are calculated from the aggregated values for benefit and cost $S(P_{+i})$ and $S(P_{-i})$ by using equation (7). The score values of the alternatives can be expressed as

$$Q_i = S(P_{+i}) + \frac{S(P_{-min}) \sum_{i=1}^{L_{min}} S(P_{-i})}{S(P_{-min}) \sum_{i=1}^{L_{min}} \frac{S(P_{-min})}{S(P_{-i})}} \quad (16)$$

- Step 10. Determine optimality criterion K for the alternatives:

$$K = max_i Q_i; i = 1,2,\dots,m \quad (17)$$

- Step 11. Determine the priority of the alternatives. The greater score value Q_i for the alternative corresponds to the highest priority (rank) of the alternative.

3 Methodology

To carry out this research, the working group selected, through document review and brainstorming, the set of components that would be analyzed. In this context, eight elements were identified that, according to expert opinion, are fundamental for proper healthcare management regarding clinical and ethical decisions. These elements were subjected to evaluation using three decision criteria and tested using the proposed initial methods.

To assess the elements to be evaluated in relation to the established criteria, the five experts forming part of the working group were asked to complete a brief form that included the most accurate possible assessment of the issues in question. Additionally, they were asked to assign an importance level to each of the evaluated criteria. In this process, the assessments were supposed to indicate to what extent the expert considered the alternative Ai to be beneficial (Tx), harmful (Fx), or if they were not entirely sure (Ix) regarding criterion Cj, using Table 1 as a guide. The experts involved in the study reached a consensus on the level of importance assigned.

The evaluation and subsequent comparison of the results obtained represent an effective way to validate the selection or efficient screening process of the elements that experts consider of particular importance.

4 Results and Discussion

For the analysis of the alternatives, three selection criteria were considered, focusing on the quality of medical care. These were C1- Effectiveness of the treatment, C2- Benefit for the patient, and C3- Quality of life of the patient.

Based on the evaluations conducted by specialists and following the COPRAS-SVNS method approach, necessary modifications were made to obtain all the elements required to facilitate the creation of the decision-making matrix. Subsequently, using equation (12), the weighted decision matrix for this analysis was calculated. Table 2 succinctly presents the results obtained in this context.

Table 2: Weighted decision matrix. Source: own elaboration.

Alternatives	**Treatment effectiveness**	**Benefit for the patient**	**Patient quality of life**
Complete clinical information	(0.531;0.469;0.433)	(0.497;0.503;0.466)	(0.277;0.802;0.835)
Risk and benefit assessment	(0.531;0.469;0.433)	(0.4;0.6;0.591)	(0.303;0.756;0.775)
Patient autonomy	(0.753;0.247;0.232)	(0.618;0.382;0.361)	(0.531;0.469;0.413)
Ethical principles	(0.573;0.427;0.383)	(0.581;0.419;0.387)	(0.542;0.458;0.424)
Interdisciplinary consultation	(0.586;0.414;0.394)	(0.495;0.514;0.508)	(0.542;0.458;0.424)
Ethical framework and institutional policies	(0.531;0.469;0.433)	(0.481;0.528;0.494)	(0.428;0.582;0.552)
Adequate documentation	(0.61;0.39;0.34)	(0.537;0.463;0.418)	(0.476;0.534;0.489)
Ethical review	(0.573;0.427;0.383)	(0.497;0.503;0.466)	(0.428;0.582;0.552)

After collecting this data, the next step was to calculate the values suggested by the method to decide between the available options. It is important to note that Criteria 2 and 3 were considered as factors that contribute benefits, so maximizing their values is sought. On the other hand, Criterion 1 was considered a cost factor, so reducing its value is considered more beneficial. The results obtained after analyzing and calculating the data are presented in Table 3.

Table 3: Values of Pi, S(P), and Q score value for each alternative. Source: own elaboration.

Alternatives	Pi+	Pi-	S(P+)	S(P-)	Q
Complete clinical information	(0.636; 0.403; 0.389)	(0.531; 0.469; 0.433)	0.61	0.5400	1.26
Risk and benefit assessment	(0.582; 0.454; 0.458)	(0.531; 0.469; 0.433)	0.55	0.5400	1.2
Patient autonomy	(0.821; 0.179; 0.149)	(0.753; 0.247; 0.232)	0.83	0.7570	1.29
Ethical principles	(0.808; 0.192; 0.164)	(0.573; 0.427; 0.383)	0.82	0.5840	1.41
Interdisciplinary consultation	(0.769; 0.235; 0.215)	(0.586; 0.414; 0.394)	0.77	0.5910	1.36
Ethical framework and institutional policies	(0.703; 0.307; 0.273)	(0.531; 0.469; 0.433)	0.7	0.5400	1.35
Adequate documentation	(0.757; 0.247; 0.204)	(0.61; 0.39; 0.34)	0.76	0.6230	1.33
Ethical review	(0.712; 0.293; 0.257)	(0.573; 0.427; 0.383)	0.72	0.5840	1.32

In this case, it can be observed that Option 4 received the highest rating, making it the primary choice of the experts. In this situation, multiple preferred alternatives were evaluated for application in healthcare, rather than selecting only the highest-scoring one. Table 3 presents the top three alternatives that received the highest ratings in the decision index, which were Alternatives 4, 5, and 6, according to expert opinion.

On the other hand, when using the approach based on neutrosophic correlation indices for evaluation, the values of the operators φ, μ, and ψ were calculated to determine the correlation coefficients, following the logic of the method. Obtaining these elements allowed for the calculation and determination of the correlation coefficients, as detailed in Table 4.

Table 4: Values of φ, μ, and ψ and Mw for each selection alternative. Source: own elaboration.

	φij			μij			ψij			
	C1	C2	C3	C1	C2	C3	C1	C2	C3	Mw
Complete clinical information	0.84	1	0.89	0.87	1	0.96	0.96	1	1	0.599
Risk and benefit assessment	0.94	1	0.89	0.91	1	1	1	0.96	0.9	0.558
Patient autonomy	0.9	0.95	1	1	0.96	1	1	0.96	1	0.697
Ethical principles	1	0.9	0.86	1	1	0.96	0.96	1	1	0.704
Interdisciplinary consultation	1	0.95	0.95	0.96	1	0.96	1	1	1	0.612
Ethical framework and institutional policies	1	0.95	0.9	1	0.96	1	1	0.96	1	0.697
Adequate documentation	0.95	1	0.95	1	1	0.96	1	0.96	1	0.697
Ethical review	0.84	1	0.84	1	0.96	0.92	0.96	1	1	0.633

In this situation, the most relevant correlation coefficient was found in relation to the fourth option. However, Options 3, 6, and 7 demonstrated a very similar level of evaluation, making them equally viable for consideration by the evaluators. When comparing the results of both methods, similarities were observed in the outcomes in both cases. Both the COPRAS method and the use of correlation coefficients showed a clear preference for Option 4 in relation to ethical principles. Additionally, in both methods, Option 5 was chosen as one of the most preferred by the experts.

However, while in the COPRAS method, Options 3 and 7 did not have significant relevance, their inclusion in the second method allows considering them as favorites for implementation. On the other hand, Options 1 and 2 did not turn out to be significant in either of the two methods, suggesting that they might have a lower priority.

The results obtained allow for establishing whether there is coherence between the methods used in relation to the chosen decision options. In essence, it was found that the most important option for the experts was the same in both methods, as well as the less desirable or lower-scoring options. Other options experienced some variation in terms of their importance or score depending on the method. However, these differences could be due to the apparent disparities in the calculation methods used or even external factors such as the subjectivity of the experts.

It is suggested that, for more accurate results, each method could be performed separately, as done in this study. Then, only select the common and relevant elements for both methods as of interest.

Certainly, in the interest of this research, it becomes evident the correctness of assertions about the importance of ethical principles. These are fundamental in clinical decision-making, as they include beneficence (doing good), non-maleficence (avoiding harm), justice (treating all patients fairly), and respecting the patient's autonomy. Therefore, it is evident that ethical principles are comprehensive enough to provide other guarantees for satisfactory patient care.

Conclusions

Decision-making in healthcare is a critical process that directly influences the quality of patient care. The importance of having complete and accurate clinical information has been emphasized, along with considering fundamental ethical principles such as beneficence, non-maleficence, and respect for patient autonomy in the decision-making process. Interdisciplinary consultation, proper documentation, and institutional policies play an essential role in ethical and clinical decision-making. Formal ethical review through ethical committees may be necessary in complex or controversial cases.

Active participation from patients, their families, and healthcare providers is crucial in the decision-making process. Patients should be informed about their medical condition and treatment options, with the opportunity to express their preferences and personal values. The use of methods such as COPRAS and neutrosophic correlation coefficients has been shown to provide valuable guidance in complex situations. However, it is essential to consider that results may vary depending on the method used and the subjectivity of the experts.

Research results suggest that the most important option for experts was the consideration of ethical principles in clinical decision-making. This underscores the relevance of these principles in healthcare, encompassing aspects such as doing good, avoiding harm, treating all patients fairly, and respecting patient autonomy. Decision-making in healthcare is a multifaceted process involving multiple stakeholders and considering a variety of factors. The combination of clinical information, ethical principles, and active participation of patients and their families is essential for making informed and ethical decisions that promote the health and well-being of patients.

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University of New Mexico

Neutrosophic Interpretation of Legal Texts and Contracts

Mario Ramiro Aguilar Martínez [1], Nivela Ortega Emver [2], Rosa Evelyn Chuga Quemac [3], and Nemis García Arias [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.marioaguilar@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Babahoyo. Ecuador. E-mail: ub.emverno47@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Tulcán. Ecuador. E-mail: ut.rosachuga@uniandes.edu.ec
[4] Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.nemisgarcia@uniandes.edu.ec

Abstract. The purpose of this research is to demonstrate the usefulness of using neutrosophic logic in determining ambiguities in legal texts. To do this, the aim is to carry out an analysis of a legal text through the use of neutrosophic operators to determine the existence of indeterminacies or ambiguities that may be the subject of deficiencies in the legal field. The use of neutrosophic correlation operators made it possible to identify a set of highly relevant elements that, according to the assessment of experts, must be subjected to mandatory evaluation in the process of analysis and interpretation of legal documents. The incorporation of neutrosophic numbers was particularly significant when examining in detail the language contained in legal clauses and provisions in order to detect vague, ambiguous, or general terms. This study has provided solid evidence of the effectiveness and versatility of the method when applied in the legal field.

Keywords: neutrosophic logic, interpretation, legal documents, neutrosophic correlation coefficients.

1 Introduction

The proper interpretation of legal documents and contracts holds significant importance in the legal and contractual field. Precise comprehension and execution of legal and contractual provisions are vital to maintain the stability and efficacy of the legal and contractual framework. The precise interpretation of these documents is a complex process that requires deciphering a dense and technical language, where each word and phrase can have substantial effects on one's rights, responsibilities, and duties.

However, the existence of indeterminacies or ambiguities in legal texts is a recurring concern in the legal field and can have significant consequences. These indeterminacies refer to situations in which legal provisions do not clearly specify how they should be applied in particular circumstances, giving rise to divergent interpretations. On the other hand, ambiguities arise when a word, phrase, or clause in a legal text may have multiple meanings or is not precise enough for application in a specific context.[1], [2]

These erroneous or ambiguous interpretations of legal texts and contracts can lead to conflicts, litigation, and legal disputes that can be costly both in financial and time terms. Furthermore, lack of clarity in interpretation can undermine confidence in the legal system and in the enforcement of contractual agreements, which in turn can negatively affect the stability of business relationships and the protection of individual rights.

Neutrosophic logic can be a valuable tool in these cases [3]. Neutrosophic logic is a branch of logic that was developed to deal with ambiguity, uncertainty, and vagueness in decision-making and knowledge representation. It was proposed by the mathematician and philosopher Florentin Smarandache in the 1990s [4]. This theory is based on the idea that truth and falsehood may not be the only truth values in complex or uncertain situations. It introduces a third truth value, called "indeterminate," which represents the uncertainty or ambiguity inherent in a statement.[5]

In neutrosophic logic, neutrosophic sets are used to express and manipulate uncertain or ambiguous information. A neutrosophic set is a set in which each element is assigned three values: true, false, and indeterminate [6]. These values allow to represent the ambiguity of a statement or the uncertainty about its truth or falsity. Commonly, neutrosophic logic is applied through neutrosophic logical operators that act on neutrosophic sets [7]. These operators include neutrosophic negation, neutrosophic conjunction, and neutrosophic disjunction, among others. These operators allow logical operations to be performed with indeterminate truth values.[8]

An important aspect of neutrosophic logic is its ability to handle situations in which truth values are not binary, that is, not limited to true or false. This is especially useful in fields where ambiguity and uncertainty are common, such as artificial intelligence [9], decision-making in uncertain environments [10], and natural language interpretation.[11]

Consequently, neutrosophic set theory can be useful in expressing and managing uncertainty in the interpretation of legal texts. By assigning neutrosophic truth values, ambiguity, and indeterminacy in legal clauses and provisions could be quantified. This would facilitate a more accurate understanding of the uncertainty inherent in legal language and could allow interpreters to address it more transparently and fairly.[8], [12], [13]

The purpose of this work is to demonstrate the benefits of using neutrosophic logic in determining ambiguities in legal texts. In this sense, correlation coefficients are a very important tool for judging the relationship between two objects. These coefficients have been widely applied to data analysis and classification, decision-making, pattern recognition, etc. [14]. The present carries out an analysis of a legal text through the use of neutrosophic operators to determine the existence of indeterminacies or ambiguities that may be the subject of deficiencies in the legal field.

In this article, the preliminary aspects of neutrosophic logic and SVNS are first discussed, as well as the formulas for the analysis of correlation coefficients defined in the domain of single-valued neutrosophic sets. Subsequently, the bases on which the analysis is carried out are established, the results achieved are presented and the conclusions derived from the study are produced.

2 Preliminaries

Definition 1. [15] Let X be a space of points (objects), with a generic element in X denoted by x. A neutrosophic set A in X is characterized by a truth-membership function TA(x), an indeterminacy-membership function IA(x), and a falsehood-membership function FA(x). The functions TA(x), IA(x) and FA(x) are real standard or nonstandard subsets of] −0, 1+ [, i.e., TA(x): X →] −0,1+ [, IA(x): X →] −0, 1+ [, and FA(x): X →] −0, 1+ [. There is no restriction on the sum of TA(x), IA(x), and FA(x), so there is −0 ≤ sup TA(x) + sup IA(x) + sup FA(x) ≤ 3+.

It is difficult to apply the neutrosophic set to practical problems. Therefore, in [16-20] Wang introduced the concept of a single-valued neutrosophic set (SVNS), which is an instance of a neutrosophic set, to be used in real scientific and engineering applications. Below is the definition of an SVNS.

Definition 2. Let X be a space of points (objects) with generic elements in X denoted by x. An SVNS A in X is characterized by a truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$, and a falsity-membership function $F_A(x)$ for each point x in X, $T_A(x)$, $I_A(x)$, $F_A(x) \in [0, 1]$. Thus, A SVNS A can be expressed as

A = {x, $T_A(x)$, $I_A(x)$, $F_A(x)$ |x ∈ X}

Then, the sum of $T_A(x)$, $I_A(x)$, and $F_A(x)$ satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

Definition 3. [16] The complement of an SVNS A is denoted by A^c and is defined as

Ac = {x, FA(x), 1 − IA(x), TA(x) |x ∈ X}

Definition 4. [16] A SVNS A is contained in the other SVNS B, A ⊆ B if and only if $T_A(x) \leq T_B(x)$, $I_A(x) \geq I_B(x)$, and $F_A(x) \geq F_B(x)$ for every x in X.

Definition 5. [16] Two SVNSs A and B are equal, written as A = B, if and only if A ⊆ B and B ⊆ A

2.1 Correlation coefficient of SVNSs

Definition 6. [17] For any two SVNSs A and B in the universe of discourse X = {x1, x2, . . . , xn}, the correlation coefficient between two SVNSs A and B is defined as follows:

$$M(A,B) = \frac{1}{3n}\sum_{i=1}^{n}[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (1)$$

Where

$$\phi_i = \frac{3-\Delta T_i - \Delta T_{max}}{3-\Delta T_{min} - \Delta T_{max}},$$

$$\varphi_i = \frac{3-\Delta I_i - \Delta I_{max}}{3-\Delta I_{min} - \Delta I_{max}},$$

$$\psi_i = \frac{3-\Delta F_i - \Delta F_{max}}{3-\Delta F_{min} - \Delta F_{max}},$$

$$\Delta T_i = |T_A(x_i) - T_B(x_i)|,$$

$$\Delta I_i = |I_A(x_i) - I_B(x_i)|,$$

$$\Delta T_i = |T_A(x_i) - T_B(x_i)|,$$

$$\Delta T_{min} = min_i|T_A(x_i) - T_B(x_i)|\,,$$

$\Delta I_{min} = min_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{min} = min_i|F_A(x_i) - F_B(x_i)|$,

$\Delta T_{max} = max_i|T_A(x_i) - T_B(x_i)|$,

$\Delta I_{max} = max_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{max} = max_i|F_A(x_i) - F_B(x_i)|$,

for any xi∈ X and i = 1, 2, . . ., n

However, the differences of importance are considered in the elements in the universe. Therefore, it is necessary to take into account the weight of the element *xi* (*i*= 1, 2,..., *n*). In the following, we introduce a weighted correlation coefficient between SVNSs.

Definition 7. [17] Let *wi* be the weight for each element *xi* (*i*= 1, 2, . . . , *n*), *wi* ∈[0, 1], and $\sum_{i=1}^{n} w_i = 1$, then we have the following weighted correlation coefficient between the SVNSs *A* and *B*:

$$M_w(A,B) = \frac{1}{3}\sum_{i=1}^{n} w_i[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (2)$$

2.2 Decision-making method using the correlation coefficient of SVNSs.

In the multiple attribute decision-making problem with single-valued neutrosophic information, the characteristic of an alternative Ai (i = 1, 2, ..., m) on an attribute Cj (j = 1, 2,..., n) is represented by the following SVNS:

$$Ai = \{Cj, TAi\ (Cj), IAi\ (Cj), FAi\ (Cj)|Cj \in C, j = 1,2,\dots,n\}$$

where $TAi\ (Cj), IAi\ (Cj), FAi\ (Cj) \in [0,1]$ and $0 \le TAi\ (Cj) + IAi\ (Cj) + FAi\ (Cj) \le 3\ for\ Cj \in C, j = 1,2,\dots$, n, and i = 1, 2, . . ., m

For convenience, the values of the three functions T_{Ai} (C_j), I_{Ai} (C_j), F_{Ai} (C_j) are denoted by a single-valued neutrosophic value (SVNV) d_{ij} = <t_{ij}, i_{ij}, f_{ij}> (i = 1, 2, . . ., m; j = 1, 2, . . ., n), which is usually derived from the evaluation of an alternative A_i with respect to a criterion C_j by the expert or decision maker. Thus, it is possible to elicit a single-valued neutrosophic decision matrix D = $(d_{ij})_{m\times n}$.

In multiple attribute decision-making problems, the concept of an ideal point has been used to help identify the best alternative in the decision set. Although the ideal alternative does not exist in the real world, it does provide a useful theoretical construct against which to evaluate alternatives.[18-21-22-23-24]

In the decision-making method, an ideal SVNV can be defined by d_j^* =<t_j^*, i_j^*, f_j^*>=< 1, 0, 0 > (j = 1, 2, . . . , n) in the ideal alternative A*. Hence, by applying Equation (2) the weighted correlation coefficient between an alternative A_i (i =1, 2, . . ., m) and the ideal alternative A* is given by

$$M_w(A_i, A^*) = \frac{1}{3}\sum_{j=1}^{n} w_j\left[\phi_{ij}\left(1-\Delta t_{ij}\right) + \varphi_{ij}\left(1-\Delta i_{ij}\right) + \psi_{ij}\left(1-\Delta f_{ij}\right)\right] \quad (3)$$

Where

$$\phi_{ij} = \frac{3 - \Delta t_{ij} - \Delta t_{i\,max}}{3 - \Delta t_{i\,min} - \Delta t_{i\,max}},$$

$$\varphi_i = \frac{3 - \Delta i_{ij} - \Delta i_{i\,max}}{3 - \Delta i_{i\,min} - \Delta i_{i\,max}},$$

$$\psi_i = \frac{3 - \Delta f_{ij} - \Delta f_{i\,max}}{3 - \Delta f_{i\,min} - \Delta f_{i\,max}},$$

$\Delta t_{ij} = |t_{ij} - t_j^*)|$,

$\Delta i_{ij} = |i_{ij} - i_j^*)|$,

$\Delta f_{ij} = |f_{ij} - f_j^*)|$,

$\Delta t_{i\,min} = min_j|t_{ij} - t_j^*|$,

$\Delta i_{i\,min} = min_j|i_{ij} - i_j^*|$,

$\Delta f_{i\,min} = min_j|f_{ij} - f_j^*|$,

$\Delta t_{i\,max} = max_j|t_{ij} - t_j^*|$,

$$\Delta i_{i\,max} = max_j \left| i_{ij} - i_j^* \right| ,$$

$$\Delta f_{i\,max} = max_j \left| f_{ij} - f_j^* \right| ,$$

for i = 1, 2, . . ., m and j = 1, 2, . . ., n. By the correlation coefficient M_w (A_i, A*) (i =1, 2, . . ., m), it is possible to obtain the ranking order of all alternatives and determine which are the best one(s).

4 Results

In order to conduct a study, it is imperative to carry out a meticulous selection of the elements to be subjected to analytical scrutiny within the realm of legal documents. Through a process of brainstorming and group discussion, the experts devise a list of six criteria for analysis that are of vital relevance to the purposes of the research in question. This criteria selection procedure is crucial in the stage of defining the variables of the study, allowing the subsequent evaluation and quantification of the key factors that affect the quality and clarity of the legal documents under analysis. In this sense, the elements defined by the experts include:

1. Cross References and Definitions: Analyze whether the legal text includes clear cross-references to other sections and precise definitions of key terms. The lack of these references may contribute to ambiguity.
2. Clarity of Language: Clarity of language is essential. Evaluates whether the legal text is written in a way that is understandable to the parties involved, without the need for specialized legal knowledge. Clear language helps reduce ambiguity.
3. Presence of Vague or Ambiguous Terms: Identifies terms or phrases that may have multiple interpretations or whose meanings are not clearly defined in the context of the contract. Vague or ambiguous terms may lead to disputes.
4. Lack of Specificity in Certain Provisions: Examines whether the legal text lacks specific details in certain clauses or provisions. Lack of specificity can lead to uncertainty about the parties' obligations and rights.
5. Possibility of Diverse Interpretations: Consider how different parties involved may interpret the legal text in different ways. If there are multiple possible interpretations, it is an indication of ambiguity.
6. Inconsistencies and Contradictions: Look for inconsistencies or contradictions within the legal text. If there are parts of the contract that appear to conflict with each other, this can lead to ambiguity and indeterminacy.

To carry out the analysis of the selected elements and determine which of them exerts a more significant influence, three specific evaluation criteria were chosen. First, the criterion of "*impact on the level of ambiguity/indeterminacy*" (C1) was selected. This criterion is designed to assess the extent to which each alternative contributes to the ambiguity or indeterminacy observed in the legal text. Ambiguity and indeterminacy are critical factors that can affect the quality and effectiveness of the legal document, and it is necessary to understand their origin and extent.

The second criterion, called "*degree of influence on understanding*" (C2), focuses on analyzing the level at which each element influences the general understanding of the legal text by the parties involved. Effectively understanding the content of a contract or legal document is essential to avoid misunderstandings and future disputes, so this criterion examines the ability of the elements to facilitate or hinder such understanding.

Finally, the third criterion, titled "*potential for negative legal consequences*" (C3), focuses on evaluating the potential of each of the alternatives to give rise to adverse legal consequences. This includes the possibility of triggering litigation, disputes, or breaches of contract. Alternatives that have the greatest potential to generate legal problems are identified as priorities since their rectification or clarification can help prevent costly disputes and protect the interests of the parties involved.

To evaluate the elements based on the selected criteria; it has been arranged that the experts complete a short form in order to obtain precise evaluations. In addition, they have been asked to weigh the importance of each of the criteria in relation to the others. This weighting is of vital importance since it allows quantifying the relevance of each criterion in the evaluation process.

In this sense, experts have been required to specify the extent to which they consider that a specific alternative, denoted as "Ai", does or does not fit a particular criterion, represented as "Cj". The options provided for evaluations are "good" (Tx), "bad" (Fx), or "unsafe" (Ix). The choice of one of these options provides a clear indication of the expert's perception of the suitability of the alternative for the criterion in question.

It is important to highlight that equal weight (wj=0.33) has been attributed to all the evaluated criteria, which guarantees equitable consideration of each of them in the evaluation process. This methodology provides a solid foundation for data collection and analysis. In this way, it is expected to facilitate informed decision-making in relation to the prioritization and improvement of elements in legal texts.

In the outlined analysis process, the calculation of the arithmetic mean is applied to the evaluations provided by the experts. This involves the aggregation of the ratings given by each expert in relation to the criteria and alternatives under consideration. The results of these collective evaluations yield a decision matrix called "D", which is generated as a consequence of this process and is presented below.

$$D = \begin{bmatrix} \langle 0.3;\ 0.2;\ 0.3\rangle & \langle 0.3;\ 0.2;\ 0.3\rangle & \langle 0.1;\ 0.2;\ 0.5\rangle \\ \langle 0.4;\ 0.2;\ 0.2\rangle & \langle 0.7;\ 0.1;\ 0.2\rangle & \langle 0.6;\ 0.2;\ 0.3\rangle \\ \langle 0.4;\ 0.3;\ 0.2\rangle & \langle 0.5;\ 0.2;\ 0.3\rangle & \langle 0.6;\ 0.1;\ 0.2\rangle \\ \langle 0.3;\ 0.2;\ 0.3\rangle & \langle 0.1;\ 0.2;\ 0.5\rangle & \langle 0.4;\ 0.2;\ 0.2\rangle \\ \langle 0.2;\ 0.3;\ 0.5\rangle & \langle 0.3;\ 0.2;\ 0.3\rangle & \langle 0.3;\ 0.2;\ 0.3\rangle \\ \langle 0.4;\ 0.2;\ 0.2\rangle & \langle 0.4;\ 0.2;\ 0.2\rangle & \langle 0.6;\ 0.1;\ 0.2\rangle \end{bmatrix}$$

In accordance with what is described for the development of the method and obtaining the results, the values of the operators φ, μ, and ψ are determined to obtain the correlation coefficients, as defined by the method. Tables 1 and 2 show the results of such operations.

Table 1: Minimum and maximum values of variation in the membership functions of truth, falsity, and indeterminacy. Source: own elaboration.

	A1	A2	A3	A4	TO 5	A6
ΔTmin	0.7	0.3	0.4	0.6	0.7	0.4
ΔImin	0.3	0.2	0.2	0.2	0.3	0.2
ΔFmin	0.2	0.1	0.1	0.2	0.2	0.1
ΔTmax	0.9	0.6	0.6	0.9	0.8	0.6
ΔImax	0.5	0.3	0.3	0.5	0.5	0.2
ΔFmax	0.2	0.2	0.3	0.2	0.3	0.2

Table 2: Values of φ, μ, and ψ for each selection alternative. Source: own elaboration

Crimes	**φ1**	**φ2**	**φ3**	**μ1**	**μ2**	**μ3**	**ψ1**	**ψ2**	**ψ3**
Cross References and Definitions	1.00	1.00	0.86	1.00	1.00	0.91	1.00	1.00	1.05
Language Clarity	0.86	1.00	0.95	1.00	1.00	0.96	0.96	1.00	1.00
Presence of Vague or Ambiguous Terms	0.90	0.95	1.00	1.00	0.96	1.00	0.92	0.96	1.04
Lack of Specificity in Certain Provisions	0.93	0.80	1.00	0.96	0.87	1.00	1.00	1.00	1.00
Possibility of Diverse Interpretations	0.93	1.00	1.00	0.91	1.00	1.00	0.96	1.00	1.00
Inconsistencies and Contradictions	0.90	0.90	1.00	1.00	1.00	1.00	0.96	0.96	1.04

Thus, through the application of equation (3), the values corresponding to the correlation coefficients $M_w(A_i, A^*)$ are derived. Table 4 shows these calculated values and presents a ranking based on the scores obtained.

The use of equation (3) allows an accurate measurement of the correlation between the evaluated alternatives and the reference alternative, which provides a quantitative basis for the comparison and classification of the alternatives. These correlation coefficients are valuable decision-making tools as they highlight the relative relationships of each alternative to the reference alternative, contributing to objective evaluation and selection of the best options.

Table 3: Weighted correlation coefficients. Source: own elaboration

Analyzed elements	**M coefficient**
Cross References and Definitions	0.55
Language Clarity	0.71

Analyzed elements	M coefficient
Presence of Vague or Ambiguous Terms	0.67
Lack of Specificity in Certain Provisions	0.56
Possibility of Diverse Interpretations	0.55
Inconsistencies and Contradictions	0.69

In this case, it can be observed that the element "*Language Clarity*" obtains the highest weighted correlation coefficient, with a value of 0.71, which indicates a strong positive correlation with the quality and clarity of the legal text. This suggests that language clarity is a critical factor in improving document quality. On the other hand, elements such as "*Presence of Vague or Ambiguous Terms*" and "*Inconsistencies and Contradictions*" also present significant correlation coefficients (0.67 and 0.69, respectively), which positions them as important elements to consider in the improvement process.

Clarity of Language, *Inconsistencies and Contradictions,* and *Presence of Vague or Ambiguous Terms* were the three elements that stand out as having the greatest influence on the quality and clarity of legal texts. These results support the need to address these three elements with priority in the process of reviewing and improving legal texts. By doing so, the quality, clarity, and effectiveness of legal documents can be improved, reducing ambiguity and mitigating potential adverse legal consequences.

4.1 Illustrative example

As part of the analytical methodology employed, a practical case study was conducted with a plastics industry firm situated in the city of Puyo. Four legal specialists with expertise in contract regulations regarding this particular industry sector participated in the study to analyze the company's compliance with applicable legal provisions.

As part of this practical study, experts examined and evaluated a particular employment contract. They were asked to provide their evaluations through a form in which the adequacy of the document in question had to be considered.

Table 4 shows the results obtained after the evaluation of one of the experts using the linguistic criteria described in [19]. To carry out this evaluation, the evaluation elements obtained previously were taken as reference.

Table 4: Neutrosophic evaluation of employment contract carried out by an expert *k*

	Language Clarity	Presence of Vague or Ambiguous Terms	Inconsistencies and Contradictions
Description of tasks	(0.90, 0.10, 0.10)	(0.60, 0.35, 0.40)	(0.90, 0.10, 0.10)
Working hours	(0.90, 0.10, 0.10)	(0.50, 0.50, 0.50)	(0.50, 0.50, 0.50)
Salary policy	(0.70, 0.25, 0.30)	(0.90, 0.10, 0.10)	(0.70, 0.25, 0.30)
Trial period	(0.90, 0.10, 0.10)	(0.50, 0.50, 0.50)	(0.70, 0.25, 0.30)
Benefits and advantages	(0.70, 0.25, 0.30)	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)
Termination Policy	(0.80, 0.15, 0.20)	(0.80, 0.15, 0.20)	(0.90, 0.10, 0.10)
Confidentiality policy	(0.60, 0.35, 0.40)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)

It is important to highlight that, in this specific case, the criteria previously identified in the initial analysis were used. However, it is crucial to recognize that each legal document may have particularities and distinctive characteristics that make certain criteria and elements acquire differentiated importance in the analysis process. In other words, the suitability of the criteria identified in this practical study may vary depending on the particularities of each contract, highlighting the need to consider and adapt the analysis approach according to the specific characteristics of each legal document.

The evaluation table used neutrosophic numbers to evaluate the elements of an employment contract in consideration of the selected criteria. Each entry in the table comprises three values that represent the expert's perception in terms of affirmation, indifference, and denial, respectively. The results derived from this analysis allow the researchers to determine that, according to the expert, both the "*Description of Tasks*" and the "*Work Schedule*" exhibit adequate levels of clarity in the contract. However, there is some uncertainty or areas for improvement regarding the clarity of the terms related to the "*Salary Policy*", "*Benefits and advantages*", and "*Confidentiality Policy*".

On the other hand, concerning the presence of vague or ambiguous terms, the expert shows a particularly critical attitude in relation to the "*Working Schedule*" and the "*Trial Period",* assigning low affirmation values. This implies that the expert identifies aspects that are confusing or ambiguous in these elements of the contract. Finally, regarding inconsistencies and contradictions, the expert tends to point out areas for improvement, mainly in relation to the "*Working Schedule*" and the "*Confidentiality Policy*". This suggests that the expert perceives the existence of certain areas where these elements of the contract could present inconsistencies or contradictions.

In summary, according to the expert's neutrosophic evaluation, some elements, such as "*Description of Tasks*" and "*Work Schedule*", stand out for their clarity of language. However, there are significant concerns regarding the presence of vague or ambiguous terms and potential inconsistencies in various elements of the contract, suggesting areas that may require review and improvement to ensure a clearer and more coherent employment contract.

4 Discussion

The results obtained confirm that neutrosophic logic appears to be an invaluable tool in the interpretation and evaluation of legal documents. Its importance lies in its ability to deal with the uncertainty and ambiguity inherent in legal language, allowing for more accurate and detailed analysis of the terms and conditions in legal documents.

In the context of contract interpretation, neutrosophy offers a structured way of handling situations where a term or clause can be interpreted in multiple ways. The use of neutrosophic numbers allows interpreters to express their level of conviction or belief in a particular interpretation. This is especially relevant in the analysis of contracts, commercial agreements, or court rulings, where nuances and subtleties are critical. In these settings, it is possible to observe that neutrosophy helps address semantic ambiguity by allowing evaluators to express how confident they are in a given interpretation, which can be crucial for making informed decisions.

Ultimately, neutrosophy provides an analytical framework that promotes a more accurate and systematic interpretation of these documents, which in turn helps reduce the risk of conflicts and litigation arising from misunderstandings or ambiguities. Clarity in the interpretation and evaluation of legal documents is essential to ensure compliance with laws and the protection of the rights of the parties involved, which highlights the significant usefulness of neutrosophy in the field of law and jurisprudence.

Conclusion

In the field of legal sciences, it is common to face vagueness and indeterminacy when analyzing legal documents. In such situations, the level of scrutiny by jurists and other stakeholders takes on a critical role. This study has highlighted the usefulness of neutrosophic logic for the identification of evaluation criteria for legal documents and their subsequent interpretation. The use of neutrosophic correlation operators has made it possible to identify a set of highly relevant elements that, according to the assessment of experts, must be subjected to mandatory evaluation in the process of analysis and interpretation of legal documents.

This study has provided solid evidence of the effectiveness and versatility of the applied method in the legal field. The use of single-valued neutrosophic numbers to carry out the analysis has practically validated the applicability of neutrosophic set logic. It is recommended to explore and adopt other multi-criteria methods related to the multiple dimensions of neutrosophic logic, in order to delve deeper into the study area and its applicability to real problems.

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University of New Mexico

Neutrosophic Assessment of Personality Traits

Roberto Aguilar Berrezueta [1], Elizabeth Mayorga Aldaz [2], Blanca Cristina Estrella López [3], and Juan Antonio Arrunátegui Aguirre [4]

[1] Universidad Regional Autónoma de Los Andes. Santo Domingo. Ecuador. E-mail: us.robertoab26@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.elizabethmayorga@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.blancaestrella@uniandes.edu.ec
[4] Universidad Nacional Mayor de San Marcos. Perú. E-mail: jarrunateguia@unmsm.edu.pe

Abstract. This paper addresses the importance of understanding the personality traits of teachers and their impact on the educational process. It mentions the existence of stable personality traits and variable personality states that vary over time. It also refers to the five-factor personality model (FFM), which includes the domains of Extraversion, Affability, Conscientiousness, Neuroticism, and Openness to Experience. The study is carried out in the context of Higher Education Institutions (HEIs) in Ecuador, where professors perform functions related to teaching, research, extension, and academic management. It is noted that emotional contagion between teachers and students can be relevant in this environment. The paper presents a qualitative analysis based on a Neutrosophic Cognitive Map (NCM) of nine personality traits: Empathy, Openness to Experience, Introversion, Emotional Stability, Kindness and Respect, Flexibility, Excessive Authoritarianism, Neuroticism and Egocentrism. The causal relationships between these traits are highlighted, emphasizing the importance of empathy as a central factor. It discusses how traits such as empathy, kindness, patience, and emotional stability contribute to a positive and productive learning environment. Furthermore, it is noted that the modification of negative traits, such as excessive authoritarianism and egocentrism, can improve the professional development of teachers and benefit students in the long term. Finally, this study is compared with previous research, and it highlights that the results may vary. For example, a study that did not find significant relationships between personality traits and teaching performance is mentioned, while this study suggests that excessive authoritarianism and egocentrism can affect communication with students and the quality of training.

Keywords: professional development, personality traits, neutrosophic cognitive maps, teachers, empathy.

1 Introduction

Most personality theories suggest that personality can be described using several entities that all have a unique stable component, personality traits, and also variable aspects, personality states, that fluctuate from moment to moment [1]. One predominant model for conceptualizing personality traits is the five-factor model (FFM), which consists of five broad domains that capture overarching patterns of personality. At the higher order, the domains are labeled: Extraversion vs. introversion, affability vs. antagonism, consciousness vs. undependability or disinhibition, neuroticism vs. emotional stability, and openness vs. closedness to experience [2]. Recent handbooks on personality development offer a more comprehensive perspective on the stability and change of other personality constructs, such as life narratives, motives, and values [3]. One of the trait theories that has generated more consensus is that developed by Costa and McCrae (1985), known as the five-factor model [4, 5]. According to this, the basic elements of personality would be neuroticism, extraversion, openness to experience, affability, and conscientiousness.

- Neuroticism: assesses emotional stability or instability; psychological distress; unrealistic ideas; non-adaptive coping responses.
- Extraversion: evaluates the amount and intensity of interaction between people; the level of activity; the need for stimulation and the ability to enjoy.
- Openness to experience: evaluates actively seeking and valuing experience for oneself; tolerance and exploration of the unknown.
- Affability: assesses the quality of one's interpersonal orientation along a continuum from compassion to rivalry.
- Conscientiousness: evaluates the degree of organization of the individual; perseverance and motivation in goal-oriented behavior.

In Ecuador, the functions of teachers from a Higher Education Institution (HEI) revolve around four axes: teaching (activities related to inter-learning), research (activities leading to the search for theoretical or practical knowledge), extension (activities aimed at social projection), and academic management. The selection process, in itself, has to do with the requirements of the Law that regulates the Higher Education processes of each country and with the specific training required for the subject to be taught in each institution. Some studies have shown that an emotional contagion occurs between the teacher and the student. HEIs could benefit from knowing the personality traits of their teachers to be able to insert them in a relevant way in the activities or functions in which they will be able to perform with excellence, thus improving their efficiency, and responding to one of the objectives regarding education. The present study aimed to know the teachers' personality traits that could influence the development of their students.

2 Material and Methods.

2.1 Theoretical methods:

The documentary research method, bibliographic research, and observation were used, as well as the inductive/deductive method to conduct the hermeneutic method. This method allows establishing and analyzing different perspectives and comparing them with the literature consulted. A bibliographic search was carried out on the elements of the teacher's personality to know the influence of these traits in the teaching process.

2.2 Methods for processing information:

Neutrosophic Cognitive Maps (NCMs) were introduced by [6] in 2003. NCMs are an integration of fuzzy cognitive maps (FCMs) introduced by Kosko in 1986 and neutrosophic sets (NSs) introduced by Smarandache in 1995 [7]. This technique overcomes the inability of traditional FCMs to represent indeterminacy. The inclusion of indeterminacy establishes that neutrality and ignorance are also forms of uncertainty. [7] explains that FCMs is a technique that has received increasing attention due to its possibilities to represent causality. The following is a set of definitions necessary to work with NCMs. First, the original definition of neutrosophic logic is shown below as defined in [8].

Definition 1. [9] Let N be a neutrosophic evaluation set. v: $N = \{(T, I, F): T, I, F \in [0,1]\}$→N is a mapping of a group of propositional formulas onto N, that is, each sentence is associated with a value p∈N, as set out in Equation 1, that is, p is T% true, I% indeterminate, and F% false.

$$\mathrm{v}\,(\mathrm{p}) = (\mathrm{T}, \mathrm{I}, \mathrm{F}) \qquad (1)$$

Therefore, neutrosophic logic is a generalization of fuzzy logic, based on the concept of neutrosophic according to [10, 11].

Definition 2. [12, 13] Let K be the ring of real numbers. The ring generated by K∪I is called a neutrosophic ring if the indeterminacy factor intervenes in it, where I satisfies *I2 = I, I+I = 2I* and, in general, *I+I+...+I = nI*, if *k∈K, then kI = kI, 0I = 0*. The neutrosophic ring is denoted by *K(I)*, which is generated by K*∪Yo*, that is, *K(I)* = <K∪i>, where <K*∪I*>denotes the ring generated by K and I.

Definition 3. A neutrosophic matrix is a matrix *A = [aij]ij i =1, 2, ..., m and j = 1, 2, ..., n; m, n≥1*, such that each a_{ij}*∈K(I),*where *K(I)* is a neutrosophic ring, see [14]

An element of the matrix may be in the form a+bI, where "a" and "b" are real numbers, while I is the indeterminacy factor. The usual neutrosophic matrix operations can be extended from the classical matrix operations.

For example,

$$\begin{pmatrix} -1 & \mathrm{I} & 5\mathrm{I} \\ \mathrm{I} & 4 & 7 \end{pmatrix} \begin{pmatrix} \mathrm{I} & 9\mathrm{I} & 6 \\ 0 & \mathrm{I} & 0 \\ -4 & 7 & 5 \end{pmatrix} = \begin{pmatrix} -21\mathrm{I} & 27\mathrm{I} & -6+25\mathrm{I} \\ -28+\mathrm{I} & 49+13\mathrm{I} & 35+6\mathrm{I} \end{pmatrix}$$

Furthermore, a neutrosophic graph is a graph that has at least one indeterminate edge or one indeterminate node [8, 15]. The neutrosophic adjacency matrix is an extension of the adjacency matrix in classical graph theory. $a_{ij} = 0$ means that nodes i and j are not connected, $a_{ij} = 1$ means that these nodes are connected and $a_{ij} = I$, means that the connection is indeterminate (it is unknown whether it is or not). Fuzzy set theory does not use such notions. On the other hand, if indeterminacy is introduced into a cognitive map as referred to in [16], then this cognitive map is called a neutrosophic cognitive map, which is especially useful in representing causal knowledge [10, 17]. It is formally defined in Definition 4.

Definition 4. A Neutrosophic Cognitive Map (NCM) is a directed neutrosophic graph with concepts such as policies, and events, among others, as nodes and causalities or indeterminates as edges. It represents the causal relationship between concepts. The measures described below are used in the proposed model, they are based on the absolute values of the adjacency matrix [16]:

- ✓ Out degree (□□) is the sum of the row elements in the neutrosophic adjacency matrix. It reflects the strength of the outgoing relations (□□□) of the variable:

$$od(v_i) = \sum c_{ij} \quad (2)$$

✓ In degree (□i) is the sum of the elements of the column. It reflects the strength of the relationships (□□□) outgoing of the variable.

$$id(v_i) = \sum_{i=1}^{n} c_{ji} \quad (3)$$

✓ Total centrality (total degree(□□)), is the sum of the out-degree and the in-degree of the variable.

$$td(v_i) = od(v_i) + id(v_i) \quad (4)$$

The variables are classified according to the following criteria, see [18]:

a) The transmitting variables are those with $od(vi) > 0$ and $id(vi) = 0$.
b) The receiving variables are those with $od(vi) = 0$ and $id(vi) > 0$.
c) Ordinary variables satisfy both $od(vi) \neq 0$ and $id(vi) \neq 0$

Static analysis is applied using the adjacency matrix, considering the absolute value of the weights [15]. Static analysis in neutrosophic cognitive maps (NCM), see [17], initially contains the neutrosophic number of the form (a + bI), where I = indeterminacy [19]. Requires a deneutrosophication process as proposed in [16], where ∈ [0, 1] and is replaced by its maximum and minimum values.

Finally, the average of the extreme values is used, which is calculated with Equation 5, to obtain a single value as referred to in [20]. This value contributes to the identification of the characteristics to be addressed, according to the factors obtained, for our case study.

$$\lambda([a_1, a_2]) = \quad (5)$$

After,

$$A > B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2} \quad (6)$$

3 Results

3.1 Background and bibliometric analysis

An analysis of the bibliography of the last decade in Elsevier [21-50-54-54-56] Using as keywords: “Assessment”, and “Personality Traits” and filtering by the last decade, yielded a result of 29 studies. Figure 1 shows a map made with the co-citations of the keywords.

Figure 1. Bibliometric map analyzed using VOSviewer software version 16.19. Source: own elaboration

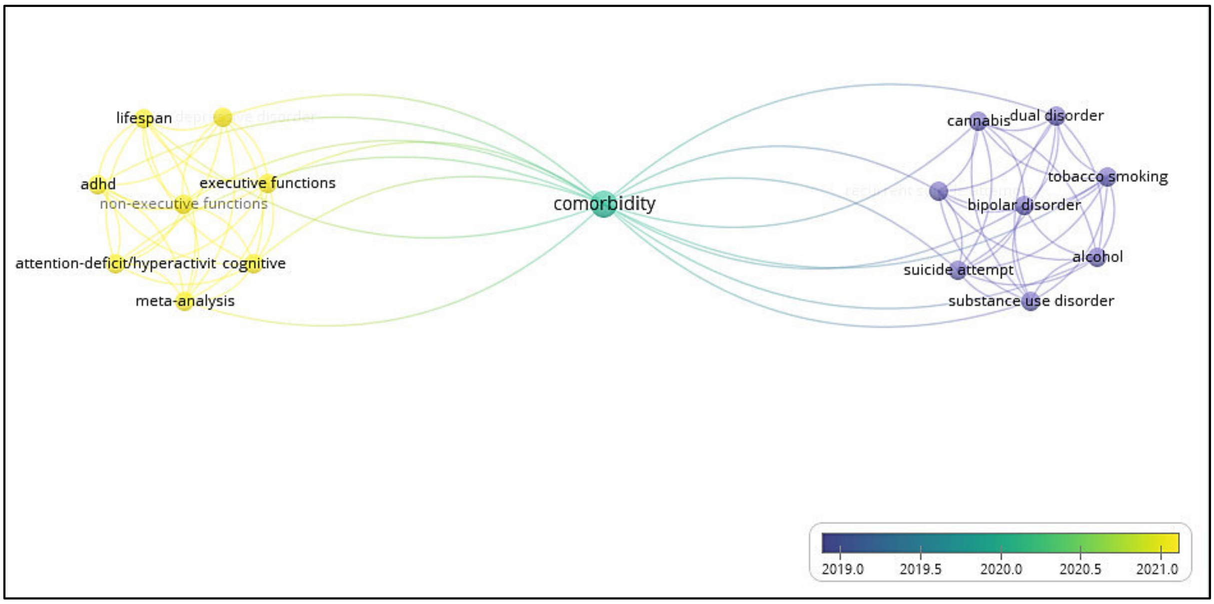
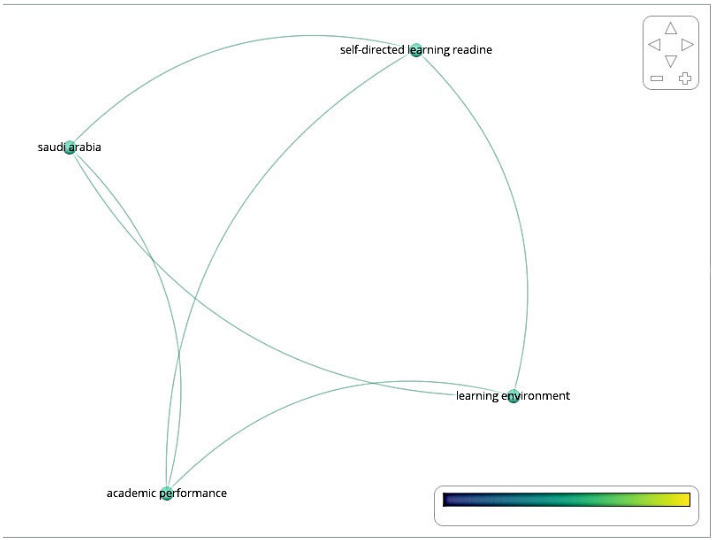


Figure 1 shows a graphic representation that highlights the transcendental importance of basing the analysis on the concept of comorbidity, also known as associated morbidity, a term of great relevance in the field of health and medicine. Comorbidity refers to the simultaneous or sequential presence of two or more disorders or diseases in the same person. This concept is essential to understanding the complexity of health conditions and their interaction in the clinical context. To carry out a comprehensive and robust analysis, the approach of the logic of neutrosophic thinking was adopted in the construction of the cognitive map and its inherent adjacency matrix. This methodological choice makes it possible to address the uncertainty and imprecision inherent in comorbidity.

Additionally, in this bibliometric review process, a specific filter including the keyword "teachers" was applied. This search strategy revealed a considerable set of studies, where 35% of these [21-29-52-53], focused on teachers in general. Importantly, these studies mostly focused on specific geographic regions, with a particular emphasis on Saudi Arabia. Figure 2 provides a graphical representation that clearly illustrates this geographic distribution of research.

Figure 2. Specific bibliometric map for teachers using VOSviewer software version 16.19. Source: own elaboration



Studies focused on teachers carefully explored the learning environment and its impact on academic performance. These findings highlight the importance of understanding the interaction between the educational environment and educators' performance, which can have significant implications for improving the quality of teaching and learning in specific educational contexts. This approach reinforces the idea that the comorbidity of factors in the educational field can be just as relevant and complex as in the health field.

3.2 Application of the NCM

University professionals, like any individual, should aspire to develop personality traits that promote a healthy professional environment and effective performance in their respective careers. Below are the common traits found in the bibliography consulted, referring to the personality of teachers:

1. Empathy: the ability to understand, and empathize with, the needs of your students.
2. Openness to experience: Provide helpful feedback and encourage growth and improvement in your students.
3. Introversion: the preference for reflection, tranquility, and concentration on the internal world. This trait makes interaction difficult; generally, the person is shy and quiet, preferring to isolate themselves. Generating an inability to communicate effectively can cause difficulties in the classroom. By not knowing how to transmit knowledge adequately.
4. Emotional stability: the ability to maintain calm and serenity in the face of adversity.
5. Kindness and respect: Treat students appropriately, being compassionate, cooperative, and friendly. And foster an environment of mutual respect in the classroom.
6. Flexibility: The adaptability to address different learning styles and individual needs.
7. Excessive authoritarianism: a teacher who is too authoritarian.
8. Neuroticism: tendency to experience frequent negative emotions such as anxiety, sadness, or worry.
9. Egocentrism: Prioritizing ego over teamwork and shared goals can be detrimental to the group.

Through the Neutrosophic Cognitive Map, these personality traits were submitted to expert consultation, where the causal relationships between the nine variables or elements that characterize the personality of the teachers with neutrosophic numbers were evaluated, an average of the evaluations of the experts. From them, an adjacency matrix and the graph that represents it were obtained, which are listed below:

Figure 3. Neutrosophic Cognitive Map of the causal relationship between factors. Source: own elaboration.

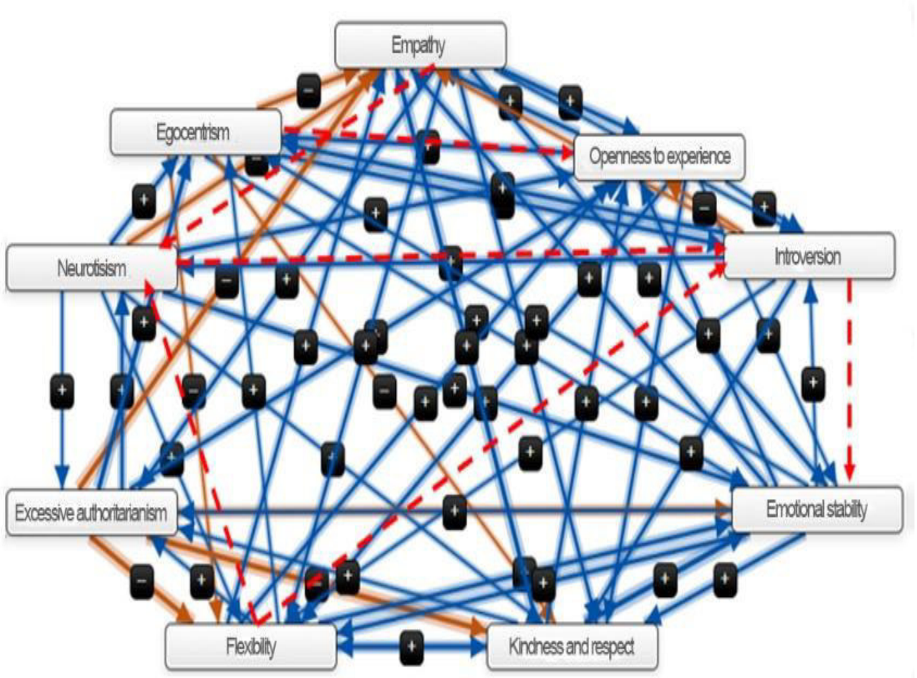


Table 1. Adjacency matrix. Source: own elaboration

	A	B	C	D	E	F	G	H	I
A	0	0.5	0.2	0.5	0.8	0.7	0.7	0	0
B	0.8	0	0.2	0.2	0.5	0.7	0	0	0.6
C	0.2	0.2	0	0.2	0.5	0.2	0	0.5	0.6
D	0.7	0.7	0.2	0	0.5	0.5	0.2	0	0.2
E	0.9	0.6	0	0.9	0	0.4	0.4	0	0
F	0.5	0.5	0.2	0.5	0.5	0	0.2	0.5	0.2
G	1	0.5	0	0.7	0.9	1	0	0.5	0.9
H	0.5	0.5	0.5	0.5	0.2	0.2	0.2	0	0.5
I	0.5	0.5	0.5	0.2	0.2	0.2	0	0	0

Table 2. Static analysis of the adjacency matrix. Source: own elaboration

Factors	id	od	TD
Empathy	0.6375	0.425	1.0625
Openness to experience	0.5	0.375	0.875
introversion	0.225	0.3	0.525
Emotional stability	0.4625	0.375	0.8375
Kindness and respect	0.5125	0.4	0.9125
Flexibility	0.4875	0.3875	0.875
Excessive authoritarianism	0.2125	0.6875	0.9
Neuroticism	0.1875	0.3875	0.575
Egocentrism	0.375	0.2625	0.6375

Table 3. Hierarchical order and classification of variables. Source: own elaboration

Factors	Order	Classification
Empathy	1	Ordinary
Openness to experience	3	Ordinary
Introversion	5	Ordinary

Factors	Order	Classification
Emotional stability	3	Ordinary
Kindness and respect	2	Ordinary
Flexibility	2	Ordinary
Excessive authoritarianism	2	Ordinary
Neuroticism	5	Ordinary
Egocentrism	4	Ordinary

Qualitative interpretation of the MCN:

1. Classification of variables: In this context, classifying them as ordinary suggests that they are considered habitual and fundamental aspects in the analysis of personality or human behavior. These variables are common in many personality and psychology studies and are used to describe and understand the typical characteristics and traits of people in a variety of situations. Furthermore, they are both receivers and transmitters of information, which makes them codependent in the analysis of causality.
2. Causality analysis based on the hierarchical order between nodes:

- There is an important relationship between the Empathy factor and the other factors, this having a higher level of causality, as this factor increases the others increase positively, except in the case of Egocentrism. That is to say, Empathy is the central factor.
- Kindness and respect as positive drivers: Kindness and respect have a positive effect when activated, positively influencing the other nodes. However, this influence does not apply to excessive authoritarianism and egocentrism.
- Excessive authoritarianism as a negative influence: Excessive authoritarianism, associated with people with strong and dominant ego characteristics, exerts a negative influence on the other personality nodes. As this node increases, empathy, emotional stability, kindness, and flexibility decrease. Therefore, it is considered to be an important aspect to consider, and on which objectives must be focused to eradicate it. Because its negative influence can interfere with teacher quality and training. This suggests that reducing excessive authoritarianism could be an important goal for improving teacher quality and training.
- Indeterminate relationships: There are indeterminate causal relationships between several pairs of personality nodes, such as empathy and neuroticism, introversion and emotional stability, flexibility and introversion, flexibility and neuroticism, neuroticism and introversion, and egocentrism and openness to experience. This suggests that the influence of these factors on others may be more complex or less clear.
- Diversity of personality traits: The analysis highlights the diversity of personality traits and how a person is built upon a combination of positive and negative factors. The importance of enhancing the traits that favor the development of students and that contribute positively to their personality is emphasized.

4 Discussion

Personality traits like empathy and patience create a more welcoming and safe learning environment for students. This facilitates participation, the exchange of ideas, and the expression of doubts. Teachers who practice constructive feedback and respect contribute to the personal and academic growth of their students, promoting self-esteem and self-confidence. Organization and effective communication can help students better understand concepts and be better prepared for academic success.

Teachers who recognize and work on improving their negative personality traits can experience significant professional growth. This may include honing communication, classroom management, and interpersonal skills, which in turn improves your ability to teach effectively. Modifying negative personality traits in teachers not only benefits students in the short term but also has a long-term impact on their development. Students can learn valuable lessons about self-evaluation, personal growth, and overcoming challenges by watching their teachers address and improve their negative traits.

In summary, teachers' ability to identify and modify negative personality traits is essential for creating a healthier educational environment and for their professional development. Additionally, this improvement process can have a lasting impact on students' lives.

The study of [51] on "*Traits of personality that affect the performance of the professors of the PUCE matrix* *in the functions of teaching and research*", concludes that it does not find significant relationships between personality traits and the performance of teachers in teaching functions; This is not the case with regard to the relationship between personality traits and performance in functions as a researcher, where it has been found that teachers with more creative, less affable and less self-controlled personalities have better performance. These results differ from those found in the present investigation. It was concluded that traits such as excessive Authoritarianism and Egocentrism in teachers can constitute a barrier to communication with their students.

Conclusions

From the text provided, several significant conclusions can be drawn:

1. Importance of Comorbidity: Comorbidity, which refers to the coexistence of multiple disorders or diseases in the same person, is an essential concept in the field of health and medicine. Its understanding is essential to address the complexity of health conditions and their interaction in a clinical context.
2. Application of the Logic of Neutrosophic Thinking: The choice to apply the logic of neutrosophic thinking in the construction of the cognitive map demonstrates the importance of addressing the uncertainty and imprecision inherent in comorbidity. This methodology is valuable for clinical decision-making and health research.
3. Focus on Teacher Studies: The bibliometric review focusing on the keyword "teachers" reveals a particular focus on teacher research, especially in Saudi Arabia. The studies explored the relationship between the learning environment and academic performance, highlighting the influence of educators' personality traits on the quality of teaching.
4. Impact of Personality Traits on Teaching: Personality traits, such as empathy, patience, organization, and effective communication, create a more positive and productive learning environment for students. Modifying negative personality traits, such as excessive authoritarianism and egocentrism, can have a significant impact on teachers' professional development and the quality of training.
5. Divergent Results with Previous Studies: A previous study mentioned that did not find significant relationships between personality traits and the performance of teachers in teaching functions but did find significant relationships in research functions. This contrasts with the findings of the current research, which highlights the importance of traits such as excessive authoritarianism and egocentrism in communication with students and the quality of training.
6. Results of the Neutrosophic Cognitive Map: The analysis through the Neutrosophic Cognitive Map revealed causal relationships between the personality traits analyzed. Positive traits, such as empathy, kindness, and flexibility, positively influence other traits. On the other hand, excessive authoritarianism shows an inversely proportional relationship with positive traits, suggesting that modifying these negative traits can lead to a more favorable learning environment.

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University of New Mexico

Neutrosophic Orthodontic Treatment Planning

Yaima Rodríguez Cuéllar [1], Andrea Miranda Achundia [2], Mery Mendoza Castillo [3], and Reátegui Paredes Víctor Raúl [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.yaimarodriguez@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Quevedo. Ecuador. E-mail: uq.andreamiranda@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.merymc74@uniandes.edu.ec
[4] Universidad Nacional de la Amazonia Peruana, Perú. E-mail: victor.reategui@unapiquitos.edu.pe

Abstract: Neutrosophy is a modern philosophical approach that emphasizes seeking balance and comprehension in a complex and polarized world. It encourages the exploration of nuance and the acceptance that truth is not always found in extremes. In the medical realm, especially in dentistry, neutrosophy plays an essential role in providing a philosophical framework for clinical decision making and work planning. This article examines the approach to orthodontic treatment planning using a neutrosophic perspective. Specific criteria are used to evaluate and rank treatment alternatives, employing methods such as TOPSIS and neutrosophic DEMATEL. Key factors considered include clinical effectiveness, long-term stability, impact on quality of life, cost-benefit, and sustainability of materials and techniques. Neutrosophic orthodontic treatment planning aims to achieve a balance amongst clinical, ethical, economic, and psychosocial aspects, enabling more customized and gratifying patient care. The outcomes highlight the significance of considering various outlooks and subtleties during the clinical decision-making process in dentistry, from a neutrosophic viewpoint.

Keywords: TOPSIS, DEMATEL, neutrosophy, dentistry, planning, treatment.

1 Introduction

Neutrosophy is a relatively contemporary philosophy that has gained increasing importance today. It focuses on the search for balance and understanding in a world characterized by polarization and complexity [1]. In a context where extreme opinions and intolerance often prevail in public and political debates. Neutrosophy offers a valuable perspective. It supports the exploration of nuances and the acceptance that the truth is not always found at the extremes, but somewhere in between. This is especially relevant in the age of social media, where information spreads quickly and opinions are easily polarized.[2]

Neutrosophy also plays an essential role in decision-making and conflict resolution. In a globalized and diverse world, it is essential to learn to understand and value different points of view and cultures. Neutrosophy promotes empathy and tolerance, encouraging people to consider multiple perspectives before making important decisions [3]. Many contemporary problems, such as artificial intelligence, biotechnology, and environmental management, require a balanced approach and careful evaluation of their ethical implications. Neutrosophy encourages ethical analysis from an impartial perspective, which can help guide ethical decision-making in an increasingly technological and complex world.[4]

Neutrosophy can be very useful in the medical field, and particularly in disciplines such as dentistry, by offering a balanced and reflective approach to clinical decision-making and work planning [5]. In dentistry, where the focus is on patients' oral health and quality of life, neutrosophy becomes a valuable philosophical framework. Considering nuances and finding balance are essential when evaluating treatment options. This is especially important in cases where different approaches must be weighed, such as in choosing dental materials or planning surgical procedures.[6]

When planning dental work, neutrosophy can be essential in helping professionals address complex clinical situations and make informed decisions. For example, when faced with a dental restoration case, neutrosophy encourages consideration of the patient's needs, budgetary constraints, and available therapeutic options. This can lead to a more personalized and balanced treatment approach, taking into account both oral health and the patient's individual situation.[7-14]

In addition, neutrosophy in dentistry is also related to ethical aspects. Dentists must constantly evaluate ethical issues, such as informed consent, confidentiality, and equity in care. The neutrosophic philosophy provides a basis for addressing these issues in an impartial and thoughtful manner, promoting a more ethical and professional dental practice.

Neutrosophy plays a significant role in the medical field, especially in dentistry. This provides a philosophical framework that favors balanced and ethical decision-making in planning work and patient care. This philosophy helps oral health professionals consider multiple perspectives and make informed decisions that holistically benefit the health and well-being of their patients.

The aim of this study is to investigate and describe in detail the approach to orthodontic treatment planning from a neutrosophic perspective. Through this research, it is intended to provide a solid basis for the implementation of neutrosophic orthodontics as a valuable alternative in contemporary orthodontic practice. Promoting more balanced and personalized care for patients, through planning based on neutrosophy.

2 Preliminaries

Definition 1. Let X be a space of points (objects) with generic elements in X denoted by x. A single-valued neutrosophic set (SVNS) A in X is characterized by truth-membership function T_A (x), indeterminacy-membership function I_A (x), and falsity membership function F_A (x). Then, an SVNS A can be denoted by A = {x, T_A(x), I_A(x), F_A(x) x ∈ X}, where T_A (x), I_A (x), F_A (x) ∈ [0,1] for each point x in X. Therefore, the sum of T_A (x), I_A (x) and F_A (x) satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.[8]

For convenience, a SVN number is denoted by A = $(a\ b\ c)$, where a, b, c ∈ [0,1] and a + b + c ≤ 3

Definition 2. Let A = (a, b, c) be a SVN number and λ∈ℝ an arbitrary positive real number, then:

$$\lambda A = \left(1-(1-a)^{\lambda}, b^{\lambda}, c^{\lambda}\right), \lambda > 0 \quad (1)$$

Definition 3. Let $A^* = \{A_1^*, A_2^*, \dots, A_n^*\}$ be a vector of n SVN numbers, such that $A_j^* = (a_j^*, b_j^*, c_j^*)$ (j= 1,2,…,n), and $B_i = \{B_{i1}, B_{i2}, \dots, B_{im}\}$ (i= 1,2,…,m), (j= 1,2,…,n). Then the separation measure between B_i and A^* based on Euclidian distance is defined as follows:

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

(i= 1, 2, …, m)

Definition 4. Let $A = \{A_1, A_2, \dots, A_n\}$ be a set of n SVN numbers, where $A_j = (a_j, b_j, c_j)$ (j= 1,2,…,n). The single value neutrosophic weighted average operator on them is defined by

$$\sum_{j=1}^{n} \lambda_j A_j = \left(1-\prod_{j=1}^{n}\left(1-a_j\right)^{\lambda_j}, \prod_{j=1}^{n} b_j^{\lambda_j}, \prod_{j=1}^{n} c_j^{\lambda_j}\right) \quad (3)$$

Whwre λ_j is the weight of A_j (j= 1,2,…,n), $\lambda_j \in [0,1]$ and $\sum_{j=1}^{n} \lambda_j = 1$

Next, a score function for ranking SVN numbers is proposed as follows:

Definition 5. Let A = (a, b, c) be a single valued neutrosophic number, a score function S of a single-valued neutrosophic value, based on the truth-membership degree, indeterminacy-membership degree and falsity membership degree is defined by

$$S(A) = \frac{1+a-2b-c}{2} \quad (4)$$

where$S(A) \in [-1,1]$

The score function S is reduced the score function proposed by Li (2005)if b = 0 and a + b ≤ 1.

The value of a linguistic variable is expressed as an element of its term set. The concept of a linguistic variable is very useful for solving decision making problems with complex content. For example, the performance ratings of alternatives on qualitative attributes can be expressed by linguistic variables such as very important, important, medium, unimportant, very unimportant, etc. Such linguistic values can be represented using single valued neutrosophic numbers.

In the method, there are *k*-decision makers, *m*-alternatives, and *n*-criteria. *k*-decision makers evaluate the importance of the *m*-alternatives under *n*-criteria and rank the performance of the *n*-criteria with respect to linguistic statements converted into single valued neutrosophic numbers. Here, the decision makers often use a set of weights such that W= {very important, important, medium, unimportant, very unimportant} and the importance weights based on single valued neutrosophic values of the linguistic terms is given as Table 1.

Table 1: Linguistic variable and Single-Valued Neutrosophic Numbers. Note: Source: [10]

Integer	Linguistic variable	SVN numbers
0	No influence/Not important	(0.1,0.8,0.9)
1	Low influence/important	(0.35,0.6,0.7)
2	Medium influence/important	(0.5,0.4,0.45)
3	High influence/important	(0.8,0.2,0.15)
4	Very high influence/important	(0.9,0.1,0.1)

Definition 8 ([10], [11]) Deneutrosophication of SVNS Ñ can be defined as a process of mapping Ñ into a single crisp output for $x f: Ñ \rightarrow \psi^* \in X$. If Ñ is discrete set then the vector of tetrads Ñ = {(x | TÑ(x), IÑ(x), FÑ(x)) | x ∈ X} is reduced to a single scalar quantity ψ∗∈X by deneutrosophication. The obtained scalar quantity ψ∗∈X best represents the aggregate distribution of three membership degrees of neutrosophic element TÑ (x), IÑ (x), FÑ (x). Therefore, the deneutrosophication can be obtained as follows.

$$\psi^* = 1 - \sqrt{[(1 - T_k(x))^2 + (I_k(x))^2 + (\mathrm{F}(x))^2]/3} \tag{5}$$

2.1 Methods

The TOPSIS method for SVNS used consists of the following:

Assuming that $\mathrm{A} = \{\rho_1, \rho_2, \dots, \rho_m\}$ is a set of alternatives and $\mathrm{G} = \{\beta_1, \beta_2, \dots, \beta_n\}$ is a set of criteria, the following steps will be carried out [12-14-16-17-18]:

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

$$\delta_t = \frac{a_t + b_t\left(\frac{a_t}{a_t + c_t}\right)}{\sum_{t=1}^{k} a_t + b_t\left(\frac{a_t}{a_t + c_t}\right)} \tag{6}$$

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

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 $d_{ij} = (u_{ij}, r_{ij}, v_{ij})$ and is used to aggregate all individual evaluations; d_{ij} 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 with the help of Equation 1. In this way, a matrix D = (dij)ij is obtained, where each d_{ij} 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 = (w_1, w_2, …, w_n), where w_j denotes the relative importance of the criterion $\lambda_t w_j^t = (a_j^t, b_j^t, c_j^t)$. S_i it is the evaluation of the criterion λ_t by the t-th expert. Then Equation 2 is used to aggregate the weights.

Step 4: Construction of the neutrosophic decision matrix from the weighted average of single values with respect to the criteria.

$$D^* = D * W, \tag{7}$$

$$where \; d_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

Step 5: Calculation of the ideal positive and negative SVNN solutions.

The criteria can be classified as cost type or benefit type. Let G_1 be the set of benefit-type criteria and G_2 be the cost-type criteria. The ideal alternatives will be defined as follows:

The positive ideal solution, corresponding to G_1.

$$\rho^{+} = a_{\rho+w}(\beta_j), b_{\rho+w}(\beta_j), ac_{\rho+w}(\beta_j) \quad (8)$$

The negative ideal solution, corresponding to G_2.

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

Where:

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

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

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

Step 6: Calculation of the distances to the positive and negative SVNN ideal solutions.

With the help of Equation 3, the following Equations are calculated:

$$d_i^{+} = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^{+}\right)^2 + \left(b_{ij} - b_j^{+}\right)^2 + \left(c_{ij} - c_j^{+}\right)^2\right\}\right)^{\frac{1}{2}} \quad (10)$$

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

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.

$$\widetilde{\rho_J} = \frac{s^{-}}{s^{+} + s^{-}} \quad (12)$$

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

Step 8: Sorting of the alternatives.

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

To determine the planning objectives in neutrosophic dental treatment, the use of the DEMATEL method in its neutrosophic variant is proposed through the steps set out below.[13]

1. *Identify the elements to evaluate*: The influencing factors or elements are evaluated by the selected experts through paired comparisons, using the score shown in table 1.
2. *Determine the relative importance of experts:* Each of the selected experts has their own importance value, based on their level of experience and knowledge in the decision problem. Therefore, the weight of each decision maker may be different from that of other decision makers. The weight given to each of the *t* decision

makers is considered linguistic variables and is transmitted in SVNN $E_t = (T_t, I_t, F_t)$ to subsequently be identified using equation 13.

$$\psi_t = \frac{1-\sqrt{[(1-T_t)^2+(I_t)^2+(F_t)^2]/3}}{\sum_{t=1}^{p}\sqrt{[(1-T_t)^2+(I_t)^2+(F_t)^2]/3}} \quad (13)$$

3. *Convert the linguistic evaluations given by the experts into SVNN:* From the individual clear integer matrixes obtained from the experts' evaluations, the individual neutrosophic matrices of the decision makers are constructed according to what is indicated in table 1.
4. *Get the initial direct relationship matrix:* To obtain the initial direct relationship matrix that is in the form of crisp numbers, the neutrosophic matrices of the individual decision makers must be aggregated using equation 3 and deneutrosophied using equation 5.
5. *Identify cause-effect relationships between factors using the DEMATEL method*: Based on the aggregate direct relationship matrix A obtained in step 4, the total relationship matrix T can be easily calculated using equations (14-16) as shown below:

$$D=A*S \quad (14)$$

Where

$$S = \frac{1}{\max_{l\leq i\leq n}\sum_{j=1}^{n} a_{ij}} \quad (15)$$

and

$$T=D*(I-D)^{-1} \quad (16)$$

where I is the identity matrix. From this, the cause-effect relationship diagram (ri + ci, ri −ci) is constructed.
6. *Analyze the cause-effect relationship diagram.* The (ri −ci) indicates the importance of each factor while (ri −ci) is the net cause or effect group. The (ri+ci) is called “Prominence” and it measures the degree of central role that the factor or criterion plays within the system. While (ri −ci): it is called “Relationship” and means the effect that the factor or criterion produces in the system. If (ri −ci) >0 the factor or criterion is placed in the group of causes. If (ri −ci) <0 the factor or criterion is in the group of effects. The pairs (ri −ci) and (ri +ci) can be represented graphically to give decision makers a graphical idea about the system.

3 Results

Planning neutrosophic orthodontic treatment involves considering a series of variables that reflect the neutrosophic philosophy of balance and understanding in clinical decision making. Some of the key variables to consider include:

- Patient Needs: Assess specific patient needs, such as orthodontic concerns, general oral health, and personal expectations.
- Costs and budget: Evaluate the costs associated with orthodontic treatment and discuss financing options with the patient.
- Techniques and materials: Select the most appropriate orthodontic techniques and materials for each case, considering factors such as durability, aesthetics, and cost.
- Clinical nuances: Consider the particularities of each case, such as the severity of the malocclusion, the health of the periodontal tissues and the conditions of the teeth and gums.
- Medical History: Review the patient's medical history for preexisting conditions that may influence orthodontic treatment, such as allergies, systemic diseases, or medications the patient takes.
- Psychosocial factors: Evaluate the psychological and emotional impact of the treatment on the patient, including their self-esteem, anxiety, and motivation for treatment.
- Treatment time: Determine the estimated duration of treatment and consider the patient's availability to comply with follow-up visits.
- Ethics and informed consent: Ensure that the patient fully understands the risks and benefits of the treatment, as well as obtain informed consent in an ethical manner.
- Long-term outcome evaluation: Plan long-term follow-up to evaluate stability and patient satisfaction with treatment results.

Planning neutrosophic orthodontic treatment is based on the comprehensive consideration of these variables. It seeks a balance between clinical, emotional, and ethical aspects to provide more personalized and satisfactory orthodontic care for the patient.

To determine the main aspects on which orthodontic treatment planning should be directed under neutrosophic standards, the criteria of specialists in the field were considered. A questionnaire was carried out on which the criteria to be evaluated in this research were concluded, and they will help make balanced and well-founded decisions.

The evaluation of the aforementioned aspects is carried out by a group of 5 highly experienced dentists. It is assumed that the individual contribution of each one to the evaluations to be carried out for the execution of the method is of the highest importance according to the linguistic values shown in table 1. The criteria to be considered in this research regarding the variables in planning neutrosophic orthodontic treatment will be the following (Table 2):

Table 2: Criteria to take into account regarding variables when planning neutrosophic orthodontic treatment. Source: Own elaboration

Criteria	
C1 Clinical effectiveness	Consider whether the proposed treatment is clinically effective in correcting the patient's malocclusion or orthodontic problem.
C2 Long-term stability	Evaluate the ability of the treatment to maintain stable and functional results in the long term.
C3 Impact on quality of life	Analyze how the treatment will affect the patient's quality of life, considering aspects such as comfort, aesthetics, and oral functionality.
C4 Cost-benefit	Compare the costs associated with the proposed treatment with the clinical and quality of life benefits expected to be obtained.
C5 Sustainable materials and techniques	Consider choosing materials and techniques that are sustainable from an environmental and economic perspective.

Establishing solid criteria based on these aspects ensures that orthodontic treatment planning from a neutrosophic perspective is comprehensive, balanced and focused on the individual needs and values of the patient, thus promoting more complete and satisfactory orthodontic care.

In this sense, Table 3 shows the aggregate decision matrix obtained after obtaining the evaluations of each of the aspects evaluated based on the selected criteria.

Table 3: Aggregate decision matrix. Source: Own elaboration

Aspects to evaluate	C1	C2	C3	C4	C5
Patient needs	(0.629,0.371,0.325)	(0.856,0.144,0.132)	(0.35,0.75,0.8)	(0.792,0.208,0.174)	(0.88,0.12,0.115)
Costs and budget	(0.856,0.144,0.132)	(0.621,0.379,0.347)	(0.35,0.75,0.8)	(0.67,0.33,0.289)	(0.827,0.173,0.152)
Techniques and materials	(0.88,0.12,0.115)	(0.81,0.19,0.19)	(0.621,0.379,0.347)	(0.827,0.173,0.152)	(0.75,0.25,0.2)
Clinical nuances	(0.725,0.275,0.251)	(0.713,0.287,0.24)	(0.5,0.5,0.5)	(0.792,0.208,0.174)	(0.621,0.379,0.347)
Medical history	(0.834,0.166,0.158)	(0.517,0.512,0.502)	(0.415,0.638,0.663)	(0.67,0.33,0.289)	(0.415,0.638,0.663)
Psychosocial factors	(0.583,0.417,0.365)	(0.517,0.512,0.502)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.67,0.33,0.289)
Treatment time	(0.289,0.711,0.711)	(0.383,0.692,0.728)	(0.383,0.692,0.728)	(0.35,0.75,0.8)	(0.713,0.287,0.24)
Ethics and informed consent	(0.5,0.5,0.5)	(0.556,0.483,0.459)	(0.415,0.638,0.663)	(0.67,0.33,0.289)	(0.415,0.638,0.663)
Long-term results evaluation	(0.67,0.33,0.289)	(0.5,0.5,0.5)	(0.383,0.692,0.728)	(0.621,0.379,0.347)	(0.75,0.25,0.2)

Considering the vector of weights obtained through the expert evaluations, shown in Table 4, the aggregate weighted decision matrix is calculated, remaining as seen in Table 5.

Table 4: Vector of weights of the criteria. Source: Own elaboration

Criterion	Criterion weight
Clinical effectiveness	(0.855;0.144;0.131)
Long term stability	(0.855;0.144;0.131)
Impact on quality of life	(0.760;0.239;0.209)
Cost-benefit	(0.712;0.287;0.240)
Sustainable materials and techniques	(0.855;0.144;0.131)

Table 5: Weighted aggregate decision matrix. Source: Own elaboration

Alternatives	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
Patient needs	(0.538;0.461;0.414)	(0.73;0.26;0.246)	(0.266;0.809;0.841)	(0.564;0.435;0.372)	(0.753;0.246;0.231)
Costs and budget	(0.732;0.267;0.246)	(0.531;0.468;0.433)	(0.266;0.809;0.841)	(0.477;0.524;0.45)	(0.707;0.292;0.263)
Techniques and materials	(0.753;0.246;0.231)	(0.693;0.306;0.296)	(0.472;0.527;0.483)	(0.589;0.410;0.355)	(0.641;0.358;0.305)
Clinical nuances	(0.620;0.379;0.349)	(0.610;0.389;0.340)	(0.380;0.619;0.604)	(0.564;0.435;0.372)	(0.531;0.468;0.433)
Medical history	(0.713;0.286;0.26)	(0.441;0.582;0.567)	(0.315;0.724;0.733)	(0.477;0.522;0.459)	(0.355;0.690;0.707)
Psychosocial factors	(0.498;0.501;0.448)	(0.442;0.582;0.567)	(0.266;0.809;0.841)	(0.249;0.821;0.848)	(0.573;0.426;0.382)
Treatment time	(0.247;0.752;0.749)	(0.327;0.736;0.763)	(0.291;0.765;0.784)	(0.249;0.821;0.848)	(0.610;0.389;0.340)
Ethics and informed consent	(0.427;0.572;0.565)	(0.475;0.557;0.530)	(0.315;0.724;0.733)	(0.477;0.522;0.459)	(0.355;0.690;0.707)
Long-term results evaluation	(0.573;0.426;0.382)	(0.427;0.572;0.565)	(0.291;0.765;0.784)	(0.442;0.557;0.503)	(0.641;0.358;0.305)

Finally, the order of the analyzed elements is shown in Table 6, according to the calculated proximity coefficient.

Table 6: Ideal positive and negative distances and proximity coefficient. Source: Own elaboration

Alternatives	**d+**	**d-**	$\tilde{\rho}_j$
Patient needs	0.43	0.64	0.598
Costs and budget	0.45	0.49	0.519
Techniques and materials	0.31	0.7	0.695
Clinical nuances	0.45	0.58	0.565
Medical history	0.7	0.49	0.412
Psychosocial factors	0.74	0.16	0.178
Treatment time	0.91	0.27	0.229
Ethics and informed consent	0.76	0.47	0.383
Long-term results evaluation	0.55	0.33	0.376

The analysis carried out indicates that the patient's needs, costs and budgets, techniques and materials and clinical nuances are the most significant elements associated with the planning of neutrosophic orthodontic treatments according to the evaluation of the experts.

4 Discussion

The results obtained are consistent with the opinion expressed by specialists in the surveys carried out. In this sense, the action plan proposed to plan neutrosophic orthodontic treatments should be focused on improving the aspects previously indicated by the method as those of greatest significance. See Table 7.

Table 7: Proposed action plan to improve neutrosophic orthodontic treatment planning. Source: Own elaboration

Action plan based on the relevant elements for planning neutrosophic orthodontic treatment	
Design of Patient Care Protocols	- Design standardized protocols to evaluate the aesthetic, functional and oral health needs of each patient, using clinical tools and questionnaires. - Train clinical staff in the application of evaluation protocols and in effective communication with patients.
Cost and Budget Evaluation	- Calculate the costs associated with neutrosophic orthodontic treatments, including materials, equipment, orthodontist fees and other indirect costs. - Create a personalized budget system for each patient, based on their specific needs and expectations, with clear and detailed options.
Selection of Techniques and Materials	- Evaluate the neutrosophic orthodontic techniques available on the market, considering their effectiveness, duration, and benefits for the patient. - Research and select high-quality orthodontic materials that conform to the principles of neutrosophy and are safe for patients.
Clinical Planning	- Perform a detailed clinical evaluation of each patient, including radiographs, facial photographs, study models and occlusion analysis. - Create specific treatment plans for each patient that address both aesthetic and functional needs, considering their concerns and expectations.

This action plan provides a comprehensive structure to address neutrosophic orthodontic treatment planning from initial evaluation to continuous improvement. It is important to involve the entire clinical team in this process and maintain open communication with patients to ensure satisfactory results and high-quality care.

In order to evaluate the level of priority to be given to the proposed action plan, the influence analysis between the analyzed elements is carried out. In this way, the aim is to determine those that have a greater impact within the system or are a priority over others. To carry out this analysis, each expert evaluates the degree of influence between the elements analyzed by applying the linguistic values in Table 1. By applying equations 3 and 5, the direct relationship matrix is obtained, as shown in Figure 1.

Figure 1: Direct relationship matrix of the factors. Source: Own elaboration

$$A = \begin{bmatrix} 0.0000 & 0.5000 & 0.8788 & 0.8558 & 0.7655 & 0.5000 & 0.6376 & 0.8788 & 0.7655 \\ 0.4370 & 0.0000 & 0.2853 & 0.1925 & 0.5000 & 0.7655 & 0.5000 & 0.3403 & 0.2853 \\ 0.3908 & 0.6833 & 0.0000 & 0.8558 & 0.8788 & 0.5376 & 0.8558 & 0.8788 & 0.8284 \\ 0.4371 & 0.1925 & 0.2853 & 0.0000 & 0.7655 & 0.5000 & 0.8284 & 0.4604 & 0.8558 \\ 0.8026 & 0.1925 & 0.8026 & 0.2853 & 0.0000 & 0.1925 & 0.5000 & 0.5000 & 0.5000 \\ 0.8558 & 0.7655 & 0.4604 & 0.1925 & 0.6092 & 0.0000 & 0.8558 & 0.1925 & 0.5710 \\ 0.2853 & 0.2293 & 0.3403 & 0.1925 & 0.1925 & 0.7746 & 0.0000 & 0.2853 & 0.6588 \\ 0.2853 & 0.1925 & 0.7655 & 0.6833 & 0.7373 & 0.2853 & 0.3706 & 0.0000 & 0.4174 \\ 0.8788 & 0.1925 & 0.2853 & 0.5000 & 0.6833 & 0.2853 & 0.5000 & 0.5710 & 0.0000 \end{bmatrix}$$

From this, the normalized initial direct relationship matrix D is obtained by using equations (14) and (15), as well as the total direct relationship matrix T, which can be calculated by using equation (16). as shown in Figure 2:

Figure 2: Total direct relationship matrix. Source: Own elaboration

$$T = \begin{bmatrix} 0.290 & 0.271 & 0.410 & 0.387 & 0.452 & 0.326 & 0.425 & 0.411 & 0.441 \\ 0.244 & 0.120 & 0.212 & 0.178 & 0.272 & 0.267 & 0.272 & 0.214 & 0.236 \\ 0.351 & 0.293 & 0.272 & 0.377 & 0.459 & 0.330 & 0.450 & 0.402 & 0.443 \\ 0.290 & 0.174 & 0.253 & 0.186 & 0.361 & 0.262 & 0.367 & 0.276 & 0.370 \\ 0.324 & 0.171 & 0.321 & 0.235 & 0.238 & 0.208 & 0.308 & 0.281 & 0.309 \\ 0.360 & 0.274 & 0.291 & 0.230 & 0.351 & 0.203 & 0.385 & 0.252 & 0.341 \\ 0.209 & 0.148 & 0.201 & 0.167 & 0.212 & 0.253 & 0.178 & 0.192 & 0.274 \\ 0.244 & 0.164 & 0.305 & 0.280 & 0.341 & 0.213 & 0.283 & 0.191 & 0.289 \\ 0.338 & 0.168 & 0.249 & 0.262 & 0.340 & 0.220 & 0.306 & 0.287 & 0.230 \end{bmatrix}$$

After obtaining the total direct relationship matrix, the direct and indirect effects of the indicated elements are determined by analyzing the axes of prominence and relationship for the cause-and-effect group, as shown in Table 8.

Table 8: Analysis of the axes of prominence and relationship for the cause-and-effect group. Source: Own elaboration

Elements to evaluate	Ri	Ci	Ri+Ci	Ri-Ci
Patient needs	3,414	2.65	6,064	0.764
Costs and budget	2015	1,784	3,799	0.231
Techniques and materials	3,377	2,514	5,891	0.863
Clinical nuances	2,539	2,302	4,841	0.237
Medical history	2,395	3,026	5,421	-0.631
Psychosocial factors	2,687	2,282	4,969	0.405
Treatment time	1,834	2,974	4,808	-1.14
Ethics and informed consent	2.31	2,506	4,816	-0.196
Long-term results evaluation	2.4	2,933	5,333	-0.533

Based on the analysis, it is evident that patient needs and techniques and materials are the most prominent elements in the system. Interestingly, these two elements also have a higher level in the relationship indicator, indicating that they have the greatest causality over the other analyzed elements. The analysis indicates that the primary focus for implementing the proposed actions and developing neutrosophic orthodontic treatment planning should be directed towards this direction.

Conclusion

Neutrosophy emerges as a relevant philosophy for decision making and planning in the dental field. Its focus on the search for balance and understanding in a world characterized by polarization and complexity proves to be a valuable perspective for dental professionals. In a context where patient needs, costs, ethics and other factors must be balanced, Neutrosophy provides a philosophical framework that promotes informed and equitable decision making.

Orthodontic treatment planning from a neutrosophic perspective focuses on the holistic consideration of multiple factors. It recognizes the importance of balancing patient needs with clinical considerations, costs, sustainability of materials and techniques, as well as ethical and psychosocial issues. This comprehensive approach results in more personalized and satisfying orthodontic care.

The involvement of dental professionals in the evaluation of key aspects of neutrosophic treatment planning is essential. The weighting of criteria and the evaluation of complex variables such as clinical effectiveness, long-term stability, and impact on quality of life require the expertise and judgment of qualified professionals. As a result of the study, it was possible to highlight that the most notable elements in neutrosophic dental treatment planning are patient needs, costs and budgets, techniques and materials, and clinical nuances. In this sense, planning actions should be strengthened for the attractiveness and quality of life of patients.

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Neutrosophic Approaches to Emotional Intelligence Measurement

Gustavo Alvarez Gómez [1], Corona Gómez Armijos [2], Ariel Romero Fernández [3], and Julio Cesar Dupotey Hernández [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: rectorado@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes. Ambato. Ecuador. E-mail: vicerrectorado@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes. Ambato. Ecuador. E-mail: dir.investigacion@uniandes.edu.ec
[4] Empresa Neuro Rehabilitar S.A.S, Bogotá. Colombia. E-mail: jcdh2016@gmail.com

Abstract. Emotional intelligence has received considerable attention in recent research. Although it emerged as a topic in the 1990s, the majority of investigations have only surfaced in recent decades. Although it emerged as a topic in the 1990s, the majority of investigations have only surfaced in recent decades. Studies have suggested that individuals with higher emotional intelligence possess greater control over their abilities, and mental wellness, and are better equipped to find quick solutions to the issues they encounter. This study introduces a method of measuring emotional intelligence levels in people based on neutrosophy. The study identifies the primary challenges found in the components of emotional intelligence among citizens from Ecuador and outlines the necessary steps for addressing them.

Keywords: Emotional intelligence, regulation, emotions, skills, neutrosophy.

1. Introduction

Emotional intelligence (EI) proves to be fundamental in making relationships and exchanges successful and beneficial for all involved. The application of emotional intelligence in relationships with others is built through the promotion of effective communication, fostering interpersonal interaction, and mutual support, both to others and to oneself.

In the last decade, it has become common among various professionals, including educators, to address the introduction of the term "emotional intelligence" in their conversations, considering that this concept is relatively recent from their perspectives. For the general audience, the notion of EI gained popularity with the presentation of psychologist and journalist Daniel Goleman in 1995 [1], through his book entitled "Emotional Intelligence", detailing the precise criteria that contributed to the development of this field.

Currently, there is a significant amount of research that suggests that emotional intelligence is the basis of social and emotional skills, as well as an indicator of success in both educational and professional settings. This can be seen in the ability to regulate, identify, and use one's own emotions, as well as the ability to understand and show empathy towards the emotions of others, which contributes to the mental health and quality of life of individuals. In other words, people with a high level of emotional intelligence tend to assume leadership roles, have a greater ability to cope with difficult situations, and demonstrate outstanding work performance.

As for EI, a variety of conceptualizations have been generated that are associated with personal maturity, wisdom, or reasonableness, terms that are used to determine that a person possesses ample knowledge to carry out the resolution of problems based on his or her experience [2]. According to [3], it is defined as "the ability to understand and manage men and women, boys and girls, and to act wisely in human relations".

In these three decades, the impact of Goleman's book on society has been so profound that most people interested in emotional education associate emotional intelligence with Goleman's outreach perspective, often ignoring the more scientifically grounded view of emotional intelligence, as well as such notable researchers as Mayer and Salovey. When examining Goleman's proposal, it becomes evident that it transcends the concept of emotional intelligence and encompasses other personal characteristics more broadly, which are sometimes confused with what in psychology are called personality traits. In the specialized literature, models similar to Goleman's are described as mixed models [4]. Mixed models conceive emotional intelligence as a fusion of mental skills such as emotional perception or emotional mastery, together with personality attributes such as assertiveness, self-esteem, independence, and optimism. Some of these approaches even incorporate emotional states such as happiness and more complex skills such as leadership and the ability to work in a team.

According to social scientists Salovey and Mayer, emotional intelligence is conceived as a true form of intelligence that is based on the ability to use emotions adaptively to adapt to the environment and solve challenges.

From this theoretical perspective, EI consists of four basic skills: emotional perception and expression, emotional facilitation, emotional understanding, and emotional regulation.

Salovey and Mayer conceive EI as a processual and circular model in which each of the basic skills provides information to the next one to continue the process and provide a solution to a specific demand or situation.[5]

The most extensive and detailed definition of EI from the Mayer and Salovey model would be:

Emotional intelligence involves the ability to perceive, evaluate, and express emotions accurately; the ability to access and/or generate feelings that facilitate thinking; the ability to understand emotion and emotional knowledge, and the ability to regulate emotions that promote emotional and intellectual growth [6].

In this same direction, according to Ortiz and Rodriguez [7], emotional skills are promoters of mental processes and act in favor of concentration and control of stressful situations, as well as self-motivation, allowing them to satisfactorily carry out their studies and academic tasks.

Likewise, those who acquire correct levels of Emotional Intelligence develop skills to adequately manage feelings such as anxiety and depression, as well as an increase in self-esteem, and satisfaction with the work done and the effort made, since they manage to deploy sufficient strategies to control emotions and understand the events, presenting a faster and more effective recovery from negative moods [8, 9].

In the field of education, it has been observed that teachers with a high level of emotional intelligence are those who focus on finding solutions. They are noted for their optimism and positive attitude, which enables them to deal with constant challenges in their work. Since education professionals face continuous challenges, they must develop their emotional intelligence to manage negative emotions and replace them with greater emotional engagement. This has a positive impact on their ability to improve performance, strengthen interpersonal relationships, and ultimately contribute to effective job performance and high-quality education. In addition, it helps them to make appropriate decisions even in stressful situations.

EI can be manifested in different ways by individuals, but its core focuses on the personality essentials that show the level of development shown by the individual and how he or she manages to use EI in his or her actions to solve everyday life situations. A neutrosophic procedural analysis is proposed for the measurement of EI based on the experiences acquired by the participants.

2 Materials and methods

2.1 Preliminaries

Definition 1: Let X be a space of points (objects) with generic elements in X denoted by x. A Single-Valued Neutrosophic Set (SVNS) A on X is characterized by the truth membership function, T_A (x), the indetermination membership function, I_A (x), and the falsity membership function F_A (x). Then, an SVNS A can be denoted by A=(x, TA(x), IA(x), FA(x) x ∈ X), where TA(x), IA(x), FA(x) ∈ [0.1] for each point x in ≤ 3. Therefore, the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$ satisfies the condition $0 \leq T_A(x)$, $+(x)+F_A(x) \leq 3$. For convenience, an SVN number is denoted by A = (a, b, c), where a, b, c ∈ [0,1] a + b + c ≤ 3 [10].

Definition 2: Let A_1= (a_1, b_1, c_1) and A_2= (a_2, b_2, c_2) be two SVN numbers, then the sum between A_1 and A_2 is defined as follows:

$$A_1 + A_2 = (a_1 + a_2 - a_1a_2, b_1b_2, c_1c_2) \quad (1)$$

Definition 3: Let A1= (a1,b1,c1) and A2= (a2,b2,c2) be two SVN numbers, then the multiplication between A1 and A2 is defined as follows:

$$A_1 * A_2 = (a_1a_2, b_1 + b_2 - b_1b_2, c_1+c_2 - c_1c_2) \quad (2)$$

Definition 4: Let A = (a, b, c) be an SVN number and λ∈ℝ an arbitrary positive real number, then:

$$\lambda A = \left(1 - (1-a)^{\lambda}, b^{\lambda}, c^{\lambda}\right), \lambda > 0 \quad (3)$$

Definition 5: Let A={A_1, A_2, …, A_n } be a set of n SVN numbers, where A_j= (a_j, b_j, c_j) (j= 1, 2, …, n). The single-valued neutrosophic weighted average operator on them is defined by:

$$\sum_{j=1}^{n} \lambda_j A_j = \left(1 - \prod_{j=1}^{n} \left(1 - a_j\right)^{\lambda_j}, \prod_{j=1}^{n} b_j^{\lambda_j}, \prod_{j=1}^{n} c_j^{\lambda_j}\right) \quad (4)$$

Where j is the weight of A_j (j= 1, 2, …, n), λ_j ∈[0,1] and $\sum_{j=1}^{n} \lambda_j = 1$.

Definition 6: Let $A^* = \{A_1^*, A_2^*, \dots, A_n^*\}$ be a vector of n SVN numbers, such that Aj* = (a*,b*,c) (j= 1, 2, …, n), and B_i={B_{i1},B_{i2},…,B_{im} } (i= 1, 2, …, m), (j= 1, 2, …, n). Then, the separation measure between Bi and

A* based on the Euclidean distance is defined as follows:

$$s_i = \left(\frac{1}{3} \sum_{j=1}^{n} \left(\left| a_{ij} - a_j^* \right| \right)^2 + \left(\left| b_{ij} - b_j^* \right| \right)^2 + \left(\left| c_{ij} - c_j^* \right| \right)^2 \right)^{\frac{1}{2}} \quad (i = 1,2,\ldots,m) \tag{5}$$

Definition 7: Let A = (a, b, c) be a single-valued neutrosophic number, a scoring function S of a single-valued neutrosophic number, based on the degree of truth membership, the degree of indeterminacy membership, and the degree Falsehood membership is defined by:

$$S(A) = \frac{1+a-2b-c}{2} \tag{6}$$

Where: $S(A) \in [-1,1]$

The scoring function S reduces to the scoring function proposed by [10] if b = 0 and a + b ≤ 1.

A linguistic variable is a variable whose values are characterized by words or phrases rather than numbers in a natural or artificial language. The value of a linguistic variable is expressed as an element of its set of terms. The concept of linguistic variables is very useful for solving decision-making problems with complex content. For example, performance ratings of alternatives can be expressed in qualitative attributes using linguistic variables such as very important, important, medium, unimportant, very unimportant, etc. Such linguistic values can be represented using single-valued neutrosophic numbers [11]. In the case of this research, the linguistic variables to be used are shown below:

Table 1: Neutrosophic values of linguistic terms. Adapted from: Kilic and Yalsin [11].

Linguistic term	SVNSs
Very No Influential / (VNI)	(0.9;0.1;0.1)
No Influential /(NI)	(0.75;0.25;0.20)
Moderately Influential /(MI)	(0.50;0.5;0.50)
Influential /(I)	(0.35;0.75;0.80)
Very Much Influential /(VMI)	(0.10;0.90;0.90)

As one of the MCDM methods that consider both the distance of each alternative from the positive ideal and the distance of each alternative from the negative ideal point, that is, the best alternative must have the shortest distance from the positive ideal solution (PIS). and the longest distance from the negative ideal. In this research, it will be used to assess by specialists the level of influence exerted by the alternatives made in the process [12].

In this study, there are 5 criteria and 13 components that are classified according to the TOPSIS method.

2.2 TOPSIS

In the method, there are k-decision makers, m-alternatives and n-criteria. k-Decision makers evaluate the importance of m-alternatives under n-criteria and rank the performance of n-criteria with respect to linguistic statements converted to single-valued neutrosophic numbers [13]. Here, decision makers often use a set of weights such that W = (very important, important, medium, unimportant, and very unimportant), and importance weights based on Single-Valued Neutrosophic Values of the linguistic terms are given in Table 1.

On the other hand, the used TOPSIS method for SVNS consists of the following: Assuming that A={ρ_1, ρ_2, …, ρ_m} is a set of alternatives and G={β_1, β_2, …, β_n} is a set of criteria, The following steps will be carried out:

Step 1: *Determine the relative importance of experts*. To do this, the specialists evaluate according to the linguistic scale that appears in Table 1, and the calculations are carried out with their associated SVNN. Let $A_t = (a_t, b_t, c_t)$ be the SVNS corresponding to the *t-th* decision maker ($t = 1,2,\ldots,k$). The weight is calculated by the following formula:

$$\delta_t = \frac{a_t + b_t\left(\frac{a_t}{a_t+c_t}\right)}{\sum_{t=1}^{k} a_t + b_t\left(\frac{a_t}{a_t+c_t}\right)} \quad where\colon \delta_t \geq 0 \; and \sum_{t=1}^{k} \delta_t = 1 \tag{7}$$

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 $(i = 1,2,..,m;\ j = 1,2,\dots,n)$ and it is used to aggregate all individual evaluations. d_{ij} 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 with the help of equation 7. In this way, a matrix D = $(d_{ij})_{ij}$ is obtained, where each d_{ij} is an SVNN.

Step 3: *Determination of Criteria Weight*. Suppose that the weight of each criterion is given by $W = (w_1, w_2, \dots, w_n)$, where w_j denotes the relative importance of the criterion $\lambda_t w_j^t = (a_j^t, b_j^t, c_j^t)$. If it is the evaluation of the criterion λ_t by the *t-th* expert, then equation 8 is used to aggregate the w_j^t with the weights λ_t [14-17-18].

Step 4: *Construction of the single-valued weighted average neutrosophic decision matrix* with respect to the criteria.

$$D^* = D * W, where\ d_{ij} = (a_{ij}, b_{ij}, c_{ij}) \tag{8}$$

Step 5: *Calculation of the ideal positive and negative SVNN solutions.* The criteria can be classified as cost or benefit type. Let G_1 be the set of benefit-type criteria and G_2 the cost-type criteria. The ideal alternatives will be defined as follows [15-19]:

The positive ideal solution corresponding to G_1.

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

The negative ideal solution corresponding to G_2.

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

Where:

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

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

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

Step 6: *Calculation of the distances to the positive and negative SVNN ideal solutions.* With the help of equations 11 and 12, the following equations are calculated:

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

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

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.[15]

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

Where: $0 \le \widetilde{\rho_J} \le 1$.

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, with the condition that $\widetilde{\rho_J} \to 1$ is the optimal solution [16], based on the results obtained in the surveys applied to five groups of people selected from different regions of Ecuador that have approximately the same characteristics.

3. Results and discussion

Emotional intelligence and its study constitute a starting point for the adaptation of treatment and modes of action at different times and spaces in the development of human life. The analysis of some components allows to determine the essential elements to work on to enable better development of EI in each space. In some activities such as the work of teaching staff, this has special importance, allowing regulation based on permanent observation of their students. Similarly, it behaves when the person is in a group, where the action of each person influences the rest positively or negatively. To assess the main components within this process, 8 experts were selected, with a close relationship with the topic addressed and a vast experience in it. The criteria and components that were considered in the development of this research are shown in Figure 1.

Figure 1: Elements relevant to the investigation. Source: own elaboration.

Criteria

- Emotional perception and expression
- Emotional facilitation
- Emotional understanding
- Emotional regulation
- Personal decision level

Components

- Ability to perceive, appraise and express emotions accurately.
- Ability to access and/or generate feelings that facilitate thinking
- Ability to understand emotion and emotional awareness
- Control of stressful situations
- Ability to regulate emotions that promote emotional and intellectual growth
- Concentration on activity
- Prioritization
- Self-motivation
- Adoption of strategies to control emotions and understand events
- Ability to carry out the activity satisfactorily
- Achievement of appropriate management of feelings such as anxiety and depression
- Level of satisfaction with one's own work
- Presence of faster and more effective recovery from negative moods

To determine the relationship of the mentioned components with the criteria, it was necessary, in advance, to determine the weights of the components, through the NCM method set out in section 2.1, with the support of the 8 experts. Below is the adjacency matrix (see Table 2) where the different relationships between them were determined through the values of the relationships that correspond to the arithmetic mean, which served as the basis for calculating the values of $od(v_i)$ and $id(v_i)$ (see Table 3).

Table 2: Adjacency matrix. Source: own elaboration.

	C1	C2	C3	C4	C5	$\sum_{i=1}^{n} c_{ij}$
C1	0	0.8	0.6	0.8	1	3.2
C2	0.4	0	0.3	0.6	0.7	2.0
C3	0.8	0.7	0	0.7	1	3.2
C4	0.7	0.8	0.3	0	0.6	2.4
C5	0.2	0.8	0	0.3	0	1.3
$\sum_{i=1}^{n} c_{ji}$	2.1	3.1	1.2	2.4	3.3	

Table 3: Determination of corresponding values of $od(v_i)$ and $id(v_i)$. Source: own elaboration.

	C1	C2	C3	C4	C5	$od(v_i)$
C1	0	0.421053	0.31579	0.421053	0.526316	1.68421053
C2	0.210526316	0	0.15789	0.315789	0.368421	1.05263158
C3	0.4210052632	0.368421	0	0.368421	0.526316	1.68421053
C4	0.368421063	0.421053	0.15789	0	0.315789	1.26315789
C5	0.105263158	0.421053	0	0.157895	0	0.68421053
$id(v_i)$	1.10526316	1.63157895	0.63156895	1.26315789	1.73684211	

Once the values were determined, the centrality value was calculated (see Table 4) which was necessary to normalize for later use. The variables were classified as ordinary as $od(v_j) \neq 0$ and $id(v_j) \neq 0$. In a relevant way, it could be observed that emotional facilitation is the most important element to achieve the development of basic skills in interacting with people through the components of EI, by facilitating the development of the attitudes and modes of action of the person. rest of the group.

Table 4: Calculation of centrality $td(v_i)$, normalization of centrality, and classification of variables. Source: own elaboration.

$td(v_i)$	W_{td_i}	Classification
2.78947368	0.2	Ordinary
2.68421053	0.2107438	Ordinary
2.31578947	0.18181818	Ordinary
2.52631579	0.19834711	Ordinary
2.42105263	0.19008264	Ordinary

In the case of determining the components most influenced by the criteria previously stated, the application of the TOPSIS method was necessary. Initially, the weight of the groups of decision-makers established in Figure 1 was determined. Due to the relevance determined within the EI and their actions by the person who guides the activity, the five with the greatest weight were selected. The results are shown below (Table 5):

Table 5: Determination of the weight of the main components. Source: own elaboration.

	Group 1	Group 2	Group 3	Group 4	Group 5
	a b c	**a b c**	**a b c**	**a b c**	**a b c**
Importance vector λ_t	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.35;0.75;0.80)
Numerical importance	0.1646	0.2236	0.2236	0.1646	0.2236

Next, it was necessary to consider the opinions of these groups, which were asked to fill out a questionnaire to evaluate components against criteria according to the neutrosophic linguistic scale determined in section 2.1 (see table 6), which gave way to the preparation of the single value criteria matrix (see table 7). The results shown below are the result of the mode of respondents' rankings.

Table 6: Evaluation of components according to criteria. Source: own elaboration.

	Group 1	Group 2	Group 3	Group 4	Group 5
			Perception and emotional expression		
P1	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.35;0.75;0.80)
P2	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.10;0.90;0.90)	(0.50;0.5;0.50)	(0.50;0.5;0.50)
P3	(0.75;0.25;0.2)	(0.35;0.75;0.80)	(0.75;0.25;0.2)	(0.75;0.25;0.2)	(0.75;0.25;0.2)
P4	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.35;0.75;0.80)	(0.50;0.5;0.50)	(0.50;0.5;0.50)
P5	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.10;0.90;0.90)	(0.50;0.5;0.50)	(0.10;0.90;0.90)

	Group 1	Group 2	Group 3	Group 4	Group 5
Perception and emotional expression					
Emotional facilitation					
P1	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.35;0.75;0.80)
P2	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.10;0.90;0.90)
P3	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)
P4	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.35;0.75;0.80)
P5	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.10;0.90;0.90)
Emotional understanding					
P1	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.35;0.75;0.80)
P2	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.35;0.75;0.80)
P3	(0.10;0.90;0.90)	(0.50;0.5;0.50)	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.10;0.90;0.90)
P4	(0.35;0.75;0.80)	(0.50;0.5;0.50)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.10;0.90;0.90)
P5	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.50;0.5;0.50)
Emotional regulation					
P1	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.10;0.90;0.90)
P2	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.50;0.5;0.50)	(0.35;0.75;0.80)	(0.35;0.75;0.80)
P3	(0.10;0.90;0.90)	(0.50;0.5;0.50)	(0.10;0.90;0.90)	(0.50;0.5;0.50)	(0.10;0.90;0.90)
P4	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.10;0.90;0.90)
P5	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.50;0.5;0.50)
Personal decision level					
P1	(0.50;0.5;0.50)	(0.35;0.75;0.80	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.50;0.5;0.50)
P2	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.50;0.5;0.50)
P3	(0.50;0.5;0.50)	(0.35;0.75;0.80)	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.35;0.75;0.80)
P4	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)
P5	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.35;0.75;0.80)

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

	C1	C2	C3	C4	C5
P1	(0.5061;0.5221;0.5161)	(0.5061;0.5221;0.5161)	(0.5061;0.5221;0.5161)	(0.5061;0.5221;0.5161)	(0.5061;0.5221;0.5161)
P2	(0.2482;0.8137;0.8433)	(0.2482;0.8137;0.8433)	(0.2482;0.8137;0.8433)	(0.2482;0.8137;0.8433)	(0.2482;0.8137;0.8433)
P3	(0.1632;0.864;0.8766)	(0.1632;0.864;0.8766)	(0.1632;0.864;0.8766)	(0.1632;0.864;0.8766)	(0.1632;0.864;0.8766)
P4	(0.2625;0.805;0.8374)	(0.2625;0.805;0.8374)	(0.2625;0.805;0.8374)	(0.2625;0.805;0.8374)	(0.2625;0.805;0.8374)
P5	(0.5718;0.4282;0.4074)	(0.5718;0.4282;0.4074)	(0.5718;0.4282;0.4074)	(0.5718;0.4282;0.4074)	(0.5718;0.4282;0.4074)

The weights of the problems determined by the group of experts were determined consecutively and logically (see Table 8). In addition, the aggregate weighted decision matrix was calculated (see Table 9).

Table 8: Vector of weights of the criteria. Source: own elaboration.

	Criterion weight
C1	(0.6431;0.36581;0.3699)
C2	(0.68262;0.31738;0.30487)
C3	(0.56289;0.45317;0.44142)

	Criterion weight
C4	(0.38126;0.65378;0.67023)
C5	(0.55363;0.45751;0.46262)

Table 9: SVNS aggregate decision weighted matrix. Source: own elaboration.

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
P1	(0.28017;0.740 74;0.73996)	(0.34547;0.6737 8;0.66363)	(0.28488;0.73867; 0.7297)	(0.19296;0.83454; 0.84042)	(0.32547;0.6969 2;0.69509)
P2	(0.09035;0.926 22;0.93369)	(0.1114;0.90716; 0.91422)	(0.09186;0.92563; 0.93107)	(0.06222;0.95291; 0.95931)	(0.10495;0.9137 5;0.92225)
P3	(0.13741;0.898 93;0.911579)	(0.16943;0.8728 3;0.89107)	(0.13971;0.89813; 0.91247)	(0.09463;0.9355;0 .94833)	(0.15962;0.8818 5;0.90126)
P4	(0.14533;0.894 21;0.91262)	(0.17919;0.8668 9;0.88697)	(0.14776;0.89337; 0.90917)	(0.10008;0.93249; 0.94638)	(0.16881;0.8763 3;0.89755)
P5	(0.31657;0.689 8;0.68155)	(0.39032;0.6096 8;0.58807)	(0.32186;0.68732; 0.66899)	(0.218;0.80203;0. 80458)	(0.36772;0.6376 7;0.6266)

The results corresponding to the values of the coefficient of proximity are shown in Table 10, which served as the basis for determining the ranking of the effects in terms of difficulties in the development of emotional intelligence of the population range under study (see Table 11).

Table 10: Positive and negative ideal values and distances. Source: own elaboration.

	Ideal value +	Ideal value -
P1	(0.10495;0.91375;0.92225)	(0.10495;0.6374;0.6678)
P2	(0.1114;0.90716;0.91422)	(0.1114;0.6097;0.5881)
P3	(0.09186;0.92563;0.93107)	(0.0918;0.6873;0.669)
P4	(0.06222;0.95291;0.95931)	(0.06222;0.802;0.8046)
P5	(0.09035;0.92622;0.93369)	(0.31657;0.6898;0.6816)

Table 11: Ranking of components according to Proximity Coefficient (CP). Source: own elaboration.

Alternatives	d+	d-	CP	Order
C1	0.35506471	0.381339	0.51784	4
C2	0.15460157	0.602875	0.7959	1
C3	0.15049808	0.565311	0.78975	2
C4	0.15340259	0.559522	0.78483	3
C5	0.45245592	0.367267	0.44804	5

In the analysis of the results, it can be seen that the control of stressful situations is the main problem within EI in the Ecuadorian population. In this regard, the development of skills must be aimed at ensuring that people first achieve adequate control in certain stressful situations and based on this, the establishment of priorities and the adoption of strategies to control emotions and understand events. In these cases, the actions of trying to understand the situation and look for new alternative solutions satisfactorily help to achieve adequate management of feelings such as anxiety and depression, which will favor rapid recovery from negative moods and find new paths in the possible solutions to the problem.

Conclusion

Emotional intelligence as a subject of the greater number of studies in recent years and that somehow affects in a generalized way in the population of Ecuador, has a significant impact on the actions in the search for solutions to daily problems in any sphere of action. An important aspect is that the studies of Neutrosophic Science and its remarkable advances, allowed to assess the same and to determine the existing situation in the attention to each of its main components and the difficulties given in them. These were weighted using the NCM technique as there were indeterminations in some cases in the comparison of the same.

Neutrosophy made it possible to confirm more accurately that, despite the various investigations and the treatment of the subject in recent years, there are still difficulties in the adequate development of the main skills and components within the personality of the Ecuadorian population. It is necessary to develop actions aimed at the attention and treatment of the subject, with emphasis on the current moments of greater influence of economic and social affectations.

The analysis of the results obtained by the benefit of the application of Neutrosophic Science allowed to determine that in emotional intelligence, the component of greater affectation is the control of stressful situations. This should lead to the correct establishment of priorities and the adoption of strategies to control emotions and understand events, which will help in the search for new ways to solve the problems faced and contribute to mental, personal, and social well-being.

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University of New Mexico

Neutrosophic Evaluation of Legal Strategies for Decision-making in a Digital Context

Mónica Isabel Mora Verdezoto [1], Caludio Antoni Teran Vaca [2], Deinier Ros Álvarez [3], and Vladimir Vega Falcón [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.monicamora@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ibarra. Ecuador. E-mail: ui.claudioteran@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Quevedo. Ecuador. E-mail: uq.deinierra09@uniandes.edu.ec
[4] International Center for Entrepreneurs in Barcelona (ICEB), España. E-mail vega.vladimir@gmail.com

Abstract. The present study focused on the protection of intellectual property rights in the digital era. A methodology incorporating neutrosophy was applied to evaluate and compare different proposed legal alternatives. The inherent complexity of legal issues, characterized by ambiguous facts and diverse perspectives, underscored the relevance of neutrosophy in this field. The ELECTRE I method was adapted to a neutrosophic structure by incorporating bipolar neutrosophic numbers to manage uncertainty and ambiguity in decision-making. The final results revealed a strong preference for the "Legal Education and Training" alternative due to its cost and time effectiveness. The study provided a solid foundation for informed decision-making in the realm of intellectual property protection in the digital era, supported by the use of neutrosophic theory and the ability to handle indeterminacies inherent in decision-making.

Keywords: legal strategies, intellectual property, neutrosophic evaluation, ELECTRE I.

1. Introduction

In the digital era, the protection of intellectual property rights has become a challenge of great complexity and a multifaceted nature. This phenomenon arises from the global interconnectedness provided by the internet, which has radically transformed the creation, distribution, and utilization of intellectual content. The term "intellectual property" encompasses a broad range of assets, including copyrights, patents, trademarks, and trade secrets, all of which have experienced profound influence and, often, have been threatened by digitization and globalization.

The digital environment has introduced new dimensions to challenges related to intellectual property. The ease of copying and distributing digital content has led to practices of massive infringement, from online piracy to the unauthorized dissemination of intellectual property. Additionally, national borders have become blurred online, complicating the enforcement of intellectual property laws and regulations in a global context. The convergence of technology and digital connectivity has also generated tensions between the interests of rights holders and the need for open access to information and innovation.

This complex challenge manifests in the necessity to adopt effective strategies for protecting intellectual property in the digital environment. Companies and organizations are compelled to consider a range of factors, from content protection technologies to legal measures, strategic alliances, and user education strategies.

Decision-making in this domain has become a critical process involving the consideration of multiple complex and variable factors [1]. Strategic decisions in this field require not only the management of legal and technical aspects but also the evaluation of risks and opportunities inherent in a constantly evolving digital environment. In this regard, the application of neutrosophy as a method becomes fundamental to dealing with the uncertainty and indeterminacies that often surround these decisions [2].

Neutrosophy, introduced by the philosopher and mathematician Florentin Smarandache in the late 20th century, has become a valuable tool for addressing uncertainty and ambiguity in decision-making across various fields, including science [3], business [4], and industry. This theory is based on the idea that truth, falsehood, and indeterminacy can coexist in a statement or proposition, reflecting the inherent complexity of many decision-making situations.

In essence, neutrosophy recognizes that real-world decisions often involve incomplete, ambiguous, or contradictory information. This contrasts with more traditional approaches that assume statements are either entirely true or entirely false [5]. Additionally, it introduces an element of indeterminacy, where the truth or falsehood of a statement may vary based on different perspectives, contexts, or degrees of knowledge.

The applicability of neutrosophy in decision-making is evident in various fields. In science, for example, experimental research often faces contradictory results or incomplete data. Neutrosophy enables scientists to consider indeterminacy in their findings and make informed decisions even when absolute truth is challenging to determine [6].

In the business field, strategic decision-making is especially prone to uncertainty [7]. Neutrosophy has enhanced companies' ability to consider diverse scenarios and assess the possibilities of success or failure, which is fundamental in a highly competitive and ever-changing business environment [8], [9].

In the industry, neutrosophy has found applications in risk management and project planning. Industry leaders can consider indeterminacy in timelines, costs, and resources, allowing them to make more realistic and adaptive decisions [10-17].

From another perspective, the inherent complexity of numerous legal issues, often characterized by ambiguous facts and divergent approaches, emphasizes the relevance of neutrosophy in this field [11-18]. Consequently, the main purpose of this study is to apply neutrosophic methodology to analyze and contrast various proposed legal alternatives for safeguarding intellectual property in the context of the digital era.

To accomplish this task, an adaptation of the ELECTRE I method is proposed, which extends to a neutrosophic structure through the incorporation of bipolar neutrosophic numbers [12]. This approach is chosen to manage the uncertainty and ambiguity present in evaluating legal alternatives in the field of intellectual property in the digital era more precisely and effectively. The use of bipolar neutrosophic numbers allows for the consideration of diverse perspectives and degrees of indeterminacy in decision-making [13-16], which is essential for addressing complex situations in the field of law, specifically in the protection of intellectual property in constantly evolving digital environments. This methodological approach provides a solid foundation for evaluating proposed legal alternatives and determining which stands out as the most effective in the short term with the least possible cost.

2. Bipolar Neutrosophic Sets

Definition 1. Let X be a space of points (objects) with generic elements in X represented by x. A single-valued neutrosophic set (SVNS) A on X is characterized by a truth membership function $T_A(x)$, an indeterminacy membership function $I_A(x)$, and a falsity membership function $F_A(x)$. Therefore, an SVNS A can be represented as $A = \{x, T_{A(x)}, I_{A(x)}, F_{A(x)x} \in X\}$, where $T_{A(x)}, I_{A(x)}, F_{A(x)} \in [0,1]$ for each point x in X. In this way, the sum of satisfies the condition $0 \leq T_{A(x)} + I_{A(x)} + F_{A(x)} \leq 3$. [14]

Definition 2. A bipolar neutrosophic set A in X is defined as an object of the form

$$\tilde{A} = \{x, \langle T_{A}^{+}(x), I_{A}^{+}(x), F_{\tilde{A}}^{+}(x), T_{\tilde{A}}^{-}(x), I_{\tilde{A}}^{-}(x), F_{\tilde{A}}^{-}(x)\rangle | x \in X\}, \tag{1}$$

Where $T_{A}^{+}(x), I_{A}^{+}(x), F_{\tilde{A}}^{+}(x): X \rightarrow [0,1]$ and $T_{\tilde{A}}^{-}(x), I_{\tilde{A}}^{-}(x), F_{A}^{-}(x): X \rightarrow [-1,0]$

2.2 ELECTRE I method with bipolar neutrosophic numbers

Given the existence of a set $S = \{S_1, S_2, \cdots, S_m\}$ of m selection alternatives, as well as a set $T = \{T_1, T_2, \cdots, T_n\}$ of n attributes or evaluation criteria. Likewise, $W = [w_{1w_2} \cdots w_n]^T$ is the vector of weights associated with the evaluation criteria, where $0 \leq wj \leq 1$ and $\sum j = 1_{nwj} = 1$. Assuming that the decision-maker gives the rating value of each alternative □□, (□=1,2,⋯,□) with respect to the attributes □□, (□=1,2,⋯,□) in the form of Bipolar Neutrosophic Sets (BNSs), the steps of the ELECTRE I method can be completed as described below:

Step 1. Each alternative is evaluated based on multiple criteria. The evaluation of each alternative with respect to each criterion is presented using (BNSs). Each entry $k_{ij} =< T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+}, T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-} >$ is characterized by $T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+}$, which represent the degree of membership of positive truth, indeterminacy, and falsity, respectively. Likewise, $T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-}$ reflect the degree of membership of negative truth, indeterminacy, and falsity, respectively. These values satisfy the constraints $T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+} \in [0,1]$, $T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-} \in [-1,0]$, and $0 \leq T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+}, T_{ij}^{-}, I_{ij}^{-}, F_{ij}^{-} \leq 6$, where □=1,2,3,…,□ and □=1,2,3,…,□.

Step 2. When the weights of the criteria are not equally distributed and their value is unknown to the decision maker, we resort to the deviation maximization method to calculate the unspecified weights of the criteria. Consequently, the weight of the attribute □□ is calculated as follows:

$$w_j = \sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}| \Big/ \sqrt{\sum_{j=1}^{n} \left(\sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}|\right)^2}, \tag{2}$$

And the normalized weight of the attribute$Tj$is established as described by equation (3):

$$w_j^{*} = \sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}| \Big/ \sum_{j=1}^{n} \left(\sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}|\right). \tag{3}$$

Step 3. The weighted neutrosophic bipolar cumulative decision matrix is calculated by multiplying the attribute weights to an aggregate decision matrix as follows: $K * W = [k_{ij}^{w_j}]_{m \times n}$ where

$$k_{ij}^{w_j} =< T_{ij}^{w_j+}, I_{ij}^{w_j+}, F_{ij}^{w_j+}, T_{ij}^{w_j-}, I_{ij}^{w_j-}, F_{ij}^{w_j-} > \\ =< 1-(1-T_{ij}^{+})^{w_j}, (I_{ij}^{+})^{w_j}, (F_{ij}^{+})^{w_j}, -(-T_{ij}^{-})^{w_j}, -(-I_{ij}^{-})^{w_j}, -(1-(1-(-F_{ij}^{-}))^{w_j}) >$$

Step 4. Bipolar neutrosophic concordance sets E_{xy} and bipolar neutrosophic discordance sets F_{xy} are defined as follows:

$$E_{xy} = \{1 \le j \le n | \rho_{xj} \ge \rho_{yj}\}, x \ne y, x, y = 1,2,\cdots,m, \\ F_{xy} = \{1 \le j \le n | \rho_{xj} \le \rho_{yj}\}, x \ne y, x, y = 1,2,\cdots,m, \tag{4}$$

Where $\rho_{ij} = T_{ij}^{+} + I_{ij}^{+} + F_{ij}^{+} + T_{ij}^{-} + I_{ij}^{-} + F_{ij}^{-}, i = 1,2,\cdots,m, j = 1,2,\cdots,n$

Step 5. Construct the bipolar neutrosophic concordance matrix E, where bipolar agreement indices $e_{xy}'s$ are calculated using equation (5)

$$e_{xy} = \sum_{j \in E_{xy}} w_j \tag{5}$$

Step 6. Construct the bipolar neutrosophic discordance matrix F, where the bipolar discordance indices $f_{xy}'s$ are calculated by equation (6):

$$f_{xy} = \frac{\max\limits_{j \in F_{xy}} \sqrt{\frac{1}{6n}\left\{\begin{array}{c}(T_{xj}^{w_j+}-T_{yj}^{w_j+})^2+(I_{xj}^{w_j+}-I_{yj}^{w_j+})^2+(F_{xj}^{w_j+}-F_{yj}^{w_j+})^2+\\ (T_{xj}^{w_j-}-T_{yj}^{w_j-})^2+(I_{xj}^{w_j-}-I_{yj}^{w_j-})^2+(F_{xj}^{w_j-}-F_{yj}^{w_j-})^2\end{array}\right\}}}{\max\limits_{j} \sqrt{\frac{1}{6n}\left\{\begin{array}{c}(T_{xj}^{w_j+}-T_{yj}^{w_j+})^2+(I_{xj}^{w_j+}-I_{yj}^{w_j+})^2+(F_{xj}^{w_j+}-F_{yj}^{w_j+})^2+\\ (T_{xj}^{w_j-}-T_{yj}^{w_j-})^2+(I_{xj}^{w_j-}-I_{yj}^{w_j-})^2+(F_{xj}^{w_j-}-F_{yj}^{w_j-})^2\end{array}\right\}}} \tag{6}$$

Step 7. Calculations of the levels of agreement and disagreement are made to rank the alternatives. The bipolar neutrosophic agreement level $\hat{e}$ is established as the average of the bipolar neutrosophic agreement indices as shown:

$$\hat{e} = \frac{1}{m(m-1)} \sum_{\substack{x=1,\\ x \ne y}}^{m} \sum_{\substack{y=1,\\ y \ne x}}^{m} e_{xy} \tag{7}$$

Analogously, the bipolar neutrosophic discordance level $\hat{f}$ is defined as the average value of the bipolar neutrosophic discordance indices, as follows:

$$\hat{f} = \frac{1}{m(m-1)} \sum_{\substack{x=1,\\ x \ne y}}^{m} \sum_{\substack{y=1,\\ y \ne x}}^{m} f_{xy} \tag{8}$$

Step 8. The bipolar neutrosophic concordance dominance matrix ϕ as a function of $\hat{e}$, and the bipolar neutrosophic discordance dominance matrix ψ, as a function of $\hat{f}$, where the values of ϕ_{xy} and ψ_{xy} are defined below:

$$\phi_{xy} = \begin{cases} 1, & \text{if} e_{xy} \ge \hat{e}, \\ 0, & \text{if} e_{xy} < \hat{e}. \end{cases} \tag{9}$$

$$\psi_{xy} = \begin{cases} 1, & \text{if} f_{xy} \le \hat{f}, \\ 0, & \text{if} f_{xy} > \hat{f}. \end{cases} \tag{10}$$

Step 9. Therefore, the bipolar neutrosophic aggregate dominance matrix π is evaluated by multiplying the corresponding entries of the matrices ϕ and ψ. Where $\pi_{xy} = \phi_{xy}\psi_{xy}$.

Step 10. Finally, the alternatives are ranked according to the π_{xy} surpassing values. That is, for each pair of alternatives S_x and S_y, there is an arrow from S_x to S_y if and only if π_{xy}= 1. As a result, we have three possible cases:

(a) There is a single arrow pointing from S_x to S_y.

(b) There are two possible arrows between S_x and S_y.

(c) There is no arrow between S_x and S_y.

For case a), S_x preferred. In the second case, S_x and S_y are indifferent, while S_x and S_y are incomparable in case c).

3 Application for determining strategic alternatives

In the current digital environment, the protection of intellectual property rights has become essential and challenging for many companies and organizations. In this context, a company named Legal Shield Innovations is at a crossroads as it seeks to identify the most effective and cost-efficient strategy to protect its intellectual property rights in the digital era. In this case, the company aims to evaluate and compare four strategic alternatives within the legal framework to determine which one is the most effective according to its objectives for intellectual property protection in the digital context. To do so, the company must choose from the following alternatives:

1. Rights and Trademarks Registration (RTR): The company explores the possibility of registering its intellectual property rights and trademarks more comprehensively and effectively to strengthen its legal position.
2. Direct Legal Actions (DLA): Considers the option of taking direct legal actions against intellectual property infringers by filing lawsuits and seeking compensation.
3. Collaboration with Compliance Agencies (CCA): The company considers collaborating with compliance agencies and government authorities to strengthen the enforcement of intellectual property infringements.
4. Education and Legal Training (ELT): The entity aims to implement education and legal training programs for its employees and collaborators, strengthening their legal defense capabilities.

For the evaluation of these alternatives, a set of high-importance criteria has been proposed for the company's management. These criteria include:

T1: Cost of implementing the measure - Evaluate the direct cost of implementing each measure, including investments in technology, human resources, and training.

T2: Short-term impact - Evaluate the short-term legal effectiveness of each alternative in protecting the company's intellectual property rights in the initial months of implementation.

T3: User experience - Assesses how each measure affects the user experience in terms of accessibility, ease of use, and the quality of available content.

T4: Long-term legal effectiveness - Evaluate the sustainability and long-term effectiveness of each alternative in protecting the company's intellectual property rights, considering possible changes in legislation.

The obtained alternatives were assessed by experts considering the selected criteria. Table 1 shows the decision matrix of bipolar numbers obtained for this purpose.

Table 1. Bipolar Number Decision Matrix

	T1	T2	T3	T4
S1	(0.4, 0.2, 0.5, -0.6, -0.4, -0.4)	(0.5, 0.3, 0.3, -0.7, -0.2, -0.4)	(0.2, 0.7, 0.5, -0.4, -0.4, -0.3)	(0.4, 0.6, 0.5, -0.3, -0.7, -0.4)
S2	(0.3, 0.6, 0.1, -0.5, -0.7, -0.5)	(0.3, 0.6, 0.1, -0.5, -0.3, -0.7)	(0.4, 0.2, 0.5, -0.6, -0.3, -0.1)	(0.2, 0.7, 0.2, -0.5, -0.3, -0.2)
S3	(0.3, 0.5, 0.2, -0.4, -0.3, -0.7)	(0.4, 0.5, 0.2, -0.3, -0.8, -0.5)	(0.8, 0.5, 0.7, -0.3, -0.4, -0.3)	(0.4, 0.7, 0.6, -0.5, -0.5, -0.4)
S4	(0.5, 0.5, 0.3, -0.2, -0.1, -0.3)	(0.7, 0.4, 0.6, -0.1, -0.3, -0.4)	(0.6, 0.3, 0.6, -0.1, -0.4, -0.2)	(0.8, 0.3, 0.2, -0.1, -0.3, -0.1)

In the present case study, the weight vector for the evaluation criteria is considered as follows: w = (0.3, 0.25, 0.2, 0.25). These weights assigned to the criteria, in combination with the initial decision matrix, allow the calculation of the normalized matrix. The normalized matrix is calculated by multiplying the values in the decision matrix by the weights assigned to each evaluation criterion, as shown in (4). See Table 2.

Table 2. Normalized decision matrix

	T1	T2	T3	T4
S1	(0.142, 0.617, 0.812, -0.858, -0.76, -0.142)	(0.159, 0.74, 0.74, -0.915, -0.669, -0.12)	(0.044, 0.931, 0.871, -0.833, -0.833, -0.069)	(0.12, 0.88, 0.841, -0.74, -0.915, -0.12)
S2	(0.101, 0.858, 0.501, -0.812, -0.899, -0.188)	(0.085, 0.88, 0.562, -0.841, -0.74, -0.26)	(0.097, 0.725, 0.871, -0.903, -0.786, -0.021)	(0.054, 0.915, 0.669, -0.841, -0.74, -0.054)
S3	(0.101, 0.812, 0.617, -0.76, -0.697, -0.303)	(0.12, 0.841, 0.669, -0.74, -0.946, -0.159)	(0.275, 0.871, 0.931, -0.786, -0.833, -0.069)	(0.12, 0.915, 0.88, -0.841, -0.841, -0.12)
S4	(0.188, 0.812, 0.697, -0.617, -0.501, -0.101)	(0.26, 0.795, 0.88, -0.562, -0.74, -0.12)	(0.167, 0.786, 0.903, -0.631, -0.833, -0.044)	(0.331, 0.74, 0.669, -0.562, -0.74, -0.026)

From this information, bipolar neutrosophic concordance sets and bipolar neutrosophic discordance sets, as shown in Tables 3 and 4.

Table 3. Bipolar neutrosophic concordance sets.

E_{xy}	1	2	3	4
E_{1y}	-	{1, 2, 3, 4}	{0}	{0}
E_{2y}	{0}	-	{0}	{0}
E_{3y}	{3,4}	{1, 2, 4}	-	{3}
E_{4y}	{1, 2, 3, 4}	{1, 2, 3, 4}	{1, 2, 4}	-

Table 4. Bipolar neutrosophic discordance sets.

F_{xy}	1	2	3	4
F_{1y}	-	{0}	{1, 2, 3, 4}	{1, 2, 3, 4}
F_{2y}	{1, 2, 3, 4}	-	{1, 2, 3, 4}	{4}
F_{3y}	{1,2}	{3}	-	{1, 2, 4}
F_{4y}	{0}	{0}	{3}	-

Based on the collected data and applying equations 6 and 7, the next step is the calculation and obtaining of the neutrosophic concordance matrix E and the neutrosophic discordance matrix F. These matrices will provide a quantitative representation of the concordance and discordance relationships among the evaluated alternatives, facilitating the decision-making process.

$$E = \begin{bmatrix} - & 1.000 & 0.000 & 0.000 \\ 0.000 & - & 0.000 & 0.000 \\ 0.450 & 0.800 & - & 0.220 \\ 1.000 & 1.000 & 0.800 & - \end{bmatrix}$$

$$F = \begin{bmatrix} - & 0.000 & 1.000 & 1.000 \\ 1.000 & - & 1.000 & 0.8589 \\ 1.000 & 0.9854 & - & 1.000 \\ 0.000 & 0.000 & 0.4524 & - \end{bmatrix}$$

With this information, calculations of the levels of concordance and discordance are performed to rank the alternatives. The bipolar neutrosophic concordance level $\hat{e}$ is calculated as 0.4375, while the bipolar neutrosophic discordance level f is obtained as 0.6914. Following this approach, by applying equations 10 and 11, the bipolar neutrosophic concordance dominance matrix ϕ and the bipolar neutrosophic discordance dominance matrix ψ are obtained. These matrices will provide essential information for classifying the alternatives and determining which of the proposed strategies is the most effective based on the previously established criteria.

$$\phi = \begin{bmatrix} - & 1 & 0 & 0 \\ 0 & - & 0 & 0 \\ 1 & 1 & - & 0 \\ 1 & 1 & 1 & - \end{bmatrix}$$

$$\psi = \begin{bmatrix} - & 1 & 0 & 0 \\ 0 & - & 0 & 0 \\ 0 & 0 & - & 0 \\ 1 & 1 & 1 & - \end{bmatrix}$$

Based on the alternatives evaluation methodology and using the resulting dominance matrix, the preference and dominance relationships between the proposed strategies for the protection of intellectual property in the digital age have been determined. The resulting matrix is presented below:

$$\pi = \begin{bmatrix} - & 1 & 0 & 0 \\ 0 & - & 0 & 0 \\ 0 & 0 & - & 0 \\ 1 & 1 & 1 & - \end{bmatrix}$$

Considering the results, it can be observed that there are preference and non-preference relationships among the proposed strategic alternatives. A single arrow going from S_1 to S_2 has been identified, indicating that S_1 is preferred to S_2. Additionally, three possible arrows from S_4 to S_1, S_2, and S_3 have been recorded, indicating the superiority of alternative S_4 over the other alternatives. These results suggest a strong supremacy of alternative S_4

"Education and Legal Training" over the other strategic alternatives. Furthermore, it has been found that alternative S_1 "Rights and Trademarks Registration" is also considered desirable in the context of the study. These findings indicate that, in retrospect, strategies S_4 and S_1 are preferred based on the defined criteria and objectives of the study. The preference for S_4 could be related to its effectiveness in terms of cost and time, making it an attractive option for protecting intellectual property rights in the digital era. On the other hand, the S_1 strategy, focusing on rights and trademark registration, is also considered a desirable option, possibly due to its effectiveness in legal and compliance terms.

Conclusions

Throughout this study, a methodology incorporating neutrosophy was applied to analyze and compare various proposed legal alternatives in the context of intellectual property protection in the digital era. The adaptation and application of the ELECTRE I method to a neutrosophic structure by incorporating bipolar neutrosophic numbers allowed for managing the inherent uncertainty and ambiguity in decision-making in the field of intellectual property law in the digital era. The results indicated a strong preference for the "Education and Legal Training" alternative over others, possibly due to its effectiveness in terms of costs and time. These findings provided a solid foundation for informed decision-making in the field of intellectual property protection in the digital era. The study offered robust support for the use of neutrosophic logic in evaluating and selecting effective and cost-efficient strategies across various fields of science and technology.

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University of New Mexico

Neutrosophic Approaches to Epidemic and Pandemic Response

Daniel Alejandro Arroyo Zumarraga [1], María Fernanda Cueva Moncayo [2], Enrique Rodríguez Reyes [3], and Rodolfo González Ortega [4]

[1] Universidad Regional Autónoma de Los Andes. Ambato. Ecuador. E-mail: ua.danielaz99@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.mariafcueva@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.enriquerodriguez@uniandes.edu.ec
[4] Feevale University, University of Holguín - Vila Nova, Novo Hamburgo Brazil.
E-mail: rodolfogonzalez1978@gmail.com

Abstract: This scientific paper focuses on the importance of health care during a pandemic or epidemic. The response to a pandemic involves the evaluation and treatment of affected patients, the implementation of preventive measures, and monitoring the evolution of the disease. In the field of nursing, the importance of nurses is highlighted in all stages of the response to a pandemic or epidemic. They play a crucial role in patient evaluation and triage, direct care of the infected, infection prevention, public education, interprofessional collaboration, resource management, and epidemiological surveillance. Furthermore, this article presents an approach based on neutrosophic sets in multi-criteria decision-making for triage selection in the nursing field during pandemics or epidemics. The COPRAS method is used to evaluate alternatives based on clinical nursing criteria. The results are used to determine the priority of the alternatives in terms of triage. The article emphasizes the importance of this methodology in decision-making in the field of nursing during pandemic or epidemic situations.

Keywords: Neutrosophic sets, COPRAS, pandemics, epidemics, nursing.

1. Introduction

The response to a pandemic or epidemic is a complex process that involves the collaboration of governments, health organizations, medical professionals, and the community in general. Health care during these types of events is crucial in containing and mitigating the spread of infectious diseases. In these situations, healthcare systems face significantly increased demand, highlighting the need for an efficient and coordinated response.

Health care not only involves the evaluation and treatment of affected patients but also the implementation of preventive measures. Added to this is monitoring the evolution of the disease and educating the community [1]. In addition, health professionals play a fundamental role in the early identification of cases. They excel in implementing isolation and quarantine measures, and managing critical resources and protective equipment [2]. Health care during a pandemic or epidemic not only saves individual lives but also contributes to controlling the spread of the disease. It protects society as a whole and reduces pressure on health systems.

One of the key elements of an effective response to a pandemic or epidemic is surveillance and early detection. This involves constant monitoring of public health indicators, identification of suspected cases, and confirmation through diagnostic tests. Furthermore, effective communication is essential to inform the public about the situation, preventive measures, and guidelines to follow. Education about the disease and proper hygiene practices also play an important role.[3]

To slow the spread of the disease, it is crucial to identify and isolate infected people. In the case of a severe pandemic, quarantines or movement restrictions may be necessary. Diagnostic testing and contact tracing help identify and isolate people who may have been exposed to the virus. This is essential to prevent the spread.

Healthcare workers and other essential professionals must have access to appropriate personal protective equipment (PPE) to protect themselves while caring for patients. Appropriate medical care should be provided to infected people, and effective treatments should be developed if available. In the case of a viral pandemic, the development and distribution of vaccines are essential for the immunization of the population. Collaboration between countries is essential to address a global pandemic. International organizations, such as the World Health Organization (WHO), play a central role in coordinating efforts globally.

Countries should have pandemic response plans in place and be prepared to implement them when necessary. This includes the storage of medical supplies and the training of health personnel. Pandemics can have a significant emotional and social impact on communities. It is important to provide psychological support and social services to address these issues.

The response to pandemics and epidemics in terms of nursing is essential for the effective management of public health and care for affected patients. Nursing professionals play a crucial role in all stages of the response to a pandemic or epidemic [4]. Here are some key areas in which nurses play an essential role:

1. Assessment and triage: Nurses are often the first to assess patients who arrive at healthcare facilities with symptoms suspected of a communicable disease. They perform triage to determine the severity of the illness and the need for isolation.
2. Patient care: Nurses provide direct care to infected patients, including administering medications, monitoring vital signs, and emotional support. They also help in managing complications and provide palliative care when necessary.
3. Infection prevention: Nurses are responsible for implementing infection prevention measures, such as proper use of personal protective equipment (PPE), hand hygiene, and surface disinfection. They also educate patients and their families about safe practices.
4. Public education: Nurses play a crucial role in public education about pandemics or epidemics, providing accurate and up-to-date information on how to prevent the spread of the disease and when to seek medical attention.
5. Interprofessional collaboration: Nurses work closely with physicians, epidemiologists, social workers, and other health professionals to plan and coordinate the response to the pandemic. They participate in team meetings and contribute their experience in nursing care.
6. Resource management: Nurses are often involved in resource management, such as allocating hospital beds, medical equipment, and supplies needed to treat infected patients.
7. Epidemiological surveillance: Nurses may be involved in collecting and analyzing epidemiological data to help track the spread of disease and make informed decisions about public health policies.
8. Emotional support: During a pandemic, nurses provide emotional support to patients and their families, who are often experiencing stress and anxiety due to illness and separation.

Nursing assessment and triage are essential processes in healthcare, especially during emergencies, such as epidemics or natural disasters. Assessment involves collecting clinical data and observing patients to determine their health status. Nurses play a critical role in this stage by taking vital signs, assessing symptoms, and gathering relevant information about the patient. This initial evaluation helps identify the severity of the patient's condition and make informed decisions about necessary medical care.

Triage, on the other hand, refers to the prioritization of patients based on the severity of their condition and the resources available. Nurses play a key role in the triage process by determining which patients require immediate attention and which can wait. This is done by evaluating the severity of symptoms, the stability of the patient, and the availability of medical resources. Triage is crucial in high-demand situations, ensuring that the most critical patients receive priority care. Thus, when faced with a triage system, nursing staff are constantly under pressure to make immediate decisions.

Decision-making is an essential aspect of human functioning, both personally and professionally. Decisions are often faced with predefined objectives, but in many situations, these objectives conflict. The need to simultaneously consider criteria and alternatives in decision problems is crucial, especially when dealing with uncertain data sets [5]. In recent years, research has focused on addressing the vagueness of initial information in solving complex practical problems, using multi-criteria decision-making (MCDM) methods. These methods allow decision-makers to address uncertainty and subjectivity in the decision-making process.

Fuzzy set theory was introduced to deal with uncertain and imprecise data. However, it has been observed that it cannot address all the uncertainties that arise in real problems in various fields of life. To address this limitation, neutrosophic set theory was proposed as a generalization of fuzzy and intuitionistic fuzzy sets. In neutrosophy, truth membership, indeterminacy membership, and false membership are independent and lie in a non-standard interval between 0 and 1. To make neutrosophic sets more practical, single-valued neutrosophic sets were defined (SVNS) and operations and properties of SVNS were proposed.

Experts in various disciplines have applied neutrosophic set theory in solving multi-criteria decision-making problems in fields such as investment, healthcare, and communication circuit design. In the field of medicine, where decision-making is complex and constant, neutrosophy has proven to be a valuable tool for addressing the indeterminacies of the real world and considering multiple factors in the decision-making process.

This research aims to make possible the possible situations of triage selection in the field of nursing in the face of pandemics or epidemics. The study will be carried out by applying single-value neutrosophic sets toward decision-making in the application of the COPRAS method.[6]

2 Preliminaries

2.1 The COPRAS method

This multicriteria decision-making technique was proposed by [7] and can be generally expressed as follows. Given a decision-making problem, which consists of *m* alternatives that must be evaluated considering *n* criteria and x_{ij} can be expressed as the value of the i^{th} alternative by the criterion. The main idea of the COPRAS technique consists of the steps described below:

Step1. Select the appropriate set of criteria that describes the chosen alternatives.

Step2. Prepare the decision matrix.

$$X = \begin{bmatrix} x_{11} & x_{12} \dots & x_{1n} \\ x_{22} & x_{22} \dots & x_{2n} \\ \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & x_{mn} \end{bmatrix} \quad (1)$$

Step 3. Determine the weights w_j of the criteria.

Step 4. Normalize decision matrix $\bar{X}$. The values of the normalized matrix are determined as

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}; i = 1,2, \dots, m; j = 1,2, \dots, n \quad (2)$$

Step 5. Compute weighted normalized decision matrix D, whose components are calculated as

$$d_{ij} = \bar{x}_{ij} \cdot w_j; i = 1,2, \dots, m; j = 1,2, \dots, n \quad (3)$$

Step 6. Calculate the summation of the criterion values with respect to the optimization direction for each alternative.

$$P_{+i} = \sum_{j=1}^{L_{max}} d_{+ij};\ P_{-i} = \sum_{j=1}^{L_{min}} d_{-ij} \quad (4)$$

where d_{+ij} values correspond to the criteria to be maximized and d_{-ij} values correspond to the criteria to be minimized.

Step 7. Determine the minimum component of P_{-i}:

$$P_{-min} = min_i P_{-i}; i = 1,2, \dots, L_{min} \quad (5)$$

Step 8. Determine the score value of each alternative Q_i:

$$Q_i = P_{+i} + \frac{P_{-min} \sum_{j=1}^{L_{min}} P_{-j}}{P_{-i} \sum_{j=1}^{L_{min}} \frac{P_{-min}}{P_{-j}}}; j = 1, \dots, L_{min} \quad (6)$$

Step 9. Determine optimality criterion *K* for the alternatives:

$$K = max_i Q_i\ ; i = 1,2, \dots, m \quad (7)$$

Step 10. Determine the priority of the alternatives. The greater Q_i score value for the alternative corresponds to the higher priority (rank) of the alternative.

2.2 Neutrosophic Sets

Definition 1. Let X be a space of the objects and $x \in X$. A neutrosophic set A in X is defined by three functions: truth-membership function $T_A(x)$, an indeterminacy- membership function $I_A(x)$ and falsity-membership function $F_A(x)$. These functions are defined on real standard or real non-standard subsets of $]0^-, 1^+[$. That is $T_A(x): X \to]0^-, 1^+[, I_A(x): X \to]0^-, 1^+[\ and\ F_A(x): X \to]0^-, 1^+[$. There is no restriction on the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$, so $0^- \le supT_A(x) + supI_A(x) + supF_A(x) \le 3^+$.

2.3 Single Valued Neutrosophic Set.

A Single Valued Neutrosophic Set (SVNS) has been defined as described in [8].

Definition 2. Let X be a universal space of the objects and $x \in X$. A single valued neutrosophic set (SVNS) $\tilde{N} \subset X$ can be expressed as

$$\tilde{N} = \{\langle x, T_{\tilde{N}}(x), I_{\tilde{N}}(x), F_{\tilde{N}}(x)\rangle : x \in X\} \quad (8)$$

where $T_{\tilde{N}}(x): X \to][0,1], I_{\tilde{N}}(x): X \to][0,1]\ and\ F_{\tilde{N}}(x): X \to][0,1]$

with $0 \leq T_{Ñ}(x) + I_{Ñ}(x) + F_{Ñ}(x) \leq 3$ or all $x \in X$. The values $T_{Ñ}(x)$, $I_{Ñ}(x)$ and $F_{Ñ}(x)$ correspond to the truth-membership degree, the indeterminacy-membership degree, and the falsity-membership degree of x to Ñ, respectively. For the case when X consists of a single element, Ñ is called a single-valued neutrosophic number [9][10]. For the sake of simplicity, a single-valued neutrosophic number is expressed by $Ñ_A = (t_A, i_A, f_A)$ where $t_A, i_A, f_A \in [0,1]$ and $0 \leq t_A + i_A + f_A \leq 3$.

Definition 3. Let $Ñ_1 = (t_1, i_1, f_1)$ and $Ñ_2 = (t_2, i_2, f_2)$ be two SVN numbers, then summation between $Ñ_1$ and $Ñ_2$ is defined as follows:

$$Ñ_1 + Ñ_2 = (t_1 + t_2 - t_1t_2, i_1i_2, f_1f_2) \tag{9}$$

Definition 4. Let $Ñ_1 = (t_1, i_1, f_1)$ and $Ñ_2 = (t_2, i_2, f_2)$ be two SVN numbers, then multiplication between $Ñ_1$ and $Ñ_2$ is defined as follows:

$$Ñ_1 * Ñ_2 = (t_1t_2, i_1 + i_2 - i_1i_2, f_1 + f_2 - f_1f_2) \tag{10}$$

Definition 5. Let $Ñ = (t, i, f)$ be an SVN number and $\lambda \in \mathbb{R}$ an arbitrary positive real number, then:

$$\lambda Ñ = \left(1 - (1 - \mathrm{t})^{\lambda}, i^{\lambda}, f^{\lambda}\right), \lambda > 0 \tag{11}$$

Definition 6. If A= $\{A_1, A_2, \ldots, A_n\}$, and B= $\{B_1, B_2, \ldots, B_n\}$ (i= 1, 2, …, m) are two single-valued neutrosophic sets, then the separation measure between A and B applying the normalized Euclidian distance can be expressed as follows:

$$q_n(A, B) = \sqrt{\frac{1}{3n}\sum_{j=1}^{n}\left(\left(t_A(x_i) - t_B(x_i)\right)\right)^2 + \left(\left(i_A(x_i) - i_B(x_i)\right)\right)^2 + \left(\left(f_A(x_i) - f_B(x_i)\right)\right)^2}$$

$$(i = 1, 2, \ldots, n) \tag{12}$$

Definition 7. 7. Let A = (a, b, c) be a single-valued neutrosophic number, then a score function $Ñ_A$ is mapped into the single crisp output $S(Ñ_A)$ as follows

$$S(Ñ_A) = \frac{3 + t_A - 2i_A - f_A}{4} \tag{13}$$

where $S(Ñ_A) \in [0,1]$. This score function is the modification of the score function proposed by [11-12-13-14] and allows to have the results in the same interval while dealing with single-valued neutrosophic numbers.

The concept of a linguistic variable is very useful for solving decision-making problems with complex content. The value of a linguistic variable is expressed as an element of its term set. Such linguistic values can be represented using single-valued neutrosophic numbers.

In the method, there are k-decision makers, m-alternatives and n-criteria. k-decision makers evaluate the importance of the m-alternatives under n-criteria and rank the performance of the n-criteria with respect to linguistic statements converted into single valued neutrosophic numbers. The importance weights based on single-valued neutrosophic values of the linguistic terms are given in Table 1.

Table 1: Linguistic variable and Single Valued Neutrosophic Numbers (SVNNs). Source: [6]

Linguistic terms	SVNNs
Extremely Good (EG)/ 10 points	(1.00, 0.00, 0.00)
Very Very Good (VVG)/ 9 points	(0.90, 0.10, 0.10)
Very Good (VG)/ 8 points	(0.80, 0.15, 0.20)
Good (G) / 7 points	(0.70, 0.25, 0.30)
Medium Good (MG) / 6 points	(0.60, 0.35, 0.40)
Medium (M) / 5 points	(0.50, 0.50, 0.50)
Medium Bad (MB) / 4 points	(0.40, 0.65, 0.60)
Bad (B) / 3 points	(0.30, 0.75, 0.70)
Very Bad (VB) / 2 points	(0.20, 0.85, 0.80)
Very Very Bad (VVB) / 1 point	(0.10, 0.90, 0.90)
Extremely bad (EB) / 0 points	(0.00, 1.00, 1.00)

The performance of the group decision-making applying COPRAS-SVNS approach can be described by the following steps.

- Step 1. Determine the importance of the experts. In the case when the decision is made by a group of experts (decision makers), firstly the importance or share of the final decision of each expert is determined. If a vector $\lambda = (\lambda_1, \lambda_2, \dots, \lambda_k)$ is the vector describing the importance of each expert, where $\lambda_k \geq 0$ and $\sum_{k=1}^{K} \lambda_k = 1$.
- Step 2. In the framework of this step, each decision maker performs his evaluations concerning the ratings of the alternatives with respect to the attributes and the attribute weights. If it is denoted by $x_{ij}^{k}, i = 1,2,\dots,m; j = 1,2,\dots,n$ the k^{th} expert's evaluation of the i^{th} alternative by the j^{th} criterion. This evaluation is expressed in linguistic terms presented in Table 1. So, the decision matrix for any particular expert can be constructed

$$X^k = \begin{bmatrix} {x^k}_{11} & {x^k}_{12} \cdots & {x^k}_{1n} \\ {x^k}_{22} & {x^k}_{22} \cdots & {x^k}_{2n} \\ \vdots & \vdots & \vdots \\ {x^k}_{m1} & {x^k}_{m2} \cdots & {x^k}_{mn} \end{bmatrix} \quad (14)$$

- Step 3. Calculate the weights of the criteria. The aggregated weights of the criteria are determined by

$$\mathrm{w}_j = \lambda_1 \mathrm{w}_j^{(1)} \cup \lambda_2 \mathrm{w}_j^{(2)} \cup \dots \cup \lambda_k \mathrm{w}_j^{(k)} = \left(1 - \prod_{k=1}^{K}\left(1 - t_j^{(w_k)}\right)^{\lambda_k}, \prod_{k=1}^{K}\left(i_j^{(w_k)}\right)^{\lambda_k}, \prod_{k=1}^{K}\left(f_j^{(w_k)}\right)^{\lambda_k}\right) \quad (15)$$

- Step 4. Construction of the aggregated weighted single-valued decision matrix

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} \cdots & \tilde{x}_{1n} \\ \tilde{x}_{22} & \tilde{x}_{22} \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} \cdots & \tilde{x}_{mn} \end{bmatrix} \quad (16)$$

where any particular element $\tilde{x}_{ij} = (\tilde{t}_{ij}, \tilde{\imath}_{ij}, \tilde{f}_{ij})$ represents the rating of the alternative A_i with respect to the j criterion and is determined as follows

$$\tilde{x}_{ij} = \lambda_1 \mathrm{x}_{ij}^{(1)} \cup \lambda_2 \mathrm{x}_{ij}^{(2)} \cup \dots \cup \lambda_k \mathrm{x}_{ij}^{(k)} = \left(1 - \prod_{k=1}^{K}\left(1 - t_j^{(x_k)}\right)^{\lambda_k}, \prod_{k=1}^{K}\left(i_j^{(x_k)}\right)^{\lambda_k}, \prod_{k=1}^{K}\left(f_j^{(x_k)}\right)^{\lambda_k}\right) \quad (17)$$

- Step 5. Determine the weighted decision matrix. Following Eq. (3), the weighted decision matrix can be expressed as $D = \lfloor d_{ij} \rfloor, d = 1,2,\dots,m; j = 1,2,\dots,n$, where $d_{ij} = \tilde{x}_{ij} * w_j$. Applying Eq. (10), a single element of the weighted decision matrix can be calculated.

$$d_{ij} = t_{ij}^{\tilde{x}} t_j^{w}, i_{ij}^{\tilde{x}} + i_j^{w} - i_{ij}^{\tilde{x}} i_j^{w}, f_{ij}^{\tilde{x}} + f_j^{w} - f_{ij}^{\tilde{x}} f_j^{w} \quad (18)$$

- Step 6. Perform a summation of the values for the benefit. Let $L_{+} = \{1,2,\dots,L_{max}\}$ be a set of the criteria to be maximized. Then the index of the benefit for each alternative can be determined.

$$P_{+i} = \sum_{j=1}^{L_{max}} d_{+ij} \quad (19)$$

where this summation of the single value neutrosophic numbers is performed applying Eq.(9).

- Step 7. Calculate the summation of the values for cost. Let be $L_{-} = \{1,2,\dots,L_{min}\}$ a set of criteria to be minimized. Then the index of the cost of each alternative can be determined.

$$P_{-i} = \sum_{j=1}^{L_{min}} d_{-ij} \quad (20)$$

- Step 8. Determine the minimum value of P_{-i}.
- Step 9. Determine the score value of each alternative Q_i. At the beginning, the score values are calculated from the aggregated values for benefit and the cost $S(P_{+i})$ and $S(P_{-i})$ applying Eq.(13). The score values of the alternatives can be expressed as:

$$Q_i = S(P_{+i}) + \frac{S(P_{-min}) \sum_{i=1}^{L_{min}} S(P_{-i})}{S(P_{-min}) \sum_{i=1}^{L_{min}} \frac{S(P_{-min})}{S(P_{-i})}} \quad (21)$$

- Step 10. Determine optimality criterion *K* for the alternatives:

$$K = max_i Q_i; i = 1,2,\dots,m \quad (22)$$

Step 11. Determine the priority of the alternatives. The greater score value Q_i for the alternative corresponds to the highest priority (rank) of the alternative.

3 Results and Discussion

Patient assessment and triage during an epidemic or pandemic are critical processes for determining disease severity and allocating healthcare resources efficiently. For the development of the study, three alternatives are considered when evaluating the triage carried out by nursing staff when caring for patients in the face of a pandemic or epidemic:

1. **Medical care capacity:**

- Availability of hospital beds, ventilators, medical personnel, and medical supplies.
- Capacity of the health system to handle additional patients.

2. **Prioritization of population groups:**

- Determination of high-risk population groups that should receive priority attention.
- Consideration of the availability of specific vaccines or treatments.

3. **Guides and protocols:**

- Use of guidelines and protocols established by public health authorities and medical organizations for evaluation and triage.

Importantly, assessment and triage may vary depending on the severity of the epidemic or pandemic, as well as local conditions and available resources. These variables help healthcare professionals make informed decisions about care and resource allocation, prioritizing those patients who need it most.

Nursing clinical criteria in the care of pandemics or epidemics are essential to guarantee safe and effective care for patients. These criteria focus on the evaluation and care of patients, as well as preventing the spread of the disease. To confront the proposed variables, four evaluation criteria were established, which are codified in Table 2. The data were analyzed by 5 experts in the case, who analyzed the selection alternatives based on the analyzed criteria. Experts are considered to have an equal degree of importance.

Table 2: Evaluation criteria. Source: own elaboration.

Criteria	
C_1 Infection Control	- Proper use of personal protective equipment (PPE). - Rigorous cleaning and disinfection of surfaces and equipment. - Isolation and quarantine measures, as necessary. - Frequent and correct hand washing. - Safe handling of medical waste and contaminated materials.
C_2 Prevention and Control of Transmission	- Educate patients and staff about hygiene and prevention practices. - Monitor compliance with infection control measures in the healthcare unit. - Quickly identify and notify suspected or confirmed cases of the disease.
C_3 Resource Management and Logistics	- Manage available resources such as personal protective equipment (PPE), medical supplies, and equipment. - Collaborate on logistics to ensure critical resources are available when needed.
C_4 Personnel Safety	- Protect the health and safety of nursing staff through the proper use of personal protective equipment (PPE) and training on safety measures.

The weight vector of the criteria is obtained through the evaluations carried out by the experts considering the values provided in Table 1. In this way, Table 3 shows the weight vector obtained after applying equation (15).

Table 3: Vector of weights of the analyzed criteria. Source: own elaboration.

Weights vector	SVNN
C_1	(0.82671;0.17329;0.15157)
C_2	(0.83428;0.16572;0.15849)
C_3	(0.79186;0.20814;0.17411)
C_4	(0.82671;0.17329;0.15157)

The evaluation of the alternatives is carried out considering the values shown in Table 1. All the initial data are transformed into neutrosophic sets. The evaluations made by the experts are shown in Table 4.

Table 4: Evaluation carried out by experts of the decision alternatives with respect to the evaluation criteria. Source: own elaboration.

		Criterion 1			
Alternatives	X1	X2	X3	X4	X5
Healthcare capacity	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.75,0.25,0.2)
Prioritization of population groups	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)
Guides and Protocols	(0.9,0.1,0.1)	(0.9,0.1,0.1)	(0.75,0.25,0.2)	(0.9,0.1,0.1)	(0.9,0.1,0.1)
		Criterion 2			
Alternatives	X1	X2	X3	X4	X5
Healthcare capacity	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.9,0.1,0.1)
Prioritization of population groups	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
Guides and Protocols	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)
		Criterion 3			
Alternatives	X1	X2	X3	X4	X5
Healthcare capacity	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)
Prioritization of population groups	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)	(0.35,0.75,0.8)
Guides and Protocols	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)
		Criterion 4			
Alternatives	X1	X2	X3	X4	X5
Healthcare capacity	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.5,0.5,0.5)	(0.75,0.25,0.2)	(0.9,0.1,0.1)
Prioritization of population groups	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)
Guides and Protocols	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)	(0.5,0.5,0.5)	(0.9,0.1,0.1)

Based on the evaluations carried out by the experts, the necessary transformations are carried out to obtain the decision matrix, using equation (17). Table 5 shows the results obtained after applying the indicated procedure.

Table 6: Weighted decision matrix. Source: own elaboration.

Alternatives	**Criterion 1**	**Criterion 2**	**Criterion 3**	**Criterion 4**
Healthcare capacity	(0.67,0.33,0.289)	(0.725,0.275,0.251)	(0.35,0.75,0.8)	(0.725,0.275,0.251)
Prioritization of population groups	(0.81,0.19,0.19)	(0.5,0.5,0.5)	(0.35,0.75,0.8)	(0.5,0.5,0.5)
Guides and Protocols	(0.88,0.12,0.115)	(0.81,0.19,0.19)	(0.621,0.379,0.347)	(0.81,0.19,0.19)

Table 5: Initial decision matrix. Source: own elaboration.

The initial decision matrix allows for obtaining the weighted decision matrix, which is constructed by applying equation (19) and is presented in Table 6.

Alternatives	**Criterion 1**	**Criterion 2**	**Criterion 3**	**Criterion 4**
Healthcare capacity	(0.554;0.446;0.397)	(0.605;0.395;0.37)	(0.277;0.802;0.835)	(0.599;0.401;0.365)
Prioritization of population groups	(0.67;0.33;0.313)	(0.417;0.583;0.579)	(0.277;0.802;0.835)	(0.413;0.587;0.576)
Guides and Protocols	(0.728;0.272;0.249)	(0.676;0.324;0.318)	(0.492;0.508;0.461)	(0.67;0.33;0.313)

At this point in the analysis, it is necessary to clarify that criteria 1 and 2 are considered benefit criteria, so their enhancement should be sought. Taking this into account, the coefficients proposed by the method are calculated and analyzed to select between the alternatives.

Table 7: Values of Pi, S(P), and Q score value for each alternative. Source: own elaboration.

Coefficients	Healthcare capacity	Prioritization of population groups	Guides and Protocols
Pi+	(0.824;0.176;0.147)	(0.808;0.192;0.181)	(0.912;0.088;0.079)
Pi-	(0.71;0.322;0.305)	(0.576;0.471;0.481)	(0.832;0.168;0.144)
S(P+)	0.831	0.81075	0.91425
S(P-)	0.69	0.53825	0.838
Q	**1,497**	**1,664**	**1,462**

When analyzing the results presented in Table 7, it can be seen that the analyzed method indicates that the most preferred alternative according to the experts is alternative 2, referring to the prioritization of population groups. The second most preferred alternative is the health care capacity, while the last place among the aspects analyzed is the use of guides and protocols. In this context, it can be concluded that the experts consider that prioritization of population groups, given the need to take action during pandemics or epidemics, should be a priority during the triage carried out by nursing staff.

Conclusions

Assessment and triage are two vital components of nursing care that allow for a rapid and effective response to emergencies and epidemics. Nurses play an essential role in collecting clinical information, prioritizing patients, and ensuring limited resources are allocated efficiently, which in turn helps save lives and reduce the spread of disease.

Research on the application of neutrosophic set theory in multi-criteria decision-making shows its usefulness in complex situations, such as triage selection in nursing during pandemics or epidemics.

The application of the COPRAS method together with the neutrosophic set theory allows for addressing uncertainty and subjectivity in triage decision-making in nursing, considering multiple criteria and alternatives. It was proven that the response to pandemics and epidemics requires effective planning and coordination, the active participation of health professionals, and the application of innovative approaches, such as neutrosophic set theory, for decision-making in highly complex situations.

Patient assessment and triage play a crucial role in public health care during these crises, and its effectiveness can make a difference in containing the disease and protecting society as a whole.

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University of New Mexico

Neutrosophic Models for Nursing Staff Allocation

Riber Fabián Donoso Noroña [1], Nairovys Gómez Martínez [2], Sara Guerrón Rodríguez [3], and Salah Hasan Saleh Al-Subhi [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.riberdonoso@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes. Ambato. Ecuador. E-mail: ua.nairovysgomez@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes. Tulcán. Ecuador. E-mail: ut.saraxge69@uniandes.edu.ec
[4] Universidad de las Ciencias Informáticas-Cuba-Asociación Latinoamericana de Ciencias Neutrosóficas, Yemen. E-mail: salahcuba@hotmail.com

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:

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

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:

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

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

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

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

$$A = (1 - (1 - a), b, c) \tag{4}$$

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 $A^* = (A_1^*, A_2^*, \dots, A_n^*)$ be a vector of n SVNN such that $A_j^* = (a_1^*, b_2^*, c_j^*)(j = 1,2, \dots, n)$ and $B_i = (B_{i1}, B_{i2}, \dots, B_{im})(i = 1,2, \dots, m)$ 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 $A = \{\rho_1, \rho_2, \dots, \rho_m\}$ is a set of alternatives and $G = \{\beta_1, \beta_2, \dots, \beta_m\}$ 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:

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

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

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

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:

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

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

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)	• 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.
	• Moderate availability (MA)	• 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.
	• Low availability (LA)	• 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)
λ_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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University of New Mexico

Neutrosophic Assessment of Human Rights and Social Justice

Jorge Gabriel Del Pozo Carrasco [1], Jairo Mauricio Puetate Paucar [2], Cristian Fernando Benavides Salazar [3], and Asnioby Hernandez Lopez [4]

[1] Universidad Regional Autónoma de los Andes, Quevedo. Ecuador. E-mail: uq.jorgedc77@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Tulcán. Ecuador. E-mail: ut.jairopuetate@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes. Santo Domingo. Ecuador. E-mail: us.cristianbenavides@uniandes.edu.ec
[4] Mercado Libre, Montevideo, Uruguay. E-mail: asnioby.hernandez@mercadolibre.com

Abstract. In a world characterized by cultural diversity, global interconnection, and growing awareness of the fundamental rights of each individual, the theme of Human Rights and Social Justice stands as a significant pillar in the quest for societies more equitable, inclusive, and respectful of human dignity. This intersection transcends geographical boundaries and encompasses a variety of crucial issues affecting local, national, and international communities. Respect for the dignity of human beings involves the recognition, fulfillment, and exercise of their rights, assumed as a primary obligation of the States under a comprehensive understanding that considers the criteria of diversity, equity, and justice. The purpose of this study is to analyze and evaluate human rights and social justice, through neutrosophic statistics, to contribute to the strengthening of more just and inclusive societies. The study concluded that the participation of citizens in activities against violations of constitutional rights is a challenge that must be met to overcome the remaining obstacles and achieve a more just and inclusive society.

Keywords: cultural diversity, fundamental rights, equality, neutrosophy.

1 Introduction

Human rights, recognized in international documents such as the United Nations Universal Declaration of Human Rights, represent the fundamental principles that guarantee the equality, freedom, and dignity of all people, regardless of their origin, gender, religion, or social status. Meanwhile, social justice focuses on the equitable distribution of resources, opportunities, and benefits in a society, to reduce economic and social inequalities that may hinder access to these fundamental rights.

The International Bill of Human Rights, consisting of the Declaration of Human Rights; the International Covenant on Civil and Political Rights; the International Covenant on Economic, Social and Cultural Rights; and the Optional Protocols to the International Covenant on Civil and Political Rights, is the main body of laws that regulate the fulfillment of the ideals under which a type of society based on freedom, respect, non-discrimination and life in peace for every person in modern societies is articulated.[1]

Ecuador, being a country subscribed to the legal commitments related to International Human Rights Law, has assumed the responsibility to ensure compliance with these norms and ensure their management in defense of the guarantees of all citizens who are under the inalienable protection of these protocols. The recognition of a right is of no use if there are not sufficient conditions to demand its respect, exercise, or reparation in case of violation.

Ecuador, as a nation located in the Andean region of South America, has undergone a significant transformation in recent decades in terms of human rights and social justice. The interaction between these two key elements has been a central theme in the process of building a more equitable society that respects human dignity in the country.

Article 10 of the 2008 Constitution of the Republic of Ecuador establishes individuals, communities, peoples, nationalities, and collectives as rights holders, and nature as the subject of constitutionally recognized rights. In this sense, the defense of rights in Ecuador takes place in two fields: those traditionally known as human rights, related to individuals and groups of people, and the rights of nature.[2]

In terms of human rights, the 2008 Constitution has been a key milestone. It recognizes a wide range of rights, from economic and social to civil and political. The Constitution guarantees fundamental aspects such as free and quality education, medical care, social security, and access to decent dwellings. It also stands out for its recognition of the rights of indigenous peoples and nature and is the first in the world to grant rights to nature itself.[2]

On one hand, in relation to the defense of human rights, the category of human rights defenders includes a broad universe of people and associations, whose common point is the peaceful protection and promotion of Human Rights.

It is the doctrine that has prevailed in the world and that has served to legally organize the social and democratic State of law or the constitutional State of rights and justice. This means that the human being who lives in the Ecuadorian State is the holder of the constitutionally guaranteed rights and that the State is created to respect them, make them respected, and create the conditions for the human being to effectively enjoy these rights, the same as the communities, peoples and nationalities that it constitutes for this purpose.

The Ombudsman's Office understands that human rights defenders are any person, community, people, nationality, or groups that promote and protect human rights, which in the country refer to the rights of a good living, rights of protection, rights of freedom, rights of participation, through peaceful mechanisms, whether institutional or disruptive, at the national or international level.

Since the adoption of its 2008 Constitution, Ecuador has taken important steps in the promotion and protection of human rights. This Magna Carta recognizes a wide range of rights, from economic and social to civil and political rights [3]. Among the notable advances are:

- Social and Economic Rights: guarantees rights such as free and quality education, medical care, social security, and access to decent dwellings. These are fundamental aspects of achieving greater social justice by providing more equitable opportunities to all citizens.
- Rights of Indigenous Peoples: recognizes and protects the rights of indigenous peoples, promoting their participation in decision-making and the recognition of their ancestral territories.
- Rights of Nature: The Ecuadorian Constitution was the first in the world to grant rights to nature, recognizing its intrinsic value and its right to exist, persist, and regenerate. This has led to important debates about environmental justice.

Challenges in the Promotion of Human Rights:

Despite these advances, Ecuador faces challenges in the full realization of human rights. Some of the problems and obstacles include:

1. Economic Inequality: Despite efforts to reduce poverty and inequality, Ecuador still faces significant economic gaps between different population groups.
2. Gender Violence: Gender violence is still a worrying problem in Ecuador and although measures have been implemented to fight it, there are challenges to guaranteeing gender equality and the safety of women.
3. Minority Rights: Despite progress in protecting the rights of indigenous peoples, tensions and conflicts related to the exploitation of natural resources in their territories persist.

The Intersection with Social Justice:

Social justice in Ecuador is closely related to the promotion of human rights. Seeking a more equitable distribution of wealth, including marginalized groups, and ensuring that all citizens have access to meaningful opportunities are key aspects of social justice in the country. The relationship between human rights and social justice is evident in areas such as education, health, and housing, where government policies seek to improve the living conditions of citizens and reduce inequalities.[4]

Human rights in Ecuador and their vindication have to do with the generalized perception of those rights and the idiosyncrasy of society. The violation of human rights does not only come from the State but also concerns citizens. Thus, Ecuador's political and social culture has been permeated by clientelism, a system that has generated relations of dependence and domination that confirm power in one sector, impede the development of citizenship, and make the democratization of power impossible.[5]

Legality is on the margins of political and social life, which allows minimum rules such as human rights to be ignored and society does not consider their vindication. The political and social culture is fundamental to understanding the skepticism and compliance with rules of conduct contrary to the exercise of citizenship and ultimately to the consolidation of dignity.[6]

Historically in Ecuador, the understanding of human rights as norms valid for all humanity has been approached from the formal legal aspect for the establishment of processes that guarantee human dignity.[7]

This approach by the Ecuadorian State has achieved the creation of subjectivities within the institutions of power themselves, which strive to regulate the construction of subjects capable of articulating demands for the surveillance and expansion of rights in the political arena, but disregarding sectors that are discarded in the processes of construction of guarantees that also include them.

Ecuador has an additional peculiarity, related to the constitutional regulations in force since 2008. In its current constitution, Ecuador defines itself as a constitutional State of rights, and Article 11, explicitly establishes the direct and immediate validity of human rights, even in the absence or ignorance of legal regulations. The Constitution itself is also explicit about the inalienability of these rights. The supremacy of human rights in the country is comparable to the Constitution itself, according to Article 426.[2]

On the other hand, it is necessary to point out that the international systems for the promotion and protection of human rights, both universal and inter-American, have paid close attention to the situation of human rights defenders and, therefore, have developed norms and mechanisms for protection and monitoring the fulfillment of their role within the States. One of their recurring concerns is related to the use of domestic laws as mechanisms to deter and threaten the work of human rights defenders.

In the social rule of law, participatory and pluralistic democracy based on respect for dignity and solidarity, indicate that the role of authorities is not limited to formally recognizing people's rights. These are obliged to act effectively to provide them with the necessary conditions so that they can overcome their shortcomings, access the real satisfaction of their needs, eliminate any form of discrimination, and fully enjoy the legal, spiritual, and material goods required for their full fulfillment. realization as individual and social beings.

The intersection between human rights and social justice is manifested in government policies aimed at improving the quality of life of Ecuadorian citizens. The pursuit of a more equitable distribution of wealth and the inclusion of marginalized groups, such as indigenous peoples, are examples of how the promotion of human rights and social justice are intrinsically linked. This relationship demonstrates the importance of addressing both aspects comprehensively to achieve a more equitable society that respects human dignity.

Human rights violations denote the lack of guarantees that still exist for the effective exercise of constitutional rights. Violations of people's rights must be investigated exhaustively and diligently.

Although Ecuador has a favorable legal framework regarding human rights, public policies, plans and government programs must be reviewed periodically, since human rights continue to be violated, while effective and timely actions are awaited. by the authorities.

This study embarks on a multidisciplinary journey aimed at conducting an evaluation of human rights and social justice in various contexts and situations. In addition, examines how the promotion of human rights can be a key driver for building more just societies and how the absence of social justice can constitute a significant barrier to the effective realization of those rights.[8]

For the analysis of the factors for the evaluation of human rights and social justice, the following objectives are defined:

General Objective: Analyze and evaluate human rights and social justice, to contribute to the strengthening of more just and inclusive societies.

Specific objectives:

- ✓ Investigate and explore the deep connections between human rights principles and the achievement of effective social justice.
- ✓ Evaluate challenges and barriers to the implementation of human rights and social justice.
- ✓ Develop strategies and recommendations for the promotion of human rights and social justice, which can be applied to improve the promotion and protection of human rights and social justice.

2 Materials and methods

2.1 Neutrosophic Statistics

Neutrosophic probabilities and statistics are a generalization of classical and imprecise probabilities and statistics. The Neutrosophic Probability of an event E is the probability that event E will occur [9], the probability that event E does not occur, and the probability of indeterminacy (not knowing whether event E occurs or not). In classical probability nsup≤1, while in neutrosophic probability nsup≤3+.

The function that models the neutrosophic probability of a random variable x is called the neutrosophic distribution:

$$NP(x) = (T(x), I(x), F(x)), \tag{1}$$

Where T(x) represents the probability that the value x occurs, F (x) represents the probability that the value x does not occur, and I (x) represents the indeterminate or unknown probability of the value x.

Neutrosophic Statistics is the analysis of neutrosophic events and deals with neutrosophic numbers, neutrosophic probability distribution, neutrosophic estimation, neutrosophic regression, etc. It refers to a set of data, which is made up totally or partially of data with some degree of indeterminacy, and to the methods to analyze them.[10]

Neutrosophic statistical methods allow you to interpret and organize neutrosophic data (data that may be ambiguous, vague, imprecise, incomplete, or even unknown) to reveal underlying patterns.[11, 12-13-14-15].

In short, Neutrosophic Logic, Neutrosophic Sets, and Neutrosophic Probabilities and Statistics have a wide application in various research fields and constitute a new study reference in full development.

Neutrosophic Descriptive Statistics comprises all techniques for summarizing and describing the characteristics of neutrosophic numerical data.

Neutrosophic Numbers are numbers of the form where a and b are real or complex numbers, while "I" is the indeterminacy part of the neutrosophic number N.

$N = a + bI.$

The study of neutrosophic statistics refers to a neutrosophic random variable where X_l and $X_u I_N$ represents the correspondingly lower and higher level that the studied variable can reach, in an indeterminate interval $[I_l, I_u]$. Following the neutrosophic mean of the variable $(\bar{x}_N)$ when formulating:

$$X_N = X_l + X_u I_N;\ I_N \in [I_l, I_u] \tag{2}$$

Where $\bar{x}_a = \frac{1}{n_N} \sum_{i=1}^{n_N} X_{il}\ \bar{x}_b = \frac{1}{n_N} \sum_{i=1}^{n_N} X_{iu}\ n_N \in [n_l, n_u]$,

is a neutrosophic random sample. However, for the calculation of neutral squares (NNS), the following formula is used:

$$\sum_{i=1}^{n} N(X_i - \bar{X}_{iN})^2 = \sum_{i=1}^{n} N \begin{bmatrix} \min\begin{pmatrix} (a_i + b_i I_L)(\bar{a} + \bar{b} I_L), (a_i + b_i I_L)(\bar{a} + \bar{b} I_U) \\ (a_i + b_i I_U)(\bar{a} + \bar{b} I_L), (a_i + b_i I_U)(\bar{a} + \bar{b} I_U) \end{pmatrix} \\ \max\begin{pmatrix} (a_i + b_i I_L)(\bar{a} + \bar{b} I_L), (a_i + b_i I_L)(\bar{a} + \bar{b} I_U) \\ (a_i + b_i I_U)(\bar{a} + \bar{b} I_L), (a_i + b_i I_U)(\bar{a} + \bar{b} I_U) \end{pmatrix} \end{bmatrix}, I \in [I_L, I_U] \tag{3}$$

Where $a_i = X_l b_i = X_u$. The variance of the neutrosophic sample can be calculated by

$$S_N^2 = \frac{\sum_{i=1}^{n_N} (X_i - \bar{X}_{iN})^2}{n_N};\ S_N^2 \in [S_L^2, S_U^2] \tag{4}$$

The neutrosophic coefficient (NCV) measures the consistency of the variable. The lower the NCV value, the more consistent the factor's performance is if compared to the other factors. The NCV can be calculated as follows.

$$CV_N = \frac{\sqrt{S_N^2}}{\bar{X}_N} \times 100;\ CV_N \in [CV_L, CV_U] \tag{5}$$

3 Results

In evaluating human rights and social justice in Ecuador, several determining factors play a crucial role in understanding the situation and progress in these areas. Here are five essential factors:

1. Legal and Constitutional Framework: The existence of a solid legal and constitutional framework is a fundamental factor in the evaluation of human rights and social justice. The 2008 Ecuadorian Constitution, which recognizes a wide range of rights and establishes key principles of social justice, provides a solid foundation for the protection and promotion of these rights.
2. Citizen Participation: The active participation of civil society in decision-making and oversight of public policies is essential to evaluate human rights and social justice.
3. Social and Economic Indicators: The measurement of social and economic indicators, such as the poverty rate, access to education and health care, income inequality, and other relevant factors, provides objective data to evaluate the human rights situation and social justice. These indicators allow us to identify areas for improvement and monitor progress.
4. Government Policies: Government policies, especially in areas such as education, health, and resource distribution, are critical to the assessment of social justice. The effective implementation of policies that seek to reduce inequalities and guarantee access to basic services is a key factor in the evaluation.

5. Continuous Monitoring and Evaluation: The existence of continuous monitoring and evaluation mechanisms, both nationally and internationally, is essential to evaluate progress and challenges in terms of human rights and social justice. Reports from human rights organizations, government agencies, and international organizations offer a critical and data-based view of the situation in the country.

From the theoretical study, it is observed that multiple factors can influence the evaluation of human rights and social justice. It is proposed to apply neutrosophic statistics to determine how the promotion of human rights can be a key driver for the construction of more just societies. To do this, it was first decided to code the factors to make the results viable (Table 1). There is a sample of n=120 for each factor (f).

Table 1: Determining factors in the evaluation of human rights and social justice.

Code	Initials	Determining factors
A	LCF	Legal and Constitutional Framework
B	CP	Citizen Participation
C	SEI	Social and Economic Indicators
D	GP	Government Policies
E	CME	Continuous Monitoring and Evaluation

For the statistical study, the neutrosophic frequencies of the determining factors in the evaluation of human rights and social justice are analyzed. For each factor, an analysis is made of the incidences that make up the set of affectations so that human rights and social justice in Ecuador are fully respected and become a reality for all its inhabitants.

Table 2: Neutrosophic frequencies of the factors.

Days	Neutrosophic frequencies				
	LCF	CP	SEI	GP	CME
1	[2, 5]	[2, 2]	[4, 4]	[0, 0]	[1, 2]
2	[1, 2]	[1, 3]	[23]	[2, 4]	[1, 3]
3	[2, 5]	[2, 4]	[5, 8]	[0, 2]	[1, 2]
4	[1, 1]	[3, 5]	[2, 2]	[1, 3]	[2, 3]
5	[1, 4]	[3. 4]	[5, 10]	[1, 3]	[2, 5]
6	[0, 0]	[2, 3]	[0, 2]	[3, 3]	[1, 1]
7	[2, 4]	[0, 2]	[5, 6]	[1, 1]	[0, 3]
8	[1, 2]	[4, 5]	[1, 5]	[3, 6]	[3, 3]
9	[2, 5]	[1, 3]	[1, 1]	[23]	[2, 2]
10	[1, 3]	[2, 2]	[4, 8]	[1, 2]	[2, 3]
11	[3, 3]	[1, 1]	[0, 5]	[2, 2]	[0, 1]
12	[1, 3]	[3. 4]	[1, 6]	[3, 5]	[23]
13	[3, 5]	[4, 7]	[3, 6]	[1, 2]	[2, 4]
14	[2, 2]	[3, 3]	[4, 4]	[0, 2]	[0, 1]
15	[0, 3]	[2, 5]	[2, 4]	[0, 2]	[2, 5]
16	[0, 0]	[1, 5]	[5, 9]	[0, 0]	[1, 4]
17	[1, 4]	[1, 1]	[1, 3]	[2, 4]	[2, 5]
18	[2, 3]	[2, 4]	[3, 3]	[1, 2]	[0, 0]
19	[1, 3]	[0, 4]	[4, 9]	[2, 4]	[0, 1]
20	[0, 0]	[3. 4]	[1, 4]	[0, 0]	[0, 3]
0-110	[160, 339]	[222, 428]	[277, 551]	[181, 339]	[155, 330]

Table 2 analyzed the neutrosophic frequency of occurrence of the determining factors, for 110 days, with an occurrence level of [0; 10] for each factor per day with a level of total indeterminacy of a=179, b=206, c=274, d=158, e=175, and a level of representativeness of [46.61%; 53.03%], on the days when 10 impacts per factor are registered, with an incidence of 53% in terms of Continuous Monitoring and Evaluation.

From the data on the effects that affect the search for equity and justice (Table 3), it will be possible to understand which factor implies a representative average, $\bar{x} = \in [\bar{x}_L; \bar{x}_U]$, the values of the neutrosophic means are calculated and to study the variations of the effects, the values of the neutrosophic standard deviation $S_N \in [S_L; S_U]. S$ and the values $CV_N \in [CV_L\ ;\ CV_U]$ are calculated to determine which condition requires a greater incidence.

Table 3: Neutrosophic statistical analysis of incidents.

Factors	$\bar{x}_N$	S_N	CV_N
LCF	[1,455; 3.08]	[0.673; 2,301]	[0.463; 0.747]
CP	[2,018; 3,891]	[1,146; 2,578]	[0.568; 0.663]
SEI	[2,518; 5,009]	[1,733; 3,547]	[0.688; 0.708]
GP	[1,645; 3,082]	[0.713; 2,079]	[0.433; 0.675]
CME	[1,409; 3,000]	[0.691; 2,206]	[0.49; 0.735]

It was determined that the factors, government policies, and citizen participation, have higher average values that affect the other factors. This means that these factors are, on average, the ones that have the most impact on the construction of a more equitable society that respects human dignity in the country; however, the value of CV_{Nb} for citizen participation is lower than the rest. This means that the result of this factor has a more consistent, coherent, and precise impact when evaluating indeterminacy than the other factors.

A comparative analysis is carried out to calculate the measure of referent indeterminacy associated with $\bar{x} = \in [\bar{x}_L; \bar{x}_U]$, $S_N \in [S_L; S_U]$ and $CV_N \in [CV_L\ ;\ CV_U]$ to the form of neutrosophic numbers (Table 5), in the results, it is observed that for the CV_N values range from 0.568 + 0.663, with the indeterminacy measure 14.3, which generates a negative impact on citizen participation.

Table 4: Neutrosophic forms with their corresponding measure of indeterminacy.

Factors	$\bar{x}_N$	S_N	CV_N
LCF	1,455 + 3,082 I;I $\in [0; 52.8]$	0.673 + 2.301I;I $\in [0; 70{,}8]$	0.463 + 0.747I;I $\in [0; 38{,}0]$
CP	2,018 + 3,891 I;I $\in [0; 48{,}1]$	1.146 + 2.578 I;I $\in [0; 55{,}5]$	0.568 + 0.663 I;I $\in [0; 14{,}3]$
SEI	2,518 + 5,009 I;I $\in [0; 49{,}7]$	1.733 + 3.547 I;I $\in [0; 51{,}1]$	0.688 + 0.708 I;I $\in [0; 2{,}8]$
GP	1.645 + 3.082 I;I $\in [0; 46{,}6]$	0.713 + 2.079 I;I $\in [0; 65{,}7]$	0.433 + 0.675 I;I $\in [0; 35{,}9]$
CME	1,409 + 3 I;I $\in [0; 53{,}0]$	0.691 + 2.206 I;I $\in [0; 68{,}7]$	0.49 + 0.735 I;I $\in [0; 33{,}3]$

With the present study, it was determined that one of the main priorities is to provide a solid foundation for a research program or an academic course that addresses the topic of human rights and social justice, from an academic and practical perspective.

Faced with this role, people or organizations that promote the defense of human rights must enjoy the rights: to study and debate whether human rights are guaranteed or not, as well as to form an opinion on the matter and disseminate it; to denounce the policies and actions of state officials and bodies that violate constitutional rights; and to participate in peaceful activities against violations of constitutional rights.

The exercise of these rights in many cases questions ministerial provisions, so the vague definition of this cause would allow State officials to interpret the norm subjectively and order the closure of these organizations for the fulfillment of tasks inherent to their essence.

The ability of citizens to express their concerns, demands, and needs contributes to accountability and the strengthening of democracy. Therefore, it is recommended:

- Educate in the culture of peace and peaceful conflict resolution.
- Enable efficient communication channels that contribute to institutional support, exchange of experiences, and material and intellectual resources for the full social inclusion of people.
- Provide more exhaustive information that contributes to the conduct of future research, the design of more inclusive social policies, and innovative development processes with an equity focus.
- Establish more direct, effective, and productive dialogues between researchers on inequalities and equity policies and decision-makers.

Conclusion

Ecuador has made notable progress in the promotion and protection of human rights, having established a solid foundation through its 2008 Constitution. However, significant challenges remain, such as economic inequality, gender-based violence, and conflicts related to minority rights. These challenges require continued attention and renewed efforts to achieve full human rights realization in the country.

The analysis of the neutrosophic statistics showed that citizen participation reached a level of indeterminacy of 14.3%. This had an inversely proportional influence with respect to the other factors so that if this factor decreases, the other factors increase and limit the identification of problems and obstacles that can contribute to the construction of a more egalitarian world that respects the dignity of all human beings.

Progress in the promotion of human rights and social justice in Ecuador requires a constant commitment on the part of society, government, and international organizations, continuous reflection, monitoring of progress, and implementation of evidence-based policies are essential to overcome the remaining obstacles and achieve a more just and inclusive society. In addition, dialogue between government actors and civil society plays a crucial role in identifying challenges and formulating effective solutions, such as training, workshops, and other government-led initiatives that fully involve citizens. Respecting the dignity of individuals and groups and achieving respectful coexistence, or at least moving in that direction, is essential and much depends on what is done as a society and on what the State does to pave the way.

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University of New Mexico

Neutrosophic Evaluation of Patient-Centered Care in Ecuador

Viviana Alejandra Beltrán Culqui[1], Juan Alberto Viteri Rodríguez[2], Jenny Maribel Moya Arizaga[3], and Beatríz María González Nuñez[4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.vivianabc06@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.juanviteri@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: docentetp54@uniandes.edu.ec
[4] Universidad de Holguín, Cuba. E-mail: bettygonzaleznuez@gmail.com

Abstract. The perception of Ecuadorian patients about medical care and the implementation of Patient-Centered Care (PCC) is a topic of profound relevance in the current health system. Lack of effective communication, variability in experiences, and lack of awareness are some of the deficiencies that influence patients' perceptions and criteria. In this context, the general objective of this neutrosophic evaluation is to identify the positive and negative aspects of PCC, as well as the perception of patients. The results revealed that the Personal Experience (PE) of the patients is a predominant factor in the acceptance of PCC. Positive experiences, such as effective communication and active participation in health decisions, generated positive perceptions. The conclusions highlight the need to improve communication, education, and institutional support to promote patient-centered care in Ecuador and address the indeterminacies present in the general perception.

Keywords: Patient-Centered Care, Healthcare, Neutrosophic Analysis.

1 Introduction

The perception of Ecuadorian patients about the medical care received can vary significantly from one individual to another and can be evaluated using the neutrosophy methodology, which involves the degrees of truth, indeterminacy, and falsehood. It is significant to note that the perception of medical care may depend on individual factors [1], such as personal experience, prior expectations, interactions with medical staff, and specific health circumstances [2]. Therefore, Ecuadorian patients' perceptions of the medical care received can vary widely in terms of neutrosophic degrees of truth, indeterminacy, and falsity. Hence more detailed and specific research is essential to obtain a complete picture of these perceptions and expectations in the Ecuadorian population (see Table 1).

Table 1: Perception of Ecuadorian patients about PCC. Source: own elaboration.

Degree of Truth	Degree of Indeterminacy	Degree of Falsehood
Satisfaction and trust: Some Ecuadorian patients may experience highly satisfactory and effective medical care. They may feel that health professionals are competent and care about their well-being. These patients trust the healthcare system and believe their needs are adequately addressed [3].	Mixed experiences: A considerable group of Ecuadorian patients may have mixed experiences in healthcare. They may have had positive experiences with certain doctors or health departments, but also face challenges at other times. This could be due to factors such as variability in quality of care, wait times, and variable communication between patients and doctors.	Dissatisfaction and mistrust: Some Ecuadorian patients may have a negative perception of medical care. They may feel that they are not given enough attention, that they are treated impersonally, or that their concerns are not taken seriously. These patients may experience significant levels of dissatisfaction and distrust in the healthcare system.
Positive opinions: They can express positive opinions about the medical care received, highlighting the empathy of the doctors, the quality of clinical care, and the ease of access to health services [4]. For	Variable expectations: Perception of medical care may somehow depend on patients' prior expectations. Those with more realistic or low expectations may rate their experience with a degree of indeterminacy, as they may accept certain	Persistent complaints and problems: They may have persistent complaints about the quality of care, problems accessing medical services, or barriers to communication with health care providers. Their perception could

Degree of Truth	Degree of Indeterminacy	Degree of Falsehood
them, patient-centered care is a reality, and the perception of it could be rated with a high degree of truth.	deficiencies as part of overall medical care.	be described as highly false in terms of satisfaction and quality of care.

Regarding the analysis of the effectiveness of the implementation of Patient-Centered Care (PCC) in Ecuador, the use of neutrosophic degrees is required. So that the obstacles that may limit successful implementation in the Ecuadorian health system could be examined (see Table 2).

Table 2: Obstacles that limit the implementation of the PCC in Ecuador. Source: own elaboration.

Obstacles	Degree of Truth	Degree of Indeterminacy	Degree of Falsehood
Cultural factors	There are significant cultural differences in Ecuador, where some communities may have a more paternalistic mentality in healthcare, which may hinder the adoption of PCC.	Cultural perception can vary from region to region and ethnic group to ethnic group, contributing to uncertainty as to how these differences influence the application of PCC.	Cultural resistance to PCC, in some cases, can be a real obstacle that limits its successful implementation.
Limited resources	The lack of financial resources and infrastructure in the Ecuadorian health system is a well-documented obstacle to the successful implementation of PCC.	The lack of resources may vary by region and health institution, leading to a degree of indeterminacy in terms of its exact impact on PCC.	Lack of adequate resources can be a significant barrier that limits the effective implementation of PCC.
Training of medical staff [5]	The lack of adequate training of medical staff in patient-centered approaches can be a real obstacle to PCC in Ecuador.	The quality of medical training can vary, contributing to indeterminacy regarding staff readiness to adopt PCC.	Lack of training can be a major limitation impeding successful implementation of PCC.
Bureaucracy and regulation	Bureaucracy and regulation in the healthcare system can make it difficult to adopt more flexible, patient-centered approaches.	The complexity of the regulation and its impact on the PCC can vary, contributing to indeterminacy in terms of its exact influence.	Excessive bureaucracy and restrictive regulation can be significant obstacles to the effective implementation of PCC.

In summary, the neutrosophic analysis reveals that the application of PCC in Ecuador faces multiple barriers and challenges. Cultural factors, limited resources, inadequate training of medical staff, and bureaucracy in the health system are obstacles that may vary in their impact, but in many cases represent real limitations for the successful implementation of PCC in the country. Addressing these barriers requires specific strategies and a personalized approach for each region and healthcare context in Ecuador. Therefore, the main objective of this study is:

- Evaluate the acceptance of Patient Centered Care, by identifying the positive and negative aspects and the perception of users.

Specific objectives:

- Determine the factors that affect the analyzed variable.
- Carry out measurement and modeling of the variable through neutrosophic analysis.
- Project potential solutions based on the factor with the greatest impact on the variable.

It is essential to recognize that the perception of medical care is highly subjective and can be influenced by individual, cultural, and contextual factors. To fully understand these neutrosophic degrees and improve patient-centered healthcare in Ecuador, it is necessary to conduct specific studies that include surveys, interviews, and qualitative analyses to capture the diversity of patient experiences and expectations in the Ecuadorian healthcare system. To achieve a complete result, the neutrosophic IADOV method is used to evaluate PCC in Ecuador.

2 Materials and methods

2.1 Neutrosophic Iadov

To apply the neutrosophic Iadov technique, experts must rely on a linguistic evaluation system that shows the expert's opinion. This system and its neutrosophic and numerical equivalents are shown in Table 3.

Table 3: Evaluation system for experts. Linguistic terms are associated with their neutrosophic evaluation and score value. Source: own elaboration.

Linguistic term	SVNU	Scale
Clearly satisfied	(1,0,0)	3
More satisfied than dissatisfied	(1,0.35,0,35)	2.3
Undefined	I	1.5
More dissatisfied than satisfied	(0.35,0.35,1)	1
Clearly dissatisfied	(0,0,1)	0
Contradictory	(1,0,1)	2

The term I in neutrosophy is interpreted as a unit of indeterminacy. Another component of the method is Iadov's Logical Table, which assigns numerical values to three closed questions that are applied to the experts (see Table 4). If necessary, open questions can be applied in the surveys.[6]

Table 4: Closed questions and their corresponding values. Source: own elaboration.

Approaches	Possible answers								
1st QUESTION	Yes			I don't know			No		
2nd QUESTION	Yes	I don't know	No	Yes	I don't know	No	Yes	I don't know	No
3rd QUESTION									
I like it a lot	1	2	6	2	2	6	6	6	6
I do not like it very much	2	3	3	2	3	3	6	3	6
I do not care	3	3	3	3	3	3	3	3	3
I dislike it more than I like it	6	3	6	3	4	4	3	4	4
It is an unconsolidated research process	6	6	6	6	4	4	6	4	5
I don't know what to say	2	3	6	3	3	3	6	3	4

To survey the level of satisfaction of the experts, the neutrosophic Iadov technique was used. This technique is based on the use of Single-Valued Neutrosophic Sets (SVNS) associated with linguistic variables for their ability to increase interpretation in recommendation models and the use of indeterminacy.[7]

The definition of SVNS is as follows, Let X be a universe of discourse. An SVNS A over X is an object of the form.

$$A = \{[x, u_a(x), r_a(x), v_a(x)] : \in X\}\, dA = \{[x, u_a(x), r_a(x), v_a(x)] : \in X\}d \quad (1)$$

Where:

$u_a(x): X \to [0,1], r_a(x): X \to [0,1]\ y\ v_a(x): X \to [0,1]$

With

$0 \leq u_a(X), r_a(X), v_a(X) \leq 3, \forall x \in X$

For convenience, a Single Value Neutrosophic Number (SVNN) will be expressed as:

$$A = (a, b, c), where\ a, b, c \in [0,1]\ and\ it\ satisfies\ 0 \leq a + b + c \leq 3.$$

Aggregation operators are used to find an SVNS that describes several sets at the same time. One of these operators is the neutrosophic weighted average (WA), which is defined as follows:

Let $\{A_{1,} A_2, \dots, A_n\} \in SVNS\ (x), where\ A_j = (a_j, b_j, c_j)(j = 1, 2, \dots, n)$, the Neutrosophic Weighted Average (WA) Operator is calculated as:

$$WA\ (A_{1,} A_2, \dots, A_n) = \sum [w_j, A_i] \quad (2)$$

Where:

$$WA\ (w_{1,} w_2, \dots, w_n) = \sum_{i=1}^{n} [w_j, A_i]\ is\ the\ vector\ of\ A_j\ (j = 1,2, \dots, n)\ such\ that\ w_n \in [0,1]\ y \sum w_j = 1$$

To deneutrosophicate this set so that a single value is obtained, a scoring function is usually used [8].

Let A = (a, b, c), the S-score function of an SVNS, based on the indeterminate membership degree and the false membership degree, is defined by the following equation:

$$S(A)=2+abc \tag{3}$$

To use an SVNS to measure individual satisfaction, this value must be associated with a linguistic variable. Therefore, the scales shown in Table 3 were specified and the corresponding score was calculated using (3)

For cases in which the evaluation corresponds to indeterminacy (not defined) (I), a process was developed.

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \tag{4}$$

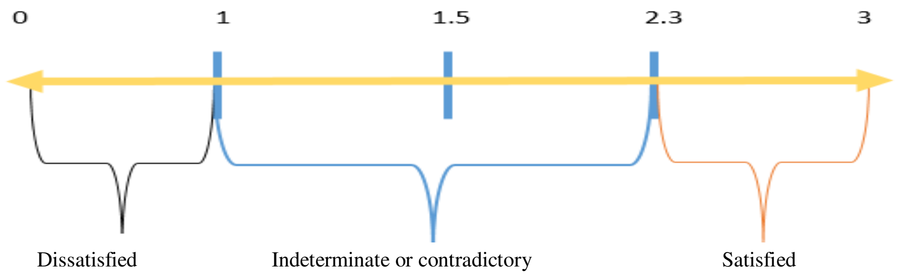
To calculate the Respondents' Global Satisfaction Index (ISG), the WA aggregation operator (2) was used, taking into consideration the score values and that all respondents have the same weight, so

$$w_i = \frac{1}{n}$$

The instrument designed for the application of the survey was a five-question questionnaire, three of which are closed (1, 3, and 5) and two are open (2 and 4). The three closed questions were related through the “Logical Iadov Chart”, which is presented in Table 4. The algorithm used for the application of the neutrosophic Iadov technique is the following:

- Once the questionnaire has been applied, the corresponding value (from 1 to 6) for the satisfaction classification of the surveyed experts is calculated in the three-entry IADOV logical table.
- The linguistic variable, the SVNS, and the score are matched to this value according to Table 2.
- The score value of each respondent is used to calculate the group satisfaction index (GSI) from the aggregation of all scores using the WA aggregation operator formula (2).
- The GSI is interpreted from the location of the value on the graph in Figure 1.

Figure 1: Scale for determining the level of satisfaction according to the scores used. Source: own elaboration.



2.2 Data collection

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

$$n = \frac{ZNpq}{E^2(N-1) + Z^2pq} \tag{5}$$

Where: n: is the ample 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

Data collection: For the study, the sample size of respondents is calculated using equation 5, which takes the probabilities as 50% or 0.05, according to the following results:

Maximum margin of error allowed=10.0%

- Population size=200
- Size for a 95% confidence level 65
- Size for a 97% confidence level 74
- Size for a 99% confidence level 91

It is decided to work with 95% confidence, so surveys are applied to determine the level of the analyzed variable. To do this, the criteria of 65 respondents are evaluated per factor.

To do this, the criteria of 65 respondents are evaluated by a group of experts in health, social communication, PCC, psychology, law, and organizational culture. From the sample, it was decided to identify the neutrosophic variable, the coding for the modeling, and the neutrosophic states in which they are found (see Table 5).

Table 5: Characteristics of the variable. Source: own elaboration.

Variable	**Coding**	**Sample**	**neutro-sophic set**	**Scale** $[0\ ;\ 1], \forall F_n$
Acceptance of Patient Centered Care (PCC) in Ecuador	A-PCC	80	*Satisfaction and acceptance of the Ecuadorian health system*	**[1 ; 0; 0]** (Truth): On this scale, there is a complete and effective acceptance of the PCC in Ecuador. The positive aspects of PCC, such as improved doctor-patient communication, shared decision-making, and user satisfaction, are clearly evident and widespread. Health professionals apply it effectively, and users rate it positively. **[0; 1; 0]** (Indeterminacy): This scale represents the uncertainty and variability in the acceptance of the PCC in Ecuador. There is a mix of positives and negatives, and user perception can vary widely. Some professionals and health centers can apply it effectively, while others may have difficulties or inconsistencies in its implementation. Users may have mixed opinions about their experience with PCC. **[0; 0; 1]** (Falsehood): On this scale, PCC is not widely accepted in the Ecuadorian health system. The negative aspects can outweigh the positives, resulting in a lack of adoption and effective implementation of PCC. Users may have negative perceptions and feel that their expectations in terms of patient-centered care are not met.

The neutrosophic variable A-PCC in Ecuador is aimed at patient satisfaction with the service received from the Ecuadorian health system. The evaluation of each element of origin and its relationship between the factors and the subset must be analyzed to decide on a possible diagnosis within the neutrosophic set called satisfaction and acceptance of the Ecuadorian health system (Table 6) [9] [10-13-14].

Table 6: Factors that influence A-PCC. Source: own elaboration.

Code	**Factor**	**Source elements**	**Relationship between factor and the source element**	**Observations**
F1	Awareness and understanding (AU)	• Patient awareness, • Patient understanding, • Health education, doctor-patient communication	Degree of CC in relation to patients' perception of PCC.	Influence on patients' perception of PCC based on their understanding and awareness of PCC principles.
F2	Personal experience (PE)	• Positive experiences, • Negative experiences with PCC	Degree of PD in relation to patients' perception of PCC	Impact of patients' personal experiences on their perception of PCC, with positive experiences and negative experiences.
F3	Training of medical personnel (TMP)	• Training level of medical personnel, • Continuing education	Degree of TMP in relation to the implementation of the PCC	Importance of training medical personnel in the effective implementation of PCC, with a high degree of TMP that promotes the adoption of patient-centered approaches.
F4	Resources and Support (RS)[11]	• Availability of resources, • Institutional support	Degree of RS in relation to the implementation of the PCC	Importance of resources and institutional support in the promotion and adoption of PCC, with a high degree of RS that facilitates implementation.
F5	Organizational culture (OC)	• Culture of the institution, • PCC prioritization	Degree of OC in relation to the implementation of the PCC	Influence of the organizational culture in hospitals and health centers on the promotion of PCC, with a positive culture that encourages its adoption [12].

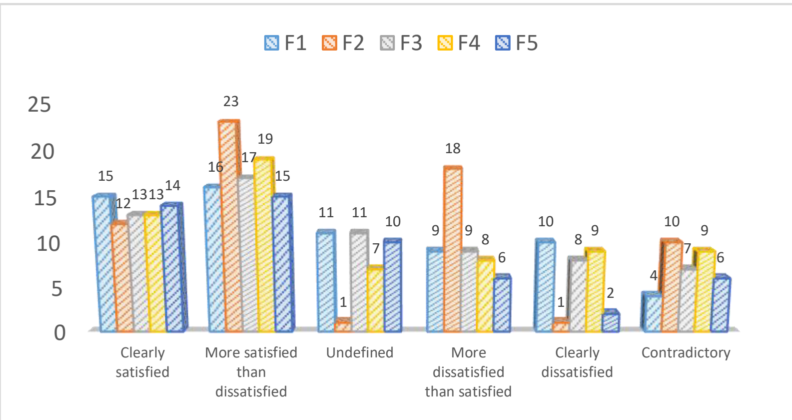
For the development of the neutrosophic IADOV method, questions are proposed for the evaluation of each factor by group. Among these, there are three closed questions and two open questions that stand out for modeling the method according to the neutrosophic scale and the previously proposed questionnaire (see Table 7).

Table 7: Open and closed questions in the questionnaire. Source: own elaboration.

No.	F1	F2	F3	F4	F5
1 (question 1 of the questionnaire)	Do you believe that the principles and benefits of PCC affect patients' satisfaction and acceptance of the Ecuadorian health system?	Do you think patients' personal experience with medical care influences their perception of PCC?	Do you think that the training of medical personnel influences their perception of the PCC and acceptance of the Ecuadorian health system by patients?	Do you believe that available resources and institutional support are essential to implement PCC with a high degree of acceptance?	Do you think that the organizational culture in hospitals and health centers can significantly affect the perception of PCC?
2 (question 2 of the questionnaire)	Do you think that the Ecuadorian health system should work on patients' perceptions of PCC?	Do you consider that the Ecuadorian health system should work on the elements that influence the negative experience in the perception of PCC by patients?	Do you consider that the Ecuadorian health system should work to achieve medical personnel trained in PCC?	Do you consider that the Ecuadorian health system should work to provide available resources and institutional support to achieve satisfactory PCC?	Do you consider that the Ecuadorian health system should work to achieve an organizational culture in hospitals and health centers that values and promotes PCC?
3 (open question)	What is your opinion about the principles and benefits of PCC?	What is your personal experience with the PCC?	What is your opinion about the training and professionalism of the medical staff at PCC?	What is your opinion about the resources and support that health institutions have to adopt PCC?	What is your opinion about the organizational culture in hospitals and health centers?
4 (open question)	What do you dislike most about the medical health system regarding PCC principles?	What do you dislike most about the medical health system regarding PCC principles?	What do you dislike most about the medical staff at PCC?	What deficiencies have you detected in health institutions regarding the resources available for patient care?	What deficiencies have you observed in healthcare institutions that indicate a culture that does not prioritize patient-centered care?
5 (question 3 of the questionnaire)	Would you like to know and understand the principles and benefits of PCC?	Would you like to know and understand the principles and benefits of PCC?	Would you like health professionals in Ecuador to be adequately trained in PCC?	Would you like healthcare institutions to have the medical resources and institutional support to adopt successful PCC?	Would you like health institutions to foster an organizational culture that values and promotes PCC?

From the application of the survey by the group of experts, the results were obtained regarding the individual satisfaction levels shown in Figure 2 and the information regarding the neutrosophic group studied.

Figure 2: Satisfaction levels of the group of experts for each factor.



Positive satisfaction levels can be seen, satisfaction and acceptance of the Ecuadorian health system regarding A-PCC, with predominance in the degree to which Ecuadorian patients are aware and understand the principles and benefits of PCC. However, dissatisfactions are observed especially in patients' personal experience with medical care and perception of PCC. Indeterminate and contradictory positions were also found between the level of membership of each element.

The calculations of the GSI according to the frequency of observation and the individual satisfaction indices of the designed categories and their corresponding scores are shown in tables 8 to 12, for each group respectively.

Table 8: Calculation of the Group Satisfaction Index (GSI) of the *awareness and understanding* element.

Linguistic term	SVNU	Scoring (S)	Frequency (F)	F*S	(F*S)/n
Clearly satisfied	(1;0;0)	3	15	45	0.69
More satisfied than dissatisfied	(1;0.35;0.35)	23	16	36.8	0.57
Undefined	I	1.5	11	16.5	0.25
More dissatisfied than satisfied	(0.35; 0.35;1)	1	9	9	0.14
Clearly dissatisfied	(0;0;1)	0	10	0	0.00
Contradictory	(1;0;1)	2	4	8	0.12
Group Satisfaction Index					**1.77**

From the analysis of the *awareness and understanding* element, it can be seen that patients are aware of and understand the principles and benefits of PCC. Although there is an undefined degree regarding patients who are unaware of the extent of PCC. Finally, a group satisfaction index of 1.77 is defined for the factor analyzed.

Table 9: Calculation of the Group Satisfaction Index (GSI) of the *personal experience* element.

Linguistic term	SVNU	Scoring (S)	Frequency (F)	F*S	(F*S)/n
Clearly satisfied	(1;0;0)	3	12	36	0.55
More satisfied than dissatisfied	(1;0.35;0.35)	2.5	23	57.5	0.88
Undefined	I	1.5	1	1.5	0.02
More dissatisfied than satisfied	(0.35; 0.35;1)	1	18	18	0.28
Clearly dissatisfied	(0;0;1)	0	1	0	0.00
Contradictory	(1;0;1)	2	10	20	0.31
Group Satisfaction Index					**2.05**

The analysis of the element of *patient's personal experience* with medical care influences their perception of the PCC: more satisfied than dissatisfied and more dissatisfied than satisfied. Therefore, a degree of contradiction is reflected between the responses of this factor. There is an existing level of indeterminacy. With this, patients have had positive experiences with PCC, which increases their acceptance. On the other hand, a high degree of negative *personal experience* would indicate that they may decrease acceptance. Finally, a group satisfaction index of 2.05 is defined for the factor analyzed.

Table 10: Calculation of the Group Satisfaction Index (GSI) of *the training of medical personnel* element.

Linguistic term	SVNU	Scoring (S)	Frequency (F)	F*S	(F*S)/n
Clearly satisfied	(1;0;0)	3	13	39	0.60
More satisfied than dissatisfied	(1;0.35;0.35)	2.5	17	42.5	0.65
Undefined	I	1.5	11	16.5	0.25
More dissatisfied than satisfied	(0.35; 0.35;1)	1	9	9	0.14
Clearly dissatisfied	(0;0;1)	0	8	0	0.00
Contradictory	(1;0;1)	2	7	14	0.22
Group Satisfaction Index					**1.86**

Of the criteria analyzed regarding the *training of medical personnel* element, it can be observed that patients are more satisfied than dissatisfied; it can be said that there is a certain undefined degree to which work should be done. Therefore, attention should be paid to the work with health professionals so that they are adequately trained, which would facilitate a level of satisfaction in the acceptance of PCC in Ecuador.

Table 11: Calculation of the Group Satisfaction Index (GSI) of the *resources and support* element.

Linguistic term	SVNU	Scoring (S)	Frequency (F)	F*S	(F*S)/n
Clearly satisfied	(1;0;0)	3	13	39	0.60
More satisfied than dissatisfied	(1;0.35;0.35)	2.5	19	47.5	0.73
Undefined	I	1.5	7	10.5	0.16
More dissatisfied than satisfied	(0.35; 0.35;1)	1	8	8	0.12
Clearly dissatisfied	(0;0;1)	0	9	0	0.00
Contradictory	(1;0;1)	2	9	18	0.28
Group Satisfaction Index					**1.89**

Of the *resources and support* element, it can be seen that, although patients are on the balance between more satisfied than dissatisfied. It can be said that there is a certain degree of patients accepting that there are adequate resources in health facilities, although work should be done to achieve solid institutional support that facilitates the implementation of PCC. A group satisfaction index of 1.89 is defined for this factor.

Table 12: Calculation of the Group Satisfaction Index (GSI) of the *organizational culture* element.

Linguistic term	SVNU	Scoring (S)	Frequency (F)	F*S	(F*S)/n
Clearly satisfied	(1;0;0)	3	14	42	0.65
More satisfied than dissatisfied	(1;0.35;0.35)	2.5	18	45	0.69
Undefined	I	1.5	11	16.5	0.25
More dissatisfied than satisfied	(0.35; 0.35;1)	1	8	8	0.12
Clearly dissatisfied	(0;0;1)	0	7	0	0.00
Contradictory	(1;0;1)	2	7	14	0.22
Group Satisfaction Index					**1.93**

As for the *organizational culture* element, there is an organizational culture in hospitals and health centers. However, it is not entirely defined that it significantly achieves the perception of PCC. The governing entities must work to achieve an organizational culture that meets the proposed standards to achieve patient satisfaction and acceptance of the Ecuadorian health system. A group satisfaction index of 1.93 is defined for this factor.

When analyzing the proposed neutrosophic factors in relation to the neutrosophic variable "Acceptance of Patient-Centered Care (PCC) in Ecuador", it can be argued that the neutrosophic factor that most affect the states of this variable and, therefore, in the perception of Ecuadorian patients about medical care, it is the "Personal Experience (PE)" Factor. The reason behind this choice is that patients' personal experience in their interaction with the health system and medical professionals has a direct and significant impact on their perception of PCC. This experience can be both positive and negative and can greatly influence how patients value and accept PCC in their healthcare. Regarding the result obtained from the *personal experience* factor, it is detailed that:

- Positive experiences (degree of truth): When patients have positive experiences with PCC, such as feeling they are heard, involved in decision-making, and well cared for, they tend to have a highly positive perception of PCC. This may lead to greater acceptance and promotion of this form of care.
- Negative Experiences (Degree of Falsehood): On the other hand, negative experiences, such as feeling ignored, misinformed, or treated impersonally, can lead to a negative perception of the PCC. Patients

who have had bad experiences may be less likely to accept or trust patient-centered approaches.
- Variability in Experiences (Degree of Indeterminacy): Variability in patients' personal experiences with PCC creates indeterminacy in overall perception. Some patients may have had positive experiences, while others may have had negative or mixed experiences. This contributes to an overall indeterminate perception of the PCC.

Given that the perception of PCC in Ecuador depends largely on the personal experiences of patients, the neutrosophic factor "Personal Experience (PE)" is the most influential in the states of the neutrosophic variable "Acceptance of Patient-Centered Care (PCC) in Ecuador". Therefore, understanding and improving these personal experiences is essential to promote the successful adoption of PCC and improve healthcare in the country.

To positively enhance the predominant factor "Personal Experience (PE)" in the states of the neutrosophic variable "Acceptance of Patient-Centered Care (PCC) in Ecuador" and improve the perception of Ecuadorian patients about medical care, proposals for solutions can be developed based on neutrosophy that address both the positive aspects and the existing indeterminacies. Among the proposed solutions are:

Improving doctor-patient communication (degree of truth):
- Promoting communication skills: Provide ongoing training to healthcare professionals in effective communication skills, including active listening and empathy, to ensure patients feel heard and understood.
- Promotion of shared decision-making: Encourage shared decision-making between doctors and patients, where treatment options are discussed, and patients' preferences and values are respected.

Problem-solving (degree of indeterminacy):
- Continuous evaluation: Conduct regular evaluations of patient satisfaction and experiences to identify specific areas for improvement and address existing indeterminacies in the perception of PCC.
- Patient feedback and active participation: Encourage patient feedback and active participation in improving healthcare processes to address individual concerns and needs.

Focus on patient satisfaction (degree of truth):
- Implementation of satisfaction surveys: Conduct regular patient satisfaction surveys to objectively measure the quality of care and use the results to make targeted improvements.
- Awards and Recognition: Recognize and reward hospitals and healthcare professionals who demonstrate exceptional commitment to PCC and patient satisfaction.

Institutional support (degree of truth):
- Committed leadership: Foster committed leadership with PCC in health institutions to establish a culture of patient-centered care from senior management.
- Allocation of adequate resources: Ensure that sufficient resources, both financial and personnel, are allocated to support the effective implementation of the PCC.

Education and public awareness (degree of truth):
- Patient education programs: Implement patient education programs that inform patients about their rights, responsibilities, and the importance of PCC in health decision-making.
- Awareness campaigns: Conduct public awareness campaigns about PCC and its benefits, targeting both patients and healthcare professionals, to create a stronger understanding of this approach.

These neutrosophic solutions directly address the "personal experience (PE)" factor and work with both the positive aspects and the existing indeterminations in the perception of PCC in Ecuador. By improving communication, problem-solving, focusing on patient satisfaction, providing institutional support, and promoting education and public awareness, a satisfactory degree of acceptance of Patient-Centered Care can be achieved and health care improved in the country. It is essential that these solutions are implemented continuously and adapted to the specific needs and characteristics of the Ecuadorian health system.

Conclusion

Patients' personal experience in their interaction with the health system and medical professionals is a critical factor that influences how they perceive Patient-Centered Care (PCC) in Ecuador. The results of the neutrosophic analysis reveal that positive experiences, such as effective communication and participation in decision-making, are associated with greater acceptance of PCC, while negative experiences may decrease this acceptance. The variability in these experiences contributes to the indeterminacy in overall perception.

Improving doctor-patient communication and education, for both patients and health professionals, are essential elements to promote the acceptance of PCC. The results of the neutrosophic IADOV support the need for effective communication and active participation of patients in their care as factors that increase the positive perception of PCC.

The results obtained provide a rigorous and multidimensional approach to understand the perception of PCC in Ecuador. This approach allows capturing the complexity of the variable "acceptance of PCC", considering both the positive aspects and the indeterminacies present in the patient's perception. This, in turn, facilitates the identification of specific areas of improvement and the formulation of more precise strategies to encourage the adoption of PCC and improve healthcare in the country.

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Neutrosophic Marketing Strategy and Consumer Behavior

Jimena Montes De Oca Sánchez [1], Myriam Paulina Barreno Sánchez [2], Miriam Janeth Pantoja Burbano [3], and Osmanys Pérez Peña [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.jimenamontesdeoca@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.myriambs36@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Ibarra. Ecuador. E-mail: ui.miriampantoja@uniandes.edu.ec
[4] CASIOPEA S.U.R.L, Cuba. E-mail: osmanysperez@gmail.com

Abstract. Selecting an appropriate marketing strategy based on consumer behavior is a complex decision that involves multi-criteria analysis and the incorporation of inherent uncertainties in such behavior. While numerous multi-criteria decision-making methods exist, few effectively address indeterminacy. In this study, the main objective is to select a suitable marketing strategy within a neutrosophic framework, accommodating the complex ambiguities of consumer behavior. Although the CRITIC method is widely used for multi-criteria decision-making, its traditional version struggles to adequately model the uncertainties inherent in consumer behavior. Neutrosophy, as a philosophical approach dealing with uncertainties, presents an opportunity to enhance the CRITIC method. This enhancement results in a more precise model of the phenomenon, facilitating the selection of the best among a set of marketing strategies. According to the outcomes, the most suitable marketing strategies based on consumer behavior and expert criteria, as processed through the CRITIC neutrosophic method, are Augmented Reality Marketing for the Food Industry, Digital Marketing for Fashion Retail, and Experiential Marketing for Real Estate.

Keywords: Neutrosophy, CRITIC, MCDM, Marketing Strategy, Consumer Behavior.

1 Introduction

In an era defined by rapid technological advancements, shifting market dynamics, and empowered consumers, the fields of marketing and consumer behavior have assumed unprecedented significance. The choices consumers make and the factors influencing those choices have a profound impact on businesses of all sizes and industries. As we navigate an increasingly interconnected global economy, understanding the intricate interplay between marketing strategies and consumer decision-making is not just an academic pursuit but a strategic imperative for companies seeking to thrive and innovate.

In this age of information overload, consumers are inundated with choices. From the products they buy to the services they use; every decision is influenced by numerous factors. For businesses, the ability to decipher and anticipate these factors can mean the difference between success and obscurity. Marketing, once seen primarily as a tool for promotion, has evolved into a multidimensional discipline that shapes not only how products and services are presented but also how they are developed and delivered.

Consumer behavior is a multi-faceted area of research [1], a complex amalgamation of psychology, sociology, economics, and culture. It is a set of actions and reactions of the social subject in the field of consumption, which includes economic interest and social interaction [2]. A dynamic field that reflects not only what consumers want but why they want it, how they perceive value, and how they make choices. Understanding these nuances can empower businesses to craft products and experiences that resonate with consumers on a profound level. But it is no easy task since decision-makers in these domains encounter uncertainties and contradictions stemming from a plethora of variables, including consumer preferences, market dynamics, and global interconnectivity. That is why this article centers on Neutrosophy, a philosophical framework known for its capacity to address uncertainty and indeterminacy in complex phenomena.

Neutrosophy is a philosophical approach that focuses on ambiguity and uncertainty, and it is closely related to the concept of indeterminacy. The process of determining the degree of indeterminacy in a text involves identifying words or phrases that indicate uncertainty, vagueness, or ambiguity, and calculating a numerical value or category that reflects that degree of indeterminacy [3]. In this context, consumer choices are influenced by an intricate interplay of factors that do not neatly conform to conventional categorizations of positivity, negativity, or neutrality. The amalgamation of emotional responses, cultural influences, individual experiences, and economic considerations creates a mesh of complexity that challenges traditional binary models of analysis.

Neutrosophy provides a unique perspective for understanding marketing strategy and consumer behavior. It encourages an acceptance of paradoxical decision-making, recognizing that choices may concurrently embody attraction and aversion, desirability, and uncertainty. This nuanced outlook allows for a more comprehensive exploration of consumer choices, acknowledging the inherent complexities.

This article examines Neutrosophic Marketing Strategy and Consumer Behavior, leveraging empirical research and philosophical insights. It investigates how Neutrosophy can guide the development of marketing strategies that align with consumers' multifaceted desires while accounting for the inherent ambiguities in their decisions. So, the scientific problem for this investigation is how to overcome the uncertainties inherent to consumer behavior to select a proper marketing strategy by using a Neutrosophic approach.

The objective of this investigation is to select a proper marketing strategy in a neutrosophic framework based on the complex ambiguities of consumer behavior. This framework uses the combination of the CRITIC multicriteria decision method within the context of a neutrosophic environment to model, analyze, and mitigate the intrinsic uncertainty and ambiguity inherent in consumer behavior. The study endeavors to achieve two secondary objectives: firstly, to enhance the precision and efficacy of marketing decision-making processes, and secondly, to improve the overall effectiveness of marketing strategies.

1.1 Marketing Strategies

A marketing strategy is a comprehensive plan formulated by an organization to achieve its specific marketing objectives and goals. It involves a systematic approach to identifying target markets, understanding consumer needs and preferences, developing competitive positioning, and outlining tactics for product development, pricing, promotion, and distribution. Effective marketing strategies aim to maximize an organization's market share, profitability, and long-term success by aligning its resources and activities with the demands of the market. [4]

A Marketing Strategy involves two major activities: selecting a target market and determining the desired positioning of the product in target customers' minds and specifying the plan for the marketing activities to achieve the desired positioning. [5]

There are many approaches when it comes to defining marketing strategies, but for the sake of this investigation, the following types of strategies will be considered:

1. Digital Marketing: All marketing initiatives that use technology or the internet [6]. Includes a range of online channels such as content marketing, social media marketing, Search Engine Optimization, email marketing, and Pay-Per-Click advertising.
2. Traditional Marketing [7]: Includes traditional marketing techniques, such as Print Marketing; TV and Radio Advertising; Direct Mail Marketing; Telemarketing, etc.
3. Experiential Marketing: Engages customers through immersive, in-person, or online experiences that create a strong emotional connection with your brand.
4. Event Marketing: Hosting or participating in events like trade shows, conferences, and product launches to engage with your target audience.
5. Cause Marketing: Aligning your brand with a social or environmental cause to build goodwill and increase brand loyalty.
6. Augmented Reality (AR) Marketing: Utilizing AR technology to provide interactive and immersive experiences to consumers, enhancing brand engagement.

1.2 Augmented reality

Augmented reality (AR) is a technology-driven concept that involves overlaying digital information or computer-generated content onto the real-world environment. It aims to enhance the user's perception of the physical world by integrating virtual elements, such as images, sounds, or data, with the surroundings they see and interact with. AR technology is often used through devices like smartphones, smart glasses, or headsets, enabling users to experience an enriched and interactive environment. Augmented reality is employed in various fields, including entertainment, education, healthcare, and industry, to provide users with a more engaging and informative experience, ultimately bridging the gap between the digital and physical realms.[8-16]

AR finds diverse applications across various sectors, including gaming, education, healthcare, architecture, retail, and more. It enhances experiences by overlaying digital content in the real world, whether for immersive gaming, interactive education, or precise medical procedures. Moreover, AR holds significant potential in marketing, offering innovative ways to engage customers, such as virtual try-ons, interactive product visualizations, and location-based marketing. Its ability to bridge the digital and physical realms makes AR a valuable tool for enhancing marketing strategies, creating immersive brand experiences, and driving consumer engagement.

2 Materials and Methods

2.1 Neutrosophic preliminaries

Definition 1. Let X be a space of points (objects) with generic elements in X denoted by x. A single-valued neutrosophic set (SVNS) A in X is characterized by the truth-membership function T_A (x), indeterminacy-membership function I_A (x), and falsity membership function F_A (x). Then, an SVNS A can be denoted by $A = \{x, TA(x), IA(x), FA(x)\ x \in X\}$, where T_A (x), I_A (x), F_A (x) ∈ [0,1] for each point x in X. Therefore, the sum of T_A (x), I_A (x) and F_A (x) satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$. [9-17-18-19-20]

For convenience, a Single-Valued Neutrosophic Number (SVNN) is denoted by A = (□ □ □), where a, b, c ∈ [0,1] and a + b + c ≤ 3

Definition 2. Let A = (a, b, c) be an SVNN and λ∈ℝ an arbitrary positive real number, then:

$$\lambda A = \left(1 - (1-a)^{\lambda}, b^{\lambda}, c^{\lambda}\right), \lambda > 0 \tag{1}$$

Definition 3. Let $A^* = \{A_1{}^*, A_2{}^*, \dots, A_n{}^*\}$ be a vector of n SVNNs, such that $A_j{}^* = (a_j{}^*, b_j{}^*, c_j{}^*)$ (j= 1,2,…,n), and $B_i = \{B_{i1}, B_{i2}, \dots, B_{im}\}$ (i= 1,2,…,m), (j= 1,2,…,n). Then the separation measure between B_i and A^* based on Euclidian distance is defined as follows:

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

(i= 1, 2, …, m)

Definition 4. Let $A = \{A_1, A_2, \dots, A_n\}$ be a set of n SVN numbers, where $A_j = (a_j, b_j, c_j)$ (j= 1,2,…,n). The single-value neutrosophic weighted average operator on them is defined by

$$\sum_{j=1}^{n} \lambda_j A_j = \left(1 - \prod_{j=1}^{n}\left(1 - a_j\right)^{\lambda_j}, \prod_{j=1}^{n} b_j{}^{\lambda_j}, \prod_{j=1}^{n} c_j{}^{\lambda_j}\right) \tag{3}$$

Where λ_j is the weight of A_j (j= 1,2,…,n), $\lambda_j \in [0,1]$ and $\sum_{j=1}^{n} \lambda_j = 1$

Next, a score function for ranking SVNNs is proposed as follows:

The value of a linguistic variable is expressed as an element of its term set. The concept of linguistic variables is very useful for solving decision-making problems with complex content. For example, the performance ratings of alternatives on qualitative attributes can be expressed by linguistic variables such as very important, important, medium, unimportant, very unimportant, etc. Such linguistic values can be represented using single-valued neutrosophic numbers.

In MCDM problems, there are k decision-makers, m different alternatives to consider, and n distinct criteria to be evaluated. These k decision-makers assess the weights of the m alternatives with respect to the n criteria and subsequently rank the performance of these criteria based on linguistic terms that have been transformed into single-valued neutrosophic numbers. In this context, decision-makers frequently assess the weights of the criteria by using common words (linguistic terms) since it is a more natural way to express their assessments. The linguistic terms used in this investigation are detailed in Table 1.

Table 1: Linguistic terms used and the corresponding SVNNs. Source: own elaboration.

Linguistic Term	SVNN
Very Influential	(0.9;0.1;0.1)
Influential	(0.75;0.25;0.20)
Moderately Influential	(0.50;0.5;0.50)
No Influential	(0.35;0.75;0.80)
Unrelated	(0.10;0.90;0.90)

Definition 5. Deneutrosophication is the process of obtaining a real number from a neutrosophic number. In this research, deneutrosophication will be obtained using the following equation.

$$s(V_i) = 2 + T_i - F_i - I_i \quad (4)$$

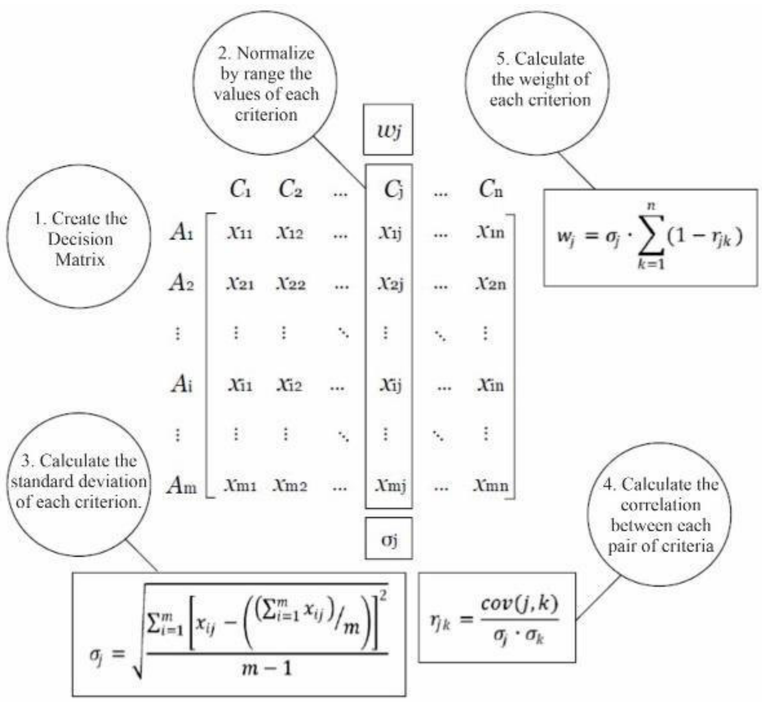
2.2 CRITIC Method

Multi-criteria decision-making (MCDM) is one of the main decision-making problems that aims to determine the best alternative by considering more than one criterion in the selection process. MCDM has manifold tools and methods that can be applied in different fields from finance to engineering design. [10, 15]

Several types of MCDM methods have been developed or improved by different authors during the last decades. The main differences between these methods are related to the complexity level of algorithms, the weighting methods for criteria, the way of representing preferences evaluation criteria, uncertain data possibility, and finally, data aggregation type [11]. One of those methods is the CRITIC technique.

CRITIC (**CR**iteria **I**mportance **T**hrough **I**ntercriteria **C**orrelation) is an approach that stands out in the context of multi-criteria decision-making methods. This method was proposed by [12] in the late 20th century. CRITIC is classified as a comparative method, as it allows for the determination of weights for all criteria or variables without being influenced by decision-makers' preferences. The weights are calculated based on the information in the decision matrix, with greater weight assigned to criteria as their variance (greater standard deviation - SD) increases, indicating that they provide more information compared to other criteria (lower correlation coefficient between the criteria). [13]

Figure 1: CRITIC method calculation procedure. Source: [14]



In order to better capture the indeterminacy of consumer behavior when analyzing the marketing strategies, the CRITC method will be complemented by incorporating SVNN in the assessment of the experts. The method will be enhanced by neutrosophy with the incorporation of the use of linguistic terms and SVNNs to evaluate the alternatives. The steps to be carried out for the completion of the neutrosophic version of the CRITIC method are described below:

Step 1. Create the Decision Matrix.
Step 2. Normalize by range the values of each criterion.
Step 3. Calculate the Standard Deviation (SD) of each criterion.
Step 4. Calculate the correlation between each pair of criteria.
Step 5. Calculate the weight of each criterion.

3 Results

For the selection of the best marketing strategy, 6 main types of marketing strategies (alternatives) were defined. Those alternatives are listed below:

1. Digital Marketing
2. Traditional Marketing
3. Experiential Marketing
4. Event Marketing
5. Cause Marketing
6. Augmented Reality Marketing

To assess those alternatives from various perspectives and to make an informed decision based on consumer behavior, the following criteria were identified (Table 2):

Table 2: Criteria to be considered for the assessment of the alternatives. Source: own elaboration.

Criterion	Code	Description
Reach and Visibility	C1	Assess how effectively each marketing strategy reaches and engages the target audience. Consider the potential for brand exposure and the ability to capture consumer attention.
Conversion Rate	C2	Evaluate the strategy's effectiveness in converting consumer interest into actual sales or desired actions. This could include conversion rates from leads to customers.
Consumer Engagement	C3	Measure the level of consumer engagement and interaction with the marketing strategy. This might involve analyzing social media engagement, customer feedback, or participation in campaigns.
Cost-Effectiveness	C4	Analyze the cost efficiency of each marketing strategy, considering factors like return on investment and the overall cost of implementation
Market Research and Adaptability	C5	Examine the strategy's ability to adapt to changing consumer behavior. Consider the inclusion of market research and the strategy's responsiveness to emerging trends.
Brand Image and Customer Loyalty	C6	Evaluate the impact on the brand's image and the ability to build long-term customer loyalty. Assess the strategy's effectiveness in fostering positive brand perception and repeat business.

In order to better test the proposed method and to be able to compare the results, it will be applied to three different sectors of the industry. Namely, Restaurants, Fashion Retail, and Real estate, which allows to tailor the evaluation criteria to the specific characteristics and consumer behaviors unique to each sector. This multi-industry approach will not only help validate the method's universality but also provide practical guidance for stakeholders in the addressed fields. The resulting aggregate decision matrix after obtaining the experts' assessments of each of the alternatives based on the selected criteria (see Table 3, 4, and 5).

Table 3: Decision Matrix for the Food Industry sector (Restaurants) using linguistic terms. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5	C6
A1	I	MI	I	MI	I	I
A2	I	MI	MI	I	MI	MI
A3	I	VI	I	MI	I	I
A4	VI	I	VI	MI	I	VI
A5	I	MI	I	I	U	I
A6	NI	I	I	MI	I	MI

Table 4: Decision Matrix for the Fashion Retail sector using linguistic terms. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5	C6
A1	I	MI	NI	I	MI	I
A2	I	I	MI	I	MI	I
A3	VI	VI	I	I	I	I
A4	MI	I	MI	VI	I	VI
A5	MI	MI	I	MI	I	I
A6	MI	VI	I	MI	I	I

Table 5: Decision Matrix for the Real State sector using linguistic terms. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5	C6
A1	VI	I	MI	VI	MI	VI
A2	I	I	I	I	NI	I
A3	MI	MI	VI	I	I	I
A4	I	I	VI	VI	MI	VI
A5	I	I	I	I	I	I
A6	MI	MI	VI	I	VI	I

The linguistic terms are converted into SVNNs applying the information provided in Table 1. The resulting matrixes are shown below in Table 6, 7, and 8.

Table 6: Decision Matrix for the Food Industry sector (Restaurants) using SVNNs. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5	C6
A1	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.75;0.25;0.20)
A2	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.50;0.5;0.50)
A3	(0.75;0.25;0.20)	(0.9;0.1;0.1)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.75;0.25;0.20)
A4	(0.9;0.1;0.1)	(0.75;0.25;0.20)	(0.9;0.1;0.1)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.9;0.1;0.1)
A5	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.10;0.90;0.90)	(0.75;0.25;0.20)
A6	(0.35;0.75;0.80)	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.50;0.5;0.50)

Table 7: Decision Matrix for the Fashion Retail sector using SVNNs. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5	C6
A1	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.35;0.75;0.80)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)
A2	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)
A3	(0.9;0.1;0.1)	(0.9;0.1;0.1)	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.75;0.25;0.20)
A4	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.9;0.1;0.1)	(0.75;0.25;0.20)	(0.9;0.1;0.1)
A5	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.75;0.25;0.20)
A6	(0.50;0.5;0.50)	(0.9;0.1;0.1)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.75;0.25;0.20)

Table 8: Decision Matrix for the Real State sector using SVNNs. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5	C6
A1	(0.9;0.1;0.1)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.9;0.1;0.1)	(0.50;0.5;0.50)	(0.9;0.1;0.1)
A2	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.35;0.75;0.80)	(0.75;0.25;0.20)
A3	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.9;0.1;0.1)	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.75;0.25;0.20)
A4	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.9;0.1;0.1)	(0.9;0.1;0.1)	(0.50;0.5;0.50)	(0.9;0.1;0.1)
A5	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.75;0.25;0.20)	(0.75;0.25;0.20)
A6	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.9;0.1;0.1)	(0.75;0.25;0.20)	(0.9;0.1;0.1)	(0.75;0.25;0.20)

To go on with the calculation process, the SVNNs are converted into crisp numbers through a process of deneutrosophication using Equation 4. Subsequently, the process continues until the weights of the criteria are calculated and the raking of the alternatives is determined (see Table 9, 10, and 11).

Table 9: Weights, normalized weightings and ranking for the Food Industry sector. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5	C6	Weighting	Norm. weighting	Ranking
A1	0.7895	0.0000	0.6667	0.0000	1.0000	0.6667	0.4232	0.1377	2
A2	0.7895	0.0000	0.0000	1.0000	0.6000	0.0000	0.5093	0.1657	3
A3	0.7895	1.0000	0.6667	0.0000	1.0000	0.6667	0.5895	0.1918	5
A4	1.0000	0.6667	1.0000	0.0000	1.0000	1.0000	0.6370	0.2073	6
A5	0.7895	0.0000	0.6667	1.0000	0.0000	0.6667	0.5598	0.1822	4
A6	0.0000	0.6667	0.6667	0.0000	1.0000	0.0000	0.3542	0.1153	1

Table 10: Weights, normalized weightings and ranking for the Fashion Retail sector. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5	C6	Weighting	Norm. weighting	Ranking
A1	0.6667	0.0000	0.0000	0.6667	0.0000	0.0000	0.2407	0.0819	1
A2	0.6667	0.6667	0.4667	0.6667	0.0000	0.0000	0.4102	0.1396	3
A3	1.0000	1.0000	1.0000	0.6667	1.0000	0.0000	0.7930	0.2699	6
A4	0.0000	0.6667	0.4667	1.0000	1.0000	1.0000	0.6647	0.2262	5
A5	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000	0.3450	0.1174	2
A6	0.0000	1.0000	1.0000	0.0000	1.0000	0.0000	0.4852	0.1651	4

Table 11: Weights, normalized weightings and ranking for the Real State sector. Source: own elaboration.

Alternatives	C1	C2	C3	C4	C5	C6	Weighting	Norm. weighting	Ranking
A1	1.0000	1.0000	0.0000	1.0000	0.3684	1.0000	0.6726	0.2094	5
A2	0.6667	1.0000	0.6667	0.0000	0.0000	0.0000	0.3983	0.1240	2
A3	0.0000	0.0000	1.0000	0.0000	0.7895	0.0000	0.3580	0.1114	1
A4	0.6667	1.0000	1.0000	1.0000	0.3684	1.0000	0.8330	0.2593	6
A5	0.6667	1.0000	0.6667	0.0000	0.7895	0.0000	0.5513	0.1716	4
A6	0.0000	0.0000	1.0000	0.0000	1.0000	0.0000	0.3988	0.1241	3

4 Discussion

For the case of the Food Industry sector, the best alternative is Augmented Reality Marketing, which is an interesting result since it is indeed a very good strategy for that sector, and it has started to become a trend in the recent times. For example, in restaurants, customers can scan a QR code or use a mobile app to view 3D models of menu dishes in AR, which entails several benefits, such as Enhanced Menu Visualization: where, for example, customers can see realistic 3D representations of menu items, helping them make more informed choices; Increased Engagement: because AR menus provide an interactive and engaging dining experience; and Reduced Language Barriers: since visualizing dishes in 3D can help overcome language barriers and boost international customer appeal.

On the other hand, for the Fashion Retail field, the best Alternative is Digital Marketing, A well-executed Digital Marketing strategy can offer several benefits to companies in the Fashion Retail sector. Digital marketing can significantly enhance a fashion brand's online visibility through tactics like search engine optimization and paid advertising. It also allows for precise audience targeting. Fashion retailers can reach their ideal customers based on demographics, interests, and online behavior. A good digital strategy can drive traffic to the company's e-commerce website, thus increasing online sales. In summary, a well-planned and executed Digital Marketing strategy can drive brand awareness, increase online sales, and improve customer engagement for fashion retailers.

As for the Real Estate sector, the best alternative is Experiential Marketing. An Experiential Marketing strategy can greatly benefit the Real Estate sector by providing potential buyers with immersive and memorable experiences that transcend traditional property viewings. Through technologies like virtual reality, prospective buyers can take virtual tours of properties, exploring them from the comfort of their own homes. This approach offers a more engaging and interactive way to showcase properties, allowing clients to envision themselves in their future homes, assess details, and gauge the spatial feel more effectively. Additionally, experiential marketing can enhance the emotional connection between buyers and properties, leading to increased sales and greater customer satisfaction, as it addresses the often emotionally charged nature of real estate decisions.

Conclusion

Selecting a proper marketing strategy based on customer behavior is a complex decision to make as it is included in the multicriteria decision methods framework. It should be noticed that it is even more complex due to the uncertainty inherent in consumer behavior itself. The use of Neutrosophy in such uncertain or indeterminate settings proves to be a valuable tool, as it allows the incorporation of uncertainty into the model.

The CRITIC method, when enhanced with the use of Neutrosophy, better captures the complexity of consumer behavior and allows for better modeling of situations where indeterminacy is involved.

According to the results obtained, the best marketing strategies based on consumer behavior and the criteria of experts processed through the CRITIC neutrosophic method are Augmented Reality Marketing, Digital Marketing and Experiential Marketing for the sectors Food Industry, Fashion Retail, and Real State, respectively. As a common feature, all those strategies are somehow related and can be enhanced with the use of technology. Which is in accordance with the modern world trends and confirms that companies should conceive their Marketing Strategies taking advantage of the use of new technologies in order to obtain better results.

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Neutrosophic Analysis of Group Dynamics and Teamwork

Jeannette Amparito Urrutia Guevara [1], Edmundo Enrique Pino Andrade [2], Ned Vito Quevedo Arnaiz [3], and Dante Manuel Macazana Fernández [4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.jeannetteurrutia@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Puyo. Ecuador. E-mail: up.edmundopino@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.nedquevedo@uniandes.edu.ec
[4] Universidad Nacional Mayor de San Marcos, Perú. E-mail: dmfedu@gmail.com

Abstract. Group dynamics refers to how members of a team interact and communicate. Understanding the personalities, skills, and roles of each member is crucial to the success of the group. Decision-making, conflict resolution, and time management are key aspects of group dynamics. Teamwork involves efficient collaboration to achieve common goals. These aspects are fundamental for group cohesion, so values in this regard must be promoted in universities. The objective of this research was to understand how group dynamics and teamwork work in university students. Twelve professors were consulted by experts to proceed with a Strategic Analysis applying Neutrosophy to Compensatory Fuzzy Logic. This theory enriches the possibilities of both quantitative and qualitative analysis and interpretation. With this analysis, it was possible to know the predominant influence of internal factors on the development of the dynamics of the group in question. Therefore, the need to work on weaknesses is highlighted, enhancing strengths to achieve better preparation for these future professionals.

Keywords: group dynamics, teamwork, university students, neutrosophy.

1 Introduction

Group work is characterized by the negotiation established by all participants, during the different phases of the task, to agree on a common response that everyone knows, and accepts and for which they are equally responsible. A channel of fluid communication is established between group members, links of collaboration, solidarity, and the development of personal characteristics [1]. A team can be defined as a set or group of people who have complementary capabilities and who collaborate to achieve common objectives, and share responsibilities [2].

Teamwork multiplies the possibilities to generate new knowledge and motivate learning. It is a dynamic, multidimensional competition. Which involves personal disposition and collaboration with others in carrying out activities to achieve common objectives, carrying out information exchange activities, assignment of responsibilities, conflict resolution, and a contribution to collective improvement and development [3]. What defines the team is a set of articulated people, with defined roles to solve a task. The essence of the team is the search for results. These results are the product of the task. However, the task is not linear, but rather a rocky path where people bring into play aspects that mobilize them and aspects that hinder them [4].

The key to making a team function properly lies, first of all, in its constitution. To form a team, it is necessary to consider not only the intellectual abilities of its potential members but also their socio-psychological and personality characteristics. From the selection and training stage, an attempt is made to assemble a group of individuals capable of performing their functions and meeting the objectives for which the work team will be created. Certain teams are formed to carry out specific tasks, others to advise and others to manage [5].

In teams where individuals with different expertise converge, it is possible to construct an interdisciplinary approach through collaborative work, provided that the team explicitly commits to it and works towards that goal. As long as the various forms of expertise within the team are embodied in individuals who identify with their respective training and models, the task faces all the challenges typical of any team that must confront the emotions stirred by the task, while simultaneously dealing with the emotions that the presence of other team members and the shared task evoke in them [6].

The degree of group dynamics is given by its expertise in transforming conflicts into problems through their explanation, its ability to manage them, and its ability to resolve them within the organizational framework. That is, not because of the absence of conflicts, but because of the degree to which they are actually assumed by its members in the performance of their tasks and functions. What defines work teams as transversal competence is their internal functioning and constantly changing dynamics. This permanent change is often expressed in the form of conflict. In this sense, conflict is inherent to any structure formed by people in interaction [2].

Various research shows the importance of integrating diverse profiles with teamwork skills into professional organizations, recognizing that this multidimensional competence is of vital importance due to its effectiveness when addressing tasks, achieving established goals, and solving problems [7]. The reasons for asking students to carry out group work are mainly two. First, it provides an environment that maximizes their learning by collaborating with other students and considering other points of view. Secondly, it prepares students for a work-like environment, improving their employability and developing the skills required for teamwork. Some examples are the development of interpersonal skills and individual responsibility or the improvement of transversal skills related to communication, presentation, problem-solving, leadership, or organization [8].

According to Johnson, Johnson and Holubec (1999), cited by [1], cooperative learning is characterized by these five dimensions:

- Positive interdependence: occurs when each member of the group understands that their success is measured based on the success achieved by the other members of the group and, with it, the group itself.
- Individual and team responsibility: occurs when all members of the group assume the responsibility of taking charge of the task entrusted to them and at the same time knowing, and if necessary, responding to the task of anyone else.
- Stimulating interaction: t is the one carried out face to face between team members and during which they support each other in their learning process by sharing their resources, knowledge, and past experiences, and connecting their own knowledge while supporting, encouraging, and congratulating others for the work done.
- Social and group work skills: these are skills that students learn to use as a result of the need for interaction. They include negotiation, decision-making, and conflict resolution mechanisms, creation of communication channels, proposal of creative ideas and constructive criticism, and also their acceptance.
- Group reflection: this evaluates the functioning and dynamics of the group, as well as its performance and the extent to which its results conform to the proposed objectives. From this, changes and improvement proposals can be established for future work, ensuring that all members receive feedback about the positive aspects and points for improvement of their intervention.

All that has been previously discussed leads to the necessity of understanding how group dynamics and teamwork function among university students, who will become the future professionals of society. Thus, the objective is to assess the dynamics and teamwork of a group of university students. With this research, the aim is to contribute to their better education, not only on an academic level but also by promoting cooperative learning and preparing them for their future professional development and team-oriented work.

2 Description of the Methodology

The research was conducted using a quantitative-qualitative methodology to strategically analyze the dynamics of a group of 40 university students from Uniandes, who specialize in Medicine. Specifically, the study focused on their hospital practice to observe and evaluate how teamwork and group dynamics unfold. For this purpose, 12 professors responsible for teaching these students, including physicians and nurses who collaborate with the students during their hospital tasks, were consulted. The educators were provided with a set of parameters to assess, including group cohesion, communication, collaboration, responsibility, and team task dynamics. They were asked to identify both positive and negative internal and external factors related to group dynamics and teamwork. Three aspects per category were selected from these factors. Subsequently, a Neutrosophic Analysis was conducted using Compensatory Fuzzy Logic.

2.1 Strategic analysis

One of the tools to carry out strategic analysis is the SWOT matrix. It is a map through which the strengths, weaknesses, opportunities, and threats of the organization are established. An internal and external analysis of the environment in which the activity is carried out to improve its profitability, operation, and market positioning. SWOT is the acronym for Strengths, Weaknesses, Opportunities, and Threats. It is a fundamental tool to know the situation in which the company finds itself, from which the future strategy will be drawn. It is a tool for studying the situation of a company, institution, project, or person, analyzing its internal characteristics (Weaknesses and Strengths) and its external situation (Threats and Opportunities) [9, 23-26]. A SWOT matrix can be used for:

- ✓ Explore new solutions to problems.
- ✓ Identify the barriers that will limit objectives.
- ✓ Decide on the most effective direction.
- ✓ Reveal the possibilities and limitations to change something.

In this article, it will be used as the predicates of compensatory fuzzy logic to describe the success factors in business management of synchronous leadership.

2.2 Compensatory Fuzzy Logic (CFL) [10-15-27].

- ✓ It is a branch of Fuzzy Logic created by the multidisciplinary scientific group Business Management in Uncertainty of the José Antonio Echeverría Higher Polytechnic Institute of Cuba.
- ✓ It consists of a new multivalent system that breaks with traditional axiomatics to achieve semantically better behavior.
- ✓ In processes that require decision-making, compound predicates are required.
- ✓ The truth values obtained on these compound predicates must be sensitive to changes in the truth values of the basic predicates.
- ✓ A predicate is a function of the universe.
- ✓ It renounces compliance with the classical properties of conjunction and disjunction, which makes it a sensible logic.
- ✓ It is flexible and tolerant of imprecision, making it possible to model natural language expressions, promoting the use of complete sentences rather than simple linguistic variables to take advantage of the knowledge accumulated by experts following the notion of Knowledge Engineering.
- ✓ It is compatible with the branches of mathematics related to decision-making by using human language, made up of interrogative, imperative, and declarative phrases, which in many cases present a degree of truthfulness.
- ✓ Vagueness and uncertainty are the objects of its modeling.

2.3 Neutrosophy applied to Compensatory Fuzzy Logic

In this case, the inclusion of the neutrosophic theory enriches the possibilities of the analysis by complementing the values presented in Table 1. This is due to two issues, firstly, the addition of the notion of indeterminacy and, secondly, the possibility of calculating using linguistic terms. For this reason, it was decided to opt for a fusion of both techniques and carry out the study through the use of neutrosophic CFL. Firstly, let us formally expose the original definition of neutrosophic logic as it is shown in [16-22-24-25-28].

Definition 1. Let X be a universe of discourse. A Neutrosophic Set (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x): X \rightarrow]^-0,1^+[$, that 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:

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

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

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

1. Given A1 = (a1, b1, c1) and A2 = (a2, b2, c2) two NNVUs, the sum between A1 and A2 is defined as:
$$A_1\, A_2 = (a_1 + a_2 - a_1a_2, b_1b_2, c_1c_2) \tag{2}$$
2. Let $A_1 = (a_1, b_1, c_1)$ and $A_2 = (a_2, b_2, c_2)$ be two SVNNs, the multiplication between A_1 and A_2 is defined as:
$$A_1\, A_2 = (a_1a_2, b_1+b_2 - b_1b_2, c_1 + c_2 - c_1c_2) \tag{3}$$

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

$$A = (1 - (1 - a), b, c) \tag{4}$$

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 Value Neutrosophic Weighted Mean Operator* (SVNWMO) over the set is calculated using the following equation:

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

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

In this article, linguistic terms will be associated with SVNNs, so that experts can carry out their evaluations in linguistic terms, which is more natural. Therefore, the scales shown in Table 1 will be considered.

Table 1: Evolution of the scale from diffuse to neutrosophic linguistic variables

Truth value	Category	SVNN
0	False	(0,1,1)
0.1	Almost false	(0.10,0.90,0.90)
0.2	Fairly false	(0.20,0.85,0.80)
0.3	Somewhat false	(0.30,0.75,0.70)
0.4	More false than true	(0.40,0.65,0.60)
0.5	As true as false	(0.50,0.50,0.50)
0.6	More true than false	(0.60,0.35,0.40)
0.7	Somewhat true	(0.70,0.25,0.30)
0.8	Fairly true	(0.8,0,15,0.20)
0.9	Almost true	(0.9, 0.1, 0.1)
1	True	(1,0,0)

To convert neutrosophic numbers into crisp numbers, the following equation will be used:

$$s(V) = 2 + T - F - I \tag{6}$$

Compensatory fuzzy logic uses mathematical operators that guarantee the effective combination of intangible elements valued through experts, considering categorical scales of truthfulness, with quantitative information, which provides truth values through predicates conveniently defined from such information:

Table 2: Presentation of mathematical operators in FCL predicate logic.

Operators	Predicate logic
Conjunction	(and), c, Λ
Disjunction	(or), d,V
Strict fuzzy order	(o)
Denial	(not)

They go from [0,1] n to [0,1], or go from [0,1] 2 to [0,1] and n from [0,1] [11]. Which satisfies the following axioms:

1. Min $(x_1, x_2, \ldots, x_n) \leq c(x_1, x_2, \ldots, x_n) \leq \max(x_1, x_2, \ldots, x_n)$ (Compensation Axiom)
2. $c(x_1, x_2, \ldots, x_i, \ldots, x_j, \ldots, x_n) = c(x_1, x_2, \ldots, x_i, \ldots, x_j, \ldots, x_n)$ (Axiom of Commutativity of Symmetry)
3. If $x_1 = y_1, x_2 = y_2, \ldots, x_{i-1} = y_{i-1}, x_{i+1} = y_{i+1}, \ldots, x_n = y_n$, such that none is zero and $x_i > y_i$, then $c(x_1, x_2, \ldots, x_n) > c(y_1, y_2, \ldots, y_n)$ (Strict Growth Axiom)
4. If $x_1 = 0$ for some i, then $c(x_1, x_2, \ldots, x_n) = 0$ (Veto Axiom)
5. If $o(x, y) \geq 0.5$ and $i(y, z) \geq 0.5$, then $o(x, z) \geq \max\{o(x, y), o(y, z)\}$ (Axiom of Fuzzy Transitivity)

6. $n(c(x_1,x_2,\dots,x_n)) = d(n(x_1),n(x_2),\dots,n(x_n)).n(d(x_1,x_2,\dots,x_n)) = c(n(c(x_1),n(x_2),\dots,n(x_n))$(Morgan's Laws)

From the previous axioms the following properties are derived:

1. $\text{Min}(x_1,x_2,\dots,x_n){:}\leq d(x_1,x_2,\dots,x_n) \leq \max(x_1,x_2,\dots,x_n)$ (Compensation Property)
2. $d(x_1,x_2,\dots,x_i,\dots,x_j,\dots,x_n) = d(x_1,x_2,\dots,x_i,\dots,x_j,\dots,x_n)$ (Property of Commutativity or Symmetry)
3. If $x_1 = y_1, x_2 = y_2, \dots, x_{i-1} = y_{i-1}, x_{i+1} = y_{i+1}, \dots, x_n = y_n$, such that none is zero and $x_i > y_i$, then $d(x_1,x_2,\dots,x_n) > d(y_1,y_2,\dots,y_n)$ (Strict Growth Property)
4. If $x_1 = 1$ for some i, then $x_1 = 1d(x_1,x_2,\dots,x_n) = 1$ (Veto Property)
5. $c(x_1,x_2,\dots,x_n) = d(x_1,x_2,\dots,x_n) = x$ (Idempotence Property)

The coefficient of variation (Cv) of the predicates will be calculated using equation 5 applying statistical decision criteria according to the following parameters:

- If Cv ≥0.20, take the modal value (rating given by the experts that is most repeated in the analyzed range)
- If Cv <0.20, take the value of the arithmetic mean (average rating of the experts)

$$Cv = \frac{S}{X_{med}} \tag{7}$$

Where S is the standard deviation of the data, and X_{med} is the Mean of the data.

3 Results

3.1 Application of Compensatory Fuzzy Logic

For the SWOT analysis, the criteria of the professors who serve as guides for the group of university students under evaluation were sought. The factors to be analyzed, both internal and external, were outlined, and the following steps were then carried out:

1. Apply the SWOT matrix for better information processing.
2. Analyze by applying compensatory fuzzy logic:
   a) Statement of simple and compound predicates.
   b) Development of the decision tree.
   c) Calculation of simple and compound predicates.
   d) Determination of status through linguistic terms.

Table 3: Statement of simple and compound Predicates and their calculation expressions. Note: own elaboration.

Group dynamics and teamwork	$\boldsymbol{GD(X) = IA(X) \wedge EA(X)}$
Internal Analysis	$IA(X) = W_{1-4}(X) \wedge S_{1-3}(X)$
External Analysis	$EA(X) = T_{1-3}(X) \wedge O_{1-3}(X)$
Weaknesses	$W_{1-3}(X) = W_1(X) \wedge W_2(X) \wedge W_3(X)$
Strengths	$S_{1-3}(X) = S_1(X) \wedge S_2(X) \wedge S_3(X)$
Threats	$T_{1-3}(X) = T_1((X) \wedge T_2(X) \wedge T_3(X)$
Opportunities	$O_{1-3}(X) = O_1(X) \wedge O_2(X)) \wedge O_3(X)$
$W_1(X)$	Interpersonal conflicts
$W_2(X)$	Lack of responsibility
$W_3(X)$	Lack of alignment with the goals
$S_1(X)$	Workload distribution
$S_2(X)$	Emotional Support
$S_3(X)$	Improved decision making
$T_1(X)$	Changes in educational technology

Group dynamics and teamwork	$\boldsymbol{GD}(\boldsymbol{X}) = \boldsymbol{IA}(\boldsymbol{X}) \wedge \boldsymbol{EA}(\boldsymbol{X})$
$T_2(X)$	Access to research resources
$T_3(X)$	Cultural and generational diversity
$O_1(X)$	Student exchange programs
$O_2(X)$	Technological advances
$O_3(X)$	Government support for higher education

Figure 1: Predicate tree. Source: own elaboration.

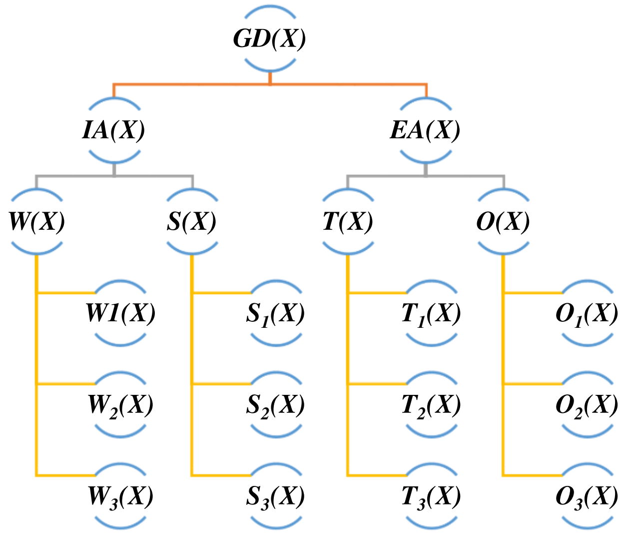

Table 4: Calculation of the truth value of the simple predicates of experts 1 to 4. Source: expert evaluation. Own elaboration

Simple Predicates	E1	E2	E3	E4
$\boldsymbol{W_1(X)}$	(0.9, 0.1, 0.1)	(1,0,0)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)
$\boldsymbol{W_2(X)}$	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.70,0.25,0.30)
$\boldsymbol{W_3(X)}$	(0.8,0,15,0.20)	(0.8,0,15,0.20)	(0.60,0.35,0.40)	(0.9, 0.1, 0.1)
$\boldsymbol{S_1(X)}$	(0.50,0.50,0.50)	(0.40,0.65,0.60)	(0.60,0.35,0.40)	(0.60,0.35,0.40)
$\boldsymbol{S_2(X)}$	(1,0,0)	(0.8,0,15,0.20)	(0.60,0.35,0.40)	(0.60,0.35,0.40)
$\boldsymbol{S_3(X)}$	(0.9, 0.1, 0.1)	(0.70,0.25,0.30)	(0.9, 0.1, 0.1)	(0.70,0.25,0.30)
$\boldsymbol{T_1(X)}$	(0.9, 0.1, 0.1)	(0.70,0.25,0.30)	(0.50,0.50,0.50)	(0.70,0.25,0.30)
$\boldsymbol{T_2(X)}$	(0.50,0.50,0.50)	(0.60,0.35,0.40)	(0.60,0.35,0.40)	(0.60,0.35,0.40)
$\boldsymbol{T_3(X)}$	(0.9, 0.1, 0.1)	(0.70,0.25,0.30)	(0.9, 0.1, 0.1)	(0.70,0.25,0.30)
$\boldsymbol{O_1(X)}$	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)
$\boldsymbol{O_2(X)}$	(0.9, 0.1, 0.1)	(1,0,0)	(0.9, 0.1, 0.1)	(1,0,0)
$\boldsymbol{O_3(X)}$	(0.9, 0.1, 0.1)	(0.8,0,15,0.20)	(0.9, 0.1, 0.1)	(0.8,0,15,0.20)

Table 5: Calculation of the truth value of the simple predicates of experts 4 to 8. Source: expert evaluation. Own elaboration

Simple Predicates	E5	E6	E7	E8
$W_1(X)$	(0.9, 0.1, 0.1)	(1,0,0)	(1,0,0)	(0.70,0.25,0.30)
$W_2(X)$	(0.8,0,15,0.20)	(1,0,0)	(1,0,0)	(0.8,0,15,0.20)
$W_3(X)$	(0.9, 0.1, 0.1)	(0.70,0.25,0.30)	(0.50,0.50,0.50)	(0.60,0.35,0.40)
$S_1(X)$	(0.70,0.25,0.30)	(0.70,0.25,0.30)	(0.8,0,15,0.20)	(0.50,0.50,0.50)
$S_2(X)$	(0.8,0,15,0.20)	(1,0,0)	(1,0,0)	(0.9, 0.1, 0.1)
$S_3(X)$	(0.9, 0.1, 0.1)	(0.70,0.25,0.30)	(0.70,0.25,0.30)	(0.50,0.50,0.50)
$T_1(X)$	(0.9, 0.1, 0.1)	(0.70,0.25,0.30)	(1,0,0)	(1,0,0)
$T_2(X)$	(0.50,0.50,0.50)	(0.40,0.65,0.60)	(0.50,0.50,0.50)	(0.20,0.85,0.80)
$T_3(X)$	(0.9, 0.1, 0.1)	(0.40,0.65,0.60)	(0.70,0.25,0.30)	(0.70,0.25,0.30)
$O_1(X)$	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.50,0.50,0.50)
$O_2(X)$	(0.9, 0.1, 0.1)	(1,0,0)	(1,0,0)	(1,0,0)
$O_3(X)$	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(1,0,0)	(1,0,0)

Table 6: Calculation of the truth value of the simple predicates of experts 7 to 12. Source: expert evaluation. Own elaboration

Simple Predicates	E9	E10	E11	E12
$W_1(X)$	(0.8,0,15,0.20)	(0.9, 0.1, 0.1)	(1,0,0)	(0.60,0.35,0.40)
$W_2(X)$	(0.8,0,15,0.20)	(0.8,0,15,0.20)	(0.8,0,15,0.20)	(0.8,0,15,0.20)
$W_3(X)$	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(1,0,0)
$S_1(X)$	(0.50,0.50,0.50)	(0.20,0.85,0.80)	(0.50,0.50,0.50)	(0.50,0.50,0.50)
$S_2(X)$	(0.9, 0.1, 0.1)	(0.8,0,15,0.20)	(1,0,0)	(0.70,0.25,0.30)
$S_3(X)$	(0.70,0.25,0.30)	(1,0,0)	(0.70,0.25,0.30)	(0.8,0,15,0.20)
$T_1(X)$	(0.70,0.25,0.30)	(0.70,0.25,0.30)	(0.50,0.50,0.50)	(0.8,0,15,0.20)
$T_2(X)$	(0.50,0.50,0.50)	(0.8,0,15,0.20)	(0.70,0.25,0.30)	(0.70,0.25,0.30)
$T_3(X)$	(0.50,0.50,0.50)	(0.60,0.35,0.40)	(0.60,0.35,0.40)	(0.40,0.65,0.60)
$O_1(X)$	(1,0,0)	(1,0,0)	(0.8,0,15,0.20)	(0.8,0,15,0.20)
$O_2(X)$	(1,0,0)	(0.70,0.25,0.30)	(1,0,0)	(1,0,0)
$O_3(X)$	(0.70,0.25,0.30)	(0.70,0.25,0.30)	(1,0,0)	(0.70,0.25,0.30)

Table 7: Calculation of Truth Values of simple predicates. Source: expert evaluation. Own elaboration.

Predicates	Mode	Mean	Truth value	Category
$W_1(X)$	(1,0,0)	(0.8,0,15,0.20)	(0.8,0,15,0.20)	Fairly true
$W_2(X)$	(0.8,0,15,0.20)	(0.8,0,15,0.20)	(0.8,0,15,0.20)	Fairly true
$W_3(X)$	(0.9, 0.1, 0.1)	(0.8,0,15,0.20)	(0.9, 0.1, 0.1)	Almost true
$S_1(X)$	(0.50,0.50,0.50)	(0.50,0.50,0.50)	(0.50,0.50,0.50)	As true as false
$S_2(X)$	(1,0,0)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	Almost true
$S_3(X)$	(0.70,0.25,0.30)	(0.70,0.25,0.30)	(0.70,0.25,0.30)	Somewhat true
$T_1(X)$	(0.70,0.25,0.30)	(0.8,0,15,0.20)	(0.70,0.25,0.30)	Somewhat true

Predicates	Mode	Mean	Truth value	Category
$T_2(X)$	(0.50,0.50,0.50)	(0.50,0.50,0.50)	(0.50,0.50,0.50)	As true as false
$T_3(X)$	(0.40,0.65,0.60)	(0.50,0.50,0.50)	(0.40,0.65,0.60)	More false than true
$O_1(X)$	(0.9, 0.1, 0.1)	(0.8,0,15,0.20)	(0.9, 0.1, 0.1)	Almost true
$O_2(X)$	(1,0,0)	(0.9, 0.1, 0.1)	(1,0,0)	True
$O_3(X)$	(1,0,0)	(0.9, 0.1, 0.1)	(0.8,0,15,0.20)	Fairly true

Table 8: Calculation of the truth values of compound predicates. Source: expert evaluation. Own elaboration

Predicates	Truth value	Category
GD(x)	(0.8,0,15,0.20)	Fairly true
IA(x)	(0.8,0,15,0.20)	Fairly true
EA(x)	(0.60,0.35,0.40)	More true than false
W(x)	(0.70,0.25,0.30)	Somewhat true
S(x)	(0.8,0,15,0.20)	Fairly true
T(x)	(0.8,0,15,0.20)	Fairly true
O(x)	(0.60,0.35,0.40)	More true than false

Based on the results obtained, it was possible to reflect on the value of internal factors in the analyzed group. As they are inherent to the students and do not depend on external factors, they have greater capacity and possibility of resolution. This reflects the need for the group to stay together, working to overcome Weaknesses, and increasing Strengths. An introspective analysis must be carried out on each member, to solve those personal aspects that influence both positively and negatively on the study group. Threats from the external environment must also be considered, such as changes in educational technology, access to research resources, and cultural and generational diversity. These aspects mentioned are not decisive in this situation, but due to their impact, they could generate disharmony in the functioning of the group dynamics.

The interpretation of the results allowed to know that the factors that most affect the dynamics of the analyzed group are the Internal ones, so the Weaknesses must be corrected by enhancing the Strengths. The actions taken will be based on modifying these Weaknesses. Teams offer a supportive environment where members can motivate each other, share knowledge, and overcome challenges together. Improve decision-making through discussion and collaboration. In groups it is important to divide tasks and responsibilities, which can increase efficiency and reduce individual workload, this encourages unity and improves their efficiency. Strengthening these skills also has a positive impact not only on the proper functioning of the group but also on an individual basis for each member.

4 Discussion

Group dynamics and teamwork are fundamental elements of the university experience. Teamwork promotes empathy, effective communication, and the ability to adapt to different personalities, which improves personal and professional relationships. University students find themselves with the constant need to collaborate with their peers on academic projects, which requires understanding and effectively applying these concepts. College students who master these skills are more likely to achieve better academic results and be better prepared for the world of work.

The need to strengthen teamwork and group dynamics is undeniable in a world that is increasingly interconnected and oriented toward collaboration. First, teamwork is essential to address complex challenges and interdisciplinary projects. In university and professional settings, solutions often require a combination of diverse skills and perspectives. Strengthening teamwork allows you to make the most of the collective potential and creativity of the group members. Learning to understand and manage differences of opinion in a collaborative environment is a crucial skill in any field. Furthermore, a group with good dynamics can make more informed and agile decisions, which is essential in a constantly changing world.

That is why the need to strengthen teamwork and group dynamics is evident in solving complex problems, making decisions, developing social skills, and improving well-being. In this process, university professors have an important mission, of transmitting ethical and moral values that promote adequate dynamics in their groups. Also important are the aspects detected as Opportunities offered by the external environment, such as student exchange programs, technological advances, and government support for higher education. The groups that know how to take advantage of the opportunities that the external environment offers will be more likely to achieve better results both academically and in terms of their practical development as future professionals.

Conclusions

University teams are usually made up of students with different skills and knowledge, which enriches the discussion and leads to the generation of creative ideas and innovative solutions. Group dynamics and teamwork promote collaboration among university students, allowing them to share knowledge and experiences to address academic challenges more effectively. In the group studied, it is important to strengthen the factors internally, due to their great importance for adequate group dynamics. Considering that teamwork at the university helps students develop communication, conflict resolution, and leadership skills, valuable skills in both the academic and professional fields.

Group dynamics and teamwork can lead to better academic performance, as students can tackle projects and challenges more effectively, sharing the workload and leveraging the strengths of their peers. Learning to work as a team in college is essential, as collaboration is an essential skill in most professions and today's work environment. The use of Compensatory Fuzzy Logic with Neutrosophic numbers allowed the establishment of a better interpretation of the strategic analysis, providing a wide possibility of interpretations, quantitatively and qualitatively.

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University of New Mexico

Neutrosophic Evaluation of CSR Practices in Ecuadorian Companies: Balancing Sustainability, Ethics, and Impact

Gustavo Alvarez Gómez[1], Corona Gómez Armijos[2], Jimena Montes De Oca Sánchez[3], and Dennys Raúl Dupotey Hernández[4]

[1]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: rectorado@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: vicerrectorado@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.jimenamontesdeoca@uniandes.edu.ec
[4]Gobernación de Cundinamarca, Secretaría de salud y dimensión vida saludable y condiciones no transmisibles, Bogotá, Colombia.
E-mail: dennysdupotey1@gmail.com

Abstract. The analysis of Corporate Social Responsibility (CSR) practices in Ecuadorian companies is a relevant topic due to the indeterminacies existing in their implementation. The general objective of this analysis is to evaluate CSR practices in companies, considering aspects such as environmental sustainability, responsibility to employees, business ethics, and financial performance. To achieve this, the criteria and comprehensive solutions were evaluated through the modeling of the neutrosophic ELECTRE method. The results of the analysis indicate that the implementation of CSR practices can have multiple benefits, and comprehensive solutions with higher scores were identified, such as the implementation of ethics and transparency policies and the implementation of training and professional development programs. To enhance these comprehensive solutions, it is significant to establish clear and transparent policies, train the personnel, and communicate effectively with the community, and other relevant stakeholders. This ensures that CSR practices in Ecuadorian companies have a positive impact on the community.

Keywords: Environmental sustainability, business ethics, corporate social responsibility.

1 Introduction

Corporate social responsibility (CSR) is a topic of debate in Ecuador [1], where companies are increasingly interested in adhering to sustainable and responsible practices [2]. CSR involves organizations committing to the community in response to the social and environmental impacts generated by their production processes. In Ecuador, CSR has become a necessity to address the effects caused by production processes and achieve sustainable development.

The implementation of CSR practices in Ecuadorian companies contributes to improving their image in front of consumers and the community at large [3]. Despite existing regulations and institutions encouraging CSR application in Ecuador, the practice of this model goes beyond mere compliance with laws and regulations; it depends on each company's level of commitment to society. It is crucial to note that CSR in Ecuador is a developing concept, with limited regulations and good practices. However, a shift is needed from business objectives focused solely on profit generation to a business consciousness oriented toward the well-being of society and the environment [4] [5].

In this context, the study aims to analyze the impact of CSR practices on the Ecuadorian community through a multi-criteria analysis [6]. This analysis considers various factors such as the implementation methods, companies' ability to measure and evaluate the real impact, and the perception of society and consumers [7]. To achieve this, the key criteria for measuring CSR practices in Ecuador are defined:

- Environmental Practices: Include the reduction of greenhouse gas emissions, the decrease of carbon footprint, and the promotion of environmental sustainability [8].
- Social Practices: Involve the promotion of gender equality, social inclusion, and community development [9].
- Ethical Practices: Include the promotion of transparency, integrity, and responsibility in business.
- Labor Practices: Encompass the promotion of occupational safety, training, and professional development.
- Innovation Practices: Cover the promotion of research and the development of sustainable products and services.

Companies that implement CSR practices seek to comply with standards and regulations, promote transparency in management, prevent corruption, and respect human rights. Below are some of the most relevant aspects of business ethics in CSR practices in Ecuador:

- Compliance with standards and regulations: Companies in Ecuador that implement practices to comply with standards and regulations, such as the implementation of compliance policies and the promotion of transparency in management.
- Transparency in management: Companies in Ecuador practice the promotion and transparency in management, such as disclosing information about their CSR practices and implementing transparency policies.
- Corruption prevention: Companies in Ecuador that take actions to prevent corruption, such as the implementation of ethics policies and the promotion of integrity in business.
- Respect for human rights: Companies in Ecuador that respect human rights, such as promoting diversity and inclusion and eliminating discrimination in the workplace [10].

In Ecuador, there are various civil society organizations working to promote CSR practices in companies. Here are some of these organizations:

- Ecuadorian Consortium for Corporate Social Responsibility (CERES): This organization aims to promote CSR in companies in Ecuador through awareness, training, and technical guidance.
- Latin American Future Foundation (FFLA): This organization aims to promote sustainable development in Latin America through the promotion of CSR in companies.
- Network of Companies for Sustainable Development (REDS): This organization aims to promote CSR in companies in Ecuador through awareness, training, and technical guidance.
- United Nations Global Compact: This organization aims to promote CSR in companies worldwide through the advocacy of the United Nations Sustainable Development Goals.
- Association of Companies for Development (AED): This organization aims to promote sustainable development in Ecuador through the promotion of CSR in companies.

In summary, there are various civil society organizations working to promote CSR practices in companies in Ecuador. These organizations promote awareness, training, technical guidance, and the advocacy of the United Nations Sustainable Development Goals. Another point to highlight is related to the profitability of CSR practices in Ecuadorian companies. This can be influenced by various factors such as improved resource efficiency, enhanced brand image, talent attraction, innovation, and regulatory compliance.

Therefore, the analysis for implementing CSR practices depends on incorporating indeterminacies into potential solutions. To achieve this, it is necessary to analyze the importance states of measurement criteria and other factors influencing the results. Thus, the main objective of this study is to evaluate CSR practices in companies in Ecuador through neutrosophic analysis. The specific objectives of the study include identifying and analyzing the challenges companies face in implementing CSR practices, proposing and evaluating comprehensive solutions focused on achieving CSR practices in companies with a positive impact on the community and identifying actions that enhance the best comprehensive solution.

2 Materials and methods

2.1 Neutrosophic ELECTRE

Neutrosophic ELECTRE is a multicriteria decision-making (MCDM) method that enables the selection of the best option from a neutrosophic set of alternatives [11]. The neutrosophic set is defined by the following elements: true μ, indeterminate γ, and false τ of x in S, respectively, and their images constitute standard or non-standard subsets within the range (0;1). For N in the universe of discourse, the neutrosophic set of a unique value S over N is defined as an object in the representation $S = \{\langle n, \mu_s(n), \gamma_s(n), \tau_s(n)\rangle : n \in N\}$.

Where $\mu_S(n), \gamma_S(n), \tau_S(n)$ satisfy the following condition $0 \leq \mu_S(n), \gamma_S(n), \tau_S(n) \leq 3$ for all $n \in N$. So, to define each neutrosophic number, it is expressed in the following way v, i, f for modeling the neutrosophic ELECTRE method.

Next, the following representations of the neutrosophic set are defined: $v = \mu_S(n)$ for the truth membership functions, where $\in \{0,1\}$, $i = \gamma_S(n)$ for the indeterminate membership functions, where $\in \{0,1\}$, and $j = \delta_A(n)$ for the false membership functions, where $\in \{0,1\}$. Therefore, the single value neutrosophic number (SVNN) defined for the study is S=(v, i, f), where $\text{v}, \text{i}, \text{f} \in \{0,1\}$.

Once the neutrosophic elements are defined in the ELECTRE framework, the linguistic terms for evaluating each relevant neutrosophic decision criterion are then defined (see Table 1). Then, the alternatives are evaluated based on the linguistic term defined in the neutrosophic set (see Table 2).

Table 1: Linguistic terms that represent the neutrosophic weight of the importance of the criteria. Source: own elaboration.

Linguistic term I	SVNN
Very Suitable (VS)	(0.9,0.35,0.1)
Moderately Suitable (MS)	(0.7,0.5,0.3)
Suitable (S)	(0.3,0.7,0.75)
Poorly Suitable (PS)	(0.2,0.8,0.85)
Not Suitable (NS)	(0.10,0.90,0.90)

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

Linguistic term	SVNN
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.95,0.05,0.15)
Very good (VG)	(0.85,0.15,0.25)
Good (G)	(0.75,0.25,0.35)
Medium good (MG)	(0.65,0.35,0.45)
Medium (M)	(0.55,0.45,0.55)
Moderately bad (MB)	(0.45,0.55,0.65)
Bad (B)	(0.35,0.65,0.75)
Very bad (VB)	(0.25,0.75,0.85)
Very very bad (VVB)	(0.15,0.85,0.95)
Extremely bad (EM)	(0,0.95,1)

Important decisions often involve considering multiple criteria simultaneously, and these criteria can be of an objective or subjective nature with the inclusion of indeterminacy in the analyzed neutrosophic set. Therefore, the neutrosophic ELECTRE method allows decision-makers to evaluate and prioritize [12-20-21], by combining neutrosophic assessments and generating a preference matrix that ranks and prioritizes alternatives [13-18-22]. Once the scales for handling neutrosophic criteria and the inclusion of indeterminacy in the modeling are defined, the steps for developing the method are as follows:

Step 1: Define the initial decision matrix r_{Sij}, as shown:

$$r_{Sij} = \begin{bmatrix} r_{S11} & r_{S12} & \cdots & r_{S1n} \\ r_{S21} & r_{S22} & \cdots & r_{S2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{Sm1} & r_{Sm1} & \cdots & r_{Smn} \end{bmatrix}$$

Step 2: The normalization of the decision matrix allows different scales and units to be transformed between several common criteria. This allows comparison across the criteria, according to Equation (1 and 2).

Minimum $$R_{Sij} = \frac{máx\, r_{Sij} - r_{Sij}}{máx\, r_{Sij} - mín\, r_{Sij}} \quad (1)$$

Maximum $$R_{Sij} = \frac{r_{Sij} - mín\, r_{Sij}}{máx\, r_{Sij} - mín\, r_{Sij}} \quad (2)$$

Step 3: Construction of the normalized weighted decision matrix V_{Sij}. For which the normalized decision matrix R_{Sij} is multiplied by its respective weight, expressed in Equation (3) respectively.

$$V_{Sij} = \begin{bmatrix} W_{S1}\, r_{S11} & W_{S2}\, r_{S12} & \cdots & W_{Sn}\, r_{S1n} \\ W_{S1}\, r_{S21} & W_{S2} r_{S22} & \cdots & W_{Sn}\, r_{S2n} \\ \vdots & \vdots & \ddots & \vdots \\ W_{Sn}\, r_{Sm1} & W_{Sn} r_{Sm2} & \cdots & W_{Sn}\, r_{Smn} \end{bmatrix}$$

$$V_{Sij} = W_{Si} \cdot R_{Sij} \quad (3)$$

Step 4: Calculation of concordance (C_{Yab}) and discordance (D_{Yab}) intervals, where C_{Yab} indicates the most preferable alternative, and D_{Yab} indicates the least preferable alternative. Equations (4), (5), and (6) are used, respectively.

$$Y(S) = \frac{1 + v - 2i - f}{2} \tag{4}$$

$$C_{Yab} = \{j|x_{aj} \geq x_{bj}\} \tag{5}$$

$$D_{Yab} = \{j|x_{aj} \leq x_{bj}\} = j - C_{Yab} \tag{6}$$

Step 5: Determination of the agreement interval matrix C_{Yab}, it is obtained by adding the weights to the weights associated with the criteria in which alternative i is better than alternative j, and vice versa; In the event of a tie, half the weight is assigned to each of the alternatives according to Equation (7).

$$C_{Yab} = \sum_{j=C_{ab}} W_{Sj} \tag{7}$$

Step 6: Determination of the discordance index matrix D_{Yab}, it is calculated as the largest difference between the criteria for which alternative i is dominated by j, then divided by the largest difference in absolute value between the results obtained by alternative i and j, according to Equation (8).

$$D_{Yab} = \frac{\left(\begin{matrix} max \\ j\epsilon D_{ab} \end{matrix}\right) |V_{Yaj} - V_{Ybj}|}{\left(\begin{matrix} max \\ j\epsilon J, m, n \in I \end{matrix}\right) |V_{Ymj} - V_{Ynj}|} \tag{8}$$

Step 7: Calculation of the maximum threshold $\bar{c}$ for the concordance index and the maximum threshold $\bar{d}$ for the discordance index, using equations (9 and 10) and respectively.

$$\bar{c} = \sum_{a=1}^{m} \sum_{b}^{m} \frac{c(a,b)}{m(m-1)} \tag{9}$$

$$\bar{d} = \sum_{a=1}^{m} \sum_{b}^{m} \frac{c(a,b)}{m(m-1)} \tag{10}$$

Step 8: Calculation of the dominant concordance matrix. Once the concordance indices and the minimum concordance threshold are determined, the dominant concordance matrix is calculated with the following conditions:

$$cd_{ij} \begin{cases} e(a,b) = 1 \; si \; c(a,b) \geq \bar{c} \\ e(a,b) = 0 \; si \; c(a,b) \leq \bar{c} \end{cases}$$

Step 9: Calculation of the dominant discordance matrix. Similarly to the previous step, the values of the dominant discordance matrix are obtained from the discordance index matrix and the maximum discordance threshold, following the condition:

$$dd_{ij} \begin{cases} f(a,b) = 1 \; si \; d(a,b) \geq \bar{d} \\ f(a,b) = 0 \; si \; d(a,b) \leq \bar{d} \end{cases}$$

Step 10: Calculation of the upper and lower net value C_a and D_a, using Equations (11) and (12) respectively.

$$C_a = \sum c_{(a,b)} - \sum c_{(b,a)} \tag{11}$$

$$D_a = \sum d_{(a,b)} - \sum d_{(b,a)} \tag{12}$$

3 Results

Companies in Ecuador face various challenges in implementing CSR practices. Some of these challenges include:

- Lack of resources: Financial and human resource limitations to implement CSR practices. The implementation of CSR practices can be costly and requires a significant investment in time and resources.
- Lack of knowledge: Lack of awareness about CSR and its benefits can lead to a lack of real commitment to the community and the environment.
- Lack of incentives: There are not enough incentives for companies to implement CSR practices. The lack of incentives can result in a lack of real commitment to the community and the environment.
- Lack of regulation: There are not enough regulations that compel companies to implement CSR practices. The lack of regulation can result in a lack of real commitment to the community and the environment.
- Lack of corporate culture: There is no corporate culture that promotes CSR. The lack of corporate culture can result in a lack of real commitment to the community and the environment.

In this case, the following criteria and weights have been defined: impact on the community (0.3, 0.7, 0.75), environmental sustainability (0.2, 0.8, 0.85), employee responsibility (0.2, 0.8, 0.85), business ethics (0.2, 0.8, 0.85), and financial performance (0.10, 0.90, 0.90). After defining the criteria weights, a scale of values is established for comprehensive solutions aimed at mitigating challenges and achieving CSR practices in Ecuador with a positive impact on the community. This is to support environmental sustainability, employee responsibility, business ethics, and financial performance [14-19]. Among the comprehensive solutions are:

- Implementation of environmental practices (SI-1): Companies in Ecuador can implement environmental practices to reduce their impact on the environment, such as reducing greenhouse gas emissions, decreasing carbon footprint, and promoting environmental sustainability. This can enhance the long-term profitability of companies and improve their brand image.
- Implementation of training and professional development programs (SI-2): Companies in Ecuador can implement training and professional development programs to enhance the skills and knowledge of their employees. This can improve the quality of personnel and the productivity of the company, leading to long-term profitability.
- Promotion of innovation (SI-3): Companies in Ecuador can promote innovation, including the implementation of clean and renewable technologies and the encouragement of research and development of sustainable products and services. This can enhance the competitiveness of companies and their long-term profitability.
- Implementation of ethics and transparency policies (SI-4): Companies in Ecuador can implement ethics and transparency policies to enhance their reputation and relationship with consumers. This can improve the long-term profitability of companies and minimize legal risks and reputational damage.
- Promotion of equal opportunities (SI-5): Companies in Ecuador can promote equal opportunities among their employees, including promoting diversity and inclusion and eliminating discrimination in the workplace. This can improve employee satisfaction and productivity and enhance the company's brand image.

Once the criteria and comprehensive solutions to be evaluated are defined, the next step is to calculate the score for each comprehensive solution based on the weights assigned to each criterion and the assessments made. The results of the evaluation of the proposed comprehensive solutions using the neutrosophic ELECTRE method are presented below (See Tables 3 to 10).

Table 3: Evaluation matrix. Source: own elaboration.

	Impact on the community	**Environmental sustainability**	**Responsibility towards employees**	**Ethics in business**	**Financial performance**
	SVNN	SVNN	SVNN	SVNN	SVNN
Solutions	**C1**	**C2**	**C3**	**C4**	**C5**
SI-1	(0.25,0.75,0.85)	(0.65,0.35,0.45)	(0.45,0.55,0.65)	(0.75,0.25,0.35)	(0.25,0.75,0.85)
SI 2	(0.15,0.85,0.95)	(0.85,0.15,0.25)	(0.55,0.45,0.55)	(0.45,0.55,0.65)	(0.55,0.45,0.55)
SI 3	(0.25,0.75,0.85)	(0.55,0.45,0.55)	(0.15,0.85,0.95)	(0.35,0.65,0.75)	(0.65,0.35,0.45)
SI-4	(0.95,0.05,0.15)	(0.25,0.75,0.85)	(0.45,0.55,0.65)	(0.55,0.45,0.55)	(0.45,0.55,0.65)
SI-5	(0.45,0.55,0.65)	(0.15,0.85,0.95)	(0.65,0.35,0.45)	(0.65,0.35,0.45)	(0.45,0.55,0.65)

Table 4: Calculation of the normalized decision matrix R_{Sij}, using Equation (1) and (2). Source: own elaboration.

	Impact on the community	Environmental sustainability	Responsibility towards employees	Ethics in business	Financial performance
	SVNN	SVNN	SVNN	SVNN	SVNN
	Max	**Max**	**Max**	**Max**	**Max**
Solutions Comprehensive	**C1**	**C2**	**C3**	**C4**	**C5**
SI-1	(0.15,0.85,0.95)	(0.65,0.35,0.45)	(0.45,0.55,0.65)	(1,0,0)	(0,0.95,1)
SI 2	(0,0.95,1)	(1,0,0)	(0.75,0.25,0.35)	(0.35,0.65,0.75)	(0.75,0.25,0.35)
SI 3	(0.15,0.85,0.95)	(0.45,0.55,0.65)	(0,0.95,1)	(0,0.95,1)	(1,0,0)
SI-4	(1,0,0)	(0.15,0.85,0.95)	(0.55,0.45,0.55)	(0.55,0.45,0.55)	(0.55,0.45,0.55)
SI-5	(0.35,0.65,0.75)	(0,0.95,1)	(1,0,0)	(0.95,0.05,0.15)	(0.55,0.45,0.55)
min	**(0,0.95,1)**	**(0,0.95,1)**	**(0,0.95,1)**	**(0,0.95,1)**	**(0,0.95,1)**
Max	**(1,0,0)**	**(1,0,0)**	**(1,0,0)**	**(1,0,0)**	**(1,0,0)**
Range	**(1,0,0)**	**(1,0,0)**	**(1,0,0)**	**(1,0,0)**	**(1,0,0)**

Table 5: Determine the weighted normalized decision matrix V_{ij}, according to Equation (3). Source: own elaboration.

	Impact on the community	Environmental sustainability	Responsibility towards employees	Ethics in business	Financial performance
	C1	**C2**	**C3**	**C4**	**C5**
Weight	**(0.3,0.7,0.75)**	**(0.2,0.8,0.85)**	**(0.2,0.8,0.85)**	**(0.2,0.8,0.85)**	**(0.10,0.90,0.90)**
SI-1	(0,0.95,1)	(0.15,0.85,0.95)	(0,0.95,1)	(0.15,0.85,0.95)	(0,0.95,1)
SI 2	(0,0.95,1)	(0.15,0.85,0.95)	(0.15,0.85,0.95)	(0,0.95,1)	(0,0.95,1)
SI 3	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)
SI-4	(0.25,0.75,0.85)	(0,0.95,1)	(0,0.95,1)	(0.15,0.85,0.95)	(0,0.95,1)
SI-5	(0,0.95,1)	(0,0.95,1)	(0.15,0.85,0.95)	(0.15,0.85,0.95)	(0,0.95,1)

Table 6: Concordance index C_{Yab} using Equation (7). Source: own elaboration.

Solutions	SI-1	SI 2	SI 3	SI-4	SI-5
SI-1	0.00	0.51	0.40	0.60	0.60
SI 2	0.49	0.00	0.40	0.49	0.69
SI 3	0.60	0.60	0.00	0.69	0.69
SI-4	0.40	0.51	0.31	0.00	0.51
SI-5	0.40	0.31	0.31	0.49	0.00

Table 7: Discordance index D_{Yab} using Equation (8). Source: own elaboration.

Solutions	SI-1	SI 2	SI 3	SI-4	SI-5
SI-1	0.00	0.62	0.55	1.00	0.77
SI 2	1.00	0.00	0.25	1.00	0.60
SI 3	1.00	1.00	0.00	1.00	1.00
SI-4	0.36	0.55	0.24	0.00	0.50
SI-5	1.00	1.00	0.50	1.00	0.00

Table 8: Dominant concordance matrix. Source: own elaboration.

Solutions	SI-1	SI 2	SI 3	SI-4	SI-5	
SI-1		1	0	1	1	Maximum threshold for concordance index $\bar{c} = 0.50$
SI 2	0		0	0	1	
SI 3	1	1		1	1	
SI-4	0	1	0		1	
SI-5	0	0	0	0		

Table 9: Dominant discordant matrix. Source: own elaboration.

Solutions	SI-1	SI 2	SI 3	SI-4	SI-5	
SI-1		1	1	0	0	Maximum threshold for discordance index $\bar{d} = 0.7470$
SI 2	0		1	0	1	
SI 3	0	0		0	0	
SI-4	1	1	1		1	
SI-5	0	0	1	0		

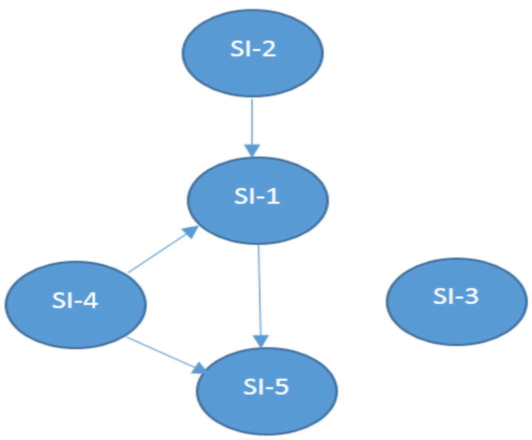
Table 10: Aggregated dominant matrix. Source: own elaboration.

Solutions	SI-1	I 2	SI 3	SI-4	SI-5	Total
SI-1		1	0	0	0	**1**
SI 2	0		0	0	1	**1**
SI 3	0	0		0	0	**0**
SI-4	0	1	0		1	**2**
SI-5	0	0	0	0		**0**
Total	**0**	**2**	**0**	**0**	**2**	

Results of the neutrosophic ELECTRE method modeling (see Figure 1):

- SI-4 over-classifies SI-1 and SI-5 and is not over-classified by any other comprehensive solution.
- SI-2 over-classifies SI-1 and is not over-classified by any other comprehensive solution.
- SI-3 neither over-classifies nor is over-classified by any other comprehensive solution. Therefore, it is outside the interrelation of the remaining comprehensive solutions.

Figure 1: Representation of integral solutions (ELECTRE graph). Source: own elaboration.



The integral solution with the highest weight determines, in the neutrosophic ELECTRE method, two priority solutions. These are defined as the implementation of ethics and transparency policies, followed by the implementation of training and professional development programs. To enhance these comprehensive solutions, incentives, and regulations that encourage the implementation of CSR practices in Ecuadorian companies should be promoted. The following are possible actions to promote:

- Establish clear and transparent policies in the company that promote ethics in business and responsibility with employees [15]. This may include the implementation of codes of conduct, the promotion of diversity and inclusion, the protection of human and labor rights, and the prevention of corruption.
- Train company personnel on ethics and corporate social responsibility [16]. This would enable staff to understand the importance of these aspects and commit to the implementation of established policies.
- Conduct an internal audit to assess compliance with ethics and transparency policies in the company. This helps identify improvement opportunities and ensures that ethical and corporate social responsibility standards are met [17].
- Communicate ethics and transparency policies effectively to the community and other relevant stakeholders. This ensures building trust and commitment with the company, which can enhance its reputation and maximize its positive impact on the community.

On another note, the implementation of CSR practices in companies in Ecuador can generate various benefits, such as improving reputation, reducing costs, attracting talent, accessing new markets, and complying with regulations. It is significant to promote constructive dialogue between companies, society, and regulators to achieve real commitment to CSR and have a positive impact on the community. Additionally, it is essential to promote incentives and regulations that encourage the implementation of CSR practices in companies in Ecuador.

These measures include promoting CSR, tax incentives, regulation, public-private partnerships, and certifications. It is crucial to foster constructive dialogue between companies, society, and regulators to achieve real commitment to CSR and have a positive impact on the community.

Conclusion

The implementation of CSR practices in companies in Ecuador can have multiple benefits, such as improving the company's reputation, increasing employee satisfaction, enhancing the relationship with customers and the community, and improving the financial performance of the company. To achieve these benefits, it is significant to implement comprehensive solutions that address multiple aspects of corporate social responsibility and focus efforts on improving specific aspects that have a greater impact on the criteria of higher weight.

The neutrosophic ELECTRE method constitutes a useful tool for decision-making in complex situations where multiple alternatives must be evaluated based on multiple criteria. Integral solutions with higher scores, such as the implementation of ethics and transparency policies and the promotion of equal opportunities, can have a positive impact on the community.

Neutrosophic evaluation has allowed for assessing comprehensive solutions and existing indeterminacies in decision-making, helping identify the strengths and weaknesses of each integral solution based on each criterion. To do this, it is necessary to enhance the integral solutions with the greatest impact by establishing policies that can improve environmental sustainability, promote ethics in business, and enhance the financial performance of Ecuadorian companies.

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Neutrosophic Nursing Workflow Optimization

Gloria Medina Naranjo[1], Greta Vallejo Ordoñez[2], Melba Narvaez Jaramillo[3], and Christian Fernando Tantaleán Odar[4]

[1]Universidad Regional Autónoma de Los Andes, Ambato, Ecuador. E-mail: ua.gloriamedina@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.gretavo25@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Tulcán. Ecuador. E-mail: ut.melbanarvaez@uniandes.edu.ec
[4]Universidad Nacional Mayor de San Marcos. Perú. E-mail: christian.tantalean@unmsm.edu

Abstract. The current nursing situation in Ecuador is characterized by complex challenges that affect health care throughout the country. The uneven geographic distribution of nurses, quality of training, and staff retention are critical areas requiring attention. Therefore, this study focused on analyzing the optimization of the nursing workflow in Ecuador from a neutrosophic perspective, which considers the indeterminacy of the existing elements. The results revealed the need for an automated system for optimizing nursing workflow based on the diversity of local conditions and needs. In conclusion, it was seen that patient retention policies and the training of health personnel are fundamental, but their impact varies depending on the region analyzed. This neutrosophic approach highlights the complexity and need for adaptation in the management and optimization of nursing workflow in Ecuador**.**

Keywords: Neutrosophy, nursing, healthcare environment, workflow optimization.

1 Introduction

A workflow is the sequence of processes that must be followed to complete a certain part of the process. Workflow is therefore an understanding of the procedures and processes necessary for each area to function [1]. This study is focused on optimizing workflow in the field of nursing [2], which constitutes a crucial issue in guaranteeing quality care in the Ecuadorian health system. Similarly, Ecuador, like many other countries, faces significant challenges in nursing resource management and in improving the efficiency of its healthcare services [3]. When analyzing the current nursing situation, different regions can be identified where the level of nursing professionals varies within the country. Among these, the following can be mentioned:

- Decrease in Nurses in Rural Areas: In various rural areas of Ecuador, there are few nursing professionals. Economic conditions, a lack of healthcare infrastructure, and limitations in employment opportunities in these regions have led to a decrease in nursing professionals. The neutrosophic analysis defines the indeterminacy of how effective government policies and programs aimed at addressing the nursing shortage in rural areas are.
- Increase in nursing professionals in urban areas: In Ecuador, especially hospitals in large cities, there is an increasing concentration of nurses, due to a greater job offer and the attraction of better-equipped health centers. So, the indeterminacy of this criterion shows how ineffective the policies aimed at redistributing nursing professionals are. Therefore, there is an imbalance between urban and rural areas regarding workload management in health centers in Ecuador.

Another point to highlight is the training of nurses in Ecuador [4]. Currently, education and training present significant challenges regarding the quality of nursing education. As well as its influence on the optimization of nursing workflow. Therefore, there are nursing education institutions in Ecuador that offer high-quality programs with adequate training standards [5]. These programs produce competent and well-prepared nursing professionals in urban areas, while in rural regions preparation is difficult due to the scarcity of resources. It should be noted that in rural areas there are some nursing programs, although they may lack resources, qualified personnel, or updated curricular structures.

Another point of interest suggests that the quality of nursing education directly influences the improvement of health care and in turn affects the workflow [6, 14]. An example of this is well-trained nurses who provide safer and more effective care with workflow optimization, which reduces errors and achieves greater patient satisfaction [7].

Establishing workflows is essential to optimize the performance of nursing professionals. The workflow, in short, allows for the establishment of all the necessary resources and the processes that must be followed to achieve a certain goal. Consequently, the quality of initial education can influence the need for continuous training. If initial training is poor, nursing professionals may require more training to be effective in the workplace, affecting workflow and resource optimization [8, 15]. In summary, indeterminacy is observed in the workflow and the distribution of nursing professionals on the following elements:

- The effectiveness of evaluation policies and systems.
- The quality of nursing education and training.
- The lack of health infrastructure, low remuneration, and lack of job opportunities.
- Work overload in urban areas leads to a decrease in the quality of care due to staff exhaustion.

In summary, the application of neutrosophy in the evaluation of the current situation of nursing professionals in Ecuador reveals that there is a truth in the decrease of nurses in rural areas. Therefore, it is necessary to develop strategies to optimize the nursing workflow in the country. With this, the aim is to include the integration of indeterminacies in the solutions to obtain satisfactory results in the face of existing problems. Therefore, the main objective of this study is:

- Analyze the optimization of the nursing workflow in Ecuador from a neutrosophic perspective, which considers the indeterminacy of the existing elements.

Specific objectives:

- Analyze the barriers that prevent an optimal nursing workflow in Ecuador.
- Determine the neutrosophic criteria to define the best strategy to optimize the workflow.
- Enhance the scope of the selected strategy based on the targeted solution proposal.

2 Materials and methods

2.1 Neutrosophic Statistics and MOORA

The neutrosophic MOORA (Multi-Objective Optimization by Ratio Analysis) method consists of calculating the overall return of each alternative as the difference between the sums of their normalized returns that belong to the cost and benefit criteria. All attributes must be defined, provided that they can be measured or valued with respect to the linguistic terms that represent the weight of importance to each of the alternatives.

In this article, linguistic terms based on the Single-Valued Neutrosophic Number (SVNN) will be associated, so that experts can carry out their evaluations in linguistic terms, which is a more natural way to express assessments. Therefore, the scales shown in Table 1 will be considered.

Table 1: Linguistic terms that represent the weight of the importance of alternatives. Source: own elaboration.

Linguistic expression	SVNN
Relevant Improvement (RI)	(0.90, 0.15, 0.10)
Significant Improvement (SI)	(0.80,0.30,0.20)
Improvement (I)	(0.50,0.45,0.50)
Limited Improvement (LI)	(0.30,0.80,0.70)
No Improvement (NI)	(0.10,0.90,0.95)

Therefore, it is defined that $A = \{\rho_1, \rho_2, \dots, \rho_m\}$ is a set of alternatives, and $T = \{\beta_1, \beta_2, \dots, \beta_m\}$ is a set of criteria, the following steps will be carried out. For the modeling of the method, it is necessary to keep in mind the definition of neutrosophic numbers within the analyzed set.

Definition 1. Let X be a universe of discourse. A Neutrosophic Set (NS) is characterized by three membership functions [9], $u_A(x), r_A(x), v_A(x): X \rightarrow]$ -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. An SVNS A on 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 $u_A, r_A, v_A: X \to [0,1]$, satisfy condition $0 \le u_A(x) + r_A(x) + v_A(x) \le 3$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ indicate the true, indeterminate, and false membership functions of x in A, respectively. For reasons of simplification and better understanding, an SVNN will be expressed as A = (a, b, c), where a, b, c [0,1] and satisfies 0 ≤ a + b + c ≤ 3.

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

Let A1 = (a1, b1, c1) and A2 = (a2, b2, c2) be two SVNNs, the sum between A1 and A2 as defined in expression (2).

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

Let A1 = (a1, b1, c1) and A2 = (a2, b2, c2) be two SVNNs, the multiplication between A1 and A2 is defined in expression (3).

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

The product of a positive scalar with an SVNN, A = (a, b, c) is defined by expression (4).

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

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 Value Neutrosophic Weighted Mean Operator (SVNWMO) on the set is calculated by the equation (5).

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

Where λ_j is the weight of Aj, $\lambda_j \in [0, 1]$ 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 $A_j^* = \left(a_1^*, b_2^*, c_j^*\right)(j = 1,2, \ldots, n)$ and $B_i = (B_{i1}, B_{i2}, \ldots, B_{im})(i = 1,2, \ldots, m)$ be m vectors of n SVNN such that $B_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right)$ (i = 1, 2, …,m)(j = 1, 2, …, n). Then the Separation Measure between Bi and A* is calculated by Equation (6).

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

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

Definition 4. Let A = (a, b, c) be an SVNN, and 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 Equation 7.

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

Where S(A) [-1, 1]∈

Having understood the nature of neutrosophic numbers, the neutrosophic MOORA method is carried out by following the subsequent steps:

Step 1: Determine the weight of the experts. To do this, the specialists evaluate according to the linguistic scale that appears in Table 1, 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:

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

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

Step 2: Formulation of the Final Decision Matrix (FDM).

Once the weight of the experts has been determined, the alternatives (A_n) and available criteria (Tx_{J+L}^{n}) are identified. Then, the decision-making matrix is constructed, which contains n rows that represent the alternatives $A_1, \ldots, A_n$ in the evaluation, and J+L the columns that represent the criteria under evaluation (J quantitative criteria and L qualitative criteria). In this way, the final decision matrix is calculated by using equation (9).

$$\text{FDM}==[VO, VST]\begin{bmatrix} A^1 \\ A^2 \\ \vdots \\ A^n \end{bmatrix}\begin{bmatrix} t_1^1 & \cdots & t_J^1 & t_{J+1}^1 & \cdots & t_{J+L}^1 \\ t_1^2 & \cdots & t_J^2 & t_{J+1}^2 & \cdots & t_{J+L}^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ t_1^n & \cdots & t_J^n & t_{J+1}^2 & \cdots & t_{J+L}^n \end{bmatrix} \quad (9)$$

Where A_i represents the alternatives, for $i = 1 \ldots n$, and x_j^i represents the inputs of alternative i with respect to criterion j.

Step 3: Calculate the normalized decision matrix.

It is feasible that the qualification criteria are expressed in various units or measurement scales; therefore, data must be normalized. Where the Euclidean norm is obtained according to equation (10) to the criterion x_j.

$$|T_j| = \sqrt{\sum_{1}^{n} t_i^2} \quad (10)$$

Therefore, the normalization of each entry in the FDM is carried out according to equation (11).

$$Nt_{ij} = \frac{t_{ij}}{|T_j|} \quad (11)$$

The results obtained after using equation (11) are dimensionless values, which allows the operations between the criteria to be additive.

Step 4: Calculate the weighted normalized decision matrix.

By considering the different importance of the criteria, the normalized weighted scores WNt_{ij} are calculated through equation (12).

$$WNt_{ij} = w_i \cdot Nt_{ij} \quad (12)$$

Selection of alternatives using distance to reference point when using Tchebycheff. The reference point or alternative $R_n[r_j]$ is constructed. This reference point is built with the best evaluation for each criterion. To measure the distance between each alternative and the reference point, the Tchebycheff metric is used, obtained by using equations (13 and 14).

$$Dist_{(i;j)} = \{max_j|r_j - WNt_{ij}|\} \quad (13)$$

The alternatives are ordered according to the shortest distance:

$$min_i = \{max_j|r_j - WNt_{ij}|\} \quad (14)$$

3 Results

For the development of the study, it was decided to explore the general causes that affect the optimal nursing workflow in Ecuador. To this end, an analysis of the causes that affect nursing workflows in health centers is included (see Table 2).

Table 2: Barriers that prevent optimal nursing workflow in Ecuador. Source: own elaboration.

No.	Cause	Effects	Observations
1	Unequal distribution of nurses	• Decrease of nurses in rural areas: The lack of adequate personnel affects the ability to provide quality care. • Increased demand in urban areas: The growing demand for medical care puts pressure on existing nursing staff, resulting in an increased workload in healthcare centers.	• It is observed that between opposites, it does not reflect the limits or a state of equilibrium. Therefore, it is deduced that the state of equilibrium is undetermined in the studied element.
2	Low automation of health processes	• Low level of implementation of electronic health record automation in urban areas. • Lack of implementation of workflow automation in nursing.	• The automation states in the regions can vary, and in the same region, one, two, or three states may converge. Therefore, there is

No.	Cause	Effects	Observations
		• The region is not included in nursing workflow automation programs.	an indeterminacy in assessing whether the region is automated.
3	Varied quality of education and training	• Differences in education: Differences in the quality of nursing education and training at different institutions can result in disparities in the skills and knowledge of professionals. • Need for ongoing training: Lack of ongoing training may leave nurses not fully prepared to meet the evolving challenges of healthcare.	• It can be observed that the agility and work performance of nursing professionals may be compromised by the key elements of all traditional manual workflows in healthcare centers.
4	Inefficient policies and management	• Ineffective human resources policies: Policies and strategies to address the unequal distribution of nurses and quality of care may be ineffective or insufficient. • Lack of strategic planning: Lack of strong strategic planning in the health system can lead to a lack of coordination and poor implementation of policies.	• Health policies must be focused on service quality and customer satisfaction. To do this, technical support focused on training and optimization of human resource flows is required.
5	Pressure on the health system	• Growing demand: The growing demand for healthcare services due to an aging population and continually changing healthcare needs puts pressure on the healthcare system and nursing staff. • Inadequate infrastructure: In many cases, health infrastructure, including the quantity and quality of healthcare facilities, is insufficient to meet the needs of the population.	• Emergency nurses work under enormous pressure. Sometimes the work environment makes it difficult for patients to receive the treatment they need and to keep records updated and organized.

These general causes address the barriers that hinder optimal nursing workflow in Ecuador. Resolving these challenges requires a combination of policies, investment in human resources, improvement in the quality of education and training, and strong strategic planning for the healthcare system in the country. Therefore, it is necessary to define a series of strategies to enhance an optimal nursing workflow, which includes the existing indeterminacies.

These strategies should provide solutions to the challenges of nursing in Ecuador, from the unequal distribution of personnel to the need to improve the quality of care and the digitization of processes. Each proposed strategy has a specific scope to optimize nursing workflow and ensure higher-quality healthcare.

- **Strategy 1**. Implement policies and programs that encourage the equitable distribution of nurses: It focuses on implementing policies and programs that promote a more equitable distribution of nurses in all regions of Ecuador. This aims to work towards mitigating the decrease in nurses in rural areas and improving access to healthcare in underserved regions and the equity in the distribution of healthcare resources.
  Integrated indeterminacy in the strategy: It should encompass the analysis of indeterminacies present in the outcomes obtained in different regions of policy and program implementation and integrate them into the expected objectives.
- **Strategy 2**. Improvement in education and training: It aims to enhance the quality of nursing education and training, ensuring that nurses are prepared to address patients' healthcare needs and the automation of processes. This is intended to produce more competent nurses who provide satisfactory patient care.
  Integrated indeterminacy in the strategy: The scope should include training and professional development, evaluating how necessary and to what extent nursing professionals should be prepared for different regions.
- **Strategy 3.** Promotion of nursing research: It is aimed at fostering research in the field of nursing to drive innovation and improve healthcare practices. Consequently, it is expected to result in the development of better healthcare practices, advancements in the field of nursing, and higher-quality patient care.
  Integrated indeterminacy in the strategy: The scope should encompass the indeterminacy arising from the different outcomes of innovation and improvement in patient care practices. However, the

variety of outcomes obtained should be integrated as part of the optimization of nursing workflow in Ecuador.

- **Strategy 4**. Staff and patient retention policies: Work should be done to implement patient and nursing staff retention policies and programs to reduce turnover and unequal distribution in urban and rural regions. To achieve this, greater stability of the nursing staff is sought as a result of working to reduce associated costs. So that continuity and patient satisfaction with the nursing service are restored, with a positive impact on patient retention in health areas.
  Indeterminacy built into strategy: It should have the scope of evaluating the effectiveness of nursing staff retention policies in different regions of Ecuador and proposing improvements to maintain patient loyalty in health centers. To do this, indeterminate results not evaluated in traditional studies must be included.
- **Strategy 5.** Interdisciplinary collaboration: It aims to promote collaboration among different nursing professionals for a more integrated and efficient approach to patient care [10, 16, 17]. Consequently, it achieves better healthcare coordination, reduced duplications and errors, and improved workflow efficiency.
  Integrated indeterminacy in the strategy: The scope should include interdisciplinary collaboration that integrates the results achieved in each region and how they optimize nursing workflow. This ensures not only homogeneous results but also those indeterminate outcomes obtained through collaboration among regions.
- **Strategy 6**. Innovation in nursing management: It promotes the introduction of innovative and efficient management practices to optimize resource allocation and nursing work organization. The expected outcomes include improved resource allocation, greater workflow efficiency, and, consequently, a reduction in non-essential workload.
  Integrated indeterminacy in the strategy: The scope should involve the integration of innovative management practices in each region of the country. It should evaluate differences in criteria through neutrosophic analysis and include the digitization of workflows.

To determine the optimal strategy, criteria evaluation is required under the linguistic terms representing the weight of the importance of each neutrosophic element, according to the measurement scale (see Table 1). These criteria assist in evaluating the proposed strategies based on achieving an optimal nursing workflow in Ecuador. Measurement scales in terms of neutrosophic numbers allow for a flexible and balanced representation of the importance of each criterion.

Criterion 1 (C1), equitable distribution of nurses: Degree to which the strategy achieves a more equitable distribution of nurses. For a measurement scale in linguistic terms from SVNN (0.90, 0.15, 0.10) for highly equitable distribution, to SVNN (0.10, 0.90, 0.95) for unequal distribution.

Criterion 2 (C2), variability in the quality of education and training: Aims to minimize variability through the evaluation of indeterminants that influence the improvement in the quality of education and training. It uses a linguistic measurement scale in terms of NNVU (0.80, 0.30, 0.20) for a significant improvement, down to NNVU (0.30, 0.80, 0.70) for limited or no improvement.

Criterion 3 (C3), variability in the contribution to nursing research: The aim is to mitigate the variability of results obtained and achieve redirection to a neutrosophic subset. With a scale of SVNN (0.80, 0.30, 0.20) for a significant contribution, up to SVNN (0.30, 0.80, 0.70) for limited or no contribution.

Criterion 4 (C4), efficiency in interdisciplinary collaboration: Evaluate the improvement in interdisciplinary coordination and efficiency. On a scale from SVNN (0.80, 0.30, 0.20) for significant improvement, to SVNN (0.30, 0.80, 0.70) for little or no improvement.

Criterion 5 (C5), job and service satisfaction: Measure staff retention and patient satisfaction. On measuring SVNN (0.90, 0.15, 0.10) for high retention and satisfaction, up to SVNN (0.10, 0.90, 0.95) for high turnover and low satisfaction.

Once the alternatives and measurement criteria are defined, the modeling of the Neutrosophic MOORA method is carried out (see Tables 3 to 5). Therefore, a comprehensive and weighted evaluation of the alternatives is performed based on multiple neutrosophic criteria. It is significant that the weights assigned to the criteria adequately reflect the relative neutrosophic importance of each one in the context of achieving an optimal nursing workflow in Ecuador.

Table 3: Normalized matrix. Source: own elaboration.

Unit	C1	C2	C3	C4	C5
Alternatives	**Max**	**Min**	**Min**	**Max**	**Max**
Alt 1	(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)
Alt 2	(0.50,0.45,0.5)	(0.8,0.3,0.2)	(0.5,0.45,0.5)	(0.9,0.15,0.1)	(0.3,0.8,0.7)
Alt 3	(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)
Alt 4	(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)
Alt 5	(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)
Alt 6	(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)
w	**(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)**

Table 4: Normalized and weighted matrix. Source: own elaboration.

	C1	C2	C3	C4	C5
Alt	**Max**	**Min**	**Min**	**Max**	**Max**
Alt 1	(0.063,0.167,0.146)	(0.063,0.167,0.146)	(0.063,0.167,0.146)	(0.063,0.082,0.051)	(0.418,0.068,0.034)
Alt 2	(0.105,0.094,0.105)	(0.167,0.063,0.042)	(0.105,0.094,0.105)	(0.188,0.015,0.007)	(0.157,0.181,0.12)
Alt 3	(0.188,0.031,0.021)	(0.188,0.031,0.021)	(0.188,0.031,0.021)	(0.188,0.015,0.007)	(0.418,0.068,0.034)
Alt 4	(0.021,0.188,0.199)	(0.167,0.063,0.042)	(0.167,0.063,0.042)	(0.063,0.082,0.051)	(0.157,0.181,0.12)
Alt 5	(0.063,0.167,0.146)	(0.021,0.188,0.199)	(0.167,0.063,0.042)	(0.021,0.092,0.069)	(0.261,0.102,0.086)
Alt 6	(0.188,0.031,0.021)	(0.188,0.031,0.021)	(0.188,0.031,0.021)	(0.188,0.015,0.007)	(0.418,0.068,0.034)
$\boldsymbol{R_{nj}}$	**(0.188,0.188,0.199)**	**(0.021,0.031,0.021)**	**(0.063,0.031,0.021)**	**(0.188,0.092,0.069)**	**(0.418,0.181,0.12)**

Table 5: Evaluation of each alternative by distance to reference point. Source: own elaboration.

	C1	C2	C3	C4	C5	Order
Alt 1	(0.125,0.021,0.042)	(0.125,0.021,0.042)	(0.125,0.021,0.042)	(0.125,0.01,0.018)	(0,0.113,0.086)	**3**
Alt 2	(0.083,0.094,0.083)	(0.021,0.125,0.146)	(0.083,0.094,0.083)	(0,0.077,0.062)	(0.261,0,0)	**1**
Alt 3	(0,0.157,0.167)	(0,0.157,0.167)	(0,0.157,0.167)	(0,0.077,0.062)	(0,0.113,0.086)	**4**
Alt 4	(0.167,0,0.011)	(0.021,0.125,0.146)	(0.021,0.125,0.146)	(0.125,0.01,0.018)	(0.261,0,0)	**1**
Alt 5	(0.125,0.021,0.042)	(0.167,0,0.011)	(0.021,0.125,0.146)	(0.167,0,0)	(0.157,0.079,0.034)	**2**
Alt 6	(0,0.157,0.167)	(0,0.157,0.167)	(0,0.157,0.167)	(0,0.077,0.062)	(0,0.113,0.086)	**4**

Once the calculation and analysis are completed, the strategies with the highest priority are determined: **Strategy 2**, Improvement in education and training, and **Strategy 4,** Staff and patient retention policies. These alternatives obtain the highest score based on the evaluated criteria, indicating that they have greater potential to contribute to the optimization of nursing workflow in Ecuador. Therefore, a group of solutions focused on optimizing nursing workflow is proposed:

1. Redesign a system that analyzes and monitors the performance of nursing professionals [11-18-19]. This seeks to measure progress and identify opportunities for improvement in nursing professionals.
    - Adaptive system design helps your organization meet specific clinical and business needs. So that it helps streamline data collection and clinical documentation. To do this, it must promote the provision of standardized care and compliance with best practices in patient care and retention.

    Advantages that the new system should achieve in optimizing the workflow:
    - Formalize health records processes.
    - Automate workflows to achieve consistency of criteria among health professionals.
    - Free up work hours so that nursing staff can focus on patient care.
    - The performance of nursing professional's increases because staff can be assigned to more meaningful, patient-oriented work.

Automated systems that process workflows allow information to be accessed, indexed, searched, and retrieved in a timely and accurate manner. Therefore, technologies must be used in the integration of health services [12]. It is essential to integrate, adapt and improve the workflows of each worker [13], to guarantee the best possible level of safety for the patient. On the other hand, the proposed solution to policies in favor of optimizing nursing workflows aims to work on:

2. Evaluation of the effectiveness of nursing staff retention policies in Ecuador: The evaluation of retention policies is characterized by the indeterminacy in the effectiveness of the strategies implemented in different regions. Some regions show positive results, while others face significant challenges in nursing staff retention. The proposed solutions constitute a response to a variety of situations, but their effectiveness presents uncertainties that may vary depending on the region and local circumstances.
   Its objectives are aimed at:
   - Analyzing the implementation of retention policies in different regions.
   - Identifying challenges and obstacles in retaining nursing staff.
   - Evaluating the impact of proposed improvements on nursing staff retention.
   - Generating specific recommendations for effective retention policies.

   While the stages to be developed in the proposed solution are:
   - Research and analysis of existing retention policies.
   - Data collection and implementation analysis.
   - Identification of challenges and obstacles.
   - Development of recommendations.
   - Impact evaluation.
   - Generation of final recommendations.

However, for data collection and processing, an investigator is required to prepare surveys, access nursing records and data, and analyze the results. This is expected to lead to a proposal focused on improving nursing personnel retention policies in Ecuador. Thus, the information obtained should provide enhancements for optimizing nursing workflow and delivering higher-quality healthcare.

Conclusion

Optimizing the nursing workflow in Ecuador is a task that involves a complex interplay of factors and challenges. Nursing in Ecuador faces a range of issues, including the unequal geographical distribution of nurses, the quality of education and training, and personnel retention. The truth lies in the need to improve healthcare across the country. However, indeterminacy prevails regarding the effectiveness of specific strategies to be implemented in each region, given the diversity of local conditions and needs.

Personnel retention policies, in particular, play a crucial role in optimizing the nursing workflow in Ecuador. The implementation of appropriate retention policies is essential to address the shortage of nurses and ensure quality healthcare in all regions. However, the effectiveness of these policies is undetermined and may vary by region, emphasizing the need to approach nursing management adaptively and flexibly.

Training and professional development are also key elements for retaining and improving the skills of nursing personnel in Ecuador. However, indeterminacy persists in terms of how these programs are implemented and adapted in different regions and their specific impact in each context. Nevertheless, an automated system is proposed for optimizing the nursing workflow based on the needs of each region.

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Neutrosophic Analysis of International Diplomacy and Conflict Resolution

Luis Andrés Crespo Berti[1], Manaces Easud Gaspar Santos[2], Salomon Alfredo Montecé Giler[3], and Wilder Fabio Ramos Palacios[4]

[1]Universidad Regional Autónoma de Los Andes, Ibarra. Ecuador. E-mail: ui.luiscrespo@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Quevedo. Ecuador. E-mail: uq.felipegc09@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.salomonmontece@uniandes.edu.ec
[4]Universidad Nacional Mayor de San Marcos, Perú. E-mail: wramosp@unmsm.edu.pe

Abstract. International diplomacy has been essential in resolving conflicts in Ecuador. Throughout its history, it has contributed to resolving border disputes and political tensions at the national and international levels. However, there are factors that can negatively influence these efforts. Despite the challenges, diplomacy will always be vital to maintaining the peace and security of the country. This study focuses on analyzing the role of international diplomacy in conflict resolution in Ecuador and evaluating its impact on the stability of the country and the region. The neutrosophic AHP method was used to obtain the factors that can act as obstacles to carrying out effective diplomacy. It was recognized that internal policy can have a negative impact, so solutions are proposed that can contribute to a more effective approach.

Keywords: international diplomacy, internal politics, conflict resolution.

1. Introduction

International diplomacy is a fundamental tool in the context of relations between nations and, particularly, in conflict resolution. In the case of Ecuador, a country with a rich history of border tensions and political disputes, diplomacy has been essential to maintaining peace and promoting cooperation. This essay explores the evolution of international diplomacy in Ecuador and its contribution to conflict resolution, both nationally and internationally.

International diplomacy is a discipline that involves negotiation and dialogue between different nations to resolve conflicts and promote cooperation. In the case of Ecuador, diplomacy has been crucial in managing relations with its neighbors, especially in border conflicts. One of the most notable examples was the conflict with Peru in 1995, which was resolved through international arbitration, highlighting the importance of diplomacy in the region [1].

Ecuador has faced several internal conflicts throughout its history, ranging from territorial disputes to political and social tensions. The resolution of these conflicts has required the intervention of national and international actors, such as mediators and observers, to achieve sustainable solutions. Conflict resolution in Ecuador has been a complex and multifaceted process that has involved various actors [1].

To effectively address the issue of diplomacy and conflict resolution, Ecuador has done the following:

Actions carried out by Ecuador:

- ✓ Negotiation of bilateral and multilateral agreements: Ecuador has participated in international treaties and agreements to address conflicts and promote cooperation, such as the Rio de Janeiro Protocol and the Itamaraty Peace Agreement.
- ✓ Mediation in regional conflicts: Ecuador has acted as a mediator in disputes between neighboring countries, demonstrating a commitment to the peaceful resolution of conflicts in the region.
- ✓ Participation in International Organizations: The country has been an active member of organizations such as the Organization of American States (OAS) and the Community of Latin American and Caribbean States (CELAC), which has enabled it to address conflicts and promote regional cooperation.

The negotiation of bilateral and multilateral agreements plays a fundamental role in international relations and in promoting peace and cooperation at a global level. These negotiations allow countries to make progress on a variety of issues, from trade and investment to security and conflict resolution. The importance of negotiating bilateral and multilateral agreements is argued below:

- Bilateral and multilateral agreements provide a framework to resolve disputes and conflicts between nations peacefully. Negotiating these agreements allows countries to address challenges and tensions constructively, contributing to international peace and stability.
- Bilateral and multilateral trade agreements foster economic cooperation by removing trade barriers, promoting investment, and stimulating economic growth. This benefits countries by creating business opportunities and jobs.
- Multilateral agreements are essential to address global issues such as climate change, nuclear proliferation, and the fight against the pandemic. These agreements allow nations to coordinate their efforts and address challenges that transcend national borders.
- The negotiation of bilateral and multilateral agreements involves constant dialogue between countries. This dialogue strengthens diplomatic relations and facilitates communication in times of crisis or tension.
- Boosting trust and predictability: Agreements establish clear rules and mutual expectations between countries. This fosters trust and predictability in international relations, which is essential for long-term stability and cooperation.

Mediation in regional conflicts is a valuable tool in international diplomacy since it can play an essential role between countries or regional actors. By intervening early in a dispute and facilitating dialogue between the parties, mediators can help prevent disagreements from escalating into armed conflict [2]. Mediation encourages diplomacy and dialogue as a means to address problems. Instead of resorting to violence, conflicting parties can sit down to negotiate under the impartial supervision of a mediator, leading to peaceful solutions.

Dispute resolution helps create an environment of greater trust and collaboration in political, economic, and security matters. Successful mediation in regional conflicts can contribute to long-term stability. Agreements reached through mediation tend to be more sustainable and lasting than solutions imposed or resulting from armed conflicts. After regional conflicts, mediation can facilitate reconciliation and reconstruction. It helps lay the foundation for sustainable peace and long-term cooperation [3].

Participation in international organizations is essential for the diplomacy and foreign policy of a country. It provides a platform for cooperation, conflict resolution, coordination of efforts, and the establishment of global norms, and offers the opportunity to influence international affairs and promote the well-being of its citizens [4].

1. Promotion of international cooperation: Promotes cooperation and dialogue between nations. These organizations offer a space where countries can meet, discuss common issues, and seek joint solutions.
2. Conflict Resolution: Many international organizations have established mechanisms and processes for the peaceful resolution of conflicts. Participation in these organizations allows countries to seek mediation and diplomatic solutions rather than resorting to violence.
3. Coordination of efforts: On global issues such as climate change, the fight against poverty, public health, and international security, international organizations allow countries to coordinate their efforts and resources to address challenges that transcend national borders.
4. Setting norms and standards: International organizations play a critical role in setting norms and standards in a wide range of areas, from trade to human rights. This creates a regulatory framework that facilitates trade, investment, and cooperation in multiple sectors.
5. Trade facilitation: Participation in organizations such as the World Trade Organization (WTO) and regional trade agreements facilitates international trade, which benefits the country's economy and its citizens.
6. Strengthening voice and influence: Participation in international organizations provides a country with a platform to express its opinion and exert influence on international affairs. This is particularly relevant for smaller countries, as it allows them to have a role in global decision-making.
7. Knowledge exchange: Participation in international organizations allows the exchange of knowledge, experiences, and best practices between countries. This can be beneficial for policy development and improved governance at the national level.

Actions Ecuador could consider taking:

- ✓ Greater investment in diplomatic training: Ecuador could strengthen its diplomatic capacity through the education and training of diplomats, which would improve its capacity for negotiation and mediation in conflicts.
- ✓ Fostering regional cooperation: Given its geographical role in South America, Ecuador could intensify cooperation with neighboring countries and regional organizations to address common challenges and prevent conflicts.
- ✓ Promoting preventive diplomacy: Ecuador could adopt a strategy of preventive diplomacy, anticipating potential conflicts and working on early mediation to avoid crises.
- ✓ Greater involvement of civil society: The inclusion of civil society in decision-making processes and conflict resolution could improve the representativeness and effectiveness of solutions.
- ✓ Greater transparency in international negotiations: Promote transparency and accountability in international negotiations to gain the trust of the international community and the public at home.

The Cenepa war between Ecuador and Peru is a prominent example of the importance of diplomacy in conflict resolution. Mediation by international actors, such as the OAS, resulted in the Itamaraty Peace Agreement in 1995, which ended the conflict and established a definitive border. The Montecristi Constitution of 2008 represented a milestone in Ecuadorian politics. Diplomacy and dialogue played an essential role in the negotiation of this new Constitution, which addressed internal issues and significant reforms [5].

To resolve a conflict in international matters, it is essential to verify under which system of rules the State or States in dispute will fall under. In addition, there are difficulties in implementing conflict resolution methods due to the presence of a fragmented international legal system and the existence of several competent bodies.

The peace summits have produced a decrease in conflicts due to the promotion of the culture of legal equality and the self-determination of peoples. Despite this, they also indicate that the powers assigned to international organizations by the sovereign interests of the States began to be questioned, compared to the systemic design based on liberal and democratic principles with the right to self-determination of peoples.

The only two Latin American countries that maintain stronger tensions due to a past armed conflict are Bolivia and Chile. These maintain stereotypes about each other, which can affect the negotiation processes, the only possible way to solve the endemic problems in the region. These consequences affect not only the international trade that exists between both countries, and its economic implication, but above all the well-being of the populations of both regions that must carry out joint activities [6, 13].

It's worth noting that among the normative guarantees for the maintenance of peace, the United Nations Charter stands at the forefront. This mentions the methods that States must resort to in order to resolve situations that may endanger international peace and security, among which stand out negotiation, investigation, mediation, conciliation, arbitration, judicial settlement, resort to regional bodies or agreements, or other peaceful means of their choice [3, 12].

The political factors raised within the territory have produced local disturbances and tensions that have very short-term solutions since the sectors' claim lies in the lack of government protection. As long as the affected population does not feel satisfied, the riots will continue and may intensify. Thus, Ecuador must be concerned about a culture of peace attached to human rights beyond paper.

Ecuador should have a permanent table for dialogue and negotiations under the same guarantees of public international law, with historically vulnerable groups. To this end, effective compliance with human rights is guaranteed and, thus, conflicts would be reduced.

The way foreign policy is developed is independent in each country and depends on the gains each seeks to satisfy its specific needs. However, the most powerful countries in the international system aim to project their power by having a foreign policy centered around their military power.

General objective:

Analyze the role of international diplomacy in conflict resolution in Ecuador, considering its historical and current context, and evaluate its impact on the stability of the country and the region.

Specific objectives:

- Examine the historical context of international diplomacy in Ecuador and identify the antecedents of border conflicts.
- Analyze specific cases to evaluate how international diplomacy has contributed to the resolution of conflicts at the national and regional levels.

- Assess current and future challenges in Ecuador's diplomatic relations, focusing on regional cooperation and international crisis management.

2 Method

2.1 Neutrosophic AHP

The Analytical Hierarchical Process (AHP) was proposed by Thomas Saaty in 1980 [7]. It is one of the most widespread methods for solving multi-criteria decision-making problems. This technique models the problem leading to the formation of a hierarchy representative of the associated decision-making scheme. This hierarchy presents at the upper level the objective pursued in solving the problem and at the lower level the different alternatives from which a decision must be made are included. The intermediate levels detail the set of criteria and attributes considered. For the description of the method it is necessary to present the following definitions [8, 9, 11, 15, 16]:

Definition 1: The Neutrosophic [10] 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 $-0 \le \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \le \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \le 3^+$. 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 $A = \{<x; T_A(x), I_A(x), F_A(x)>: x \in U\}$a, where $T_A: U \to [0, 1]$, $I_A: U \to [0, 1]$, and $F_A: U \to [0, 1]$, $0 \le T_A(x) + I_A(x) + F_A(x) \le 3$. The Single-Valued Neutrosophic Number (SVNN) is represented by N = (t, I, f), such that $0 \le t, i, f \le 1$ and $0 \le t+i+f \le 3$.

Definition 3: 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:

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

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

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

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:

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

Definitions 3 and 4 refer to single-valued triangular neutrosophic numbers when the condition $a_2 = a_3$. For simplicity, we use the linguistic scale of triangular neutrosophic numbers, see Table 1 and also compare with the scale defined in. The hierarchical analytical process was proposed by Thomas Saaty in 1980 [7-14]. 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 level. At the lowest level, the decision options are understood. The levels of importance or weighting of the criteria are estimated using paired comparisons between them. This comparison is carried out using a scale, as expressed in equation (6)

$$S = \left\{\frac{1}{9}, \frac{1}{7}, \frac{1}{5}, \frac{1}{3}, 1,3,5,7,9\right\} \tag{5}$$

We can add the neutrosophic theory to the AHP technique in order to create a neutrosophic framework. Thus, we can model the indeterminacy of decision-making by applying neutrosophic AHP or NAHP for short. Equation 7 contains a generic neutrosophic pair-wise comparison matrix for NAHP.

$$\widetilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \tag{6}$$

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

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

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{7}$$

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

Table 1: Saaty's scale translated to 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	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$
		$\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$
		$\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$
		$\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

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 6.

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 9 and 10. To get the score and the accuracy degree of $\tilde{a}_{ji}$ the following equations are used:

$$S(\tilde{a}_{ji}) = 1/S(\tilde{a}_{ij}) \tag{9}$$

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

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

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \tag{11}$$

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 calculus 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 the equation:

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n-1} , \tag{12}$$

where n is the order of the matrix. In addition, the *Consistency Ratio* (CR) is defined by equation:

$$CR = \frac{CI}{RI} \tag{13}$$

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≤0.1 we can consider that the experts' evaluation is sufficiently consistent and hence we can proceed to use NAHP. We apply this procedure to matrix "*A"* in Equation 12.

3 Results

The experts classified six factors that can negatively influence diplomacy and conflict resolution, to analyze the challenges that may arise in this area.

1. Economic interests (F1)
2. Distrust (F2)
3. Excessive nationalism (F3)
4. Internal policy (F4)
5. Pressure from external actors (F5)
6. Shortage of diplomatic resources (F6)

With the Neutrosophic AHP method, the weights of the factors that can act as obstacles to diplomacy and conflict resolution on which they will rely to apply focused procedures to measure ambiguity in public opinions about the effectiveness of diplomacy in conflict resolution and expectations.

Table 3: Neutrosophic AHP paired matrix.

Factors	F1	F2	F3	F4	F5	F6
F1	1	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(6,7,8);0.90,0.10,0.10⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(2,3,4);0.30,0.75,0.70⟩
F2	⟨(1,1,1);0.50,0.50,0.50⟩	1	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(2,3,4);0.30,0.75,0.70⟩
F3	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(1,1,1);0.50,0.50,0.50⟩	1	⟨(6,7,8);0.90,0.10,0.10⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(2,3,4);0.30,0.75,0.70⟩
F4	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(6,7,8);0.90,0.10,0.10⟩	1	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(1,2,3);0.40,0.65,0.60⟩
F5	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(1,1,1);0.50,0.50,0.50⟩	1	⟨(2,3,4);0.30,0.75,0.70⟩
F6	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(1,2,3);0.40,0.65,0.60⟩	⟨(2,3,4);0.30,0.75,0.70⟩	1
Sum	1.00	1.00	1.00	1.00	1.00	1.00

Table 4: Determination of weights of the criteria applying the Neutrosophic AHP method

Factors	F1	F2	F3	F4	F5	F6	Weight
F1	0.06	0.08	0.06	0.05	0.07	0.03	0.06
F2	0.06	0.08	0.06	0.07	0.07	0.24	0.10
F3	0.06	0.08	0.06	0.05	0.07	0.03	0.06
F4	0.31	0.38	0.39	0.37	0.34	0.39	0.36
F5	0.31	0.38	0.28	0.37	0.34	0.24	0.32
F6	0.19	0.03	0.17	0.07	0.11	0.08	0.11

Table 5: Analysis of the consistency of the paired matrix.

Factors		Approximate eigenvalues	
F1	0.36	6.35247098	Eigenvalue
F2	0.67	7.008398082	
F3	0.36	6.35247098	6.4668596
F4	2.38	6.538487714	
F5	2.05	6.426219636	CI - 0.09
F6	0.66	6.123110376	RC-0.07 <= 0.10

From the consistency analysis, it is found that the modeling meets the parameters, obtaining that its eigenvalue is 6.40, CI=0.09, and RC=0.07.

After analyzing the factors, it was determined that internal politics has greater weight in determining the country's ability to carry out effective diplomacy. For this, the experts proposed possible solutions. These solutions can contribute to a more effective approach to diplomacy and conflict resolution in Ecuador, promoting peace, stability, and cooperation both nationally and internationally. The application of these measures must be adapted to the specific circumstances of each situation and consider individual challenges and opportunities.

1. Strengthening preventive diplomacy: Promote preventive diplomacy as a proactive approach to identifying and addressing potential conflicts before they escalate. This could involve early mediation, dialogue, and collaboration between neighboring nations and international actors.
2. Diplomatic capacity development: Invest in the education and training of Ecuadorian diplomats, including negotiation and mediation skills. Strengthening the diplomatic corps can improve the country's ability to represent itself effectively on the international stage.
3. Promote regional cooperation: Strengthen cooperation with neighboring countries and regional organizations. Regional cooperation can play a key role in conflict prevention and dispute resolution.
4. Promoting conflict resolution education: Promote education and public awareness of conflict resolution and diplomacy as peaceful means to address challenges. This may include educational programs, seminars, and awareness campaigns.
5. Transparency and accountability: Promote transparency in diplomatic negotiations and accountability in the implementation of agreements. This will help build trust in international relations.
6. Civil society participation: Include civil society in the process of conflict resolution and diplomacy. The participation of non-state actors can enrich perspectives and solutions.
7. Monitoring and early warning: Establish monitoring and early warning systems to detect possible tensions and conflicts in the region and take timely preventive measures.
8. International mediation: Promote international mediation in cases of complex conflicts. Impartial third-party mediation can help facilitate communication and dispute resolution.

Conclusion

International diplomacy has been a determining factor in the resolution of conflicts in Ecuador, both nationally and internationally. The country's history shows that, through agreements, mediations, and treaties, it is possible to avoid destructive conflicts and promote cooperation. However, current and future challenges will require continued focus on diplomacy and international collaboration to maintain peace and stability in Ecuador and the region.

International diplomacy and conflict resolution in Ecuador are crucial areas that require innovative approaches and analytical tools such as the neutrosophic AHP to address the complexity of international relations and the country's internal challenges. The application of this methodology can contribute to a better understanding and management of conflicts in Ecuador, promoting peace and stability in the region.

Despite past achievements, Ecuador still faces challenges in its diplomacy, especially in the context of relations with neighboring countries and international crisis management. Diplomacy and international cooperation are crucial to maintaining peace and stability in the country and the region. The history of diplomacy in Ecuador serves as a reminder of the continued importance of this tool in an interconnected world.

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University of New Mexico

Neutrosophic Evaluation of Healthcare System Resilience

Elsy Labrada González[1], Marcia Alexandra Silva Mata[2], Carlos Valverde González[3], and Juan Antonio Arrunátegui Aguirre[4]

[1] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.elsylabrada@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.marciasilva@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.carlosvalverde@uniandes.edu.ec
[4] Universidad Nacional Mayor de San Marcos, Perú. E-mail: jarrunateguia@unmsm.edu.pe

Abstract. Currently, the resilience of the healthcare system in Ecuador is at the forefront of attention due to the need to address crises such as pandemics, natural disasters, and economic crises. Therefore, this study has focused on evaluating six proposed programs aimed at enhancing the resilience of the Ecuadorian healthcare system and selecting the best proposal to protect the health and well-being of communities in Ecuador. The evaluated programs aim to enhance the system's capacity for adaptation, preparedness, and response to crises and disruptions. Due to existing indeterminacies in assessing the resilience of the healthcare system for each program, the application of the neutrosophic VIKOR method is necessary. The results emphasize the need to diversify approaches to strengthen resilience, including the formation of multidisciplinary teams and the enhancement of Ecuador's public health response capacity. In conclusion, the modeling of the neutrosophic method has been essential for assigning weights and evaluating the proposed programs. Furthermore, strengthening the resilience of the healthcare system in Ecuador is crucial to ensure effective and equitable medical care during times of crises and future challenges.

Keywords: Resilience, neutrosophy, health crises, healthcare system.

1 Introduction

The resilience of the health system has become a topic of increasing relevance today, especially in the Ecuadorian context. In recent years, Ecuador has faced significant challenges, such as pandemics, natural disasters, and economic crises [1]. The ability of a health system to adapt, prepare, and respond effectively to crises and disruptions has become a critical indicator of its quality and efficiency [2].

After Covid 19, evaluating the resilience of the health system has become a fundamental objective to understand its capabilities and weaknesses, as well as to identify areas for improvement in the public health and well-being of Ecuadorian communities. Therefore, this process should not be understood as a static characteristic, but as a dynamic process of rapid response to unforeseen events. To understand this concept in depth, it is necessary to analyze the following key components:

- Adaptive capacity: Health system resilience implies the ability to adapt to changes and disruptions efficiently and effectively. This may include flexibility to adjust resources, policies, and procedures based on changing population needs and circumstances [3].
- Preparation and planning: Preparation is essential for resilience. This involves creating contingency plans, identifying potential risks, and investing in emergency infrastructure and resources. Health systems must be prepared to face a variety of scenarios, from pandemics to natural disasters.
- Coordination and collaboration: Collaboration between various stakeholders, such as hospitals, clinics, government agencies, aid organizations, and the community in general, is essential for resilience. The ability to coordinate efforts and resources in times of crisis can make a significant difference in the system's capacity to withstand adverse situations.
- Evaluation and continuous learning: Health system resilience implies the ability to learn from past experiences and critical evaluations. This allows for constant improvement and adaptation to new threats. Self-assessment and feedback are essential in this process.
- Equity and access: A truly resilient healthcare system must be equitable in the delivery of services and access to healthcare. Equity ensures that all populations, regardless of their ethnic background, socioeconomic status, or geographical location, have access to quality services and care in times of crisis.

- Effective communication: Transparent and effective communication with the public is essential to maintain trust in the health system. Lack of accurate and timely information can undermine crisis response and jeopardize system resilience.

Among the events that occurred with the emergence of the COVID-19 pandemic, it has been highlighted that Ecuadorian health systems faced unprecedented challenges and difficulties [4] [5-15]. Therefore, it is necessary to work through preparedness programs to promote and enhance the resilience of the healthcare system in Ecuador [6]. These programs should prepare the Ecuadorian healthcare system to quickly adapt to new circumstances and reallocate resources. This will enable them to develop effective treatment protocols and maintain open communication with the public. Thus, the main objective of this study is to focus on this matter:

- ❖ Evaluate six program proposals focused on enhancing the resilience of the Ecuadorian health system and select the best proposal in order to protect the health and well-being of communities in Ecuador.

Due to the variety of criteria and indetermination provided in the evaluations, it is necessary to proceed through an analysis using the neutrosophic VIKOR method. Through this methodology, the key uncertainties in the selection of the best alternative are analyzed. It is essential in the neutrosophic evaluation that the selected proposal includes indeterminacy as part of the multiple elements that can impact the resilience of the Ecuadorian health system. Therefore, the following specific objectives are determined:

- ❖ Analyze the six proposals for programs focused on enhancing the resilience of Ecuadorian health systems.
- ❖ Select the most important proposal to enhance the resilience of the Ecuadorian health system, through the analysis of the VIKOR neutrosophic method.

2 Materials and methods

2.1 Neutrosophic VIKOR

The Neutrosophic VIKOR method provides one or several compromise solutions for a set of alternatives. The compromise solution obtained includes indeterminacy as part of the result of the analyzed problem. The Neutrosophic VIKOR method is suitable for solving decision problems with conflicting and non-commensurable criteria by using single-valued neutrosophic units. The compromise solution is determined as the one closest to the ideal solution. To implement the method, it is proposed to define the neutrosophic decision matrix (see Figure 1).[7-16]

Figure 1. Neutrosophic decision matrix. Source: own elaboration based on [7-10].

$$
\begin{array}{ccc}
 & & \begin{array}{cccccc} k_{Q1} & k_{Q2} & \dots & k_{Qj} & \dots & k_{Qn} \\ w_1 & w_2 & \dots & w_j & \dots & w_n \end{array} \\
 & \boldsymbol{F_j} & \begin{array}{cccccc} Min & Max & \dots & \dots & \dots & \dots \end{array} \\
\begin{array}{c} \boldsymbol{Max\,V_i} \\ \\ \\ \boldsymbol{Min\,V_i} \end{array} & \begin{array}{c} T_1 \\ T_2 \\ \vdots \\ T_i \\ \vdots \\ T_m \end{array} & \begin{bmatrix} m_{11} & m_{12} & \dots & m_{1j} & \dots & m_{1n} \\ m_{21} & m_{22} & \dots & m_{2j} & \dots & m_{2n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ m_{i1} & m_{i2} & \dots & m_{ij} & \dots & m_{in} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ m_{m1} & m_{m2} & \dots & m_{mj} & \dots & m_{mn} \end{bmatrix} \\
 & \boldsymbol{f^*_{Qi}} & \begin{array}{cccccc} m_{i1} & m_{22} & \dots & \dots & \dots & \dots \end{array} \\
 & \boldsymbol{f^-_{Qi}} & \begin{array}{cccccc} m_{11} & m_{i2} & \dots & \dots & \dots & \dots \end{array}
\end{array}
$$

Before analyzing the neutrosophic decision matrix of the method, the neutrosophic set must be defined. The neutrosophic set is defined by the following elements: true ϑ, indeterminate η, and false δ of x in Q, respectively and their images constitute standard or non-standard subsets within the range $\{0,1\}$. For X of the universe of discourse, it is defined from the single-valued neutrosophic set Q over X as an object in the representation $Q = \{\langle x, \vartheta_A(x), \eta_A(x), \delta_A(x)\rangle : x \in X\}$.

Where $\vartheta_A(x), \eta_A(x), \delta_A(x)$ satisfy the following condition $0 \leq \vartheta_A(x), \eta_A(x), \delta_A(x) \leq 3$ for all $x \in X$. So, to define each neutrosophic number, it is expressed in the following way h, i, j for modeling the Neutrosophic VIKOR method. Therefore, the following functions are defined:

$h = \vartheta_A(x)$ for true membership functions, where ∈ {0,1}.
$i = \eta_A(x)$ for indeterminacy membership functions, where ∈ {0,1}.
$j = \delta_A(x)$ for false membership functions, where ∈ {0,1}.

Therefore, the neutrosophic number defined for the study is determined as $Q = (h, i, j)$, where h, i, j ∈ {0,1} and satisfy the following condition $0 \leq h + i + j \leq 3$. In this way, the scoring function B for a neutrosophic number is defined as the following equation:

$$B(Q) = \frac{1 + h - 2i - j}{2} \tag{1}$$

Analysis of the elements of the neutrosophic decision matrix:

Decision criteria $K_Q = K_{Q1}, K_{Q2}, K_{Qj}, \dots, K_{Qn}$ can be defined as the conditions or parameters that allow discriminating alternatives and establishing important preferences of the decision-maker. The decision-making criteria for each alternative are evaluated based on the linguistic terms in single-valued neutrosophic numbers (SVNN) according to the scales shown in Table 1.

Table 1: Linguistic terms that represent the weight of the importance of alternatives. Source: own elaboration based on [7-10].

Linguistic scale	SVNN(h, i, j)
Very high (VH)	(0.95,0.05,0.05)
High (H)	(0.8,0.15,0.1)
Medium (M)	(0.5,0.4,0.5)
Low (L)	(0.45,0.6,0.85)
Very low (VL)	(0.25,0.75,0.95)

The weights or weightings constitute measures of the neutrosophic importance that the criteria have for the decision maker. Associated with the criteria, a vector of weights $(w_Q) = (w_{Q1}, w_{Q2} \dots w_{Qj} \dots w_{Qn})$ is assigned, where w ∈ with n as the number of criteria of the linguistic terms used (SVNN). The weight reflects the importance of the criterion in each decision of the neutrosophic set and is assumed positive. To assign weights by criterion, the direct assignment method or the eigenvector method can be applied (see Table 2).

Table 2: Linguistic terms that represent the weight of importance for(w_Q). Source: own elaboration based on [7-10].

Linguistic scale	SVNN(h, i, j)
Very Important (VI)	(0.9;0.1;0.1)
Important (I)	(0.75;0.25;0.20)
Medium (M)	(0.50;0.5;0.50)
Not Important (NI)	(0.35;0.75;0.80)
Very Not Important (VNI)	(0.10;0.90;0.90)

Each set of alternatives T are different, exclusive, and exhaustive alternatives that are represented as $T = \{t_1, t_2, \dots, t_n\}$, where $T \epsilon m$ $(i = 1, 2, \dots, m)$ as the number of each of the possible alternatives.

The assessment or decision matrix is defined once the criteria and their weights associated with the linguistic term used (SVNN) have been established. The decision-maker can give, for each of the criteria considered and for each alternative of the neutrosophic set of choice, an SVNN or symbolic Q_{ij} value that expresses an evaluation or judgment of the alternative T_i with respect to the criterion k_j. This neutrosophic evaluation can be represented in the form of a matrix, evaluation, or decision matrix. Each row of the matrix expresses qualities of the alternative T_i with respect to the n criteria considered. Each column of the matrix collects the evaluations or judgments issued by the decision maker of all the alternatives with respect to the criterion k_j. Therefore, to obtain the compromise solution (or solutions), one must:

I. Calculate the f^*_{Qi}, and the worst f^-_{Qi}, values of each criterion.

$f^*_{Qi} = max_i f_{Qij}$	$f^-_{Qi} = min_i f_{Qij}$	If function i represents a benefit
$f^*_{Qi} = min_i f_{Qij}$	$f^-_{Qi} = max_i f_{Qij}$	If function i represents a cost

II. Calculate the values S_{Qj}, R_{Qj} and P_{Qj} for each alternative:

$$S_{Qj} = \sum_{i=1}^{n} w_{Qj} \frac{f_{Qi}^{*} - f_{Qij}}{f_{Qi}^{*} - f_{Qi}^{-}} \tag{2}$$

$$R_{Qj} = max_i \left\{ w_{Qj} \frac{f_{Qi}^{*} - f_{Qij}}{f_{Qi}^{*} - f_{Qi}^{-}} \right\} \tag{3}$$

$$P_{Qj} = v \frac{S_{Qj} - S_{Q}^{*}}{S_{Q}^{-} - S_{Q}^{*}} + (1 - v) \frac{R_{Qj} - R_{Q}^{*}}{R_{Q}^{-} - R_{Q}^{*}} \tag{4}$$

Where:

$$S_{Q}^{*} = min_j\, S_{Qj};\; S_{Q}^{-} = max_j\, S_{Qj}$$
$$R_{Q}^{*} = min_j\, R_{Qj};\; R_{Q}^{-} = max_j\, R_{Qj} \tag{5}$$

And v is introduced as a weight of the group's maximum utility strategy, while $(1 - v)$, is the weight of the individual opposition.

- $v > 0.5$ *Majority vote*
- $v \sim 0.5$ *Consensus vote*
- $v < 0.5$ *Veto vote*

III. The alternatives are ordered, according to the values of S_Q, R_Q and P_Q (see Figure 2)

Figure 2. Matrix according to the values of S_Q, R_Q and P_Q. Source: own elaboration based on [7-10].

$$\begin{bmatrix} S_{Q1} \\ S_{Q2} \\ \vdots \\ S_{Qj} \\ \vdots \\ S_{Qm} \end{bmatrix} \begin{bmatrix} R_{Q1} \\ R_{Q2} \\ \vdots \\ R_{Qj} \\ \vdots \\ R_{Qm} \end{bmatrix} \begin{bmatrix} P_{Q1} \\ P_{Q2} \\ \vdots \\ P_{Qj} \\ \vdots \\ P_{Qm} \end{bmatrix}$$

IV. Determine as a compromise solution the alternative $T_b^{(1)}$ that is the best classified according to the value of P_b (according to equation 1), that is, with the value of $P_{b\,min}$, if the following two conditions are satisfied:

a. Condition 1: Acceptable advantage.
$P_b\left(T_b^{(2)}\right) - P_b\left(T_b^{(1)}\right) \geq DP_b$,
Where $T_b^{(2)}$ is the second alternative according to the classification of the values of P_b, and $DP_b = \frac{1}{N-1}$, with N as the number of alternatives.

b. Condition 2: Acceptable stability in the decision process.
The alternative $T_b^{(1)}$ must be the best classified according to the list of values of S_b and/or R_b, this is the stable compromise solution within a decision process.
If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

- Alternatives $T_b^{(1)}$ and $T_b^{(2)}$ if condition 2 is not satisfied.
- Alternatives $T_b^{(1)}, T_b^{(2)}, \ldots, T_b^{(m)}$ and if condition 1 is not satisfied; $T_b^{(m)}$ is determined by taking into account the relationship $T_b^{(m)}$. These alternatives are considered to be close to the ideal solution.

3 Results

Below are six programs designed to enhance the resilience of the healthcare system in Ecuador. These programs address various dimensions of resilience, including adaptability, preparedness, coordination, and equity in healthcare service delivery (See Tables 3 to 8). Each program is described in terms of its impact (C1), benefits (C2), recovery time (C3), regional scope (C4), and preparation and training (C5). The criteria or elements classified from C1 to C5 define the conditions or parameters that help define the alternatives and establish the decision maker's importance preferences.

Table 3: Formation of multidisciplinary disaster response teams. Source: own elaboration.

Program 1	**Formation of multidisciplinary disaster response teams**
Aspect	**Detail**
Impact	This program has a high impact on improving the resilience of the health system in Ecuador. By forming multidisciplinary teams trained to respond to disasters, the capacity to respond to catastrophic events is strengthened, reducing human and material losses.
Benefits	• Improvement of the healthcare system's preparedness and response to natural disasters and catastrophic events. • Reduction of human and material losses. • Enhanced coordination among various institutions and stakeholders. • Strengthening public trust in the healthcare system.
Recovery time	The benefits of this program become evident in the medium term, approximately within 2-3 years.
Regional scope	The program has a national scope, with an emphasis on disaster-prone areas in Ecuador.
Preparation and Training	• To successfully implement this program, a significant investment in training and resource development is required. Training centers must be established and resources and equipment necessary for the formation of multidisciplinary teams should be provided. In addition, collaboration between different institutions and disaster response organizations must be promoted. • Training is a crucial component of this program. Health professionals and other members of multidisciplinary teams should receive specialized training in disaster management, response protocols [11-17], coordination, and communication in emergencies. Ongoing training and simulation exercises are essential to maintain team readiness.

Table 4: Strengthening public health response capacity. Source: own elaboration.

Program 2	**Strengthening of public health response capacity**
Aspect	**Detail**
Impact	This program has a significant impact on improving the resilience of the health system in Ecuador. By strengthening public health response capacity, the spread of diseases can be more efficiently controlled and critical resources managed.
Benefits	• Enhanced control of disease outbreaks. • Reduction in the spread of infectious diseases [12-18]. • Improved management of health resources.
Recovery time	The results of this program would be visible in the short term, with effective implementation in one year.
Regional scope	The scope of this program would be the entire country.
Preparation and training	• To implement this program, an initial investment in infrastructure would be required, as well as the training of health personnel in the management of public health emergencies. • Training would be essential to train health personnel in epidemiology and the management of outbreaks and health emergencies [13-19].

Table 5: Development of telemedicine and telehealth strategies. Source: own elaboration.

Program 3	**Development of telemedicine and telehealth strategies**
Aspect	**Detail**
Impact	This program has a significant impact on improving the resilience of the health system in Ecuador, as it facilitates access to health care, especially in rural and remote areas.
Benefits	• Expansion of health care coverage. • Better control of chronic diseases. • Reduction of geographical barriers
Recovery time	The results of this program would be visible in the medium term, with effective implementation in 2-3 years.
Regional scope	The scope of this program would be national, with a special focus on rural and remote areas.
Preparation and training	It requires investment in information technology infrastructure and staff training in telemedicine. Health professionals would need training in the use of telemedicine technologies.

Table 6: Implementation of advanced public health surveillance systems. Source: own elaboration.

Program 4	**Implementation of advanced public health surveillance systems**
Aspect	**Detail**
Impact	This program has a significant impact on improving the resilience of the health system in Ecuador. By implementing advanced public health surveillance systems, early detection of disease outbreaks and public health threats is improved.
Benefits	• Faster response to disease outbreaks. • Reduction in the spread of diseases. • Better health resource planning
Recovery time	The benefits of this program would be visible in the short and medium term, with effective implementation in 2-3 years.
Regional scope	The program has a national scope, with an emphasis on areas with high population density.
Preparation and Training	To implement this program, investment in technology and training in epidemiology is required. Health Professionals would need training in advanced epidemiological surveillance.

Table 7: Promotion of inclusive public health policies. Source: own elaboration.

Program 5	**Promotion of inclusive public health policies**
Aspect	**Detail**
Impact	This program has a significant impact on improving the resilience of the healthcare system in Ecuador by promoting equity in healthcare.
Benefits	• Reduction of disparities in healthcare. • Improved health of disadvantaged populations. • Strengthening social cohesion.
Recovery time	The benefits of this program become evident in the long term, with effective implementation in 3-5 years.
Regional scope	The program has a national scope, with special emphasis on areas with health inequalities.
Preparation and training	• It requires the development of inclusive policies and awareness programs. • Training of health professionals in culturally sensitive care is needed.

Table 8: Establishment of research centers in health resilience. Source: own elaboration.

Program 6	**Establishment of research centers in health resilience**
Aspect	**Detail**
Impact	This program has a high impact by facilitating research and development of best practices in health resilience.
Benefits	• Data-driven evidence generation. • Healthcare innovation. • Knowledge dissemination
Recovery time	The benefits of this program become evident in the long term, with effective implementation in 3-5 years.
Regional scope	The program has a national scope, with the potential for international collaboration.
Preparation and training	• Requires investment in research and development infrastructure. • Training of researchers and professionals in health research methods is needed.

Each program has its own set of impact, benefits, recovery time, regional scope, preparation, and training. The choice of the most relevant program depends on the specific priorities and needs of the healthcare system in Ecuador, as well as the available resources. The programs contribute to improving the resilience of the healthcare system from different perspectives. Once the programs are defined, the next step is to select the best proposal through the analysis of the Neutrosophic VIKOR method.

Development of the Neutrosophic VIKOR method

The first step in the development of the method is to define the weights of each criterion according to the scale in Table 2. Then, the assessment of each alternative for each criterion is carried out according to Table 1. This results in a ranking of alternatives, and thus, the determination of the compromise solution or solutions (see Tables 9 to 12). These solutions constitute the most suitable programs to enhance the resilience of the Ecuadorian healthcare system.

Table 9: Neutrosophic normalization of the decision matrix. Source: own elaboration.

	C1	C2	C3	C4	C5
Weight	**(0.75;0.25;0.20)**	**(0.35;0.75;0.80)**	**(0.10;0.90;0.90)**	**(0.9;0.1;0.1)**	**(0.75;0.25;0.20)**
fj	**Max**	**Max**	**Min**	**Max**	**Max**
P1	(0.95,0.05,0.05)	(0.8,0.15,0.1)	(0.25,0.75,0.95)	(0.95,0.05,0.05)	(0.95,0.05,0.05)
P2	(0.95,0.05,0.05)	(0.95,0.05,0.05)	(0.45,0.6,0.85)	(0.8,0.15,0.1)	(0.8,0.15,0.1)
P3	(0.8,0.15,0.1)	(0.45,0.6,0.85)	(0.95,0.05,0.05)	(0.5,0.4,0.5)	(0.5,0.4,0.5)
P4	(0.5,0.4,0.5)	(0.25,0.75,0.95)	(0.8,0.15,0.1)	(0.45,0.6,0.85)	(0.45,0.6,0.85)
P5	(0.45,0.6,0.85)	(0.95,0.05,0.05)	(0.5,0.4,0.5)	(0.95,0.05,0.05)	(0.25,0.75,0.95)
P6	(0.45,0.6,0.85)	(0.95,0.05,0.05)	(0.45,0.6,0.85)	(0.8,0.15,0.1)	(0.5,0.4,0.5)
Betterf_{Qi}^{*}	(0.95,0.15,0.1)	(0.95,0.15,0.1)	(0.25,0.9,0.95)	(0.95,0.15,0.1)	(0.95,0.3,0.25)
Worsef_{Qi}^{-}	(0.45,0.9,0.95)	(0.25,0.4,0.5)	(0.95,0.15,0.1)	(0.45,0.85,0.75)	(0.25,0.9,0.95)

Table 10: Measurement of utility S_{Qj} and regret R_{Qj} for each program. Source: own elaboration.

Program	C1	C2	C3	C4	C5	S_j	R_j
P1	(0,0,0)	(0.04,0.03,0.01)	(0,0,0)	(0,0,0)	(0,0,0)	(0.04,0.03,0.01)	(0.04,0.03,0.01)
P2	(0,0,0)	(0,0,0)	(0.04,0.03,0.02)	(0.09,0.05,0.02)	(0.02,0.01,0.01)	(0.15,0.09,0.05)	(0.09,0.05,0.02)
P3	(0.08,0.05,0.02)	(0.14,0.16,0.18)	(0.15,0.15,0.15)	(0.27,0.19,0.17)	(0.06,0.05,0.05)	(0.7,0.6,0.57)	(0.27,0.19,0.18)
P4	(0.23,0.16,0.14)	(0.2,0.2,0.2)	(0.12,0.13,0.14)	(0.3,0.3,0.3)	(0.07,0.08,0.09)	(0.92,0.87,0.87)	(0.3,0.3,0.3)
P5	(0.25,0.25,0.25)	(0,0,0)	(0.05,0.08,0.08)	(0,0,0)	(0.1,0.1,0.1)	(0.4,0.43,0.43)	(0.25,0.25,0.25)
P6	(0.25,0.25,0.25)	(0,0,0)	(0.04,0.03,0.02)	(0.09,0.05,0.02)	(0.06,0.05,0.05)	(0.44,0.38,0.34)	(0.25,0.25,0.25)

Table 11: Index P_{Qj} of each program. Source: own elaboration.

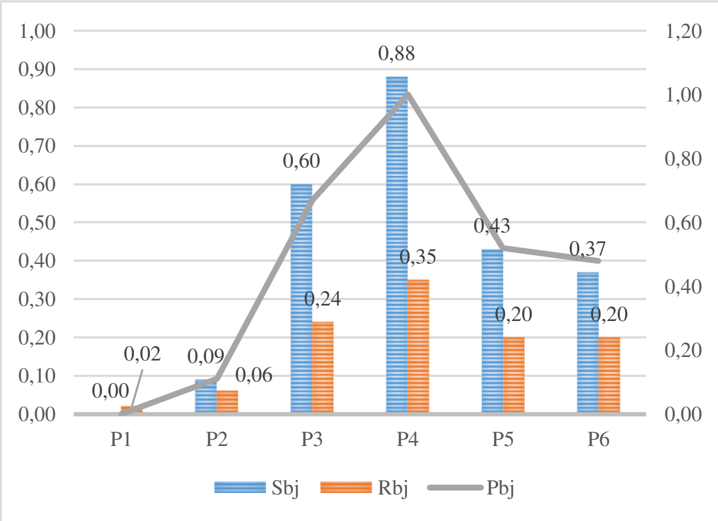
Program	S_{Qj}	R_{Qj}	v	P_{Qj}	Hierarchy	
P1	(0.04,0.03,0.01)	(0.04,0.03,0.01)	0.5	(0.71,0.64,0.62)	4	For the classification of the alternatives, evaluation is made for a v ~ 0.5 (Vote by consensus)
P2	(0.15,0.09,0.05)	(0.09,0.05,0.02)		(0.38,0,0)	1	
P3	(0.7,0.6,0.57)	(0.27,0.19,0.18)		(0.71,0.64,0.62)	4	
P4	(0.92,0.87,0.87)	(0.3,0.3,0.3)		(1,1,1)	6	
P5	(0.4,0.43,0.43)	(0.25,0.25,0.25)		(0.02,0.53,0.59)	3	
P6	(0.44,0.38,0.34)	(0.25,0.25,0.25)		(0.41,0.62,0.59)	2	

Table 12: Acceptable advantage condition. Source: own elaboration.

Program	$P_b\,(a")$	Hierarchy	$P_b\,(a')$	N	$P_b\,(a") - P_b\,(a')$	DP_b	$Q_b\,(a") - P_b\,(a') \geq DP_b$
P1	0.00	1	0	6	0.00	0.2	DOES NOT COMPLY
P2	0.11	2			0.11		DOES NOT COMPLY
P3	0.67	5			0.67		COMPLIES
P4	1.00	6			1.00		COMPLIES
P5	0.52	4			0.52		COMPLIES
P6	0.48	3			0.48		COMPLIES

The acceptable advantage condition is met in Program 3. Therefore, Programs 1 and 2 are defined as part of the compromise solution group. Meanwhile, Program 2 is the highest ranked on the index P_{b_j}. It should be determined if it is the highest ranked based on the list of values of S_b and/or R_b. To do this, a representation of S_{bj}, R_{bj} and P_{bj} is shown in Figure 3.

Figure 3: Analysis of S_{bj}, R_{bj} and P_{bj}. Source: own elaboration.



The graph shows that for program 1 it is at the minimum of the values S_{bj}, R_{bj} and P_{bj}. Therefore, it meets the second condition of being best classified in and is also the best classified by with a value of (0;0.02).

Therefore, the training of multidisciplinary disaster response teams is defined as the best program to enhance the resilience of the health system in Ecuador. Although the P2 program is present as a compromise condition.

In summary, the study has defined Ecuador as a country with a diverse geography and population, facing unique challenges in healthcare management. Therefore, neutrosophic evaluation of healthcare system resilience has provided a deeper understanding of the complexity of this environment and a solid basis for selecting the best alternative.

In general, the diversification of the proposed Programs P1 and P2 allows for a comprehensive approach to strengthen the resilience of the healthcare system in Ecuador [14]. The choice of programs depends on the needs and available resources. The combination of these programs could substantially improve the healthcare system's responsiveness to future crises and ensure more effective healthcare for the population.

Conclusion

The study has emphasized the importance of considering a variety of programs to strengthen the resilience of the healthcare system in Ecuador. Each proposed program addresses key aspects such as disaster response, telemedicine, epidemiological surveillance, inclusive health policies, and resilience research. The combination of these programs would enable the healthcare system to address a wide range of challenges and threats, which is essential for ensuring effective and equitable healthcare.

The analysis using the neutrosophic Vikor method has identified two programs to enhance the resilience of the Ecuadorian healthcare system. These include the formation of multidisciplinary disaster response teams and the strengthening of public health response capacity. The integration of these two programs is essential for assessing the effective implementation of healthcare system resilience in Ecuador.

Assessing resilience requires the formation of teams capable of effectively coordinating in emergencies to reduce human and material losses. Investing in the training and necessary resources for these teams is essential to strengthen the healthcare system's response capacity. Addressing healthcare system resilience in Ecuador is a multidimensional challenge that requires the implementation of several complementary programs.

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Neutrosophic Approaches to Environmental Law and Policy

Santiago Fernando Fiallos Bonilla[1], Diego Fernando Coka Flores[2], Janneth Ximena Iglesias Quintana[3], and Víctor Raúl Reátegui Paredes[4]

[1]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.santiagofiallos@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Tulcán. Ecuador. E-mail: ut.diegocoka@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Riobamba. Ecuador. E-mail: ur.jannetiglesias@uniandes.edu.ec
[4]Universidad Nacional de la Amazonia Peruana, Perú. E-mail: victor.reategui@unapiquitos.edu.pe

Abstract. Currently, the environmental approach is included in the legal regulations of countries to achieve sustainable development. The development of public policies that demand the care and preservation of the environment is an urgency for the territories. In Ecuador, social and legal transformations led to the inclusion of the environmental perspective in the Constitution of the Republic, and subsequently to the development of the Organic Code of the Environment (CODA). Environmental principles are considered in the various legislations; however, no priority is established among them. The objective of this work is to determine the priority established in the environmental principles of CODA. For this, it was necessary to consult experts and, based on their criteria, the Pareto Diagram technique was applied, the fundamental principles were selected, and a hierarchical order was determined based on the Analytic Hierarchy Process, AHP Saaty, with a neutrosophic approach, for the decision making. The most relevant principles were Comprehensive Responsibility, Best Available Technology and Best Environmental Practices, and Comprehensive Repair.

Keywords: Laws, Politics, Environment, Ecuador, Neutrosophic AHP

1 Introduction

Caring for the environment is fundamental for the development of the economic, social, and political processes that take place in society. The Rio Declaration on Environment and Development seeks to achieve sustainable development, recognizing the right of human beings to a healthy life in harmony with the environment. Furthermore, it points out how states must preserve the environment and use its resources according to their environmental and development policies.[1]

Today it is essential to have laws, policies, and programs for the care and preservation of the environment. This is why the 2030 Agenda for Sustainable Development, which aims to achieve transformation, places the equality and dignity of people at the center of action, and calls for a change in the style of development in search of sustainability, inclusion, and respect for the environment. Nine of its 17 goals take into account the protection and care of the environment, directly or indirectly (SDGs 2, 6, 7, 8, 8, 11, 12, 13, 14, 15) [2].

For this reason, the "environmental" approach to law must be considered in the legislation of the countries since it implies the consideration not only of the instituted social logic but the historical and political contexts that originated or transformed them. The environmental issue is conducive to serving as a catalyst for questioning both political and academic discourses, even the most established ones. [3]

One of the branches of law that have been inserted into legislation is environmental law, which consists of "the set of legal norms that regulate human behavior that can influence in a relevant way the interaction processes that take place between environmental systems, living organisms, and their environmental systems, by generating effects that are expected to significantly modify the conditions of existence of those organisms".[4]

In the Latin American area, research has been carried out to analyze the legal regulations that consider the environmental approach [3.5-6]. Ecuador is a country that in recent decades has made changes to its legal regulations. The environmental approach is considered in the country's Magna Carta promulgated in 2008. Article 395, Section 1, recognizes that "The State will guarantee a sustainable development model, environmentally balanced and respectful of cultural diversity, which conserves biodiversity and the natural regeneration capacity of ecosystems and ensures the satisfaction of the needs of present and future generations" [7]. Many laws stand out, such as The Environmental Management Law; Law for the Prevention and Control of Environmental Pollution; Law that

Protects Biodiversity in Ecuador, Unified Text of Secondary Environmental Legislation (TULSMA), and the Organic Code of the Environment (CODA), among others[8]. The latter (CODA) [9], summarizes and updates a series of environmental principles, and establishes as a means of protection, the insertion of environmental criteria in the planning and ordering of territories [8].

The principles to consider are: Comprehensive Responsibility; Best Available Technology and Best Environmental Practices; Sustainable development; The polluter pays; In dubio pro natura; Access to information, Participation and Justice in Environmental Matters; Caution; Prevention; Comprehensive Reparation and Subsidiarity [9,10]

Considering these principles, and the analysis of the bibliography consulted on environmental policies, laws, and legal regulations in Ecuador [11-16], it is determined that there are no systematized criteria for prioritizing them in current legislation. So, the objective of this research is to determine the priority established in the environmental principles of CODA, to be considered in the teaching of environmental law. For this, the use of the Analytic Hierarchy Process formulated by Tomas Saaty (AHP Saaty) is necessary.

Based on an analysis of studies on this topic [17-20], it was possible to establish that researchers show algorithmically relevant multi-criteria evaluation models, where the AHP Saaty is used together with other heterogeneous methods and decision-making techniques. These methods used are mostly supported by expert judgment. The environment of uncertainty and possible indeterminacies that this social phenomenon entails will be considered. Neutrosophy is the segment of philosophy that studies the beginning, nature, and scope of neutralities. It guarantees that assuming the uncertainty inherent in decision-making, containing the indeterminacies where experts will express their judgments using linguistic and non-numerical knowledge, which is a more natural way for human beings to measure [21-27].

To fulfill the general objective of this research, the following specific objectives are necessary: Select the principles to prioritize using a Pareto Diagram and Prioritize using AHP Saaty in a neutrosophic environment, to be later considered for the teaching of Environmental Law.

2 Materials and Methods

2.1 Pareto diagram

The Pareto Diagram is based on what was described by Vilfredo Federico Pareto in 1896, in the Political Economy Course [28]. One of the main disseminators of this tool was Joseph M Jurán [29], which is based on analyzing a problem, considering the causes of greatest incidence, and aims to determine the 20% of the causes that cause 80% of the problems.[30]

One of its main advantages is that it focuses on the aspects whose improvement will have the bigger impact, optimizing efforts. An optimal view of the relative importance of problems. Preventing some causes from aggravating while trying to solve others of less significance and being able to be analyzed graphically encourages continuing work to improve the process.

Preparing a Pareto Diagram has the following steps: selecting the data, grouping and tabulating them (calculating absolute and cumulative frequency, unitary and cumulative relative frequency), drawing the Pareto diagram, representing the bar graph (by locating all the causes along the coordinates axis, ordered from highest to lowest incidence and placing their corresponding percentages along the ordinates axis), outline the cumulative curve, identify the diagram and analyze it (causes that are up to 80% will be those with the highest incidence.

In the case of this research, experts on the subject of Environmental Law from different Law Schools in the country, and from organizations related to the topic, both in person and virtually, were consulted to determine the priority of the environmental principles of the CODA.

2.2 AHP Saaty Neutrosophic:

The Analytic Hierarchy Process was proposed by Thomas Saaty in 1980 [21]. This technique models the problem that leads to the formation of a hierarchy representative of the associated decision-making scheme [22, 23]. 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 [24],[25,26]. 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 [27]. The levels of importance or weighting of the criteria are estimated through paired comparisons between them.

For the description of the method, the following definitions must be presented:

Definition 1: ([31, 32, 42,43]) 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 $^-0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+$. 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: ([31,32, 44]) The *Single-Valued Neutrosophic Set* (SVNS) N over U is A = {<x; $T_A(x)$, $I_A(x)$, $F_A(x)$>: $x \in U$}, where T_A: U→[0, 1], I_A: U→[0, 1], and F_A: U→[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: ([31-34]) 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 ℝ, whose truth, indeterminacy, and falsehood membership functions are defined as follows, respectively:

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

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

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

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 $a_1 \leq a_2 \leq a_3 \leq a_4$.

Definition 4: ([31-34]) 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:

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

Definitions 3 and 4 refer to single-valued triangular neutrosophic numbers when the condition $a_2 = a_3$, [35-37]. For simplicity, we use the linguistic scale of triangular neutrosophic numbers, see Table 1 and also compare with the scale defined in [38]. 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) [39].

$$S = \left\{ \frac{1}{9}, \frac{1}{7}, \frac{1}{5}, \frac{1}{3}, 1,3,5,7,9 \right\} \tag{5}$$

The theory of the AHP technique in a neutrosophic framework can be found in [38]. Thus, the indeterminacy of decision-making by applying neutrosophic AHP, or NAHP for short, can be modeled. Equation 7 contains a generic neutrosophic pair-wise comparison matrix for NAHP.

$$\widetilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \tag{6}$$

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

To convert neutrosophic triangular numbers into crisp numbers, there are two indexes defined in [38], they are the so-called score and accuracy indexes, respectively, see Equations 7 and 8:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{7}$$

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

Table 1: Saaty's scale translated to 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	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$
		$\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$
		$\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$
		$\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

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 [40]. The neutrosophic pair-wise comparison matrix of factors, sub-factors, and strategies are as described in Equation 6.

Step 3 Check the consistency of experts' judgments.

If the pair-wise comparison matrix has a transitive relation, ie., $a_{ik} = a_{ij}a_{jk}$ 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 into a deterministic matrix using Equations 9 and 10. To get the score and the accuracy degree of $\tilde{a}_{ji}$ the following equations are used:

$$S(\tilde{a}_{ji}) = 1/S(\tilde{a}_{ij}) \tag{9}$$

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

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

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \tag{11}$$

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 calculus 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 the equation:

$$CI = \frac{\lambda_{max} - n}{n-1} \text{ [41]}, \tag{12}$$

where n is the order of the matrix. In addition, the *Consistency Ratio* (CR) is defined by equation:

$$CR = \frac{CI}{RI} \tag{13}$$

RI is given in Table 2.

Table 2: RI associated with every order.

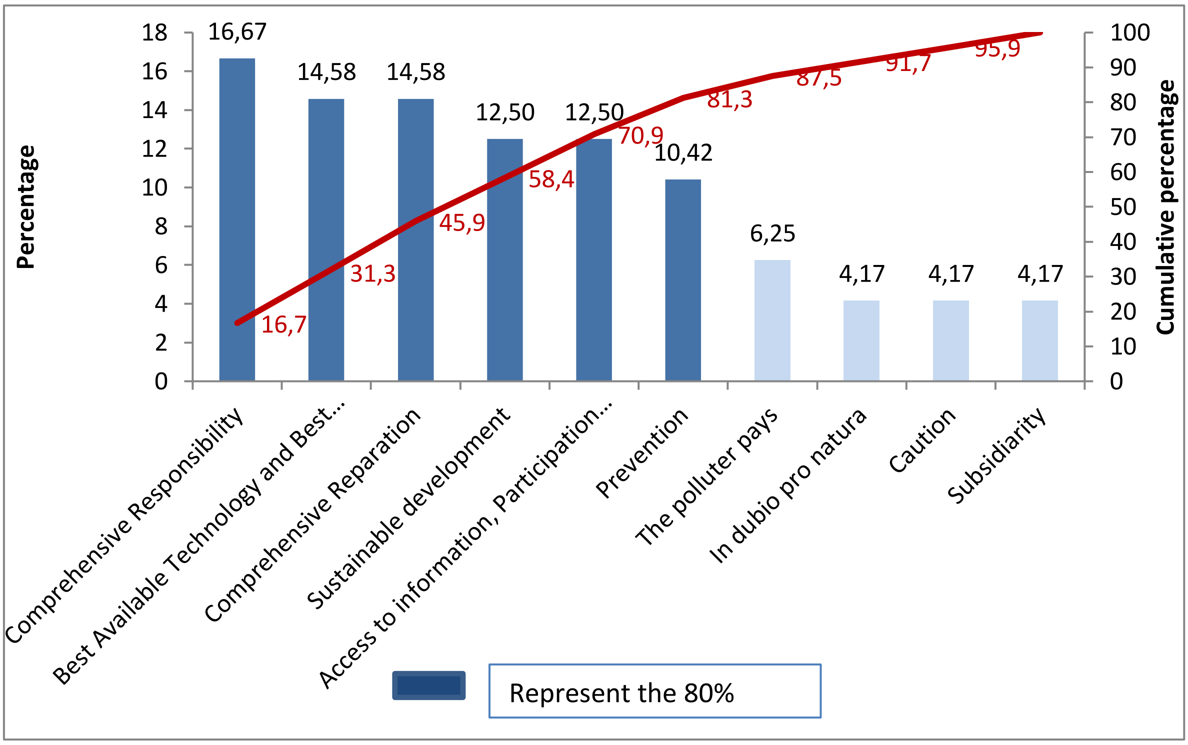
Order (n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

If CR≤0.1 It can be considered that the experts' evaluation is sufficiently consistent and hence we can proceed to use NAHP. We apply this procedure to matrix "A" in Equation 12.

3 Results

For the development of the research, the environmental principles that appear in CODA are considered [9-11], and the Pareto Diagram is applied to the criteria of the selected experts.

Figure 1. Pareto diagram for the selection of principles. Source: own elaboration.



Subsequently, the Saaty Neutrosophic AHP is applied to the principles resulting from the analysis of the Pareto Diagram: Comprehensive Responsibility, Best Available Technology and Best Environmental Practices, Comprehensive Reparation, Sustainable Development, Access to information, Participation and Justice in Environmental Matters And Prevention.

Table 3: Paired matrix for Neutrosophic AHP Saaty. Source: own elaboration.

Criteria	Comprehensive Responsibility	Best available technology and best environmental practices	Comprehensive Reparation	Sustainable development	Access to information, participation and justice in environmental matters	Prevention
Comprehensive Responsibility	**⟨(1,1,1); 0.50,0.50,0.50⟩**	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(2,3,4); 0.30,0.75,0.70⟩
Best available technology and best environmental practices	$\frac{1}{\langle(1,1,1);0.50,0.50,0.5}$	**⟨(1,1,1); 0.50,0.50,0.50⟩**	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(2,3,4); 0.30,0.75,0.70⟩
Comprehensive Reparation	$\frac{1}{\langle(1,1,1);0.50,0.50,0.5}$	$\frac{1}{\langle(1,1,1);0.50,0.50,0.50\rangle}$	**⟨(1,1,1); 0.50,0.50,0.50⟩**	⟨(2,3,4); 0.30,0.75, 0.70⟩	⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(2,3,4);

Criteria	Comprehensive Responsibility	Best available technology and best environmental practices	Comprehensive Reparation	Sustainable development	Access to information, participation and justice in environmental matters	Prevention
						0.30,0.75,0.70〉
Sustainable development	1 / 〈(2,3,4); 0.30,0.75,0.7	1 / 〈(2,3,4); 0.30,0.75,0.70〉	1 / 〈(2,3,4); 0.30,0.75,0.7	**〈(1,1,1); 0.50,0.50, 0.50〉**	〈(2,3,4); 0.30,0.75,0.70〉	〈(2,3,4); 0.30,0.75,0.70〉
Access to information, participation and justice in environmental matters	1 / 〈(2,3,4); 0.30,0.75,0.7	1 / 〈(2,3,4); 0.30,0.75,0.70〉	1 / 〈(2,3,4); 0.30,0.75,0.7	1 / 〈(2,3,4) 0.30,0.75,0	**〈(1,1,1); 0.50,0.50,0.50〉**	〈(4,5,6); 0.80,0.15,0.20〉
Prevention	1 / 〈(2,3,4); 0.30,0.75,0.7	1 / 〈(2,3,4); 0.30,0.75,0.70〉	1 / 〈(2,3,4); 0.30,0.75,0.7	1 / 〈(2,3,4) 0.30,0.75,0	1 / 〈(4,5,6); 0.80,0.15,0.20〉	**〈(1,1,1); 0.50,0.50,0.50〉**

Table 4: Determination of weights of the principles applying the Neutrosophic AHP method. Source: own elaboration.

Criteria	Comprehensive Responsibility	Best available technology and best environmental practices	Comprehensive Reparation	Sustainable development	Access to information, participation and justice in environmental matters	Prevention	**Weight**	**A x Weight**	**Approx. Eigenvalues**
Comprehensive Responsibility	0.25	0.25	0.25	0.28	0.23	0.17	0.24	1.57	**6.6299**
Best available technology and best environmental practices	0.25	0.25	0.25	0.28	0.23	0.17	0.24	1.57	**6.6299**
Comprehensive Reparation	0.25	0.25	0.25	0.28	0.23	0.17	0.24	1.57	**6.6299**
Sustainable development	0.08	0.08	0.08	0.09	0.23	0.17	0.12	0.85	**6.9448**
Access to information, participation and justice in environmental matters	0.08	0.08	0.08	0.03	0.08	0.28	0.11	0.68	**6.4048**
Prevention	0.08	0.08	0.08	0.03	0.02	0.06	0.06	0.36	**6.1087**

When analyzing the consistency, according to the proposed method, an eigenvalue of 6.558 was obtained, the consistency index, CI=0.11, and the Consistency Ratio RC=0.09, which allows to affirm that the exercise was performed correctly.

In the research, consent among the consulted experts is achieved, by identifying six environmental principles to include in teaching in Law Schools, and that must comply with the evaluation process and the weighting of weights that determines their level of relevance. The search for the best alternatives allowed to identify that the greatest weight falls on Comprehensive Responsibility, Best Available Technology and Best Environmental Practices and Comprehensive Reparation.

The consistency analysis of the paired matrix allows for determining the consistency of the research by presenting a value of 0.09, which is less than 0.10.

Conclusion

- Legal regulations associated with the environment are a key issue for the sustainable development of cities. There should be no territorial development strategies and plans in which respect for the environment is not considered. This allows a better quality of life for people and animals, and the preservation of natural resources, so necessary for the preservation of life on the planet.
- The teaching of Environmental Law must focus on environmental principles. Considering those presented in the CODA, Comprehensive Responsibility, Best Available Technology and Best Environmental Practices and Comprehensive Repair are fundamental. However, although these have higher priority, the rest should not be ignored.
- The synergy established between the Pareto Diagram and the AHP Saaty allowed establishing a hierarchical order for the principles, which should be taught in this way according to experts: Comprehensive Responsibility, Best Available Technology and Best Environmental Practices, Comprehensive Repair, Sustainable Development, Access to information, Participation and Justice in Environmental Matters and Prevention.
- Environmental principles must be disseminated to the entire population, not only among those who work in the Law field. Children, young adults, and the elderly must have a legal and environmental culture that allows them to realize when their environmental rights are violated and know where to go to amend them. Economic, political, social, and sustainable development can only be possible if it is in harmony with the environment, which will allow a better life for Ecuadorian citizens.

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University of New Mexico

Neutrosophy Analysis of Medical Ethics and Bioethics

Iruma Alfonso González[1], María de Lourdes Llerena Cepeda[2], Blanca Cristina Estrella López[3], and Beatríz María González Nuñez[4]

[1]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.irumaalfonso@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.mariallerena@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.blancaestrella@uniandes.edu.ec
[4]Universidad de Holguín (EICT SA), Cuba. E-mail: bettygonzaleznuez@gmail.com

Abstract. The current situation of medical ethics and bioethics in Ecuador highlights the need to address the complexity of decision-making in the field of health. Under a neutrosophic approach, the situation of medical ethics and bioethics in Ecuador was explored to define the neutrosophic subsets of elements that affect the formation of values and the development of medical ethics and bioethics in Ecuador. The results reveal the need for training health professionals in issues of medical ethics and bioethics. Therefore, projects and study plans that respond to the promotion of effective ethical practices must be approved. Without leaving aside the fact that supervision and accountability mechanisms must be created to guarantee compliance with ethical and bioethical principles among health professionals. Furthermore, the need for constant evaluation is highlighted to ensure that ethical policies evolve and adjust to changing values and objectives. In conclusion, the neutrosophic approach provides a holistic and adaptable perspective to address medical ethics and bioethics in Ecuador, by recognizing indeterminacies and promoting effective ethical practices.

Keywords: Neutrosophy, health, medical ethics, bioethics.

1 Introduction

Medical ethics and bioethics constitute crucial fields in the area of medicine and health care in Ecuador [1]. These disciplines are responsible for establishing the ethical and moral guidelines that should guide health professionals in making clinical decisions and considering issues related to the life and health of patients [2] [3]. However, in the Ecuadorian context, the application and compliance of ethical standards in medical practice often face complex challenges and dilemmas [4] [5].

In Ecuador, as anywhere else, medical ethics is a complex issue that involves diverse perspectives. On the one hand, some argue that health care should be accessible to all citizens, regardless of their ability to pay, raising questions of distributive justice. Others argue that physicians have a responsibility to make difficult decisions, such as the allocation of limited resources, which can lead to ethical conflicts.

The Ecuadorian health system has gone through significant changes in recent decades. These include the implementation of the Universal National Health System, which has had an impact on the way healthcare is provided. The fight for equity in access to health care and the distribution of health resources raises ethical questions.

Another notable aspect to consider is the presence of conflicts of interest in the field of medicine. In Ecuador, doctors may face situations where they must balance the interests of their patients with economic or institutional interests. These conflicts raise ethical issues related to professional integrity and impartiality.

Bioethics also raises questions in Ecuador, particularly with regard to medical research. Patient participation in clinical trials and obtaining informed consent raises ethical questions about the protection of the rights and autonomy of research subjects.

The introduction of advanced medical technologies [6-18], such as genomic medicine, telemedicine, and artificial intelligence [7], raises ethical issues related to patient privacy [8-19], clinical decision-making, and equity in access to these technologies [9-20].

Ethical decision-making in everyday clinical practice is also an important topic in Ecuadorian bioethics. Physicians face ethical dilemmas when determining end-of-life, limiting therapeutic effort, and providing patient care in resource-limited situations. Therefore, the main objective of this study is:

I. Analyze the subsets of elements that affect the formation of values and the development of medical ethics and bioethics in Ecuador using a neutrosophic approach.

Among the specific objectives are:

i. Analyze and group into subsets the elements of medical ethics and bioethics in Ecuador.
ii. Determine which of the subsets has greater relevance in the development of medical ethics and bioethics in Ecuador.
iii. Propose actions according to the levels of indeterminacy obtained to promote medical ethics and bioethics in health centers in Ecuador.

2 Materials and methods

2.1 Neutrosophic Statistics and Delphi

The neutrosophic Delphi method is appropriate for obtaining information from experts based on their knowledge of the sector, capacity, and ability to analyze the items consulted. So, it is suitable in the "complex, dynamic and indeterminate areas of knowledge of the Neutrosophic Set (NS), characterized by the three membership functions". Furthermore, its use is recommended in studies in which indeterminacy is shown in the information on previous empirical evidence.

In the development, after the different rounds applied in a neutrosophic Delphi method, the responses of the panelists are analyzed based on Single-Valued Neutrosophic Numbers (SVNNs). Thus, the objective of the neutrosophic Delphi method is to achieve the greatest possible consensus among the panelists involved. The proposed phases define questions to obtain criteria and agreed answers to be evaluated by the Coordinating Group.

The composition of the group presented in the expert panel must guarantee the heterogeneity and significance necessary to address the research object of the study. For the final selection of experts by the coordination group, the neutrosophic expert competence coefficient (K_N) is used. Its calculation is done based on the following definition:

Definition 1. Let X be a universe of discourse. A Single-Valued Neutrosophic Set (SVNS) A over X is an object of the form as described in the following equation:

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

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 $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the true, indeterminate, and false membership functions of x in A, respectively. So let it be expressed as A = (a, b, c), where a, b, c ∈ {0,1} and satisfies 0 ≤ a + b + c ≤ 3 for the modeling of the method.

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:

$$S(K_N) = \frac{1 + a - 2b - c}{2} \tag{2}$$

Where $S(K_n) \in \{-1; 1\}$ and where after applying equation (1), it is obtained:

$$K_N = \{\langle x, u_K(x), r_K(x), v_K(x)\rangle : x \in X\}$$

In this coefficient, two factors were averaged, the knowledge coefficient (K_{cn}) and the argumentation coefficient (K_{an}).

$$K_N = \frac{1}{2}(K_{aN} + K_{cN}) \tag{3}$$

Where S (K_{an}) and S (K_{cn}) ∈ $\{-1; 1\}$ and where after applying equation (1), it is obtained:

$$K_{aN} = \{\langle x, u_{Ka}(x), r_{Ka}(x), v_{Ka}(x)\rangle : x \in X\}$$
$$K_{cN} = \{\langle x, u_{Kc}(x), r_{Kn}(x), v_{Kn}(x)\rangle : x \in X\}$$

The so-called neutrosophic knowledge coefficient is determined by the information that the expert himself presents about the object of study, defined through a self-assessment process on a scale to establish knowledge of the topic analyzed and object of study (see Table 1).

Table 1: Linguistic terms used to determine$K_{aN,}K$ and evaluate the proposed criteria. Source: own elaboration.

Linguistic term	SVNN
Full knowledge of the subject of study (FK)	(1,0,0)
Very very good in the subject of study (VVGK)	(0.9, 0.1, 0.1)
Very good in the subject of study (VGKS)	(0.8,0,15,0.20)
Good in the subject of study (GK)	(0.70,0.25,0.30)
Moderately good in the subject of study (MGK)	(0.60,0.35,0.40)

Linguistic term	SVNN
Knows the topic of study (K)	(0.50,0.50,0.50)
Moderately poorly knows the subject of study (MBK)	(0.40,0.65,0.60)
Poorly knows the topic of study (BK)	(0.30,0.75,0.70)
Barely knows the topic of study (VBKS)	(0.20,0.85,0.80)
Very very poor knowledge of the topic of study (VVBK)	(0.10,0.90,0.90)
No knowledge of the study topic (NK)	(0,1,1)

The neutrosophic argumentation coefficient that evaluates the criteria through linguistic terms SVNN with consensus of expert opinion substantiation, (see Table 2), from the weighted sum of values obtained in a series of influence elements determined by the Coordinating Group on the experience obtained through its activity and practice.

For the evaluation and validation of questionnaires using the Delphi method, the scale of the neutrosophic Torgerson model was used, to achieve greater objectivity in the treatment of information that allows the assessment of the criteria used by the judges of each panel of experts of each item individually (see Table 2).

Table 2: Linguistic terms used in the neutrosophic Torgerson model. Source: own elaboration.

Linguistic term I	SVNN	Linguistic term II
Very Suitable (VS)	(0.92,0.1,0.12)	Essential (ES)
Fairly Suitable (FS)	(0.7,0.2,0.25)	Very Useful (VU)
Suitable (S)	(0.50,0.55,0.5)	Useful (U)
Poorly Suitable (PS)	(0.3,0.75,0.80)	Not useful (NU)
Not Suitable (NS)	(0.10,0.90,0.95)	Useless (UL)

To determine the consensus among the participants of the expert panel, the agreement coefficient was used. It is calculated using the following equation:

$$Cc = \left(1 - \frac{V_n}{V_t}\right)100 \tag{4}$$

where: V_n is the number of negative votes cast by the judges and V_t is the number of total votes cast by the judges. Therefore, a level of consensus must be reached when the agreement coefficient Cc obtains a value greater than 75%, and the process is concluded. However, if the agreement coefficient does not reach a value greater than 75%, a new round of evaluation must be established to consider the appropriate assessments provided by the panel of experts.

3 Results

To carry out the study, the neutrosophic Delphi method is modeled. Given the characteristics of the study, it was decided to carry out a neutrosophic evaluation of the experts (academics, lawyers, doctors, economists, and psychologists). To do this, the neutrosophic expert competence coefficient of each expert is determined for panel selection (see Table 3). After selecting the panel of experts, the necessary information for the development of the study is provided by the coordinating group.

Table 3: Determination of the neutrosophic expert competence coefficient. Source: own elaboration.

Expert	Profile	Kc	Ka	K	Assessment
E1	Academic	(0.7;0.25;0.3)	(0.7,0.2,0.25)	(0.7,0.2,0.25)	HIGH
E2	Lawyer	(0.3;0.75;0.7)	(0.7,0.2,0.25)	(0.50,0.55,0.5)	MEDIUM
E3	Lawyer	(0.2;0.85;0.8)	(0.7,0.2,0.25)	(0.3,0.75,0.80)	LOW
E4	Lawyer	(0.5;0.5;0.5)	(0.7,0.2,0.25)	(0.50,0.55,0.5)	MEDIUM
E5	Lawyer	(0.4;0.65;0.6)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E6	Lawyer	(0.1;0.9;0.9)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E7	Lawyer	(0.1;0.9;0.9)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E8	Lawyer	(0;1;1)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E9	Psychologist	(0.9;0.1;0.1)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E10	Psychologist	(0.9;0.1;0.1)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E11	Lawyer	(0.4;0.65;0.6)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E12	Lawyer	(0.1;0.9;0.9)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E13	Lawyer	(0.1;0.9;0.9)	(0.7,0.2,0.25)	(0.3,0.75,0.80)	LOW
E14	Doctor	(1;0;0)	(0.50,0.55,0.5)	(0.7,0.2,0.25)	HIGH
E15	Lawyer	(0.2;0.85;0.8)	(0.3,0.75,0.80)	(0.3,0.75,0.80)	LOW

Expert	Profile	Kc	Ka	K	Assessment
E16	Psychologist	(0.9;0.1;0.1)	(0.3,0.75,0.80)	(0.50,0.55,0.5)	MEDIUM
E17	Lawyer	(0.5;0.5;0.5)	(0.3,0.75,0.80)	(0.3,0.75,0.80)	LOW
E18	Psychologist	(0.9;0.1;0.1)	(0.3,0.75,0.80)	(0.50,0.55,0.5)	MEDIUM
E19	Doctor	(1;0;0)	(0.50,0.55,0.5)	(0.7,0.2,0.25)	HIGH
E20	Economist	(0.6;0.35;0.4)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E21	Lawyer	(0;1;1)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E22	Economist	(0.6;0.35;0.4)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E23	Lawyer	(0.1;0.9;0.9)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E24	Lawyer	(0.5;0.5;0.5)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E25	Doctor	(1;0;0)	(0.50,0.55,0.5)	(0.7,0.2,0.25)	HIGH
E26	Lawyer	(0.1;0.9;0.9)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E27	Academic	(0.7;0.25;0.3)	(0.3,0.75,0.80)	(0.50,0.55,0.5)	MEDIUM
E28	Lawyer	(0.4;0.65;0.6)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E29	Lawyer	(0.1;0.9;0.9)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E30	Economist	(0.6;0.35;0.4)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E31	Doctor	(1;0;0)	(0.3,0.75,0.80)	(0.50,0.55,0.5)	MEDIUM
E32	Lawyer	(0;1;1)	(0.7,0.2,0.25)	(0.3,0.75,0.80)	LOW
E33	Lawyer	(0.3;0.75;0.7)	(0.7,0.2,0.25)	(0.50,0.55,0.5)	MEDIUM
E34	Lawyer	(0.3;0.75;0.7)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E35	Lawyer	(0.5;0.5;0.5)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E36	Lawyer	(0.5;0.5;0.5)	(0.92,0.1,0.12)	(0.7,0.2,0.25)	HIGH
E37	Lawyer	(0.3;0.75;0.7)	(0.7,0.2,0.25)	(0.50,0.55,0.5)	MEDIUM
E38	Lawyer	(0.2;0.85;0.8)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E39	Lawyer	(0.3;0.75;0.7)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E40	Lawyer	(0.2;0.85;0.8)	(0.7,0.2,0.25)	(0.3,0.75,0.80)	LOW
E41	Lawyer	(0.5;0.5;0.5)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E42	Economist	(0.6;0.35;0.4)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E43	Lawyer	(0.3;0.75;0.7)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E44	Lawyer	(0.2;0.85;0.8)	(0.3,0.75,0.80)	(0.3,0.75,0.80)	LOW
E45	Doctor	(1;0;0)	(0.3,0.75,0.80)	(0.50,0.55,0.5)	MEDIUM
E46	Academic	(0.7;0.25;0.3)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E47	Lawyer	(0.3;0.75;0.7)	(0.7,0.2,0.25)	(0.50,0.55,0.5)	MEDIUM
E48	Economist	(0.6;0.35;0.4)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E49	Lawyer	(0.4;0.65;0.6)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E50	Lawyer	(0.4;0.65;0.6)	(0.3,0.75,0.80)	(0.3,0.75,0.80)	LOW
E51	Doctor	(1;0;0)	(0.7,0.2,0.25)	(0.92,0.1,0.12)	VERY HIGH
E52	Psychologist	(0.9;0.1;0.1)	(0.50,0.55,0.5)	(0.7,0.2,0.25)	HIGH
E53	Psychologist	(0.9;0.1;0.1)	(0.3,0.75,0.80)	(0.50,0.55,0.5)	MEDIUM
E54	Psychologist	(0.9;0.1;0.1)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E55	Academic	(0.7;0.25;0.3)	(0.7,0.2,0.25)	(0.7,0.2,0.25)	HIGH
E56	Lawyer	(0.5;0.5;0.5)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E57	Lawyer	(0.5;0.5;0.5)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E58	Lawyer	(0.4;0.65;0.6)	(0.7,0.2,0.25)	(0.50,0.55,0.5)	MEDIUM
E59	Lawyer	(0.4;0.65;0.6)	(0.7,0.2,0.25)	(0.50,0.55,0.5)	MEDIUM
E60	Academic	(0.7;0.25;0.3)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E61	Lawyer	(0.5;0.5;0.5)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E62	Lawyer	(0.1;0.9;0.9)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E63	Lawyer	(0.5;0.5;0.5)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	MEDIUM
E64	Doctor	(1;0;0)	(0.50,0.55,0.5)	(0.7,0.2,0.25)	HIGH
E65	Lawyer	(0.4;0.65;0.6)	(0.7,0.2,0.25)	(0.50,0.55,0.5)	MEDIUM
E66	Lawyer	(0.2;0.85;0.8)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E67	Lawyer	(0.1;0.9;0.9)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E68	Lawyer	(0.1;0.9;0.9)	(0.92,0.1,0.12)	(0.50,0.55,0.5)	MEDIUM
E69	Lawyer	(0;1;1)	(0.3,0.75,0.80)	(0.10,0.90,0.95)	VERY LOW
E70	Lawyer	(0.4;0.65;0.6)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E71	Lawyer	(0.2;0.85;0.8)	(0.7,0.2,0.25)	(0.3,0.75,0.80)	LOW
E72	Lawyer	(0.3;0.75;0.7)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E73	Lawyer	(0.3;0.75;0.7)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E74	Doctor	(1;0;0)	(0.7,0.2,0.25)	(0.7,0.2,0.25)	HIGH
E75	Doctor	(1;0;0)	(0.50,0.55,0.5)	(0.7,0.2,0.25)	HIGH
E76	Academic	(0.7;0.25;0.3)	(0.7,0.2,0.25)	(0.7,0.2,0.25)	HIGH
E77	Lawyer	(0.4;0.65;0.6)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	LOW
E78	Economist	(0.6;0.35;0.4)	(0.7,0.2,0.25)	(0.7,0.2,0.25)	HIGH
E79	Lawyer	(0;1;1)	(0.7,0.2,0.25)	(0.3,0.75,0.80)	LOW

Expert	Profile	Kc	Ka	K	Assessment
E80	Lawyer	(0.5;0.5;0.5)	(0.7,0.2,0.25)	(0.50,0.55,0.5)	MEDIUM

The experts were grouped based on the defined neutrosophic level of importance (see Table 4). Due to the difficulty of the study, a competency assessment for the study was assigned to the experts who obtained an evaluation of *high* and *very high*. Therefore, the panel of experts is made up of 7 doctors, 1 psychologist, 3 academics, 1 economic, and 1 Lawyer for a total of 13 experts necessary for the modeling of the neutrosophic Delphi method.

Table 4: Evaluation of experts according to the competence coefficient. Source: own elaboration.

Profile	Very high	High	Medium	Low	Very low	Total
Lawyer	0	1	18	32	1	52
Economist	0	1	5	0	0	6
Academic	0	3	3	0	0	6
Psychologist	0	1	6	0	0	7
Doctor	1	6	2	0	0	9
Total	**1**	**12**	**34**	**32**	**1**	**80**

Interpretation of responses and evaluation of actions.

First phase: The panel of experts must analyze and determine what are the elements that affect medical ethics and bioethics in Ecuador.

Consolidation of responses: Based on the diversity of responses obtained, it is decided by the coordinating group to define five neutrosophic subsets (NS). Each subset refers to each element determined by the panel of experts. These are the neutrosophic subsets:

Neutrosophic Subset 1 (NS1): Legal and Regulatory Framework. For this subset, three groups of responses are defined:

- Part of the panel advocates that the legal framework in Ecuador establishes the basis for medical ethics and bioethics [10]. The 2008 Constitution and related laws recognize the right to health and the protection of patients' rights. The creation of research ethics committees reflects a commitment to ethics in medical research [11].
- Another party argues that, despite existing regulations and laws, the lack of uniformity in application and supervision can generate indeterminacy. The interpretation and application of ethical regulations may vary between institutions and regions.
- While to a lesser extent some experts consider that when ethical regulations are not applied effectively, they give rise to unethical practices, such as malpractice or lack of transparency in research.

Neutrosophic Subset 2 (NS2): Resources and Equity. For this subset, three groups of responses are defined:

- Some experts define that Ecuador faces challenges in the equitable distribution of health resources. Efforts have been made to promote equity in access to health care through the National Universal Health System.
- Another response analyzed upholds the lack of sufficient resources in some regions and the variability in the quality of medical care. Lack of resources can lead to difficult ethical situations, such as limiting therapeutic effort.
- Another response with opposition is manifested when a lack of resources translates into discrimination in healthcare. It is argued that some patients receive lower-quality treatment due to lack of resources.

Subset 3 (NS3): Education in medical ethics and bioethics. This subset was analyzed based on the preparation of the different study centers.

- In response, the experts indicated that progress has been made in education in medical ethics and bioethics in Ecuador. Examples were provided of several universities and training programs that offer courses and training in medical ethics and bioethics [12].

- However, there was some disagreement that the quality and scope of medical ethics education may vary in some regions. Because not all health professionals can receive adequate training in medical ethics and bioethics [13].
- As a third proposal, experts have alluded to the fact that on some occasions when health professionals do not apply ethical principles on a daily basis, it could lead to unethical practices.

Subset 4 (NS4): Technological development in medicine. For this subset, experts defend the following ideas:

- Technological advancement in medicine, such as genomic medicine, telemedicine, and artificial intelligence, has improved healthcare and research in Ecuador.
- It manifests itself in the need to establish clear regulations and guidelines for the use of these technologies and guarantee transparency in their application.
- It is declared when these technologies are used inappropriately, without respecting the privacy of patients, or without complying with ethical standards in research.

Subset 5 (NS5): Culture and Social Values. The experts say that:

- Cultural and social values in Ecuador [14], such as solidarity and respect for the family, influence medical ethics. The interaction of Western medicine and traditional indigenous medicine is also a relevant aspect to consider.
- The variability of values and beliefs in Ecuadorian society can give rise to different expectations and perspectives on medical care and ethical decision-making [15].
- Cultural beliefs clash with ethical principles, which can lead to difficult ethical dilemmas in clinical practice.

After defining the subsets, the coordinating group summarizes that there are ethical regulations and efforts are made to promote equity and advances in medical technology. However, greater effort is required to ensure the uniform application of ethical principles and the protection of patients' rights throughout the Ecuadorian health system [16]. In addition, the analyzed set of influential components in medical ethics and bioethics in Ecuador was determined.

Second round

The experts are asked the following question: What is the level of importance between each subset? It must consider those with the greatest impact on medical ethics and bioethics in Ecuador. To do this, it was requested to evaluate according to the Torgerson neutrosophic scale (see Tables 5 and 6), to determine the cut-off points and scale of the neutrosophic indicators (see Table 7).

Table 5: Criteria validation level. Source: own elaboration.

Expert	NS1	NS2	NS3	NS4	NS5
E1	(0.92,0.1,0.12)	(0.50,0.55,0.5)	(0.92,0.1,0.12)	(0.3,0.75,0.80)	(0.92,0.1,0.12)
E14	(0.50,0.55,0.5)	(0.3,0.75,0.80)	(0.3,0.75,0.80)	(0.7,0.2,0.25)	(0.92,0.1,0.12)
E19	(0.7,0.2,0.25)	(0.50,0.55,0.5)	(0.7,0.2,0.25)	(0.10,0.90,0.95)	(0.92,0.1,0.12)
E25	(0.7,0.2,0.25)	(0.7,0.2,0.25)	(0.92,0.1,0.12)	(0.7,0.2,0.25)	(0.10,0.90,0.95)
E36	(0.50,0.55,0.5)	(0.3,0.75,0.80)	(0.7,0.2,0.25)	(0.50,0.55,0.5)	(0.3,0.75,0.80)
E51	(0.10,0.90,0.95)	(0.10,0.90,0.95)	(0.3,0.75,0.80)	(0.7,0.2,0.25)	(0.3,0.75,0.80)
E52	(0.50,0.55,0.5)	(0.10,0.90,0.95)	(0.50,0.55,0.5)	(0.7,0.2,0.25)	(0.92,0.1,0.12)
E55	(0.92,0.1,0.12)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	(0.7,0.2,0.25)	(0.10,0.90,0.95)
E64	(0.92,0.1,0.12)	(0.50,0.55,0.5)	(0.3,0.75,0.80)	(0.3,0.75,0.80)	(0.3,0.75,0.80)
E74	(0.10,0.90,0.95)	(0.92,0.1,0.12)	(0.92,0.1,0.12)	(0.3,0.75,0.80)	(0.10,0.90,0.95)
E75	(0.10,0.90,0.95)	(0.10,0.90,0.95)	(0.7,0.2,0.25)	(0.7,0.2,0.25)	(0.3,0.75,0.80)
E76	(0.92,0.1,0.12)	(0.3,0.75,0.80)	(0.7,0.2,0.25)	(0.3,0.75,0.80)	(0.92,0.1,0.12)
E78	(0.10,0.90,0.95)	(0.50,0.55,0.5)	(0.50,0.55,0.5)	(0.10,0.90,0.95)	(0.50,0.55,0.5)

Table 6: Relative frequency, neutrosophic cumulative probability. Own elaboration.

INDICATORS	(0.9;0.1;0.1)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.35;0.75;0.80)	(0.10;0.90;0.90)
Representation	**ES**	**VU**	**U**	**NU**	**UL**
NS1	0.3077	0.4615	0.6923	0.6923	1.0000
NS2	0.0769	0.1538	0.5385	0.7692	1.0000
NS3	0.2308	0.5385	0.6923	1.0000	1.0000
NS4	0.0000	0.4615	0.5385	0.8462	1.0000
NS5	0.3846	0.3846	0.4615	0.7692	1.0000

Table 7: Calculation of cut-off points and scale of neutrosophic indicators. Source: own elaboration.

Ind.	ES	VU	U	NU	UL	$\bar{x}$	N -$\bar{x}$	$\bar{N}$	SVNN	Order
NS1	-0.50	-0.10	0.50	0.50	3.50	0.78	**-0.09**	**-0.09**	(0.50,0.55,0.5)	**2**
NS2	-1.43	-1.02	0.10	0.74	3.50	0.38	**0.31**	**0.31**	(0.3,0.75,0.80)	
NS3	-0.74	0.10	0.50	3.50	3.50	1.37	**-0.68**	**-0.68**	(0.7,0.2,0.25)	**1**
NS4	-3.50	-0.10	0.10	1.02	3.50	0.20	**0.49**	**0.49**	(0.3,0.75,0.80)	
NS5	-0.29	-0.29	-0.10	0.74	3.50	0.71	**-0.02**	**-0.02**	(0.50,0.55,0.5)	**2**
Cut points	**-1.29**	**-0.28**	**0.22**	**1.30**	**3.50**	**0.69**	=N			

The determination of the degree of neutrosophic relevance of each dimension analyzed by the experts indicates that *subset 3* (NS3*), education in medical ethics and bioethics*, represents a degree of representativeness or *very useful* according to the classification obtained from the cut-off points. Therefore, work must be done to enhance medical ethics and bioethics in health professionals in Ecuador. To this end, the solution actions are proposed for each response presented in the analyzed subset:

- Strengthening training and education programs in medical ethics and bioethics is essential. This includes required courses in ethics for medical students and practicing health professionals.
- Evaluate and improve the quality and coherence of training programs. An accreditation body can be created to ensure that programs meet established ethical standards.
- Implement oversight and accountability mechanisms to ensure that health professionals comply with ethical principles in their daily practice. Sanctions may be applied in case of ethical breach.

In addition, the subsets *NS1 legal and regulatory framework* and *NS5 culture and social values* with secondary impact on medical ethics and bioethics in Ecuadorian health professionals were selected within the classification as *useful*. Ultimately, choosing the subset most effective in advancing medical ethics and bioethics in Ecuador depends on judgment and balance, as well as adaptability and willingness to address ongoing challenges.

Finally, consensus among the participants of the expert panel must be determined. To this end, the coordinating group considered such a level of consensus to have been reached, thus producing the conclusion of the process (see Table 8). Therefore, the consensus among the responses for the five subsets analyzed is met.

Table 8: Coefficient of agreement between the participants of the Expert Panel. Source: own elaboration.

Expert	NS1	NS2	NS3	NS4	NS5
E1	YES	YES	YES	YES	YES
E2	YES	YES	YES	YES	YES
E3	YES	YES	YES	NO	YES
E4	YES	NO	YES	YES	YES
E5	YES	YES	YES	YES	YES
YES	**5**	**4**	**5**	**4**	**5**
NO	**0**	**1**	**0**	**1**	**0**
Coefficient	**100**	**80**	**100**	**80**	**100**

Conclusion

The neutrosophic analysis of medical ethics and bioethics in Ecuador reveals the complexity of these fields in the context of medical care in the country. There are multiple perspectives, challenges, and ethical dilemmas that healthcare professionals must address. Health policy, conflicts of interest, medical research, advanced technology, and clinical dilemmas are principles that contribute to this complexity. To advance in these fields, a multidisciplinary approach that takes into consideration the different opinions and ethical values that converge in the Ecuadorian health system is essential. Furthermore, continued dialogue and ethical reflection are needed to find solutions that respect patients' rights and promote the quality of medical care in Ecuador.

The analysis of the neutrosophic Delphi method has defined that the greatest problems that affect the development of medical ethics and bioethics in Ecuador are found in the NS3, NS1, and NS5 subsets. Among them stands out the *education in medical ethics and bioethics*. Additionally, solution actions were identified to address deficiencies in medical ethics and bioethics in Ecuador. From a neutrosophic perspective, the need to establish clearer standards and protocols is recognized. So that effective sanctions and supervision are carried out to guarantee ethical and bioethical compliance.

Policies and practices in medical ethics and bioethics are not static, they evolve and must adapt to new circumstances and challenges. Reflection and constant feedback are essential to ensure that policies and practices remain aligned with the ethical values and objectives of bioethics in Ecuador. Addressing these issues requires a continued commitment to medical ethics and bioethics, as well as improving training and ethical oversight in the Ecuadorian health system.

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Evaluation of the Quality of Care in Nursing Homes

Mónica Bustos Villarreal[1], Nairovys Gómez Martínez[2], and Roberto Enrique Alvarado Chacón[3]

[1]Universidad Regional Autónoma de Los Andes, Tulcán. Ecuador. E-mail: ut.monicabv32@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.nairovysgomez@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.robertoac58@uniandes.edu.ec

Abstract. The purpose of this research was to use neutrosophic logic as an approach to evaluate the quality of nursing care in a nursing home in the city of Puyo, Ecuador. To achieve this objective, the AHP method was used in its neutrosophic modality, using trapezoidal neutrosophic numbers for the selection of a set of criteria of interest that would later be subjected to evaluation by experts in the field. During the analysis, the critical importance of certain aspects such as patient safety, resident and family satisfaction, and other specific factors were emphasized as fundamental components to be considered when looking for indicators that contribute to improving the quality of the services provided in this nursing home. The incorporation of neutrosophy and neutrosophic numbers in the evaluation of medical quality in the context of elderly care provided a comprehensive and accurate approach, taking into account the intricate nature and subjectivity that characterize this area of study.

Keywords: neutrosophic logic, quality, nursing, nursing home, NAHP, neutrosophic trapezoidal number

1 Introduction

Increased longevity is a remarkable achievement of modern medicine and public health. However, this achievement comes with significant long-term challenges. In a scientific context, these implications lie primarily in the growing proportion of older people in the world's population due to the demographic transition, a phenomenon that has manifested itself in recent decades.

The evaluation of the quality of nursing care in nursing homes represents a topic of deep interest in the scientific and public health field. As the world's population ages, the demand for specialized aged care becomes increasingly critical. In this context, nursing homes play an essential role in the long-term care of this vulnerable population. The quality of nursing care in these facilities takes on primary value, as it directly affects the well-being, safety, and quality of life of the residents.

Nursing care in nursing homes is characterized by complexity, as patients often present with a variety of medical, physical, cognitive, and emotional needs. The quality of care in these residences is closely related to the promotion of autonomy, quality of life, and psychological well-being of residents. Scientific studies have shown that a high-quality care environment contributes to patient satisfaction and a better quality of life while decreasing symptoms of depression and anxiety. Patient-centered care and individualization of care are fundamental pillars of care in nursing homes, and these practices have proven to be essential to promoting healthy aging.

As such, an effective decision-making process is essential to ensure that elderly patients receive appropriate care. Nursing professionals often must deal with a wide range of clinical and management situations in their daily work, from administering medications to managing complex medical cases. Proper decision-making requires an accurate assessment of the patient's condition, consideration of best clinical practices, and adaptation to the individual needs of each resident.[1]

To evaluate and improve the quality of nursing care in nursing homes, a robust, evidence-based decision-making process is essential. Neutrosophic decision-making has become a relevant approach in this context, as it addresses the complex and multidimensional nature of healthcare in almost any setting. The use of neutrosophic assessment in nursing care allows for consideration of the uncertainty and ambiguity inherent in clinical decisions

[2], which is common in the care of elderly patients with varied and often changing needs.

Neutrosophic assessment provides a framework to quantify the quality of nursing care in nursing homes more accurately, taking into account not only quantitative aspects but also qualitative and subjective aspects. This makes it possible to evaluate factors of various kinds through the use of neutrosophic systems.[3-18]. Additionally, neutrosophic assessment offers the ability to identify areas for improvement and adapt care based on residents' changing needs over time.[4]

Neutrosophic logic was proposed by mathematician and philosopher Florentin Smarandache in the 1990s. This theory represents an innovative approach to addressing complex situations involving uncertainty, ambiguity, and contradictory data. Unlike conventional fuzzy logic, which focuses primarily on uncertainty, neutrosophic logic incorporates three fundamental elements: true, false, and neutral. This extension allows uncertainty to be represented in a broader sense, which is especially relevant in situations in which information is incomplete or even conflicting.[5]

Over the years, the application of neutrosophic logic has spread to various fields, including artificial intelligence [6], decision-making, and risk management in multifaceted and complex scenarios. In the agricultural industry, for example, neutrosophic sets have been used to deal with uncertain data in the analysis and selection of optimal criteria for smart agriculture [7]. In risk management and the evaluation of investment projects, it has been widely used for decision-making in environments where the available information is usually partial and contradictory.[8]

In the field of science, its potential lies in the ability to model and analyze deep uncertainty, allowing professionals to make more informed decisions in complex and multifaceted contexts. In this sense, neutrosophic logic has found various applications in fields such as biomedicine [9], psychology [10], and education [11], environments where decision-making is often affected by incomplete or inconsistent data.

One of the fields where the application of neutrosophic logic stands out with special relevance is medicine. Decision-making in the medical setting is inherently complex due to the multifaceted nature of health conditions, variability in patient responses, and uncertainty in clinical data. Neutrosophic logic allows healthcare professionals to address ambiguity and uncertainty in treatment evaluation [12], the diagnosis of diseases [13] and clinical decision-making [14].

In line with the previous information, the present study focuses on the use of neutrosophic logic as a means to evaluate the quality of nursing care in a nursing home in the city of Puyo, Ecuador. The choice to use neutrosophic logic as part of the methodological approach to quality assessment is based on its ability to model and analyze uncertainty and ambiguity in data and perceptions. Given the diversity of factors that impact the satisfaction of residents and their families in a nursing home, neutrosophic logic provides an appropriate perspective to address the multidimensionality of this evaluation.

This study aims to contribute to the understanding of the factors that influence the satisfaction of residents and their families, and ultimately to improving the quality of care in nursing homes. Neutrosophic logic stands as a key tool in this process, allowing a more precise and nuanced evaluation in a context where uncertainty and ambiguity are recurrent elements.

2 Preliminaries

In this section, the fundamental meanings related to the neutrosophic set, single-valued neutrosophic sets, trapezoidal neutrosophic numbers, and the operations performed on trapezoidal neutrosophic numbers are established.

Definition 1. [15] introduces the concept of a neutrosophic set A within the space of points X, denoted as $x \in X$. This neutrosophic set is characterized by three distinct components: a truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$, and a falsity-membership function $F_A(x)$. Each of these functions, namely $T_A(x)$, $I_A(x)$, and $F_A(x)$, maps to real standard or real nonstandard subsets of the interval $[-0, 1+]$, indicating that $T_A(x)$ $(x): X \rightarrow [-0, 1+]$, $I_A(x)$ $(x): X \rightarrow [-0, 1+]$, and $F_A(x)$ $(x): X \rightarrow [-0, 1+]$. It is important to note that there are no specific constraints imposed on the sum of $T_A(x)$, $I_A(x)$, and $F_A(x)$, allowing for flexibility in their values. In other words, the condition $0- \leq \ sup\, T_A(x) + sup\, I_A(x) + sup\, F_A(x) \leq 3+$ holds true.

Definition 2. Consider a universe of discourse X. A single-valued neutrosophic set A over X can be defined as an entity expressed in the format $A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle : x \in X\}$ where the following conditions apply:

- $T_A(x): X \rightarrow [0, 1]$
- $I_A(x): X \rightarrow [0, 1]$
- $F_A(x) : X \rightarrow [0, 1]$

Additionally, it is essential to note that $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$ holds true for all $x \in X$. These intervals, namely $T_A(x)$, $I_A(x)$, and $F_A(x)$, signify the degrees of truth-membership, indeterminacy-membership, and falsity-membership of x with respect to the set A, respectively.

For the sake of convenience, a single-valued neutrosophic number (SVNN) can be denoted as A = (a, b, c), where a, b, and c belong to the interval [0, 1], and their sum adheres to the condition $a + b + c \leq 3$.

Definition 3: Consider three values $\tilde{a}, \tilde{a}, \tilde{a} \in [0,1]$, along with four values $a_1, a_2, a_3, a_4 \in \mathbb{R}$, where $a_1 \leq a_2 \leq a_3 \leq a_4$. In such a scenario, a single-valued trapezoidal neutrosophic number denoted as $\tilde{a} = \langle (a_1, a_2. a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, represents a specific neutrosophic set defined on the set of real numbers, R. This set's truth-membership, indeterminacy-membership, and falsity-membership functions are described as follows:

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

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

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

where $\alpha\tilde{a}$, $\beta\tilde{a}$, and $\gamma\tilde{a}$ represent the maximum truth-membership degree, minimum indeterminacy-membership degree, and minimum falsity-membership degree, respectively.

Definition 4: Consider two single-valued trapezoidal neutrosophic numbers, $\tilde{a} = \langle (a_1, a_2, a_3, a_4);\ \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3, b_4);\ \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$, as well as any non-null number on the real number line, denoted as λ. In this context, a set of defined operations is introduced as follows:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$ (4)
2. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$ (5)
3. 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 $a_1, a_2, a_3, a_4 \neq 0$. (6)
4. Multiplication by a scalar number: $\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3, \lambda a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_4, \lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases}$ (7)

2.2 Methodology

Section 2.2 of the study introduces the concept of the Neutrosophic Analytical Hierarchical Process (Neutrosophic AHP or NAHP) and provides a framework for its application. The Neutrosophic AHP is an extension of the Analytical Hierarchical Process (AHP) proposed by Thomas Saaty in 1980. AHP is a decision-making technique that structurally organizes complex problems into a hierarchical format, allowing for a systematic evaluation of decision criteria and alternatives. In the Neutrosophic AHP, a set of linguistic scales is utilized for the representation of factors, sub-factors, and strategies involved in the decision-making process. These scales are defined based on expert opinions and are aligned with the neutrosophic framework [16-20-21-22]. The neutrosophic pair-wise comparison matrix is established following these scales, allowing experts to evaluate the relationships between factors and sub-factors. Consistency in expert judgments is an essential consideration in the Neutrosophic AHP. A pair-wise comparison matrix is considered consistent when it maintains a transitive relation, ensuring that the lower, median, and upper values of triangular neutrosophic numbers within the matrix are consistent. The weight of factors is calculated by transforming the neutrosophic pair-wise comparison matrix into a deterministic matrix. The result is a deterministic matrix that represents the importance or weight of each factor.

The ranking of priorities is determined based on the Eigenvector X, which is derived from the deterministic matrix. This involves normalizing column entries and calculating the total of row averages, providing a clear understanding of the factors' importance. Consistency checks, by considering the Consistency Index (CI), help assess the reliability of expert evaluations. A formula that involves the maximum eigenvalue (λ_{max}) d, the order of the matrix (n) is used to calculate the CI. If the Consistency Ratio (CR) is less than or equal to 0.1, it is considered that expert evaluations are sufficiently consistent, allowing for the application of NAHP. For reviewing the whole methodology see [17-19].

2.3 Study Methodology

The present study focuses on establishing the parameters for evaluating the quality of nursing care in a nursing home located in the city of Puyo, Ecuador. To conduct this evaluation, a methodology was employed involving the participation of three experts in the field of nursing care and decision-making. Through a collaborative process, the Idea Generation and Consensus technique was applied to identify and define the fundamental criteria for assessing the quality of care in the nursing home. The analysis resulting from this technique yielded a set of criteria and sub-criteria for evaluation that were considered highly relevant to nursing care in the nursing home. The selected criteria, which will serve as a guide for measuring the quality of nursing care, are broken down as follows:

Criterion 1: Competence of Nursing Staff
- Subcriterion 1.1: Evaluation of Qualifications and Training of Nurses.
- Subcriterion 1.2: Evaluation of Perceived Experience in Elderly Care.
- Subcriterion 1.3: Evaluation of Participation in Continuous Training Programs.

Criterion 2: Personalized Care Planning
- Subcriterion 2.1: Evaluation of the Development of Individualized Care Plans.
- Subcriterion 2.2: Evaluation of Recording and Monitoring of Provided Care.

Criterion 3: Patient Safety
- Subcriterion 3.1: Evaluation of the Implementation of Measures to Prevent Falls and Injuries.
- Subcriterion 3.2: Evaluation of the Safe Administration of Medications.
- Subcriterion 3.3: Evaluation of Response Protocols for Emergency Situations.
- Subcriterion 3.4: Evaluation of Infection Prevention in the Care Environment.

Criterion 4: Communication and Interpersonal Relations
- Subcriterion 4.1: Evaluation of Effective Communication with Residents and their Families.
- Subcriterion 4.2: Evaluation of Respect and Empathy in Interactions with Residents.
- Subcriterion 4.3: Evaluation of Encouraging Resident Participation in Decision-Making.
- Subcriterion 4.4: Evaluation of Effective Communication with Other Professionals for Comprehensive Patient Care.

Criterion 5: Living Conditions and Resident Well-being
- Subcriterion 5.1: Evaluation of Food Quality and Nutrition.
- Subcriterion 5.2: Evaluation of Comfort and Cleanliness of Facilities.
- Subcriterion 5.3: Evaluation of Recreational and Social Activities Programs.

Criterion 6: Dignity and Respect
- Subcriterion 6.1: Evaluation of the Quality and Satisfaction Level with the Treatment Provided to Residents and Families.
- Subcriterion 6.2: Evaluation of the Implementation of Activities Promoting Resident Autonomy.
- Subcriterion 6.3: Evaluation of Privacy Respect During Daily Activities.
- Subcriterion 6.4: Evaluation of Privacy Respect for Patients and Families During Visits and Common Activities.

Criterion 7: Resident and Family Satisfaction
- Subcriterion 7.1: Evaluation of Service and Activity Accessibility.
- Subcriterion 7.2: Evaluation of Staff Availability.
- Subcriterion 7.3: Evaluation of Quality of Life in the Residence.
- Subcriterion 7.4: Evaluation of Resource Availability.

These criteria and subcriteria, selected following a collaborative analysis with experts, constitute the foundation for evaluating the quality of nursing care in the nursing home. The application of the Neutrosophic AHP Method will enable the assessment and prioritization of these criteria based on their importance and attractiveness, providing a systematic and scientific approach to decision-making in the field of elderly care nursing.

3 Results

To assess the quality of nursing care in the nursing home, the Neutrosophic AHP Method was applied to the criteria and subcriteria defined in the methodology. Through a weighting and evaluation process by experts, the relative importance of each criterion and subcriterion in the quality of nursing care was determined. For this purpose, the linguistic variable evaluation scale proposed by Saaty and described in [16] was used. Each of the groups and subcriteria was assessed by each expert to obtain matrices as shown in Table 1.

Table 1: Criteria evaluation matrix, according to Expert 1.

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7
Criterion 1	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$
Criterion 2	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$
Criterion 3	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$
Criterion 4	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$1/\tilde{3}$	$1/\tilde{5}$
Criterion 5	3	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{1}$
Criterion 6	$\tilde{1}$	$\tilde{1}$	$1/\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$
Criterion 7	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{5}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$

Taking into account the average values of the evaluations, a weight vector was derived for each of the criteria and subcriteria. This methodology allowed for quantifying the contribution or importance of each subcriterion in the context of the evaluated system. The results of this process are summarized in Table 2.

This weight calculation strategy is crucial in decision-making as it provides a quantitative basis for identifying which of the subcriteria have a greater impact on the evaluated system. This information is essential for directing efforts and resources to specific areas that require improvement or prioritized interventions, thus maximizing the effectiveness of decisions and actions taken in the context of nursing care in the nursing home.

Table 2: General evaluation matrix of the analyzed criteria and sub-criteria.

Criteria and Subcriteria	**Relative importance**	**Contribution to the general system**
Nursing Staff Competence	**0.09**	
Evaluation of the Qualification and Training of Nurses	0.325	0.028
Elderly Care Experience Evaluation	0.590	0.051
Evaluation of Participation in Continuing Training Programs	0.085	0.007
Personalized Care Planning	**0.0967**	
Evaluation of the Development of Individualized Care Plans	0.500	0.048
Evaluation of the Registry and Monitoring of the Care Provided	0.500	0.048
Patient safety	**0.2208**	
Evaluation of the Implementation of Measures to Prevent Falls and Injuries	0.116	0.026
Assessment of Safe Medication Administration	0.144	0.032
Evaluation of Response Protocols in Emergency Situations.	0.468	0.103
Evaluation of Infection Prevention in the Care Environment	0.272	0.060
Communication and Interpersonal Relationships	**0.0685**	
Effective Communication with Residents and Their Families	0.091	0.006
Respect and Empathy in Interactions with Residents	0.217	0.015
Promoting Resident Participation in Decision Making	0.518	0.036
Effective Communication with Other Professionals	0.174	0.012
Living Conditions and Wellbeing of Residents	**0.1543**	
Food Quality and Nutrition	0.590	0.091
of the Comfort and Cleanliness of the Facilities	0.325	0.050
Recreational and Social Activities Programs	0.085	0.013
Dignity and Respect	**0.1598**	
Quality and Satisfaction with the Treatment Provided to Residents and Family Members	0.178	0.028
Autonomy of Residents	0.466	0.074
Respect for Patient Privacy	0.178	0.028
Privacy of Patients and Families During Visits and Common Activities.	0.178	0.028
Resident and Family Satisfaction	**0.2141**	
Accessibility of Services and Activities	0.294	0.063
Personnel Availability.	0.196	0.042
Quality of Life in the Residence	0.351	0.075
Resource Availability	0.159	0.034

The conducted analysis has helped identify the most relevant criteria in the context of evaluating the quality of nursing care services in the assessed nursing home. In this regard, patient safety and resident and family satisfaction stand out as the most prominent criteria in terms of importance, as perceived by the experts. These results indicate the significant importance attached to patient safety and resident and family satisfaction in the nursing care assessment process within the nursing home.

A comprehensive analysis of all evaluated variables that influence the system revealed that the evaluation of emergency response protocols, the assessment of infection prevention in the care environment, the quality of food and nutrition, resident autonomy, accessibility of services and activities, as well as the quality of life in the nursing home, are elements of paramount importance from the experts' perspective. These findings highlight the need for a detailed evaluation of these aspects to obtain clear indicators that allow for measuring and improving the quality of the service provided in the nursing home.

Based on the obtained results, a pilot interview was conducted on 10 residents and 10 family members associated with these residents. Each of them was asked to complete the provided form, taking into account the assessments they perceived as correct considering each of the previously selected criteria. These assessments are associated with neutrosophic numbers so that the level of certainty, falsity, and indeterminacy of each evaluation can be evaluated. Using the related operations, the following summary table was obtained.

Table 3: Average evaluations obtained by residents and family members.

Evaluated Aspects	Residents (Average)	Relatives (Average)
Evaluation of Response Protocols in Emergency Situations	⟨(0.2, 0.4, 0.6, 0.7); 0.8, 0.1, 0.1⟩	⟨(0.3, 0.5, 0.6, 0.8); 0.6, 0.2, 0.2⟩
Evaluation of Infection Prevention in the Care Environment	⟨(0.1, 0.3, 0.4, 0.6); 0.9, 0.05, 0.05⟩	⟨(0.2, 0.4, 0.5, 0.7); 0.7, 0.15, 0.15⟩
Food Quality and Nutrition	⟨(0.4, 0.6, 0.7, 0.9); 0.6, 0.2, 0.2⟩	⟨(0.5, 0.7, 0.8, 0.9); 0.5, 0.3, 0.2⟩
Resident Autonomy	⟨(0.1, 0.3, 0.4, 0.6); 0.9, 0.05, 0.05⟩	⟨(0.2, 0.4, 0.5, 0.7); 0.7, 0.15, 0.15⟩
Accessibility of Services and Activities	⟨(0.2, 0.4, 0.6, 0.7); 0.8, 0.1, 0.1⟩	⟨(0.3, 0.5, 0.6, 0.8); 0.6, 0.2, 0.2⟩
Quality of Life in the Residence	⟨(0.4, 0.6, 0.7, 0.9); 0.6, 0.2, 0.2⟩	⟨(0.5, 0.7, 0.8, 0.9); 0.5, 0.3, 0.2⟩

In the context of evaluating the quality of care in the nursing home, trapezoidal neutrosophic numbers have been employed to represent the assessments made by residents and family members. Specifically, the evaluation of food and nutrition quality shows differences in the perceptions of residents and family members. Residents assign a relatively high degree of truth, indicating a reasonable perception in this regard, but with some ambiguity in their assessments. On the other hand, family members assign a slightly higher degree of truth, suggesting a more positive perception, although with greater variability in opinions.

Patient safety, assessed through emergency protocols and infection prevention, receives reasonable evaluations from both residents and family members. However, the indeterminacy is significant, reflecting uncertainty and variability in perceptions. This highlights the importance of addressing these aspects more effectively to ensure resident safety.

Resident autonomy is an aspect that receives high degrees of truth from both residents and family members, indicating a positive perception in this area. However, the high indeterminacy emphasizes the variability in opinions, suggesting that some residents may feel more autonomous than others.

4 Discussion

The use of neutrosophy, particularly neutrosophic numbers, contributes significantly to the field of medical quality assessment in contexts related to the care of the elderly. This approach is particularly relevant in a context where subjectivity, uncertainty, and variability in perceptions are inherent factors. By incorporating neutrosophic numbers into the assessment, a more precise representation of the opinions of residents, family members, and healthcare professionals can be obtained, effectively addressing ambiguity and doubt in their assessments.

Medical care in nursing homes is characterized by being multidimensional and complex, involving multiple factors and agents. The use of neutrosophic logic in this aspect provides a tool that reflects the richness of opinions and perspectives in this environment. The evaluation of medical quality in elderly care settings requires continuous adaptability as the needs of residents evolve. Neutrosophic numbers offer the necessary flexibility to reflect changes in perceptions over time and adjust strategies accordingly. Additionally, by considering not only the degree of truth but also the degree of indeterminacy and falsity in assessments, the complexity of medical care is recognized, and inherent uncertainty is captured.

In this context, the evaluation of medical quality is not limited to rigid quantitative metrics. Instead, it opens up to understanding nuances, contexts, and the experiences of those involved. Neutrosophic numbers allow for weighing perceptions, identifying areas of consensus and disagreement, and ultimately guiding decision-making to improve the care of elderly residents.

Conclusion

The study conducted in the nursing home in the city of Puyo, Ecuador, has validated the utility of neutrosophic logic as an effective approach to evaluating the quality of nursing care. The application of the neutrosophic version of the AHP method has provided valuable guidance in identifying the criteria and elements of utmost relevance in the evaluation of nursing care. The critical importance of patient safety, the satisfaction of both residents and their families, and other specific factors have been highlighted as fundamental areas in the search for indicators to improve the quality of services in this nursing home.

The inclusion of neutrosophy and neutrosophic numbers in the assessment of medical quality in elderly care settings has provided a comprehensive and precise approach, considering the intricate nature and subjectivity that characterizes this area of study. Furthermore, the analysis conducted in this study equips healthcare professionals, administrators, and family members with a deeper understanding of residents' perceptions, enabling them to make informed decisions aimed at optimizing care and the quality of life in this elderly care institution.

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University of New Mexico

Application of Neutrosophic Correlation in the Identification of Deficiencies in Animal Protection

Teresa De Jesús Molina Guitérrez[1], Mesías Elías Machado Maliza[2], Milena Álvarez Tapia[3], and Noel Moreno Lemus[4]

[1]Universidad Regional Autónoma de Los Andes, Ibarra. Ecuador. E-mail: ui.teresamolina@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Riobamba. Ecuador. E-mail: ur.mesiasmachado@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Tulcán. Ecuador. E-mail: ut.milenaalvarez@uniandes.edu.ec
[4]Procter & Gamble International Operations S.A. Panamá. E-mail: nmlemus@gmail.com

Abstract. The purpose of this study was to assess the utility of neutrosophic logic in identifying gaps and areas for improvement in animal protection in Ecuador. The methodology employed was exploratory and relied on the experience and knowledge of experts in the field of animal protection. It was framed within a qualitative perspective, adopting a descriptive and exploratory design to comprehend and analyze deficiencies in animal protection in Ecuador. The results of this research allowed for the identification of the most significant areas for improvement in animal protection in Ecuador through the definition of the gaps with the greatest impact on the study subject. Deficiencies related to the lack of protocols for animal rescue and inadequate enforcement of sanctions stood out as the most severe and impactful on animal welfare. The use of neutrosophic logic enabled a precise evaluation and quantification of deficiencies in animal protection. Its application is recommended in future research in the field to obtain a more accurate understanding of the situation.

Keywords: neutrosophic logic, evaluation, animal welfare, correlation coefficient.

1. Introduction

In the early 21st century, animal welfare preservation emerged as a topic of recent relevance on the international stage. The lack of a comprehensive regulatory framework regarding the protection of animal welfare appeared to create a gap in international law. In recent years, animal rights advocacy movements in Ecuador, primarily led by civil society, have experienced a significant increase. These movements have emerged mainly in response to the shortcomings of the legal and administrative framework in not only protecting but also regulating the relationship between the human species and animals.

Currently, animal protection mechanisms in Ecuador are characterized by a complex interaction of legislative, implementation, and socioeconomic factors. Despite having a solid regulatory framework in the form of the Organic Law on Animal Welfare and specific regulations, the effectiveness of these mechanisms is limited due to deficiencies in implementation and the lack of adequate resources. Government agencies responsible for enforcing animal protection laws often face budgetary and logistical constraints that hinder their ability to monitor and sanction non-compliance with regulations. This results in a lack of effective prevention against animal abuse and the illegal exploitation of wildlife.

The situation of animal shelters in Ecuador is a cause for concern, as inadequate conditions are observed in many of these places, including overcrowding and insufficient veterinary care. These inadequate conditions not only jeopardize the welfare of animals but also perpetuate the cycle of abandonment and mistreatment. Furthermore, Ecuadorian society largely lacks awareness of animal welfare. Public education in this regard is scarce, contributing to the persistence of harmful practices towards animals and irresponsible pet ownership.

The situation in Ecuador demands a scientific and systematic assessment of animal protection mechanisms, taking into account the availability of resources, the efficiency of law enforcement, and the promotion of public education. Such an evaluation is essential for developing more effective animal protection strategies that ensure a safer and more humane environment for animals in the country. However, in this context, it is imperative to identify the elements with the greatest potential to exponentially impact the current situation to achieve effective changes.

In this regard, multiple criteria decision-making methods hold significant consideration in the discipline of decision sciences [1]. In recent years, the need to simultaneously consider criteria and alternatives in decision problems has become more crucial, especially in the presence of uncertain datasets. Therefore, decision-makers employ subjective evaluation methods to address this challenge.[2]

Neutrosophic set theory is presented as a solid formal framework with a generalizability that covers the spectrum of concepts that includes the classical set, fuzzy set, interval-valued fuzzy set, intuitionistic fuzzy set, and interval-valued intuitionistic fuzzy set, among others [3, 4]. Neutrosophy, a philosophical branch with its roots in the work of [5], focuses on the investigation of the origin, nature, and scope of neutralities, and how they interact with various ideational conceptions.

The introduction of neutrosophy has given rise to an innovative concept called "<NeutA>" that addresses the indeterminacy related to <A>. The author maintains that this element is capable of solving certain problems that escape resolution through fuzzy logic [6]. Everyday problems, such as weather forecasting, stock price estimation, and electoral processes, often involve conditions of indeterminacy that are not effectively handled by fuzzy set theory. Therefore, neutrosophic set theory focuses on addressing imprecise and ambiguous situations, in which precise analysis becomes difficult or even unattainable [7]. In the context of animal protection in Ecuador, this theoretical approach could provide a valuable tool to address the complexity of decision-making, especially when faced with uncertain or vague situations where conventional precision is limited.

As a result of Smarandache's contributions, various notions aimed at neutrosophic sets have been introduced, which provide a more solid mathematical framework to address information characterized by its indeterminacy and inconsistency [8], [9]. Within this framework, concepts such as the interval neutrosophic set (INS) [10] and the single-valued neutrosophic set (SVNS) [11] have emerged. These elements represent subcategories of neutrosophic sets and have established set-theoretic operators as well as various properties inherent to SVNS and INS. Consequently, SVNS and INS can find concrete applications in the fields of science and engineering.[12],[13]

Subsequently, the use of SVNS correlation coefficients has been proposed, which are based on the extension of the correlation coefficient of intuitionistic fuzzy sets. This approach has shown that the SVNS cosine similarity measure is a particular case of the SVNS correlation coefficient, and has consequently been applied in the context of single-valued neutrosophic numbers in the field of decision-making.[14], [15], [19], [20-23]

The purpose of this study is to demonstrate the usefulness of neutrosophic logic in identifying deficiencies and areas for improvement in animal protection in Ecuador. In this context, correlation coefficients are revealed as a highly relevant tool to evaluate the relationship between two objects, being widely applied in data analysis and classification, decision-making, and other related areas [16]. The article initially addresses the foundations of neutrosophic logic and SVNS, as well as the formulas intended for the analysis of correlation coefficients in the field of single-valued neutrosophic sets. Subsequently, the foundations to carry out the analysis are set, the results obtained are presented and, finally, the conclusions of the study are derived.

2 Methodology

2.1 Preliminary information on neutrosophy

Definition 1: Let X be a space of elements (objects), where a generic element in X is represented as x. A neutrosophic set A in X is defined by three distinct functions: the membership function in terms of truth, $T_A(x)$, the membership function in terms of indeterminacy, $I_A(x)$, and the membership function in terms of falsity, $F_A(x)$. These functions, $T_A(x), I_A(x)$, and $F_A(x)$, represent subsets that are standard or non-standard real numbers and are constrained to the open interval $]0^-, 1^+[$, which means $T_A(x): X \to]0^-, 1^+[, I_A(x): X \to]0^-, 1^+[$ and $F_A(x): X \to]0^-, 1^+[$. It is worth noting that there is no limitation on the sum of the functions $T_A(x), I_A(x)$, and $F_A(x)$, which implies that $0^- \leq supT_A(x) + supI_A(x) + supF_A(x) \leq 3^+$. [17-22]

Since the application of neutrosophic sets in practical situations is often challenging, the notion of a single-valued neutrosophic set (SVNS) has been proposed, which is configured as a specific instance of a neutrosophic set. This approach is intended to be used in real applications in scientific and engineering fields. The definition of SVNS is presented below.[12-21]

Definition 2. [12] Let X be a space of points (objects) with generic elements in X denoted by x. An SVNS A in X is characterized by a truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$, and a falsity-membership function $F_A(x)$ for each point x in X, where $T_A(x), I_A(x), F_A(x) \in [0,1]$. Therefore, a SVNS A can be expressed as $A = \{x, T_A(x), I_A(x), F_A(x) \mid x \in X\}$. This means that the sum of $T_A(x), I_A(x)$, and $F_A(x)$ satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

Definition 3. An SVNS A is included in another SVNS B, denoted as $A \subseteq B$, when it holds that $T_A(x) \leq T_B(x), I_A(x) \geq I_B(x), y\ F_A(x) \geq F_B(x)$ for all elements x in the set X.

Definition 4. In accordance with [12], the complement of an SVNS A can be denoted by Ac and can be defined as: $Ac = \{x, F_A(x), 1 - I_A(x), T_A(x) \mid x \in X\}$

Definition 5. Two single-valued neutrosophic sets A and B are considered identical, denoted as A = B, if and only if $A \subseteq B$ and $B \subseteq A$.

Definition 6. The correlation coefficient between two single-valued neutrosophic sets A and B in the universe of discourse $X = \{x_1, x_2, \dots, x_n\}$ is defined as follows:

$$M(A,B) = \frac{1}{3n}\sum_{i=1}^{n}[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (1)$$

where

$$\phi_i = \frac{3-\Delta T_i - \Delta T_{max}}{3-\Delta T_{min} - \Delta T_{max}},$$

$$\varphi_i = \frac{3-\Delta I_i - \Delta I_{max}}{3-\Delta I_{min} - \Delta I_{max}},$$

$$\psi_i = \frac{3-\Delta F_i - \Delta F_{max}}{3-\Delta F_{min} - \Delta F_{max}},$$

$\Delta T_i = |T_A(x_i) - T_B(x_i)|$,

$\Delta I_i = |I_A(x_i) - I_B(x_i)|$,

$\Delta T_i = |T_A(x_i) - T_B(x_i)|$,

$\Delta T_{min} = min_i|T_A(x_i) - T_B(x_i)|$,

$\Delta I_{min} = min_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{min} = min_i|F_A(x_i) - F_B(x_i)|$,

$\Delta T_{max} = max_i|T_A(x_i) - T_B(x_i)|$,

$\Delta I_{max} = max_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{max} = max_i|F_A(x_i) - F_B(x_i)|$,

For all $xi \in X$ and i = 1, 2, . . ., n

However, the differences in the importance of the elements in the universe must be taken into account. Consequently, it is necessary to consider the weight of the element $x_i(i = 1,2,\dots,n)$. Below, a weighted correlation coefficient between the SVNS is presented.

Definition 7. Given that w_i is the weight of each element x_i $(i = 1,2,\dots,n), w_i \in [0,1]$, and $\sum_{i=1}^{n} w_i = 1$, it is possible to obtain the weighted correlation coefficient between the SVNS A and B as shown in equation (2):

$$M_w(A,B) = \frac{1}{3}\sum_{i=1}^{n} w_i[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (2)$$

2.2 Correlation coefficient of SVNSs for decision-making.

In the context of a multi-attribute decision-making problem, considering single-valued neutrosophic information, the representation of the characteristic of an alternative A_i $(i = 1,2,\dots,m)$ with respect to an attribute C_j $(j = 1,2,\dots,n)$ is represented by the following Single-Valued Neutrosophic Set (SVNS): $A_i = \{C_j, T_{Ai}(C_j), I_{Ai}(C_j), F_{Ai}(C_j) | Cj \in C, j = 1,2,\dots,n\}$, $T_{Ai}(C_j)$, $I_{Ai}(C_j), F_{Ai}(C_j)) \in [0,1]$, and $0 \le T_{Ai}(C_j)$, $I_{Ai}(C_j), F_{Ai}(C_j) \le 3$ for $Cj \in C, j = 1,2,\dots,n,$ and $i = 1,2,\dots,m.$. For the sake of simplicity and convenience in the analysis, the values of the three functions $T_{Ai(C_j)}, I_{Ai(C_j)}$, and $F_{Ai(C_j)}$ are represented using a Single-Valued Neutrosophic Value (SVNV) $d_{ij} = < t_{ij}, i_{ij}, f_{ij} >$ (where i = 1, 2, ..., m; j = 1, 2, ..., n). These values are often derived from the evaluation of an alternative A_i with respect to a criterion C_j by an expert or decision-maker. Consequently, a Single-Valued Neutrosophic Decision Matrix, $D = (d_{ij})_{mxn}$, is constructed.

In accordance with [18], in multi-attribute decision-making problems, the ideal point concept is used to help identify the best alternative within the decision set. Although the ideal alternative does not exist in reality, it provides a useful theoretical reference for evaluating the other alternatives.

In the decision-making method, an ideal Single-Valued Neutrosophic Value (SVNV) is defined as $d_j^* = < t_j^*, i_j^*, f_j^* > = < 1,0,0 > (j = 1,2,\dots,n)$ for the ideal alternative A^*. Therefore, by applying Equation (2), the weighted correlation coefficient between an alternative A_i (where i = 1, 2, ..., m) and the ideal alternative A^* is calculated as follows:

$$M_w(A_i, A^*) = \frac{1}{3}\sum_{j=1}^{n} w_j\left[\phi_{ij}(1-\Delta t_{ij}) + \varphi_{ij}(1-\Delta i_{ij}) + \psi_{ij}(1-\Delta f_{ij})\right] \quad (3)$$

where

$$\phi_{ij} = \frac{3 - \Delta t_{ij} - \Delta t_{i\,max}}{3 - \Delta t_{i\,min} - \Delta t_{i\,max}},$$

$$\varphi_i = \frac{3 - \Delta i_{ij} - \Delta i_{i\,max}}{3 - \Delta i_{i\,min} - \Delta i_{i\,max}},$$

$$\psi_i = \frac{3 - \Delta f_{ij} - \Delta f_{i\,max}}{3 - \Delta f_{i\,min} - \Delta f_{i\,max}},$$

$$\Delta t_{ij} = |t_{ij} - t_j^*)|,$$

$$\Delta i_{ij} = |i_{ij} - i_j^*)|,$$

$$\Delta f_{ij} = |f_{ij} - f_j^*)|,$$

$$\Delta t_{i\,min} = min_j|t_{ij} - t_j^*|,$$

$$\Delta i_{i\,min} = min_j|i_{ij} - i_j^*|,$$

$$\Delta f_{i\,min} = min_j|f_{ij} - f_j^*|,$$

$$\Delta t_{i\,max} = max_j|t_{ij} - t_j^*|,$$

$$\Delta i_{i\,max} = max_j|i_{ij} - i_j^*|,$$

$$\Delta f_{i\,max} = max_j|f_{ij} - f_j^*|,$$

For $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$. By calculating the correlation coefficient $M_w\,(A_i, A^*)$ $(i = 1, 2, \ldots, m)$, it is possible to subsequently obtain the ranking order of all the alternatives and the best one(s).

2.3 Methodological framework

The research was based on an approach focused on evaluating the gaps and deficiencies inherent in the field of animal protection in Ecuador, using neutrosophic logic as its primary analytical tool. The methodology employed in this study was characterized by its exploratory approach, supported by the expertise and knowledge of experts in the field of animal protection. This study was framed within a qualitative perspective, adopting a descriptive and exploratory design to precisely understand and analyze the existing deficiencies in the field of animal protection in Ecuador. It is worth noting that the inherent indeterminacies in the decision-making process were considered.

To identify the gaps and deficiencies related to animal protection in Ecuador, an exhaustive documentary review of the legislation and regulations related to animal protection in the country was conducted. This analysis allowed for the detection of potential legal gaps and weaknesses in the implementation of existing regulations. In parallel, structured interviews were conducted with a panel of five experts in the field of animal protection in Ecuador. These experts significantly contributed by providing detailed information about the deficiencies they identified in both the legislation and the practice of animal protection in the country.

Additionally, three evaluation criteria were defined to assess the impact of the deficiencies on animal protection rights. These criteria were based on considerations regarding the severity of the identified deficiencies (Criterion 1), the magnitude of their influence on animal welfare (Criterion 2), and the effectiveness of existing measures (Criterion 3).

Once the identification of gaps and deficiencies through documentary review and expert interviews was achieved, neutrosophic correlation coefficients were applied. These coefficients allowed for a rigorous quantification and analysis of the relationship between the identified gaps and the previously established criteria, providing a precise measure of the magnitude of these gaps and their impact on animal rights.

The results obtained from the evaluation of the deficiencies under the proposed criteria will enable the identification of the most significant areas for improvement in animal protection in Ecuador. These areas of improvement will form a solid basis for the formulation of strategies that have a significant impact on the promotion and guarantee of animal rights in the country. The main goal of this research lies in its contribution to strengthening policies and legislation in favor of animal protection in Ecuador, as well as promoting positive changes in public awareness regarding this issue. These improvements are made possible through the implementation of neutrosophy as a tool to address aspects involving indeterminacies in the decision-making process.

3 Results

The exhaustive literature review and consultations with experts in the field of animal protection in Ecuador allowed to identify seven fundamental categories of gaps and deficiencies in the country's animal protection. Each of these categories represents critical areas that require substantial improvements:

1. Need to promote research: Scientific research in the field of animal welfare proved to be limited in Ecuador. The scarcity of studies and research in this area hindered informed and evidence-based decision-making, which is crucial for driving significant improvements.
2. Inadequate application of sanctions: Despite having animal protection laws, there was inconsistent application of sanctions in cases of animal abuse or mistreatment. The existing sanctions did not always reflect the severity of the crimes committed, resulting in inadequate punishments.
3. Limited public education: The lack of educational programs and public awareness campaigns on animal welfare contributed to widespread indifference towards animal protection in society. The lack of adequate information on the rights and needs of animals was evident.
4. Deficient supervision and control: Authorities responsible for supervising compliance with animal protection laws faced significant limitations in terms of resources and personnel. This lack of capacity resulted in inadequate supervision, allowing harmful practices to persist.
5. Lack of protocols for rescue and rehabilitation: The absence of standardized protocols for the rescue and rehabilitation of abused or endangered animals limited the effectiveness of rescue efforts and the care provided to animal abuse victims.
6. Limited international cooperation: Ecuador lacked agreements and collaboration with other countries in the field of animal protection. International cooperation, essential for combating the illegal wildlife trade and promoting global animal welfare standards, was identified as an area of deficiency.
7. Legal gaps and regulatory ambiguities: Animal protection legislation in Ecuador showed deficiencies in terms of the clarity and consistency of its provisions. The lack of precise definitions and specific provisions created ambiguities that complicated the effective application of regulations.

Each of these gaps and deficiencies was thoroughly evaluated based on three key criteria: severity, impact on animal welfare, and the effectiveness of existing measures. The application of neutrosophic logic allowed for assigning values of truth, indeterminacy, and falsehood to each gap in relation to these criteria. The assessment of these gaps was based on the previously defined criteria, and neutrosophic logic was used to accurately quantify their impact on animal rights in Ecuador.

The analysis conducted was based on obtaining the arithmetic mean of the evaluations provided by the experts in the study. This methodology was applied to combine and synthesize the individual perspectives of the experts, enabling the creation of a resulting decision matrix. The decision matrix, denoted as "D," was generated from the assessments of the identified gaps and deficiencies concerning the three previously defined criteria: severity, impact on animal welfare, and effectiveness of existing measures. The decision matrix D is presented below:

$$D=\begin{vmatrix} (0.4; 0.2; 0.2) & (0.4; 0.2; 0.3) & (0.5; 0.2; 0.3) \\ (0.5; 0.2; 0.3) & (0.7; 0.1; 0.2) & (0.6; 0.2; 0.3) \\ (0.4; 0.3; 0.2) & (0.5; 0.2; 0.3) & (0.6; 0.1; 0.2) \\ (0.5; 0.2; 0.3) & (0.4; 0.2; 0.2) & (0.4; 0.2; 0.2) \\ (0.4; 0.2; 0.2) & (0.6; 0.1; 0.2) & (0.3; 0.2; 0.3) \\ (0.6; 0.1; 0.2) & (0.5; 0.2; 0.3) & (0.6; 0.1; 0.2) \\ (0.7; 0.1; 0.2) & (0.6; 0.1; 0.2) & (0.6; 0.1; 0.2) \end{vmatrix}$$

According to the previously established methodology and the obtained results, the next step involved determining the minimum and maximum values in the membership functions for truth, falsehood, and indeterminacy.

These values are crucial for understanding the uncertainty in the data and assessments because they provide specific values for each gap in relation to the evaluation criteria. The inherent uncertainty in the assessments is reflected in these minimum and maximum values, contributing to a more precise and evidence-based assessment of deficiencies in animal protection in the country. The values obtained after conducting this analysis are presented in Table 1.

Table 1: Minimum and maximum values in the membership functions of truth, falsehood, and indeterminacy. Source: own elaboration.

	ΔTmin	ΔImin	ΔFmin	ΔTmax	ΔImax	ΔFmax
Need to promote research	0.5	0.2	0.2	0.6	0.3	0.2
Inadequate application of sanctions	0.3	0.2	0.1	0.5	0.3	0.2
Limited public education	0.4	0.2	0.1	0.6	0.3	0.3
Deficient supervision and control	0.5	0.2	0.2	0.6	0.3	0.2
Lack of protocols for rescue and rehabilitation	0.4	0.2	0.1	0.7	0.3	0.2
Limited international cooperation	0.4	0.2	0.1	0.5	0.3	0.2
Legal gaps and regulatory ambiguities	0.3	0.2	0.1	0.4	0.2	0.1

On the other hand, the values of φ, μ, and ψ for each selection alternative are essential to determine the relationship between the identified gaps and the evaluation criteria. These values reflect the uncertainty and ambiguity in the evaluations of each alternative based on the established criteria. These values are crucial for the calculation of neutrosophic correlation coefficients. The results obtained in this regard are shown in Table 2.

Table 2: Values of φ, μ, and ψ for each selection alternative. Source: own elaboration.

	ϕ			μ			ψ		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
Need to promote research	0.95	0.95	1	1	0.96	0.96	1	1	1
Inadequate application of sanctions	0.91	1	0.95	0.96	1	0.96	0.96	1	1
Limited public education	0.9	0.95	1	1	0.96	1	0.92	0.96	1
Deficient supervision and control	1	0.95	0.95	0.96	1	1	1	1	1
Lack of protocols for rescue and rehabilitation	0.89	1	0.84	1	1	0.96	0.96	1	1
Limited international cooperation	1	0.95	1	1	0.96	1	1	0.96	1
Legal gaps and regulatory ambiguities	1	0.96	0.96	1	1	1	1	1	1

The use of equation (3) allows calculating the values of the M_w correlation coefficients (A_i, A^*). These coefficients reflect the relationship between each alternative A_i and the ideal alternative A^*, based on the previously established evaluation criteria. Table 3 shows the calculated values of the M_w correlation coefficients (A_i, A^*) and their corresponding ranking. These values are crucial for identifying the most significant areas for improvement in animal protection in Ecuador, serving as a basis for the formulation of effective strategies and the promotion of animal rights in the country.

Table 3: Weighted correlation coefficients. Source: own elaboration.

Detected deficiencies	M
Need to promote research	0.6447
Inadequate application of sanctions	0.7046
Limited public education	0.6732
Deficient supervision and control	0.6589
Lack of protocols for rescue and rehabilitation	0.6614
Limited international cooperation	0.7283
Legal gaps and regulatory ambiguities	0.7758

In the presented table, the deficiencies are ranked according to the values of "M." The gap with the highest "M" value is related to "Legal gaps and regulatory ambiguities," with a weighted correlation coefficient of 0.7758. This highlights the importance of addressing the lack of precise definitions and specific provisions in animal protection legislation in Ecuador. Legal ambiguity can hinder the effective implementation of regulations and should, therefore, be considered a priority.

In second place, the deficiencies related to "Limited international cooperation" and "Inadequate application of sanctions," with "M" values of 0.7283 and 0.7046, respectively. These deficiencies indicate that improving international cooperation on animal protection issues and ensuring consistency in the application of sanctions are crucial aspects for strengthening animal protection in the country.

The deficiencies of "Limited public education," "Lack of protocols for rescue and rehabilitation," and "Deficient supervision and control" are also considered critical areas for improvement, with "M" values ranging between 0.6614 and 0.6732. This suggests the need to implement public education programs, establish protocols for the rescue and rehabilitation of abused animals, and strengthen the supervision and control of animal protection laws.

Finally, the "Need to promote research" has an "M" value of 0.6447. Although slightly less significant than other deficiencies, it remains a priority for strengthening the knowledge base in the field of animal welfare.

Conclusions

The present study demonstrated the utility of neutrosophic logic in identifying deficiencies and areas for improvement in animal protection in Ecuador. The use of neutrosophic logic as an analytical tool allowed for the assessment of the magnitude of these deficiencies based on three key criteria: severity, impact on animal welfare, and the effectiveness of existing measures. The results revealed seven main categories of gaps and deficiencies in animal protection in Ecuador. The most significant deficiency was related to "Legal gaps and regulatory ambiguities," followed closely by "Limited international cooperation" and "Inadequate application of sanctions." These gaps emphasized the need to address the lack of clear definitions in legislation, strengthen international cooperation, and ensure consistent sanctions for animal abuse.

Neutrosophic logic played a crucial role in evaluating these deficiencies by addressing the inherent uncertainty in this type of analysis. Neutrosophic correlation coefficients provided a precise measure of the magnitude of the deficiencies and their impact on animal rights. The use of neutrosophic logic as an analytical tool allowed for a precise and quantifiable assessment of the extent of gaps and deficiencies in animal protection. It is recommended that future research in the field of animal protection consider the use of neutrosophic logic as an effective tool for evaluating gaps and deficiencies, as it can offer a more comprehensive and accurate understanding of the situation.

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University of New Mexico

Neutrosophic Analysis of Equity in the Justice System

Bolívar David Narváez Montenegro[1], Oscar Fabian Silva Montoya[2], Julián Rodolfo Santillan Andrade[3], and Christian Fernando Tantaleán Odar[4]

[1]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.bolivarnarvaez@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Puyo. Ecuador. E-mail: up.oscarsilva@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.juliansantillan@uniandes.edu.ec
[4]Universidad Nacional Mayor de San Marcos, Perú. E-mail: christian.tantalean@unmsm.edu

Abstract. Equity in the justice system is a fundamental principle of law that seeks to ensure fair and impartial treatment for all individuals, regardless of their characteristics. The Ecuadorian justice system faces challenges regarding its equity and efficiency, including concerns about access to justice, impartiality in decision-making, corruption, and the lack of independence in the judicial system. Neutrosophy, as a philosophical theory that promotes neutrality and impartiality, is useful in the analysis of equity in the justice system. It helps identify systematic inequalities and discrimination in the justice system, which is essential for finding fair and equitable solutions. Evaluating equity in the Ecuadorian justice system involves considering multiple aspects and factors. Six study alternatives were identified and the most significant elements for the analysis of equity in the Ecuadorian justice system were analyzed using neutrosophic techniques. This contributes to improving equity in the justice system and ensuring fair and equitable treatment for all Ecuadorian citizens.

Keywords: Equity, Law, justice system, neutrosophy, philosophical theory.

1. Introduction

Equity in the justice system is a fundamental principle of law. It involves treating all people fairly and impartially, regardless of their ethnicity, gender, religion, sexual orientation, socioeconomic status, or other personal characteristics [1]. Equity seeks to ensure that all individuals have equal opportunity and access to a fair legal process. Some fundamental aspects of equity in the justice system are listed below:

1. Equality before the law: All individuals, regardless of their social status or personal characteristics, must be treated equally under the law. This means that laws and legal procedures apply uniformly to everyone.
2. Equal access to justice: Equity implies that all people have equal access to legal resources and legal representation. This ensures that people are not excluded from justice due to economic or social limitations.
3. Protection of human rights: Fairness in the justice system involves the protection of the fundamental human rights of all people, including the right to a fair trial, the right to a defense attorney, and the right to an impartial legal process.
4. Elimination of prejudice and discrimination: To achieve equity, it is essential to eliminate prejudice and discrimination at all stages of the legal process, from police investigation to trial and sentencing.
5. Education and awareness: Promoting education and awareness about equity in the justice system is essential to ensure that both legal professionals and the general public understand the importance of treating everyone fairly and equitably.
6. Legal and policy reforms: Legal and policy reforms need to be implemented to promote equity in the justice system, such as reviewing laws and practices that may have a disproportionate impact on marginalized communities.
7. Supervision and accountability: Supervision and accountability are essential to ensure that the justice system meets fairness standards. This involves reviewing cases, investigating allegations of misconduct, and sanctioning those who violate principles of fairness.

Equity in the justice system is a fundamental goal for society. It ensures that all individuals have the opportunity to seek justice in a fair and equitable manner, regardless of their background or personal circumstances. Achieving this goal is a constant challenge that requires the commitment of legal institutions, legal professionals, and society as a whole. [2]

The Ecuadorian justice system faces challenges and concerns regarding its equity and efficiency. Over the years, there have been issues related to access to justice, impartiality in decision-making, and the protection of human rights. One of the fundamental concerns is equal access because disparities in access to legal representation and judicial resources often exist, which can disadvantage individuals with low incomes and marginalized communities. Additionally, problems of corruption and a lack of independence in the judicial system have been pointed out, raising questions about impartiality in decision-making. The need to improve transparency and accountability in the justice system is also evident [3].

In the Ecuadorian context, it is important to highlight specific challenges related to ethnic and racial equity. Indigenous and Afro-Ecuadorian populations often face obstacles in the justice system and can be victims of discrimination. Ensuring genuine equity in the justice system requires addressing these inequalities and ensuring that all individuals, regardless of their ethnic background, are treated fairly and with respect for their cultural rights.[4]

The prison system in Ecuador is also under scrutiny. Prison overcrowding and detention conditions are concerning. The rehabilitation of inmates often faces challenges as well. Implementing effective rehabilitation policies and reducing recidivism are fundamental issues for improving equity in the justice system.

In recent years, the Ecuadorian government has taken some measures to promote equity in the justice system. For example, a public defender system has been established to provide free legal assistance to people who cannot afford a lawyer. Programs have also been implemented to increase the participation of women and minorities in the judicial system.

While efforts have been made in Ecuador to address these challenges and improve equity in the justice system, there are still areas that require ongoing attention and reforms. It is essential to maintain an open and collaborative dialogue among authorities, civil society, and affected communities. They will be responsible for addressing these issues effectively and achieving a more equitable and accessible justice system for all Ecuadorians.

To achieve equity in the justice system in Ecuador, a concerted effort is needed from all stakeholders, including the government, civil society, and the private sector. To promote equity in the Ecuadorian justice system, some actions as described below would be necessary.

- Strengthen the public defender system: The public defender system should be strengthened to provide free and quality legal assistance to people who cannot afford a lawyer. This can be achieved by increasing the budget of the system and providing training to public defenders.
- Promote the participation of women and minorities in the judicial system: The government should promote the participation of women and minorities in the judicial system through recruitment and training programs. This will help ensure that the judicial system reflects the diversity of Ecuadorian society.
- Implement procedural reforms: Procedural reforms should be implemented to streamline the judicial system and reduce corruption. This can be done, for example, by automating processes and establishing internal control mechanisms.
- Promote human rights education: It is necessary to promote human rights education so that people are aware of their rights and how to defend them. This can be achieved through educational programs in schools and within the community.

Equity in the justice system is a fundamental human right. By promoting equity in the justice system in Ecuador, a fair and equitable society for everyone is potentiated.

Neutrosophy is a philosophical theory that focuses on the idea of neutrality and the search for an impartial perspective. In the context of evaluating equity in the justice system, neutrosophy could be used as an approach to examine this concept from a neutral and unbiased standpoint. This is crucial because biases can distort the perception of equity and lead to inaccurate conclusions.

Neutrosophy encourages analysts to adopt a neutral perspective and examine facts and data impartially. This helps in assessing whether the principles of equity are being applied in the justice system fairly. It promotes objectivity in analysis, which involves relying on concrete data and evidence rather than subjective opinions. In the context of justice, this is essential for evaluating whether the rights of all individuals are being respected equitably.

It can help identify systematic inequalities and discrimination in the justice system, as it focuses on an impartial assessment of data and policies. Once issues related to equity in the justice system have been identified, neutrosophy can guide the search for solutions that are fair and equitable for all parties involved.

It advocates for an ongoing and continuous review of policies and practices to ensure that equity in the justice system is maintained over time. By adopting a neutral and impartial approach, neutrosophy promotes transparency in the analysis of equity in the justice system. This can help make the analysis process more reliable and credible. In summary, neutrosophy can be useful in analyzing equity in the justice system by providing a framework that encourages neutrality, impartiality, and objectivity. These are essential elements for understanding, evaluating, and improving equity in the justice system, which in turn contributes to a fair and equitable system for all citizens.

The present research aims to assess the equity of judicial decisions and the functioning of the justice system in Ecuador. The study will be conducted using neutrosophic correlation coefficients.

2 Preliminaries

Definition 1. Consider a set X, comprising various points (objects), with a typical element labeled as x. A neutrosophic set A within X is defined by three core functions [5], [6]: the truth-membership function, $T_A(x)$, the indeterminacy-membership function, $I_A(x)$, and the falsity-membership function, $F_A(x)$. These functions, $T_A(x)$, $I_A(x)$, and $F_A(x)$, represent real, standard, or nonstandard subsets of the range between -0 and 1 (exclusive). In mathematical terms, $T_A(x)$: X →] -0, 1+ [, $I_A(x)$: X →] -0, 1+ [, and $F_A(x)$: X →] -0, 1+ [. Importantly, there are no restrictions on the sum of $T_A(x)$, $I_A(x)$, and $F_A(x)$, allowing -0 ≤ sup $T_A(x)$ + sup $I_A(x)$ + sup $F_A(x)$ ≤ 3+.

The practical application of neutrosophic sets to real-world problems is inherently challenging. Hence, an innovative concept, known as a Single Valued Neutrosophic Set (SVNS), was introduced to facilitate its use in scientific and engineering contexts. It will now delve into the definition of an SVNS [7], [8-13-14-15].

Definition 2. Within a set X, consisting of various points (objects), denoted as x, an SVNS A is characterized by a truth-membership function, $T_A(x)$, an indeterminacy-membership function, $I_A(x)$, and a falsity-membership function, $F_A(x)$, for each point x in X. These functions, $T_A(x)$, $I_A(x)$, and $F_A(x)$, are bounded within the range of [0, 1]. Therefore, an SVNS A can be represented as follows [9-16-17]:

A = {x, $T_A(x)$, $I_A(x)$, $F_A(x)$ |x ∈ X}

Then, the sum of $T_A(x)$, $I_A(x)$, and $F_A(x)$ satisfies the condition 0 ≤ $T_A(x) + I_A(x) + F_A(x)$ ≤ 3.

Definition 3. The complement of an SVNS A is denoted by A_c and is defined as

Ac = {x, FA(x), 1 − IA(x), TA(x) |x ∈ X}

Definition 4. A SVNS A is contained in the other SVNS B, A ⊆ B if and only if $T_A(x) \le T_B(x)$, $I_A(x) \ge I_B(x)$, and $F_A(x) \ge F_B(x)$ for every x in X.

Definition 5. Two SVNSs A and B are equal, written as A = B, if and only if A ⊆ B and B ⊆ A

2.1 Correlation coefficient of SVNSs

Definition 6. For any two SVNSs A and B in the universe of discourse X = {x1, x2, . . . , xn}, the correlation coefficient between two SVNSs A and B is defined as follows [10]:

$$M(A,B) = \frac{1}{3n}\sum_{i=1}^{n}[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (1)$$

Where

$$\phi_i = \frac{3-\Delta T_i - \Delta T_{max}}{3-\Delta T_{min} - \Delta T_{max}},$$

$$\varphi_i = \frac{3-\Delta I_i - \Delta I_{max}}{3-\Delta I_{min} - \Delta I_{max}},$$

$$\psi_i = \frac{3-\Delta F_i - \Delta F_{max}}{3-\Delta F_{min} - \Delta F_{max}},$$

$\Delta T_i = |T_A(x_i) - T_B(x_i)|$,

$\Delta I_i = |I_A(x_i) - I_B(x_i)|$,

$\Delta T_i = |T_A(x_i) - T_B(x_i)|$,

$\Delta T_{min} = min_i|T_A(x_i) - T_B(x_i)|$,

$\Delta I_{min} = min_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{min} = min_i|F_A(x_i) - F_B(x_i)|$,

$\Delta T_{max} = max_i|T_A(x_i) - T_B(x_i)|$,

$\Delta I_{max} = max_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{max} = max_i|F_A(x_i) - F_B(x_i)|$,

for all x_i ∈ X and i = 1, 2, . . ., n

Definition 7. In the context of weights for individual elements x_i (where i = 1, 2, ..., n) with values in the interval [0, 1], and the sum of all the values w_i from i = 1 to n is equal to 1, the weighted correlation coefficient between SVNSs A and B is obtained as follows:

$$M_w(A,B) = \frac{1}{3}\sum_{i=1}^{n} w_i[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \tag{2}$$

2.1.1 Decision-making method using the correlation coefficient of SVNSs.

For each element x_i (i = 1, 2, ..., n), a weight w_i is assigned, which varies in the interval [0, 1], and the sum of all the weights $\sum_{i=1}^{n} w_i$ is equal to 1. Consequently, the weighted correlation coefficient between the standard normal random variables A and B is obtained:

$A_i = \{C_j, T_{Ai}(C_j), I_{Ai}(C_j), F_{Ai}(C_j) | C_j \in C, j = 1, 2, ..., n\}$
where $T_{Ai}(C_j), I_{Ai}(C_j), F_{Ai}(C_j) \in [0, 1]$ and $0 \le T_{Ai}(C_j) + I_{Ai}(C_j) + F_{A}i(C_j) \le 3$ for $C_j \in C$, j =1, 2, . . ., n, and i = 1, 2, . . ., m.

For the sake of convenience, the values of the three functions T_{Ai} (Cj), I_{Ai} (Cj), and F_{Ai} (Cj) are represented using a single-valued neutrosophic values (SVNV) d_{ij} = <t_{ij}, i_{ij}, f_{ij} > (i = 1, 2, . . ., m; j = 1, 2, . . ., n). Typically, this SVNV is derived through the evaluation of an alternative A_i concerning a criterion C_j by an expert or decision-maker. As a result, we can extract a single-valued neutrosophic decision matrix D = (d_{ij})m×n [11].

In the context of problems involving multiple-attribute decision-making, the concept of an ideal point has been employed to facilitate the identification of the best alternative within the decision set. While it's important to note that an ideal alternative doesn't have a real-world existence, it serves as a valuable theoretical framework for the evaluation of alternatives.

Within the decision-making methodology, we can define an ideal SVNV as dj* = < tj*, ij*, fj* > = < 1, 0, 0 > (j = 1, 2, . . . , n) for the ideal alternative A* [12]. Consequently, by applying Equation (2), the weighted correlation coefficient between an alternative Ai (i =1, 2, . . ., m) and the ideal alternative A* can be calculated by:

$$M_w(A_i,A^*) = \frac{1}{3}\sum_{j=1}^{n} w_j[\phi_{ij}(1-\Delta t_{ij}) + \varphi_{ij}(1-\Delta i_{ij}) + \psi_{ij}(1-\Delta f_{ij})] \tag{3}$$

Where

$$\phi_{ij} = \frac{3-\Delta t_{ij}-\Delta t_{i\,max}}{3-\Delta t_{i\,min}-\Delta t_{i\,max}},$$

$$\varphi_i = \frac{3-\Delta i_{ij}-\Delta i_{i\,max}}{3-\Delta i_{i\,min}-\Delta i_{i\,max}},$$

$$\psi_i = \frac{3-\Delta f_{ij}-\Delta f_{i\,max}}{3-\Delta f_{i\,min}-\Delta f_{i\,max}},$$

$$\Delta t_{ij} = |t_{ij} - t_j^*)|,$$

$$\Delta i_{ij} = |i_{ij} - i_j^*)|,$$

$$\Delta f_{ij} = |f_{ij} - f_j^*)|,$$

$$\Delta t_{i\,min} = min_j|t_{ij} - t_j^*|,$$

$$\Delta i_{i\,min} = min_j|i_{ij} - i_j^*|,$$

$$\Delta f_{i\,min} = min_j|f_{ij} - f_j^*|,$$

$$\Delta t_{i\,max} = max_j|t_{ij} - t_j^*|,$$

$$\Delta i_{i\,max} = max_j|i_{ij} - i_j^*|,$$

$$\Delta f_{i\,max} = max_j|f_{ij} - f_j^*|,$$

for i = 1, 2, . . ., m and j = 1, 2, . . ., n. By the correlation coefficient $M_w(A_i, A^*)$ (i =1, 2, . . ., m), the ranking order of all alternatives and the best one(s) can be obtained.

2.2 Methods

A literature review was conducted, involving the analysis of original articles and systematic reviews published in the last five years related to the topic of interest. The search was performed by querying specialized databases using Google Scholar as the search engine.

The scientific data collected were compiled and subsequently subjected to a scientific review process. This process was conducted by a team of three experts in the field, each with a minimum of eight years of experience in the subject matter. To streamline the work process and data analysis, it was decided to synthesize the gathered information. As a result of the preliminary analysis, a sample of alternatives for conducting the study was selected. The following are the alternatives that will be evaluated:

A1. Evaluation of Crime Prevention Policies: Examine the policies and strategies used by law enforcement and judicial authorities to prevent crime and promote public safety. This could include reviewing crime prevention programs and their impact on reducing criminality.
A2. Evaluation of Restorative Justice: Analyze the implementation of restorative justice practices in the justice system, such as mediation and dialogue between the parties involved in a crime. Evaluate their effectiveness in conflict resolution and damage reparation.
A3. Review of Victim Protection Policies: Examine policies and practices related to the protection of crime victims. Evaluate whether adequate support is provided to victims throughout the legal process and whether their rights are respected.
A4. Examination of Environmental Justice: In the Ecuadorian context, it might be relevant to evaluate policies and practices related to environmental justice. This would include reviewing cases of environmental crimes and the effective application of sanctions to offenders.
A5. Evaluation of the Implementation of Technology in the Justice System: Assess how technology has been integrated into the justice system, from case management to online trial proceedings, and how it has affected equity and efficiency.
A6. Analysis of Alternative Sentencing: Investigate the application of non-custodial sentences, such as probation programs, community service, or treatment programs. Evaluate their effectiveness in rehabilitating offenders and reducing prison overcrowding.

The evaluation of equity in the justice system is a complex process that involves considering multiple aspects and factors. In Figure 1, some criteria and their key considerations are presented for the study that will be conducted in the assessment of equity in the Ecuadorian justice system. They were coded for better management as C_1, C_2, and C_3, according to their appearance order.

Figure 1: Analysis criteria for the study. Source: own elaboration.

The criteria were subjected to evaluation by experts, comparing them with each of the alternatives based on equity in the Ecuadorian justice system. To this end, the evaluations to be granted must specify to what extent the expert considers that alternative A_i is good (T_x), bad (F_x), or is not entirely sure (I_x) with respect to criterion C_j. It is considered that the evaluated criteria have the same weight w_j=0.33.

3 Results

The results obtained from the assessments of all experts are considered equally important, and the average of the results is calculated for processing and obtaining the information. In this way, the resulting decision matrix D is shown below (Figure 2).

Figure 2: Decision matrix D. Source: own elaboration.

$$D=\begin{bmatrix} \langle 0.5; 0.3; 0.2\rangle & \langle 0.4; 0.2; 0.3\rangle & \langle 0.2; 0.2; 0.5\rangle \\ \langle 0.6; 0.1; 0.2\rangle & \langle 0.6; 0.1; 0.2\rangle & \langle 0.4; 0.2; 0.3\rangle \\ \langle 0.5; 0.3; 0.2\rangle & \langle 0.5; 0.2; 0.3\rangle & \langle 0.6; 0.1; 0.2\rangle \\ \langle 0.7; 0.1; 0.1\rangle & \langle 0.2; 0.2; 0.5\rangle & \langle 0.4; 0.2; 0.2\rangle \\ \langle 0.3; 0.2; 0.3\rangle & \langle 0.6; 0.1; 0.2\rangle & \langle 0.3; 0.2; 0.3\rangle \\ \langle 0.6; 0.1; 0.2\rangle & \langle 0.5; 0.2; 0.3\rangle & \langle 0.6; 0.1; 0.2\rangle \end{bmatrix}$$

Following the logic of the method used, the values of the operators necessary to determine each correlation coefficient are determined, as shown in Tables 1 and 2.

Table 1: Values of φ, μ, and ψ for each alternative. Source: own elaboration.

	φ_{C1}	φ_{C2}	φ_{C3}	μ_{C1}	μ_{C2}	μ_{C3}	ψ_{C1}	ψ_{C2}	ψ_{C3}
A1	1	0.94	0.82	1	0.96	0.87	0.96	1	1
A2	1	1	0.9	1	1	0.96	1	1	1
A3	0.95	0.95	1	1	0.96	1	0.92	0.96	1
A4	1	0.74	0.84	1	0.83	0.96	1	0.96	1
A5	0.84	1	0.84	0.96	1	0.96	0.96	1	1
A6	1	0.95	1	1	0.96	1	1	0.96	1

Table 2: Minimum and maximum values of variation in the membership functions of truth, falsity, and indeterminacy. Source: own elaboration.

	A1	A2	A3	A4	A5	A6
ΔTmin	0.5	0.4	0.4	0.3	0.4	0.4
ΔImin	0.2	0.2	0.2	0.1	0.2	0.2
ΔFmin	0.2	0.1	0.1	0.1	0.1	0.1
ΔTmax	0.8	0.6	0.5	0.8	0.7	0.5
ΔImax	0.5	0.3	0.3	0.5	0.3	0.3
ΔFmax	0.3	0.2	0.3	0.2	0.2	0.2

In this way, by using equation (3) the values of the correlation coefficients $M_w(A_i, A^*)$ are obtained. Table 3 shows the values obtained and their ranking accordingly.

Table 3: Weighted correlation coefficients. Source: own elaboration.

	A6	A2	A3	A4	A5	A1
M_w	0.7243	0.7147	0.6862	0.6338	0.6318	0.5797

In this way, it is valid to point out that, according to the analysis conducted, the assessment of the implementation of alternative penalties is the most preferred among all those evaluated. In second place is the assessment of restorative justice. Therefore, it can be concluded that these elements are the most observed and analyzed when providing a solution for the cracks in the Ecuadorian legal system in the quest for equity in the administration of justice.

The results show that the evaluation of the implementation of alternative penalties and the assessment of restorative justice are the preferred alternatives in terms of equity in the Ecuadorian justice system. This suggests that addressing these areas can have a significant impact on improving equity in the justice system.

4 Discussion

The research focused on evaluating equity in the Ecuadorian justice system using neutrosophic set correlation coefficients. Throughout the research, several key concepts were defined, and weighted evaluation techniques were applied to determine the preference for different alternatives concerning equity in the justice system.

Neutrosophic definitions are crucial for understanding how the alternatives were assessed in relation to equity in the Ecuadorian justice system. The analysis of alternatives provided a ranking based on weighted correlation coefficients. The results indicated that "Alternative Sentencing" obtained the highest correlation coefficient (0.7243), suggesting that this alternative is considered the most favorable in terms of equity in the Ecuadorian justice system. It was closely followed by "Restorative Justice Evaluation" with a correlation coefficient of 0.7147. These two alternatives stand out as the main areas of interest for improving equity in the system.

The results of this research have several important implications. Firstly, it provides a solid foundation for prioritizing focus areas in the Ecuadorian justice system. Alternative sentencing and the promotion of restorative justice emerge as key strategies to address equity concerns in the system.

The high ranking of "Alternative Sentencing" suggests a strong interest in considering more rehabilitation and reintegration-oriented approaches in the justice system. This can help reduce prison overcrowding and provide better reintegration opportunities for offenders.

The Evaluation of Restorative Justice is also considered a valuable strategy. This form of justice focuses on conflict resolution and damage reparation, which can contribute to greater equity in the legal process.

The study used a weighted evaluation that considered expert opinions and the relative importance of different criteria. This approach is valuable for making informed, data-driven decisions in the justice system. The overall research results highlight the importance of addressing equity issues in the Ecuadorian justice system. This analysis offers an initial insight into areas that require further attention and improvement.

Finally, equity in the justice system is a fundamental goal that requires a concerted effort from all stakeholders. The government, civil society, and the private sector must work together to strengthen the public defender system, promote the participation of women and minorities in the judicial system, implement procedural reforms, promote human rights education, and address specific challenges related to ethnic and racial equity. Continuous evaluation and the adoption of impartial approaches, such as neutrosophy, are essential to achieve a fairer and more equitable justice system in Ecuador.

Conclusions

Equity in the justice system is a fundamental principle of law that seeks to ensure fair and impartial treatment for all individuals, regardless of their characteristics. To achieve equity, it is essential to promote equality before the law, equal access to justice, the protection of human rights, the elimination of biases and discrimination, education and awareness, legal and policy reforms, and oversight and accountability.

The Ecuadorian justice system faces challenges in terms of equity and efficiency. Concerns have been raised regarding access to justice, impartiality in decision-making, corruption, and the lack of independence in the judicial system. Additionally, there are specific challenges related to ethnic and racial equity, as well as issues in the prison system.

Neutrosophy, a philosophical theory that promotes neutrality and impartiality, can be useful in analyzing equity in the justice system. It provides a framework that encourages objectivity and impartiality when examining data and policies. It helps identify systematic inequalities and discrimination in the justice system, which is essential for finding fair and equitable solutions.

The evaluation of equity in the Ecuadorian justice system involves considering multiple aspects and factors. Six study alternatives have been identified, including the evaluation of crime prevention policies, restorative justice, victim protection, environmental justice, technology implementation, and alternative sentencing.

The evaluation of these alternatives was based on specific criteria, using a method involving weighted neutrosophic correlation coefficients. The results indicate that the evaluation of alternative sentencing is the preferred alternative, followed by the evaluation of restorative justice.

Equity in the Ecuadorian justice system is an ongoing challenge that requires the collaboration of legal institutions, legal professionals, and society at large. The application of approaches like neutrosophy and the evaluation of specific alternatives can contribute to improving equity in the justice system and ensuring fair and equitable treatment for all Ecuadorian citizens.

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Neutrosophic Analysis of Ethics in a Supply Chain

Gustavo Álvarez Gómez[1], Corona Gómez Armijos[2], Ariel José Romero Fernández[3], and Adonis Ricardo Rosales García[4]

[1]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: rectorado@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: vicerrectorado@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: dir.investigacion@uniandes.edu.ec
[4]Asociación Iberoamericana de Scrum (AIBES), Quebec, Canada. E-mail: adonis.rosales@aibes.org

Abstract. The present study aimed to conduct a neutrosophic analysis of internal and external ethical factors affecting the supply chain of a painting company in the city of Quito. To achieve this, the SWOT method was applied, coupled with the neutrosophic AHP method for prioritizing and weighting the most influential factors. The results obtained allowed for the identification of the factors that had the greatest impact on the system, as per the opinions of the consulted experts. The combination of the neutrosophic AHP and SWOT analysis methods has proven to be a powerful tool for addressing ethical challenges in business decision-making, and the results obtained can serve as a guide for implementing effective ethical strategies in the supply chain.

Keywords: business ethics, supply chain, SWOT analysis, neutrosophic AHP.

1 Introduction

Ethics in the supply chain is an essential component of organizational management, playing a crucial role in the viability and sustainability of an organization. It refers to the implementation of ethical principles and values at all stages and activities involved in the supply chain, from the procurement of raw materials to the delivery of products or services to the end consumer. This perspective implies the consideration and respect for fundamental issues such as labor rights, environmental sustainability, transparency, and corporate social responsibility.

Ethical supply chain management is vital to ensure the survival of an organization in an increasingly complex and globalized business environment. Firstly, ethics in the supply chain contributes to building and preserving the company's reputation. Ethical practices in the supply chain convey an image of responsibility and social commitment, which can attract consumers and business partners who value these ethical aspects in their purchasing decisions and collaborations.

Furthermore, ethical supply chain management reduces legal and financial risks [1]. Compliance with ethical regulations and standards prevents fines and lawsuits, helping to prevent reputational crises that can significantly harm the organization's profitability. Ethics in the supply chain also optimizes operational efficiency by avoiding costly disruptions in production or supply due to labor, environmental, or quality issues [2]. This, in turn, enhances the relationship with suppliers, promoting long-term relationships based on trust and mutual collaboration.

In the context of corporate sustainability, adherence to ethical principles promotes sustainable business practices with a focus on responsible management of natural resources and reducing environmental impact [3]. This ethical perspective provides tangible benefits to the organization, including the consolidation of its reputation, greater operational efficiency, regulatory compliance, and ultimately ensuring its persistence and long-term success in the dynamic contemporary business environment. In this regard, the SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) stands as a useful tool to identify ethical risks and opportunities related to the supply chain.[4]

The SWOT analysis, also known as the SWOT matrix, is a strategic planning technique that allows for the identification of an entity's or project's Strengths, Weaknesses, Opportunities, and Threats [5]. When applying this methodology to the supply chain, both the ethical aspects that strengthen the organization and areas of ethical vulnerability can be recognized. Additionally, ethical opportunities and threats within the supply chain can be identified [6]. Strengths and weaknesses are internal attributes, while opportunities and threats represent external factors. An effective strategic plan focuses on leveraging strengths and opportunities, mitigating weaknesses, and preventing threats.

However, it is imperative to emphasize that the SWOT analysis, by itself, does not provide quantitative assessments or specific measures. Therefore, this research is integrated with the Neutrosophic Analytic Hierarchy Process (AHP). The AHP is a multicriteria decision-making technique used to address complex problems. It is a vital branch of operations research that aims to build mathematical and programming tools for selecting the best alternative from various options based on specific criteria [7].

In the real world, decision-making criteria are often characterized by their imprecise, intricate, and inconsistent nature. This is exacerbated by the uncertainty and the availability of non-definitive information faced by decision-makers. In response to these limitations, several researchers have turned to fuzzy set theory [8]. However, fuzzy set theory focuses only on the notion of the degree of truth-membership, which omits aspects related to falsity and, more crucially, indeterminacy [9].

To overcome these disadvantages associated with both fuzzy sets and the intuitionistic fuzzy set theory introduced by Atanassov, the theory of neutrosophic sets, proposed by Smarandache [10], has been introduced. Neutrosophic sets address uncertainty, indeterminacy, and falsity jointly, making them a more realistic representation of the complexity inherent in real-world situations. Consequently, neutrosophic sets emerge as a more accurate representation of the complexity of reality. As a result, in this research, the Neutrosophic Analytic Hierarchy Process (NAHP) method presented by [11] is implemented to address this context of uncertainty and variability.

The present research aims to conduct a neutrosophic analysis of the internal and external ethical factors that impact the supply chain of a painting company in the city of Quito. The objective is to identify, prioritize, and optimize the ethical components, thereby enabling the organization to make informed decisions based on its ethical strategy, using neutrosophic logical foundations.

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 $^-0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+$ [10]. 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: 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 in [12].

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: $$\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \quad (1)$$

Subtraction: $$\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \quad (2)$$

Inversion: $$\tilde{a}^{-1} = \langle ({a_4}^{-1}, {a_3}^{-1}, {a_2}^{-1}, {a_1}^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, \text{ where } a_1, a_2, a_3, a_4 \neq 0. \quad (3)$$

Multiplication by a scalar number: $$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3, \lambda a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_4, \lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases} \quad (4)$$

Division by a scalar number: $$\frac{\tilde{a}}{\lambda} = \left\{ \begin{array}{l} \langle (\frac{a_1}{\lambda}, \frac{a_2}{\lambda}, \frac{a_3}{\gamma\lambda}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle \ if\ (\lambda > 0) \\ \langle (\frac{a_3}{\gamma\lambda}, \frac{a_2}{\lambda}, \frac{a_1}{\lambda}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \beta\gamma_{\tilde{a}} \rangle \ if\ (\lambda < 0) \end{array} \right\} \quad (5)$$

Division: $$\frac{\tilde{a}}{\tilde{b}} = \left\{ \begin{array}{l} \langle (\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \theta\beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \ if\ (a_3 > 0, b_3 > 0) \\ \langle (\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \ if\ (a_3 < 0, b_3 > 0) \\ \langle (\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \ if\ (a_3 < 0, b_3 < 0) \end{array} \right. \quad (6)$$

2.2 Neutrosophic AHP (N-AHP) in SWOT Analysis

In the application of Neutrosophic AHP, a linguistic scale can be used instead of a numerical scale, which is more natural for experts [13-16]. The original Saaty numerical scale is adapted to a linguistic scale. This allows experts to evaluate ethical elements in the supply chain using linguistic terms, which they find more natural than numerical evaluations. This article will use the Saaty scale translated into a neutrosophic triangular scale, as described in [11-14-15-17].

The SWOT-NAHP involves the execution of the following procedures:

Step 1. Formulate a team of proficient individuals with expertise in conducting SWOT analysis. During this initial phase, the experts utilize questionnaires or interviews to identify both the internal and external factors essential for the SWOT analysis.

Step 2. Establish the hierarchical structure of the problem. The hierarchical structure, in this context, encompasses four distinct stages: The initial stage pertains to the organizational objective that the entity aims to accomplish. The second stage encompasses the four strategic criteria as ascertained through the SWOT analysis, denoted as "criteria." The third stage entails the elements encompassed within each strategic factor identified at the preceding level, referred to as "sub-criteria." The ultimate stage encompasses the strategies that warrant evaluation and comparison, with the understanding that the issue at hand is fundamentally rooted in the ethics of the supply chain. The subsequent phase involves the assessment of the relative importance of factors (criteria), sub-factors (sub-criteria), and strategies (alternatives) based on expert judgments.

Step 3. Construct the neutrosophic pairwise comparison matrix for factors, sub-factors, and strategies as described in Table 1. This process relies on the integration of experts' opinions to quantify the relationships and significance among these elements within the framework of supply chain ethics. The neutrosophic scale is attained according to expert opinion. Matrix $\widetilde{A}$ must satisfy condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, based on the inversion operator of Definition 4.

Step 4. Evaluate the coherence of the expert assessments. To ascertain the consistency of the pair-wise comparison matrix, an examination is conducted. If the matrix displays a transitive relationship, specifically when $a_{ik} = a_{ij}a_{jk}$ holds for all combinations of i,j, and k, the comparison matrix is deemed consistent. This analysis centers on the lower, middle, and upper values within the triangular neutrosophic numbers found in the comparison matrix.

Step 5. Compute the weights associated with the factors (S, W, O, T), sub-factors $\{(S_1, \ldots, S_n), (W_1, \ldots, W_n), (O_1, \ldots, O_n), (T_1, \ldots, T_n)\}$, and strategies/alternatives ($Alt_1, \ldots, Alt_n$) based on the information contained in the neutrosophic pair-wise comparison matrix. This is achieved by converting the matrix into a deterministic form using the following equations. Let $\tilde{a}_{ij} = \langle (a_1, b_1, c_1), \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ represent a singular triangular neutrosophic number; then,

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{7}$$

and

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

which are the score and accuracy degrees of $\tilde{a}_{ij}$ respectively.

To get the score and the accuracy degree of $\tilde{a}_{ij}$, the following equations are used:

$$S(\tilde{a}_{ji}) = 1/S(\tilde{a}_{ij}) \tag{9}$$

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

Through the evaluation and scoring of each triangular neutrosophic number within the neutrosophic pair-wise comparison matrix, the subsequent deterministic matrix is obtained. As certain the order of precedence, denoted as the Eigenvector X, from the preceding matrix, through the following steps:

- Normalize the values within each column by dividing each entry by the sum of the respective column.
- Calculate the accumulative average for each row.

Step 6. Determine the comprehensive priority for each strategy (alternative) to establish the ultimate ranking of all strategies. The overall weight value for alternative j (□=1, …, □) can be expressed as follows:

$$Tw_{\text{Alt}_j} = w_S * \sum_{i=1}^{n} w_{S_i} * w_{\text{Alt}_j} + w_W * \sum_{i=1}^{n} w_{W_i} * w_{\text{Alt}_j} + w_O * \sum_{i=1}^{n} w_{O_i} * w_{\text{Alt}_j} + w_T * \sum_{i=1}^{n} w_{T_i} * w_{\text{Alt}_j} \quad (11)$$

where (□=1, …, □) and (□□, □□, □□, □□) are the weights of Strengths, Weaknesses, Opportunities, and Threats; (□□□,□□□,□□□,□□□) are the sub-factor weights; and □Alt□ is the weight of the alternative j, corresponding to its sub-factor.

3 Results

The analysis began with the identification of internal and external factors that have a direct influence on the ethical system related to the supply chain of the company under study. In this process, the collaboration of five experts with extensive experience in the system under analysis and a strong track record in supply chain management was sought. To obtain a list of relevant factors, rounds of idea generation were used, and the elements of interest were subsequently selected through consensus. These factors are presented below:

External factors:

1. Changes in ethical regulations that may require adjustments in the company's practices and increase compliance costs.
2. Competing companies that promote higher ethical impact practices.
3. Adherence to ethical standards can increase operating costs, which could affect the company's profitability.
4. Growing demand for ethical and environmentally friendly products.
5. Collaboration with business partner suppliers who share the same ethical values.
6. Gradual opening to international markets with a focus on sustainability.

Internal Factors:

1. Development of programs and adherence to ethical practices during the production process and customer interaction.
2. Strong reputation that builds trust with customers and enhances brand loyalty.
3. Supply chain management under strict ethical standards to ensure efficiency and collaboration with suppliers.
4. Organizational internal culture based on ethical principles that boost employee morale and talent retention.
5. Innovation in sustainable products and processes and transparent supplier selection.
6. Lack of adherence to the company's ethical standards by some key raw material suppliers.
7. Deficiencies in internal disclosure of ethical practices in the supply chain.
8. Waste management shortcomings in the production of paints in some parts of the production process.
9. Lack of ethical awareness among newly hired employees in sensitive areas of the supply chain (warehouses, transportation, and commercial management).

These elements form the basis on which the study was conducted, following the proposed methodology.

Once the internal and external factors that influence the system have been identified, the evaluation of these factors is carried out to determine which of them has a more significant impact on the proper functioning of the system, according to expert judgment. The analysis process unfolds sequentially, starting with the evaluation of each of the components that make up the SWOT matrix, as illustrated in Table 1. Subsequently, an analysis is conducted within each group of factors to establish a hierarchy reflecting their relative levels of importance.

Table 1: Evaluation matrix for the criteria Weaknesses, Threats, Strengths and Opportunities.

	S	W	O	T
S	(1,1,1); 0.5, 0.5, 0.5	(2. 3. 4); 0.3, 0.75, 0.7	(4, 5, 6); 0.8, 0.15, 0.2	(2. 3. 4); 0.3, 0.75, 0.7
W	(1/4, 1/3, 1/2); 0.3, 0.75, 0.7	(1,1,1); 0.5, 0.5, 0.5	(1,1,1); 0.5, 0.5, 0.5	(4, 5, 6); 0.8, 0.15, 0.2
O	(1/6, 1/5, 1/4); 0.8, 0.15, 0.2	(1,1,1); 0.5, 0.5, 0.5	(1,1,1); 0.5, 0.5, 0.5	(2. 3. 4); 0.3, 0.75, 0.7
T	(1/4, 1/3, 1/2); 0.3, 0.75, 0.7	(1/6, 1/5, 1/4); 0.8, 0.15, 0.2	(1/4, 1/3, 1/2); 0.3, 0.75, 0.7	(1,1,1); 0.5, 0.5, 0.5

By using the corresponding calculations on the data presented in Table 1, a numerical matrix is generated, which will be subjected to the standard process of the AHP Method. This process involves verifying the consistency ratio and deriving the weight matrix W corresponding to these criteria. See Table 2.

Table 2: Evaluation matrix for the criteria Weaknesses, Threats, Strengths, and Opportunities

	S	W	O	T
S	0.49	0.55	0.70	0.22
W	0.21	0.20	0.12	0.47
O	0.10	0.20	0.12	0.22
T	0.21	0.04	0.05	0.08

This allowed obtaining the weight vector for this matrix, as presented below.

$$w = \begin{bmatrix} 0.49 \\ 0.25 \\ 0.16 \\ 0.10 \end{bmatrix}$$

A similar analysis was carried out for each of the criteria that make up the SWOT analysis. After this analysis, it was possible to obtain the weight vector for each of the internal and external factors initially identified. Table 3 shows a summary of the results obtained.

Table 3: Matrix of weights of internal and external factors.

	External factors	**Weights**
T1	Changes in ethical regulations that could require adaptations in company practices and increase compliance costs.	0.218
T2	Competing companies that promote practices with a greater ethical impact.	0.218
T3	Adhering to ethical standards may increase operating costs, which could affect profitability.	0.564
O1	The growing demand for ethical and environmentally friendly products.	0.49
O2	Collaboration with business partner suppliers that share the same ethical values.	0.12
O3	Progressive opening to international markets with a focus on sustainability.	0.38
	Internal factors	
S1	Development of programs and adherence to ethical practices during the production process and customer interactions.	0.12
S2	Strong reputation that builds customer trust and enhances brand loyalty.	0.08
S3	Supply chain management under strict ethical standards to ensure efficiency and collaboration with suppliers.	0.28
S4	Internal organizational culture based on ethical principles that boost employee morale and talent retention.	0.09

S5	Innovation in sustainable products and processes and transparent supplier selection.	0.43
W1	Lack of adherence to ethical standards by some key raw material suppliers.	0.16
W2	Deficiencies in internal disclosure of ethical practices in the supply chain.	0.33
W3	Issues in waste management in the paint production process at some stages.	0.40
W4	Lack of ethical awareness among newly hired employees in sensitive areas of the supply chain (warehouses, transportation, and commercial management).	0.12

Based on this data, it is feasible to calculate the overall weight of each of the factors and their direct influence on the system under analysis. The resulting values are presented in Table 4:

Table 4: Vectors of global weights of each of the factors analyzed.

Threats	Opportunities	Strengths	Weaknesses
$\boldsymbol{W_T} = \begin{bmatrix} \mathbf{0.024} \\ \mathbf{0.024} \\ \mathbf{0.063} \end{bmatrix}$	$W_O = \begin{bmatrix} 0.098 \\ 0.025 \\ 0.077 \end{bmatrix}$	$W_S = \begin{bmatrix} 0.059 \\ 0.041 \\ 0.138 \\ 0.046 \\ 0.215 \end{bmatrix}$	$W_W = \begin{bmatrix} 0.029 \\ 0.060 \\ 0.074 \\ 0.021 \end{bmatrix}$

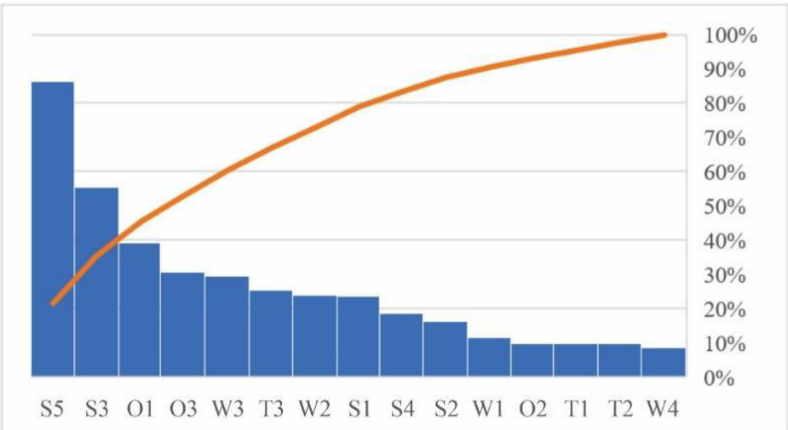
These results allowed the elaboration of a Pareto analysis using the overall weights of the sub-criteria. The Pareto analysis is a technique used to identify and prioritize the most significant factors in a dataset. In this case, the sub-criteria represent different aspects related to ethical factors in the supply chain of the painting company.

Figure 1 allows for identifying which sub-criteria are most influential in the context of the ethical analysis of the company's supply chain. These sub-criteria, including S5, S3, O1, and O3, play a fundamental role and should receive priority attention to strengthen ethics in the supply chain.

Sub-criteria O1, which relates to the growing demand for ethical and environmentally friendly products, highlights the importance of adapting to changing market needs and environmental ethics. Consideration and focus on this aspect can help the company meet the demands of consumers concerned with ethical and environmental issues. Sub-criteria O3, referring to the progressive opening to international markets with a focus on sustainability, indicates that international expansion and sustainability are closely related. Ethics in the supply chain becomes crucial when accessing international markets, and this sub-criterion emphasizes the need to consider ethical aspects in the expansion process.

S3, which relates to managing the supply chain under strict ethical standards to ensure efficiency and collaboration with suppliers, underscores the importance of establishing ethical practices in supply chain operations. Meanwhile, S5, focusing on innovation in sustainable products and processes and transparent supplier selection, demonstrates the relationship between innovation and ethics. Introducing sustainable and transparent practices in the supply chain not only strengthens ethics but can also drive innovation and competitiveness.

Figure 1. Vectors of global weights of each of the factors analyzed.



Taken together, these sub-criteria provide valuable guidance for the company in improving its ethics in the supply chain and in making strategic decisions that effectively address these key aspects.

Conclusion

In the context of this study, a neutrosophic analysis of the ethical factors influencing the supply chain of a painting company located in the city of Quito has been conducted. The methodology applied involved the combination of two approaches: the AHP (Analytic Hierarchy Process) method in its neutrosophic variant and the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. This methodological combination has proven to be highly practical and precise, allowing for addressing the inherent indeterminacy in ethical decision-making processes. The analysis carried out has yielded significant results that are crucial for the organization. It has led to a comprehensive identification of ethical factors, both internal and external, that have a direct influence on the painting company's supply chain. This identification process is an essential component in making decisions based on an ethical strategy. The weighting and ranking of ethical elements enable the organization to focus its efforts on the most critical aspects for strengthening its supply chain from an ethical perspective. This prioritization has been based on neutrosophic logical foundations, adding a layer of rigor and precision to the decision-making process.

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Ethics in Medical Research and Experimentation

Carlos Castañeda Guillot[1], Icler Sisalema Aguilar[2], Alex Valencia Herrera[3], and Wilder Fabio Ramos Palacios[4]

[1]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.carloscastaneda@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.iclersisalema@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.alexvalencia@uniandes.edu.ec
[4]Universidad Nacional Mayor de San Marcos, Perú. E-mail: wramosp@unmsm.edu.pe

Abstract. Medical advancements have arisen as a result of technological development, scientific progress, and the numerous investigations conducted in various medical fields. It is essential to establish the relationship between ethical principles and medical research and experimentation, where the protection of the subject should take precedence in any experimental trial. Medical ethics has been a historical topic since the inception of medicine, and its principles are of immeasurable value in the development of scientific research and experimentation. The study presented here conducts an evaluation based on neutrosophic to assess the levels of ethical application in medical research and experimentation involving human subjects. The major challenges present in its components are identified, and the necessary actions for their resolution are carried out through the analysis of neutrosophic criteria and the application of the TOPSIS method and Fuzzy Cognitive Maps.

Keywords: ethics, research, experimentation, medical, protection

1. Introduction

In the field of medicine, historical contributions have been made by figures such as Hippocrates, Aristotle, Maimonides, and Percival, among others. These individuals indirectly addressed ethical issues related to medical practice in all its aspects. They did not perceive clinical practice as an isolated act devoid of human goodness. On the contrary, it was seen as a commitment and dedication to others, as affirmed by Paco Maglio [1], concerning ethics: "recognizing in others a moral agent, demanding beneficence, non-maleficence, justice, and autonomy."

Percival's most recognized work and contribution to both medicine and ethics was his book "Code of Medical Ethics," published in 1803. Leake describes it as "procedures of etiquette among professionals, which directly impact the physician-patient relationship." This became the first institutional code of medical ethics, laying the foundation for the American Medical Association, which published its own code of ethics in 1847. Furthermore, the concept of ethics ceased to be individual and became collective, governed by norms, codes, and sanctions in the morality of medical acts and their relationship with patients [2].

Scientific research constitutes a cultural process of human development based on both inquiry and argumentation, mediated by innovation and the creation of scientific knowledge [3]. Advanced scientific research is a process involving the consideration of science and research, based on the interpretation and transformation of social reality. It implies qualitative changes in researchers, particularly in society, and in progressive and cyclical social relationships [4].

Clinical research refers to the activity aimed at determining whether an intervention or product has diagnostic or therapeutic properties in humans. This practice has existed since the early days of medicine. As humanity began experimenting with products and treatments to improve human health, ethical dilemmas arose in clinical research. Ultimately, scientific research, in general, and biomedical research, in particular, aim to increase our understanding of the real world for the benefit of humanity [5]. Science and research have a dual purpose: to uncover the truth immediately and, in the long term, to serve humanity. Both aspects are essential and fundamental in scientific activity.

Regarding the ethics of scientific research, two aspects should be emphasized: the ethical framework of research and the ethics of the researcher [4]. Following the arguments presented, the goal of a biomedical study or a clinical trial is to acquire novel and applicable knowledge in a specific area, whether in diagnosis, prevention, or treatment. However, methods that go against the intrinsic dignity of a human being as an end in itself should not be employed. Ethically acceptable applications of science are those that honor and contribute to the integral growth of the individual and their environment.

The classic experiment involving human subjects has always been characterized by three conditions: the marginalization of those affected, lack of consent, and the absence of objective criteria for risk and benefit assessment. Faced with these conditions, a new approach or attitude towards research with human subjects has been developed: the ethics of clinical research, whose basic principle is the protection of research subjects [4].

It is considered that humans have been conducting research since ancient times, initially based on subjective observations and later on objective observations. The rapid scientific development that has occurred in various fields is even more accelerated in the field of medicine, as evidenced by technological advances in increasingly specialized diagnostics, innovative treatments that extend human life, the development of biological products through cell cultures and recombinant DNA technology and genetic engineering, with various methodological designs. These include the evaluation of different epidemiological aspects of various diseases to the conduct of clinical trials to determine the effectiveness and safety of new products developed [6].

The primary goal of clinical research is to generate generalizable knowledge that serves to improve health, and well-being, and/or increase the understanding of human biology. The subjects who participate are merely a means to ensure such knowledge. Consequently, in all clinical research, there is the potential for exploitation by placing these subjects at risk of harm for the benefit of others [7]. The ethical requirements for clinical research are aimed at minimizing the possibility of exploitation to ensure that they are not only used but treated with respect while contributing to the social good [8,9,16].

Reality is quite pragmatic and not linked to any supernatural force. Medicine, like many other scientific disciplines, is based on experimentation. However, trials are complex as they involve testing on human subjects. Typically, the discovery of new drugs is carried out through a selective process. For instance, when identifying a molecule from a plant or chemical synthesis that is highly effective against a pathogenic bacterium, its potential as an antibiotic is considered. Laboratory tests are initially conducted. Subsequently, animal tests are carried out to determine its toxicity and effective dose. Once these experiments indicate that the drug is safe, trials with patients commence.

To determine the efficacy of a drug or treatment, experiments commonly known as "double-blind" trials are conducted. In these trials, two substances are used: the test drug itself and a substance presented to the patient as a drug but is not actually one. Neither the patient nor the physician knows the identity of each, to prevent subjectivity or a desire to heal from influencing the results. If a drug or treatment proves its efficacy in such trials, it is considered valid because it has experimental support. On the other hand, if it does not outperform the controls in experiments or if it shows toxicity or side effects that make it unsafe, its use is discarded. In general terms, this is the basic operation of an experiment in the field of medicine. Anything beyond these types of tests is considered a valid medical treatment and is incorporated into treatment protocols.

All of the above shows how medical research, since ancient times, has been a necessary process in the discovery and testing of different drugs, the cure of diseases, and the analysis of the behavior of these products in humans. In these processes, compliance with medical ethics and established guidelines for human research and experimentation studies is very important and must be respected and strictly followed in every medical investigation. In this regard, the aim is to evaluate the ethics of medical research and clinical trials through investigative methods.

2. Materials and methods

Definition 1: Let X be a space of points (objects) with generic elements in X denoted by x. A Single Valued Neutrosophic Set (SVNS) A in X is characterized by the truth-membership function $T_A(x)$, the indeterminacy-membership function $I_A(x)$, and the falsity-membership function $F_A(x)$. Thus, an SVNS A can be denoted as A = (x, $T_A(x)$, $I_A(x)$, $F_A(x)$, x ∈ X), where $T_A(x)$, $I_A(x)$, $F_A(x)$ ∈ [0,1] for each point x in X. Therefore, the sum of $T_A(x)$, $I_A(x)$, and $F_A(x)$ satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$. For convenience, an SVN number is denoted as A = (a, b, c), where a, b, c ∈ [0,1], and a + b + c ≤ 3.

Definition 2: Let A_1= (a_1,b_1,c_1) and A_2= (a_2,b_2,c_2) be two SVN numbers, then the sum of A_1 and A_2 is defined as follows:

$$A_1 + A_2 = (a_1 + a_2 - a_1a_2, b_1b_2, c_1c_2) \quad (1)$$

Definition 3: Let A_1= (a_1,b_1,c_1) and A_2= (a_2,b_2,c_2) be two SVN numbers, then the multiplication between A_1 and A_2 is defined as follows:

$$A_1 * A_2 = (a_1a_2, b_1 + b_2 - b_1b_2, c_1+c_2 - c_1c_2) \quad (2)$$

Definition 4: Let A = (a, b, c) be an SVN number and an arbitrary positive real number, then: $\lambda \in \mathbb{R}$

$$\lambda A = \left(1 - (1 - a)^{\lambda}, b^{\lambda}, c^{\lambda}\right), \lambda > 0 \quad (3)$$

Definition 5: Let A={A1,A2, …, An } be a set of n SVN numbers, where Aj= (aj, bj, cj) (j= 1, 2, …, n). The single-valued neutrosophic weighted average operator on them is defined by:

$$\sum_{j=1}^{n} \lambda_j A_j = \left(1 - \prod_{j=1}^{n} (1-a_j)^{\lambda_j}, \prod_{j=1}^{n} b_j^{\lambda_j}, \prod_{j=1}^{n} c_j^{\lambda_j}\right) \quad (4)$$

Where j is the weight of A_j (j= 1, 2, …, n), $\lambda_j \in [0,1]$ and $\sum_{j=1}^{n} \lambda_j = 1$

Definition 6: Let $A^* = \{A_1^*, A_2^*, \ldots, A_n^*\}$ be a vector of n SVN numbers, such that Aj* = (a*,b*,c) (j= 1,2,…,n), and $B_i=\{B_{i1}, B_{i2}, \ldots, B_{im}\}$ (i= 1,2,…,m), (j= 1,2,…, n). Then, the separation measure between Bi and A* based on the Euclidean distance is defined as follows:
Next, a scoring function to rank SVNNs is proposed:

$$s_i = \left(\frac{1}{3}\sum_{j=1}^{n}\left(|a_{ij} - a_j^*|\right)^2 + \left(|b_{ij} - b_j^*|\right)^2 + \left(|c_{ij} - c_j^*|\right)^2\right)^{\frac{1}{2}} \quad (i = 1,2,\ldots,m) \quad (5)$$

Definition 7: Let A = (a, b, c) be a single-valued neutrosophic number, a scoring function S of a single-valued neutrosophic number, based on the degree of truth membership, the degree of indeterminacy membership, and the degree Falsehood membership is defined by:

$$S(A) = \frac{1+a-2b-c}{2} \quad (6)$$

Where: $S(A) \in [-1,1]$

The scoring function S reduces to the scoring function proposed by [10] if b = 0 and a + b ≤ 1.

A linguistic variable is a variable described using words or expressions in a natural or artificial language, as opposed to numerical values. The values of this variable are represented using specific terms within a set. The concept of linguistic variables is highly useful for addressing problem-solving and decision-making involving complex aspects. For instance, one can express the performance ratings of alternatives in qualitative attributes using linguistic variables such as very important, important, medium, slightly important, very slightly important, etc. These linguistic values can be represented using single-valued neutrosophic numbers [11-15]. In the case of the research, the linguistic variables to be used are presented below:

Table 1: Neutrosophic values of linguistic terms. Adapted from: Kilic and Yalsin [1].

Linguistic term	SVNSs
Very no influential / (VNI)	(0.9;0.1;0.1)
No influential /(NI)	(0.75;0.25;0.20)
Medium influence /(MI)	(0.50;0.5;0.50)
Influential /(I)	(0.35;0.75;0.80)
Very high influential /(VHI)	(0.10;0.90;0.90)

As one of the Multiple Criteria Decision-Making (MCDM) methods that consider both the distance of each alternative from the positive ideal solution and the distance of each alternative from the negative ideal solution, meaning the best alternative should have the shortest distance from the Positive Ideal Solution (PIS) and the longest distance from the Negative Ideal Solution. In the research, it will be used to assess the level of influence that the alternatives have in the process by specialists [12]. In this study, there are 5 criteria and 13 components classified using the TOPSIS method and Fuzzy Cognitive Maps.

In the procedure, there are *k* decision-makers, *m* options, and *n* criteria. These K decision-makers, assess the importance of the m options through the n criteria and rate the performance of these criteria using linguistic statements that are converted into single-valued neutrosophic numbers [13]. In this context, decision-makers typically use a set of weights represented by W = (very important, important, medium, slightly important, and very slightly important), where the importance values are based on single-valued neutrosophic values for the linguistic terms, as detailed in Table 1. Additionally, the Fuzzy Cognitive Maps method is used to complement the TOPSIS for the weight vector. For the working procedure, please refer to [14].

3. Results and discussion

Medical ethics is a discipline that accompanies the physician throughout his professional life. Applied medical ethics allows the analysis of ethical problems to make decisions based on personal values and the moral conscience acquired previously. Medical inquiries and studies have the responsibility to respond to their ethical value. This research must be meticulously planned to provide useful results capable of reducing the risks involved in the investigations. The efforts made must be justified through the observation of the benefits obtained [2-17-18-19].

In any study related to the field of health, it is essential to conduct a preliminary evaluation for approval to ensure that the process adheres to established ethical principles. When embarking on research, the goal is to meet a need by seeking the truth through knowledge, but each step must be supported by an ethical framework to ensure that what is done contributes to the benefit of humans, society, and the ecological environment. To evaluate the key components in this process, 39 experts with relevant experience and specific knowledge in the field were selected. The criteria and components considered in the development of the research are shown in Figure 1.

Figure 1: Elements relevant to the investigation. Source: own elaboration.

Criteria

- Benefits to public health
- Ethics of experimentation on humans
- Protection of the rights of subjects
- Potential for abuse in research
- Scientific progress

Components

- Disease under study
- Primary symptoms or conditions
- Existence of other medications
- Patient's medical condition at the time of experimentation
- Voluntariness of the participant for experimentation
- Product's action on the body
- Possible reactions that may occur
- Trial organization strategies
- Underlying diseases of the participant
- Correct completion of the participant's form
- Behavior of indicators during the experimentation

To establish the relationship between the mentioned components and criteria, it was necessary, beforehand, to determine the weights of the components through the NCM method, as described in section 2.2, with the support of the 39 experts. Below is the adjacency matrix (see Figure 2) where the different relationships between them were determined through the values of the relationships, which correspond to the arithmetic mean, serving as the basis to calculate the values of $od(v_i)$ and $id(v_i)$ (see Table 2).

Figure 2: Adjacency matrix. Source: own elaboration.

	C1	**C2**	**C3**	**C4**	**C5**	$\sum_{i=1}^{n} c_{ij}$
C1	0	0.8	0.6	0.8	1	3.2
C2	0.8	0.7	0	0.7	1	3.2
C3	0.4	0	0.3	0.6	0.7	2.0
C4	0.2	0.8	0	0.3	0	1.3
C5	0.7	0.8	0.3	0	0.6	2.4
$\sum_{i=1}^{n} c_{ji}$	2.1	3.1	1.2	2.4	3.3	

Table 2: Determination of the values corresponding to $od(v_i)$ and $id(v_i)$. Source: own elaboration.

	C1	C2	C3	C4	C5	$od(v_i)$
C1	0	0.421053	0.31579	0.421053	0.526316	1.68421053
C2	0.4210052632	0.368421	0	0.368421	0.526316	1.68421053
C3	0.210526316	0	0.15789	0.315789	0.368421	1.05263158

C4	0.105263158	0.421053	0	0.157895	0	0.68421053
C5	0.368421063	0.421053	0.15789	0	0.315789	1.26315789
$id(v_i)$	1.10526316	1.63157895	0.63156895	1.26315789	1.73684211	

Once the values were determined, the centrality value $td(v_i)$ was calculated (see Table 3), which needed to be normalized for further use. The variables were classified as ordinary since $od(v_j) \neq 0$ and $id(v_j) \neq 0$. It was notably observed that the protection of the rights of the subjects is the most important element to ensure the proper development of medical research under the compliance of medical ethics principles, as it facilitates the implementation of necessary actions with the participation of individuals and the least amount of external influences on the research conducted.

Table 3: Calculation of centrality, normalization of centrality, and classification of variables. Source: own elaboration.

$td(v_i)$	W_{td_i}	Classification
2.78947368	0.2	Ordinary
2.31578947	0.18181818	Ordinary
2.68421053	0.2107438	Ordinary
2.42105263	0.19008264	Ordinary
2.52631579	0.19834711	Ordinary

In the case of determining the components most influenced by the previously mentioned criteria, the TOPSIS multicriteria method was applied. To begin with, the weight of the decision-maker groups established in Figure 1 was determined. Taking into account the relevance determined within medical ethics in research and the role played by the person guiding the activity, the top five in terms of weight were selected, and the results are shown below (Table 4):

Table 4: Determination of the weight of the main components. Source: own elaboration.

	Group 1	Group 2	Group 3	Group 4	Group 5
	a b c	**a b c**	**a b c**	**a b c**	**a b c**
Importance vector λ_t	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.35;0.75;0.80)
Numerical importance	0.1646	0.2236	0.2236	0.1646	0.2236

Subsequently, it was necessary to consider the input from these groups, who were asked to complete a questionnaire to evaluate components against criteria using the neutrosophic linguistic scale determined in section 2.1 (see Table 5). This led to the creation of the matrix of unique values criteria (see Table 6). The mode of the respondents' ratings is the results presented below.

Table 5: Evaluation of components according to criteria. Source: own elaboration.

	Group 1	Group 2	Group 3	Group 4	Group 5
			Benefits to public health		
P1	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.35;0.75;0.80)
P2	(0.75;0.25;0.2)	(0.35;0.75;0.80)	(0.75;0.25;0.2)	(0.75;0.25;0.2)	(0.75;0.25;0.2)
P3	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.10;0.90;0.90)	(0.50;0.5;0.50)	(0.50;0.5;0.50)
P4	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.10;0.90;0.90)	(0.50;0.5;0.50)	(0.10;0.90;0.90)
P5	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.35;0.75;0.80)	(0.50;0.5;0.50)	(0.50;0.5;0.50)
			Ethics of experimentation on humans		
P1	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.35;0.75;0.80)

	Group 1	Group 2	Group 3	Group 4	Group 5
P2	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)
P3	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.10;0.90;0.90)
P4	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.10;0.90;0.90)
P5	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.35;0.75;0.80)
			Protection of the rights of subjects		
P1	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.35;0.75;0.80)
P2	(0.10;0.90;0.90)	(0.50;0.5;0.50)	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.10;0.90;0.90)
P3	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.35;0.75;0.80)
P4	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.50;0.5;0.50)
P5	(0.35;0.75;0.80)	(0.50;0.5;0.50)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.10;0.90;0.90)
			Potential for abuse in research		
P1	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.10;0.90;0.90)
P2	(0.10;0.90;0.90)	(0.50;0.5;0.50)	(0.10;0.90;0.90)	(0.50;0.5;0.50)	(0.10;0.90;0.90)
P3	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.50;0.5;0.50)	(0.35;0.75;0.80)	(0.35;0.75;0.80)
P4	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.50;0.5;0.50)
P5	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.10;0.90;0.90)	(0.35;0.75;0.80)	(0.10;0.90;0.90)
			Scientific progress		
P1	(0.50;0.5;0.50)	(0.35;0.75;0.80	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.50;0.5;0.50)
P2	(0.50;0.5;0.50)	(0.35;0.75;0.80)	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.35;0.75;0.80)
P3	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.50;0.5;0.50)
P4	(0.35;0.75;0.80)	(0.35;0.75;0.80)	(0.50;0.5;0.50)	(0.50;0.5;0.50)	(0.35;0.75;0.80)
P5	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)	(0.50;0.5;0.50)	(0.75;0.25;0.20)

Table 6: Single value criteria matrix. Source: own elaboration.

	C1	C2	C3	C4	C5
P1	(0.5061;0.5221;0.5161)	(0.5061;0.5221;0.5161)	(0.5061;0.5221;0.5161)	(0.5061;0.5221;0.5161)	(0.5061;0.5221;0.5161)
P2	(0.1632;0.864;0.8766)	(0.1632;0.864;0.8766)	(0.1632;0.864;0.8766)	(0.1632;0.864;0.8766)	(0.1632;0.864;0.8766)
P3	(0.2482;0.8137;0.8433)	(0.2482;0.8137;0.8433)	(0.2482;0.8137;0.8433)	(0.2482;0.8137;0.8433)	(0.2482;0.8137;0.8433)
P4	(0.5718;0.4282;0.4074)	(0.5718;0.4282;0.4074)	(0.5718;0.4282;0.4074)	(0.5718;0.4282;0.4074)	(0.5718;0.4282;0.4074)
P5	(0.2625;0.805;0.8374)	(0.2625;0.805;0.8374)	(0.2625;0.805;0.8374)	(0.2625;0.805;0.8374)	(0.2625;0.805;0.8374)

Next, the weights of the problems defined by the group of experts were determined (see Table 7). In addition, the aggregate weighted decision matrix was calculated (see Table 8).

Table 7: Vector of weights of the criteria. Source: own elaboration.

	Criterion weight
C1	(0.6431;0.36581;0.3699)
C2	(0.56289;0.45317;0.44142)
C3	(0.68262;0.31738;0.30487)
C4	(0.55363;0.45751;0.46262)
C5	(0.38126;0.65378;0.67023)

Table 8: SVNS aggregate decision weighted matrix. Source: own elaboration.

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
P1	(0.28017;0.74074;0.73996)	(0.34547;0.67378;0.66363)	(0.28488;0.73867;0.7297)	(0.19296;0.83454;0.84042)	(0.32547;0.69692;0.69509)
P2	(0.13741;0.89893;0.911579)	(0.16943;0.87283;0.89107)	(0.13971;0.89813;0.91247)	(0.09463;0.9355;0.94833)	(0.15962;0.88185;0.90126)
P3	(0.09035;0.92622;0.93369)	(0.1114;0.90716;0.91422)	(0.09186;0.92563;0.93107)	(0.06222;0.95291;0.95931)	(0.10495;0.91375;0.92225)
P4	(0.31657;0.6898;0.68155)	(0.39032;0.60968;0.58807)	(0.32186;0.68732;0.66899)	(0.218;0.80203;0.80458)	(0.36772;0.63767;0.6266)
P5	(0.14533;0.89421;0.91262)	(0.17919;0.86689;0.88697)	(0.14776;0.89337;0.90917)	(0.10008;0.93249;0.94638)	(0.16881;0.87633;0.89755)

Table 9 shows the results corresponding to the proximity coefficient values, which served as the basis for determining the ranking of the effects regarding the difficulties in the development of medical ethics in the research under study (see Table 10).

Table 9: Positive and negative ideal values and distances. Source: own elaboration.

	Ideal + value	Ideal - value
P1	(0.10495;0.91375;0.92225)	(0.10495;0.6374;0.6678)
P2	(0.09186;0.92563;0.93107)	(0.0918;0.6873;0.669)
P3	(0.1114;0.90716;0.91422)	(0.1114;0.6097;0.5881)
P4	(0.09035;0.92622;0.93369)	(0.31657;0.6898;0.6816)
P5	(0.06222;0.95291;0.95931)	(0.06222;0.802;0.8046)

Table 10: Ranking of components according to Proximity Coefficient (CP). Source: own elaboration.

Alternatives	d+	d-	CP	Order
C1	0.35506471	0.381339	0.51784	4
C2	0.15049808	0.565311	0.78975	2
C3	0.15460157	0.602875	0.7959	1
C4	0.45245592	0.367267	0.44804	5
C5	0.15340259	0.559522	0.78483	3

Based on the analysis of the results, it can be determined that the behavior of indicators during experimentation is the main issue within medical research. In this regard, the action of the product and the main symptoms or conditions that may appear or be eradicated constitute the class in research to determine the positive or negative action of a product. Throughout the entire process, medical ethics in research is a fundamental element in working with the participants, ensuring that organizational strategies prioritize the well-being of the individuals involved in the trial and minimize any other potential side effects resulting from the product's action. Ethics in medical research and experimentation should be paramount at all stages involving different individuals participating in ongoing research.

Conclusion

Ethical issues related to scientific research have a long history throughout human civilization. Current debates about the social role of science, its ethical dimension, and the moral responsibility of scientists extend beyond specific fields of science. It is of great importance to promote ethics as a key element in clinical care, health research, and ethical guidance in biomedical research involving human subjects. Significant advancements in Neutrosophic Science have allowed for the evaluation and understanding of the current situation regarding each essential component and the challenges faced in this area. These aspects were assessed through the NCM technique due to the presence of indeterminacies in some cases when comparing them.

Neutrosophic has provided a more precise insight into the fact that, despite numerous research efforts and ongoing discussions on the topic in recent years, there are still challenges in the correct implementation of its fundamental principles and elements in the context of medical ethics in research. It is essential to take actions aimed at addressing and dealing with this issue, particularly focusing on the current era of scientific advancement and the emergence of diseases impacting the population.

The analysis of the results obtained through the application of Neutrosophic Science revealed that in the context of ethics in medical research and experimentation, the most impacted aspect is behavior during clinical trials. This implies the need for establishing proper priorities and adopting strategies to control the emotions of participants and understand events related to the action of the product in the testing phase. These measures aim to explore new ways to address the disease under study and contribute to human well-being.

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University of New Mexico

Evaluation of the Effectiveness of Preventive Dental Education in Primary Schools

Marianela Buitrón Recalde[1], Sandra Rojas Rojas[2], Marco Zúñiga Llerena[3], and Anthony Rafael Sotolongo León[4]

[1]Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.marielabr36@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Ibarra. Ecuador. E-mail: ui.sandrarr80@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.marcozuniga@uniandes.edu.ec
[4]Ongres, Santiago de Chile, Chile. E-mail: asotolongo@ongres.com

Abstract. The study conducted focused on assessing the effectiveness of preventive dental education in a primary school in Puyo, using neutrosophic logic as the main approach. To achieve this purpose, the TOPSIS method was adapted to perform a quantitative evaluation of various alternative dental prevention education programs. In parallel, the traditional TOPSIS method was applied to compare the results obtained. Despite numerical discrepancies between both methods, there was a consensus in favor of the "Dental Health Clubs" program. However, the most notable aspect was that the Neutrosophic TOPSIS method stood out for its greater effectiveness in managing ambiguity and uncertainty present in the evaluation. This was reflected in higher proximity coefficient scores, suggesting that this approach provides a more solid foundation for selecting the most suitable educational program in the context of preventive dental education. This finding underscores the importance of incorporating neutrosophic logic in decision-making in situations where uncertainty and ambiguity are key factors.

Keywords: evaluation, education, dentistry, prevention, neutrosophic logic.

1. Introduction

A fundamental and inescapable aspect of every scientific research process lies in decision-making. This dimension is essential both in the scientific context and in the broader human sphere. The intrinsic necessity of addressing uncertain data in this decision-making process has led to the incorporation of fuzzy set theory (FS) as a tool for dealing with the uncertainty and imprecision of data [1]. Over the subsequent years, substantial efforts have been made in various research fields to integrate the vagueness present in initial information, thus seeking the capacity to solve complex real-life problems.[2], [3]

In this context, Florentín Smarandache introduced the neutrosophic set theory in 1995 as a generalization of "fuzzy" sets and "intuitionistic fuzzy" sets. Neutrosophy falls within the realm of philosophy and is dedicated to studying the origin, nature, and scope of neutralities [4]. Within this new branch, it is postulated that membership in truth, membership in indeterminacy, and membership in falsity are independent concepts and are situated in the non-standard unit interval [0-, 1+].[5-21]

Throughout the years, the applicability of neutrosophy has extended to various disciplines, including the sciences [6], engineering, society, and psychology [7], among others. This has prompted specialists in the field to develop neutrosophic models related to various conventional problem-solving techniques, allowing for a more personalized and effective approach to specific challenges in these fields.

To facilitate the practical application of neutrosophic sets, the concept of Single-Valued Neutrosophic Set (SVNS) has been defined, and theoretical set operations have been proposed, along with some properties of SVNS [8]. Likewise, the use of neutrosophy in combination with multi-criteria decision-making tools (MCDM) has been suggested. In such cases, to incorporate the vagueness of information into problem-solving, decision-makers tend to use methods of subjective evaluation. [9]–[11-22]

The application of neutrosophic logic has already been successfully applied in decision-making in the education sector. Due to its characteristics as a philosophical logic, neutrosophy provides a solid framework for evaluating and making decisions in virtually any educational context. Dental health is an essential component in the lives and health of all individuals, which takes on special significance in children during early childhood. Pediatric dentistry is a proposal currently applied in some countries to promote oral health during early childhood. Oral health is an integral part of a child's overall health.

Dental conditions can cause local problems such as pain, chewing difficulties, decreased appetite, weight loss, dental occlusion problems, speech and mastication difficulties, aesthetic deficiencies, difficulty sleeping, and behavioral disturbances. Similarly, these problems can lead to infections that trigger systemic diseases or the loss of dental organs.

Among the key tools for reducing the prevalence of oral diseases in children is education. To promote infant oral health, early involvement in guidance programs on healthy eating and hygiene habits is necessary. Furthermore, it is essential to provide education in oral health, which means acquiring information and developing skills that promote a change in behavior and attitudes, creating new values that benefit the oral health of both parents and infants.

In the context of preventive education, where decision-making focuses on the implementation of strategies to promote oral health and prevent oral diseases, the use of neutrosophic logic can allow for the consideration of uncertainty related to the effectiveness of different interventions. By integrating the vagueness of information into decision-making, educators and healthcare professionals can adapt their approaches more precisely, taking into account the variability in student responses and changing conditions.

In this regard, the present research aims to verify the applicability and effectiveness of neutrosophic logic for the evaluation of preventive dental education in a primary school in Puyo. To address this purpose, the TOPSIS method (Technique for Order of Preference by Similarity to Ideal Solution), a decision-making technique developed by Hwang and Yoon in 1981 [12], will be applied. This method can combine heterogeneous attributes into a unique dimensionless index, which is particularly useful when the attributes being evaluated are expressed in different units or scales. The basis of TOPSIS lies in the principle that the chosen alternative should have the smallest Euclidean distance to an ideal solution and the greatest Euclidean distance to an anti-ideal solution. [13-18] presented an adaptation of the TOPSIS method for selecting suitable suppliers in an intuitionistic fuzzy environment. Subsequently, the TOPSIS method has been expanded to address multicriteria decision-making problems in the context of fuzzy intuitionistic sets valued in intervals, as demonstrated by [14-19].

In this research, the contributions from neutrosophy and neutrosophic sets are integrated. Consequently, Neutrosophic TOPSIS will be used to discern the alternatives that, under quantitative evaluation, exhibit both the greatest strengths and the greatest weaknesses concerning certain specified criteria.

2 Preliminaries

Definition 1. Let X be a space of points (objects) with generic elements in X denoted by x. A single-valued neutrosophic set (SVNS) A in X is characterized by the truth-membership function T_A (x), indeterminacy-membership function I_A (x), and falsity membership function F_A (x). Then, an SVNS A can be denoted by A = {x, $T_A(x)$, $I_A(x)$, $F_A(x)$ x ∈ X}, where T_A (x), I_A (x), F_A (x) ∈ [0,1] for each point x in X. Therefore, the sum of T_A (x), I_A (x) and F_A (x) satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.[15]

For convenience, an SVN number is denoted by A = $(a\ b\ c)$, where a, b, c ∈ [0,1] and a + b + c ≤ 3

Definition 2. Let A_1= A_1= (a_1,b_1,c_1) and A_2 = (a_2,b_2,c_2) be two SVN numbers, then summation between A_1 y A_2 is defined as follows:

$$A_1 + A_2 = \left(a_1 + a_2 - a_{1a_2}, b_{1b_2}, c_{1c_2}\right) \quad (1)$$

Definition 3. Let A_1= (a_1,b_1,c_1) and A_2 = (a_2,b_2,c_2) be two SVN numbers, then multiplication between A_1 y A_2 is defined as follows:

$$A_1 * A_2 = \left(a_{1a_2}, b_1 + b_2 - b_{1b_2}, c_1 + c_2 - c_{1c_2}\right) \quad (2)$$

Definition 4. Let A = (a, b, c) be an SVN number and λ∈ℝ an arbitrary positive real number, then:

$$\lambda A = \left(1-(1-a)^{\lambda}, b^{\lambda}, c^{\lambda}\right), \lambda > 0 \quad (3)$$

Definition 5. Let $A = \{A_1, A_2, \dots, A_n\}$ be a set of n SVN numbers, where $A_j = (a_j, b_j, c_j)$ (j= 1, 2, …, n). The single value neutrosophic weighted average operator on them is defined by:

$$\sum_{j=1}^{n} \lambda_j A_j = \left(1-\prod_{j=1}^{n}(1-a_j)^{\lambda_j}, \prod_{j=1}^{n} b_j^{\lambda_j}, \prod_{j=1}^{n} c_j^{\lambda_j}\right) \quad (4)$$

Where λ_j is the weight of A_j (j= 1, 2, …,n), $\lambda_j \in [0,1]$ and $\sum_{j=1}^{n} \lambda_j = 1$

Definition 6. Let $A^* = \{A_1^*, A_2^*, \dots, A_n^*\}$ be a vector of n SVN numbers, such that $A_j^* = (a_j^*, b_j^*, c_j^*)$ (j= 1,2,…,n), and $B_i = \{B_{i1}, B_{i2}, \dots, B_{im}\}$ (i= 1,2,…,m), (j= 1,2,…,n). Then the separation measure between B_i and A^* based on Euclidian distance is defined as follows:

$$s_i = \left(\frac{1}{3}\sum_{j=1}^{n}\left(\left|a_{ij}-a_j^*\right|\right)^2 + \left(\left|b_{ij}-b_j^*\right|\right)^2 + \left(\left|c_{ij}-c_j^*\right|\right)^2\right)^{\frac{1}{2}} \quad (5)$$

(i= 1, 2, …, m)

Next, a scoring function for ranking SVN numbers is proposed:

Definition 7. Let A = (a, b, c) be a single-valued neutrosophic number, a scoring function S of a single-valued neutrosophic value, based on the truth-membership degree, indeterminacy-membership degree and falsity membership degree is defined by:

$$S(A) = \frac{1+a-2b-c}{2} \tag{6}$$

where $S(A) \in [-1,1]$

The scoring function S is reduced to the score function proposed by [16-20] if b = 0 and a + b ≤ 1.

The utilization of a linguistic variable proves to be highly advantageous in addressing decision-making scenarios of an intricate nature. The quantification of a linguistic variable is delineated as an element contained within its set of terms. These linguistic values can be effectively represented through the utilization of single-valued neutrosophic numbers.

Table 1. Linguistic variable and SVNSs. Source: [17].

Linguistic term	SVNSs
Very no influential/ (VNI)	(0.9;0.1;0.1)
No influential/(NI)	(0.75;0.25;0.20)
Medium influential/(M)	(0.50;0.5;0.50)
Influential/(I)	(0.35;0.75;0.80)
Very high influential/(VHI)	(0.10;0.90;0.90)

In this particular methodology, the scenario involves k decision-makers, *m* alternatives, and *n* criteria. Each of the k decision-makers assesses the significance of the *m* alternatives within the context of the *n* criteria and subsequently ranks the performance of the *n* criteria based on linguistic expressions that have been transformed into single-valued neutrosophic numbers. The assignment of importance weights is accomplished by considering single-valued neutrosophic values associated with the linguistic terms, as illustrated in Table 1.

2.1 The TOPSIS method for SVNS

The TOPSIS procedure applied to single-valued neutrosophic sets (SVNS) involves a series of specific steps. Suppose there is a set of alternatives $A = \{\rho_1, \rho_2, \dots, \rho_m\}$ and a set of criteria $G = \{\beta_1, \beta_2, \dots, \beta_n\}$. The steps to follow are these:

- Step 1: The determination of the relative importance of the experts is carried out. To perform this evaluation, experts use the linguistic scale detailed in Table 1. The calculations are performed considering the Single Value Neutrosophic Set (SVNS) denoted as $A_t = (a_t, b_t, c_t)$, associated with the t-th decision-maker (where t = 1, 2, ..., k). The weight is calculated using Equation (7).

$$\delta_t = \frac{a_t + b_t\left(\frac{a_t}{a_t+c_t}\right)}{\sum_{t=1}^{k} a_t + b_t\left(\frac{a_t}{a_t+c_t}\right)} \tag{7}$$

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

- Step 2: The neutrosophic decision matrix is generated, which aggregates the individual single values. This matrix, represented as D, is defined through the expression $D = \sum_{t=1}^{k} \lambda_t D^t$, where each element d_{ij} takes the form of (u_{ij}, r_{ij}, v_{ij}). The purpose is to merge all the individual evaluations made by each expert $(u_{ij}^t, r_{ij}^t, v_{ij}^t)$ using their respective weights λ_t, as established in Equation 4. This results in a matrix $D = (d_{ij})_{ij}$, where each d_{ij} represents a Single Value Neutrosophic Number (SVNN), considering i as the index of alternatives (i = 1, 2, ..., m) and j as the index of criteria (j = 1, 2, ..., n).

- Step 3: It involves determining the weights assigned to the criteria. Let's assume that the criterion weights are described as $W = (w_1, w_2, \ldots, w_n)$, where w_j denotes the relative relevance of criterion j and is represented by the value $\lambda_t w_j^t = (a_j^t, b_j^t, c_j^t)$. Each w_j^t represents the evaluation of criterion λ_t by the t-th expert. Equation 4 is applied to combine the w_j^t with the corresponding weights λ_t.
- Step 4: The neutrosophic decision matrix is developed from the weighted average of unique values in relation to the criteria.

$$D^* = D * W, \tag{8}$$

Where $d_{ij} = (a_{ij}, b_{ij}, c_{ij})$

- Step 5: The calculation of the ideal solutions in Single Value Neutrosophic Numbers (SVNNs), both positive and negative, is carried out. It is important to note that criteria can be categorized into two types: those of a beneficial or cost type. For this purpose, the set G_1 encompasses the beneficial criteria, and the set G_2 includes the cost-type criteria. The ideal solutions are established as follows:

The positive ideal solution, which corresponds to the criteria contained in G_1

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

The negative ideal solution corresponding to G_2

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

Where:

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

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

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

- Step 6: Calculate the distances with respect to the ideal solutions in Single Value Neutrosophic Numbers (SVNNs), both positive and negative. These distances are obtained by applying Equation 5, which is used to calculate the following expressions:

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

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

- Step 7: Calculate the Coefficient of Proximity (CP) of each alternative in relation to the ideal solutions, both positive and negative.

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

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

- Step 8: The order of the alternatives is determined. These are classified based on the values of $\widetilde{\rho_J}$, where the order is established from highest to lowest. The condition that corresponds to the optimal solution $(\widetilde{\rho_J}) \rightarrow 1$ is met.

3 Results

In the context of this research, the aim is to evaluate the effectiveness of different interactive programs recently implemented to promote preventive dental education in the school environment. This study focuses on the identification and application of programs that offer the greatest potential for prevention and educational impact on students. To achieve this goal, discrimination is made through the execution of three specific programs:

1. The first program involves the establishment of "Dental Health Clubs," which are extracurricular groups dedicated to promoting dental health. In these clubs, students have the opportunity to acquire knowledge about oral hygiene, share advice, and encourage preventive practices in an interactive environment.
2. The second program focuses on "Educational Theater," characterized by the creation and performance of theatrical works with educational content related to dental health. This strategy actively involves students in the interpretation of scenes that address oral care and the importance of dental visits.
3. The third approach, known as the "Mentorship Program," is based on pairing older students with their younger peers, assigning the former the role of mentors in matters related to dental health. These mentors play a crucial role in providing personalized support and sharing relevant information with younger students.

To conduct the evaluation and selection among these alternatives, the experience and expertise of three highly qualified professionals in the fields of dentistry and education are enlisted. These experts will play a fundamental role in analyzing the results and making informed decisions about the implementation of the most effective programs in terms of promoting dental health and preventive education among school students.

To effectively evaluate the assessed programs, the experts are asked to analyze the methodology, educational content, and scope of each of the programs under review. Subsequently, they are requested to provide an evaluation of each program, taking into account four criteria for necessary analysis.

- Criterion 1: Theoretical and Practical Foundation for Achieving Oral Hygiene Change: Evaluate the strength of the theoretical foundation on which the programs are based. This involves assessing whether the programs are supported by current scientific evidence and whether they are based on recognized theories in the fields of dentistry and education.
- Criterion 2: Application of Teaching Methodologies and Strategies Focused on Healthy Dietary Education: Evaluate the teaching strategies proposed in the programs that encourage the reduction of the consumption of sugary foods and sugary beverages, which exacerbate the occurrence of dental caries.
- Criterion 3: Evaluation and Measurement of the Impact Associated with the Reduction of Oral Diseases: Evaluate whether the programs include evaluation methods that allow measuring their impact and effectiveness in the context of the progressive and demonstrable reduction of oral diseases, healthy behaviors, etc.
- Criterion 4: Adaptability and Flexibility: Determine if the programs can be adapted to different educational contexts and student groups.

Expert decision-makers use a set of weighted linguistic assessments to establish performance on each criterion. In this sense, the evaluations offered to determine the weight of each criterion allow us to obtain the weight vector shown below:

Table 2. Vector of weights associated with each of the selected evaluation criteria.

Criteria	Criterion category	Weights vector
Criterion 1	Benefit	(0.85573;0.14427;0.13195)
Criterion 2	Benefit	(0.85573;0.14427;0.13195)
Criterion 3	Benefit	(0.76091;0.23909;0.20913)
Criterion 4	Benefit	(0.71283;0.28717;0.24022)

With this analysis, the experts can assess each of the proposed programs in light of the evaluation criteria. The gathered data is transformed into neutrosophic sets for further use. This allows for the normalization and weighting of matrices. The evaluations conducted by the experts form the basis on which the mentioned method's operations are applied to obtain the decision matrix.

After applying Equation (8), the neutrosophic decision matrix is generated, representing the single-valued weighted average with respect to the criteria (refer to Table 3), where the results obtained after following the procedure are presented.

Table 3. Vector of weights associated with each of the selected evaluation criteria.

Programs	Criterion 1	Criterion 2	Criterion 3	Criterion 4
Dental Health Clubs	(0.704;0.295;0.264)	(0.521;0.478;0.447)	(0.716;0.283;0.275)	(0.441;0.558;0.387)
Educational Theater	(0.665;0.334;0.29)	(0.413;0.586;0.539)	(0.302;0.783;0.825)	(0.432;0.567;0.396)
Mentor Program	(0.611;0.388;0.326)	(0.500;0.499;0.47)	(0.716;0.283;0.275)	(0.441;0.558;0.387)

The use of this approach is crucial in the field of decision-making and program evaluation, as it allows for a more precise and structured representation of data and expert preferences. By converting data into neutrosophic sets, it takes into account both uncertainty and ambiguity in criterion evaluations, which can be common in complex decision-making situations. The resulting matrix, showing the weighted average of single values, provides a clear view of how programs are ranked based on criteria assessed by experts.

At the end of the process, the results enable the determination of both positive and negative ideal values for each criterion. This information is subsequently used to calculate ideal distances, which are employed in the calculation of the proximity coefficient. Table 4 presents a summary showing the distances with respect to the positive and negative ideal values for each alternative, considering the criteria used, and also includes the calculated proximity coefficients.

Obtaining ideal values, both positive and negative, is essential in multi-criteria decision-making, as it provides a reference point to assess how close or far each alternative is from the ideals based on different criteria. The determination of ideal distances is crucial for calculating the proximity coefficient, which provides a quantitative measure of how suitable each alternative is in relation to the defined ideals.

Table 4. Positive and negative ideal distances and proximity coefficients calculated in comparative analysis in TOPSIS neutrosophic and TOPSIS.

Neutrosophic TOPSIS Method				TOPSIS method		
Alternatives	d+	d-	CP	d+	d-	Pi
Dental Health Clubs	0.00885	0.6	0.985	0.0221	0.044	0.667
Educational Theater	0.50318	0.33	0.396	0.0879	0.066	0.427
Mentor Program	0.08776	0.59	0.871	0.0244	0.033	0.577

The comparative analysis conducted using the TOPSIS method and the Neutrosophic TOPSIS method for the evaluation of alternatives in the context of a specific problem reveals notable divergences in the classification of alternatives. In the Neutrosophic TOPSIS method, it is observed that the alternative "Dental Health Clubs" has the highest coefficient of proximity (CP), with a value of 0.427, followed by "Educational Theater" with 0.345 and "Mentorship Program" with 0.210. These results indicate that, according to the Neutrosophic TOPSIS method, "Dental Health Clubs" is considered the preference.

In parallel, in the conventional TOPSIS method, while the calculation values may not be identical, the overall results show significant similarity. In both methods, the preference order of the alternatives remains consistent. The method preferred by the experts is still "Dental Health Clubs," while "Educational Theater" is ranked as the least favored alternative in both methods.

It is intriguing to note that, despite the consistency in the priority order in both methods, the proximity coefficient between "Educational Theater" and "Mentorship Program" is lower in the conventional TOPSIS method. This suggests that perhaps the ambiguity and uncertainty in the evaluation of "Educational Theater" and "Mentorship Program" are handled more efficiently in the Neutrosophic TOPSIS method, resulting in a higher CP score compared to the traditional TOPSIS method.

In this regard, despite the differences in numerical values, the consistency in the overall ranking of alternatives in both methods indicates that "Dental Health Clubs" is the preferred choice, while "Educational Theater" is the least favored. However, the Neutrosophic TOPSIS method seems to handle ambiguity and uncertainty in the evaluation more effectively, resulting in a higher CP score compared to the conventional TOPSIS method.

3 Discussion

The application of neutrosophy and the Neutrosophic TOPSIS method in the evaluation of the effectiveness of preventive dental education in the study plays a crucial role in informed decision-making. Neutrosophy, as an approach that considers ambiguity and uncertainty, is particularly valuable in the evaluation of educational programs, where results can depend on multiple factors and are not always absolute. The Neutrosophic TOPSIS method, derived from neutrosophy, expands the utility of this approach in multi-criteria decision-making. In the context of the study of preventive dental education, this method has enabled the effective and systematic evaluation of multiple educational programs through a variety of criteria of interest.

The importance of this methodology lies in its ability to handle the inherent ambiguity in the evaluation of educational programs, as expert perceptions and results can vary depending on interpretation and uncertainty. By using the Neutrosophic TOPSIS method, more robust and consistent results could be obtained by considering uncertainty and ambiguity in the evaluations, providing a stronger foundation for the selection of the best educational program in the context of preventive dental education.

Ultimately, the application of neutrosophy and the Neutrosophic TOPSIS method in this study has improved the quality of decision-making by providing a more comprehensive and accurate evaluation of educational programs. This has contributed to the selection of the program that offers the best opportunities for prevention and education in students, considering the multifaceted nature of preventive dental education and the inherent uncertainty in its evaluation.

Conclusion

The present study has allowed us to verify the applicability and effectiveness of neutrosophic logic in the evaluation of the effectiveness of preventive dental education in a primary school located in Puyo. An adaptation of the TOPSIS method that incorporates neutrosophic logic was introduced to distinguish between different alternatives for the selection of a dental prevention education program through quantitative evaluation. Simultaneously, the conventional TOPSIS method was applied to compare the results obtained using both approaches. Despite numerical discrepancies, both methodologies supported the preference for the "Dental Health Clubs" program. However, the Neutrosophic TOPSIS method proved to be more efficient in managing the ambiguity and uncertainty present in the evaluation, as reflected in higher proximity coefficient scores. This suggests that the Neutrosophic TOPSIS method provides a more robust basis for selecting the most suitable educational program in the context of preventive dental education, considering the complexity of results and expert perceptions.

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University of New Mexico

Neutrosophic Evaluation of Eligibility Variables in Asylum and Immigration Processes

Edison Joselito Naranjo Luzuriaga[1], Marco Rodrigo Mena Peralta[2], Leonso Torres Torres[3], and Arlen Martín Rabelo [4]

[1]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.edisonnaranjo@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Puyo. Ecuador. E-mail: up.marcomena@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.leonsotorres@uniandes.edu.ec
[4]Exxis, Avda. Aviadores del Chaco N° 1669 c/ San Martin; Edif. Aymac I, 4to. piso, Asunción, Paraguay.
E-mail: arlen.martin@exxis-group.com

Abstract. The objective of this study was to apply neutrosophic logic in the context of the DEMATEL method to evaluate the variables involved in the eligibility of individuals in asylum requests and immigration processes. To achieve this, information acquisition methods were employed to gather the variables necessary for inclusion in the study. An expert panel was engaged to assess these variables, taking into account the inherent indeterminacy and uncertainties associated with decision-making. The study's results highlighted variables such as "Persecution in the country of origin" and "Reasons for the application" as highly influential elements in the eligibility process. This information provided decision-makers with a clearer understanding of which aspects should be prioritized in the evaluation of asylum and immigration requests. The combination of neutrosophic logic and the DEMATEL method proved to be an effective tool in addressing the complexity of this process and provided a more robust framework for decision-making.

Keywords: asylum, immigration, DEMATEL, SVNS, neutrosophy, neutrosophic logic.

1. Introduction

Eligibility for asylum and immigration is a matter of great significance in the context of international migration and human rights. This process involves the assessment of individuals seeking refuge in a foreign country or wishing to establish permanent residence in a new territory. Eligibility determination is based on a set of legal criteria and specific factors that vary according to the laws and regulations of each receiving country.

In the context of immigration, eligibility is based on a series of factors that vary depending on the destination country. These factors may include the existence of close relatives who are already residents or citizens of the country, the applicant's ability to integrate into the host society, as well as their potential economic contribution to the country. Additionally, immigration authorities often evaluate the applicant's criminal background and may deny the application in case of certain crimes or illegal activities.

Often, eligibility for asylum and immigration involves a meticulous assessment of multiple legal and personal factors. Applicants must meet specific criteria set by the receiving country, and decisions are made to protect the individual's rights and the security and stability of the host country. This process is complex and multidimensional, and its nature varies according to the circumstances and laws of each nation. Decision-making in this field is of paramount importance.

One of the most significant challenges in decision-making regarding eligibility for asylum and immigration is the presence of indeterminacies and uncertainty in the evaluation of the criteria. Indeterminacies refer to the lack of clear information or ambiguity in the data provided by the applicants [1]. Uncertainty, on the other hand, is related to the unpredictability of the results and the possible consequences of the decision [2]. These indeterminacies and uncertainties can arise in various aspects, such as the credibility of the applicant's statements, the authenticity of the documentation presented, and the interpretation of the situation in the country of origin.

To address these difficulties, decision-making approaches have been developed to systematically handle indeterminacy and uncertainty. Multi-criteria decision-making methods such as the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) enable decision-makers to weigh and assess different factors and criteria within a structured framework. These methods can accommodate the lack of precise information by allowing the comparison and evaluation of alternatives based on multiple criteria.[3]

However, in reality, decision-makers may express a preference for evaluating attributes using linguistic variables instead of precise values, either due to their partial knowledge of the attributes or due to a lack of information in the problem domain [4]. The tool of fuzzy sets, introduced by Zadeh in 1965, becomes one of the resources employed to mathematically represent such imprecision [5]. However, fuzzy sets are limited to considering the degree of affiliation of not clearly defined parameters or events, without the ability to address the degree of non-affiliation and the imprecision associated with uncertainty parameters.[6]

In an effort to partially address the limitations in defining imprecise parameters, Atanassov in 1986 introduced intuitive fuzzy sets (IFS), characterized by the simultaneous representation of degrees of affiliation and non-affiliation. However, it is important to note that, in the IFS, the sum of the degrees of affiliation and non-affiliation of the unclear parameter does not reach unity, which poses certain restrictions.[7]

To overcome these deficiencies, Smarandache presented the neutrosophic concept in 1999 as an approach to address unspecified or inconsistent information that is commonly found in reality [8]. The notion of a neutrosophic set establishes a general platform that extends the principles of classical sets, the fuzzy sets proposed by Zadeh in 1965, the intuitive fuzzy sets of Atanassov in 1986, and the intuitive interval fuzzy sets proposed by Atanassov and Gargov in 1989. Distinguishing from intuitive and interval fuzzy sets, in the neutrosophic set, indeterminacy is described explicitly. [9]

In the context of decision-making, neutrosophic logic has been used to deal with the uncertainty inherent in evaluating multiple criteria that may be qualitative or quantitative. Criteria can be ambiguous, contradictory, or subject to different interpretations, making accurate decision-making difficult. Neutrosophic logic allows degrees of truth, falsity, and indeterminacy to be assigned to each criterion, which more accurately reflects the uncertain and ambiguous nature of the data.[10]

When neutrosophic logic is applied to multi-criteria decision-making, specific methods that take into account these degrees of membership, non-membership, and indeterminacy can be used to calculate the relative importance of each criterion and the alternatives. Some of these methods may include the AHP, TOPSIS; analytic network process (ANP), and others, as neutrosophic extensions of traditional MCDM techniques [11], [12].

The proposed study aims to apply neutrosophic logic in the context of the DEMATEL method to evaluate the variables involved in the eligibility of individuals in asylum applications and immigration processes. Neutrosophic logic becomes a crucial tool to address the complexity and uncertainty associated with this selection process.

The DEMATEL (Decision-Making Trial and Evaluation Laboratory) method is a technique widely used in multi-criteria decision-making to analyze causal relationships between different factors or criteria. Incorporating neutrosophic logic allows for the representation of degrees of truth, falsehood, and ambiguity in these relationships, which is particularly relevant when it comes to assessing the eligibility of individuals in complex and often ambiguous situations.

In the context of asylum and immigration, the criteria used to evaluate applicants can be vague, contradictory, or imprecise, making it difficult to make fair and objective decisions. Neutrosophic logic allows consideration not only of the uncertainty associated with these criteria but also the possibility that the data is true to some extent and false to some extent, reflecting the complex nature of the information provided by applicants.

Ultimately, this study seeks to contribute to the improvement of decision-making processes in asylum and immigration matters, by more effectively addressing the indeterminacies and uncertainties that often characterize these decisions. This could result in fairer and more objective decisions that balance the rights and needs of applicants with the interests and security of recipient countries.

2 Neutrosophy preliminaries

In the context of a space of points (objects) X, where the generic elements in X are represented as x, the concept of a Neutrosophic Single-Valued Set (SVNS) is introduced. An SVNS A in X is characterized by three membership functions: the truth membership function TA(x), the indeterminacy membership function IA(x), and the falsity membership function FA(x). Therefore, an SVNS A can be represented as A = {x, TA(x), IA(x), FA(x) | x∈X}, where TA(x), IA(x), and FA(x) take values in the interval [0,1] for each point x in X. It is important to note that the sum of TA(x), IA(x), and FA(x) satisfies the condition 0 ≤ TA(x) + IA(x) + FA(x) ≤ 3 [14].

In [13], a neutrosophic number $E_k = (T_k, I_k, F_k)$ is defined to assess the *k-th* decision maker. Then, the weight of the *k-th* decision-maker can be expressed as:

$$\psi_k = \frac{1-\sqrt{[(1-T_k(x))^2+(I_k(x))^2+(F(x))^2]/3}}{\sum_{k=1}^{p}\sqrt{[(1-T_k(x))^2+(I_k(x))^2+(F(x))^2]/3}} \quad (1)$$

Furthermore, to attain a positive outcome, collective decision-making plays a crucial role in any decision-making procedure. Within the group decision-making process, it is imperative to combine the assessments provided by each decision-maker into a comprehensive neutrosophic decision matrix. This task can be accomplished by using the single-value neutrosophic weighted average (SVNWA) aggregation operator as introduced by [14-

20-21-22].

Consider the single-valued neutrosophic decision matrix $D_k = \left(d_{ij(k)}\right)_{mxn}$ representing the evaluations of the *k-th* decision-maker, and let $\psi = (\psi_1\psi_2, \ldots, \psi_p)^T$ be the weight vector of the decision-maker, where each $\psi_k \in [0,1]$, Here, D represents the matrix $D = (d_{ij})_{mxn}$,[14] where:

$$d_{ij} = \langle 1 - \prod_{k=1}^{p}\left(1 - T_{ij}^{(p)}\right)^{\psi_k}, \prod_{k=1}^{p}\left(I_{ij}^{(p)}\right)^{\psi_k}, \prod_{k=1}^{p}\left(F_{ij}^{(p)}\right)^{\psi_k}\rangle \quad (2)$$

Deneutrosophication of an SVNS $\tilde{N}$ can be defined as a process of transforming $\tilde{N}$ into a single crisp output, denoted as $\psi^* \in X$, through the mapping function x $f: \tilde{N} \rightarrow \psi^*$.When $\tilde{N}$ is a discrete set, the vector of tetrads $\tilde{N} = \{(x \mid T\tilde{N}(x), I\tilde{N}(x), F\tilde{N}(x)) \mid x \in X\}$ simplifies to a single scalar value $\psi^* \in X$ during the deneutrosophication process. This resulting scalar value more effectively represents the overall distribution of the three degrees of membership within the neutrosophic element, namely, $T_{\tilde{N}(x)}, I_{\tilde{N}(x)}$, and $F_{\tilde{N}(x)}$. Hence, the deneutrosophication process can be achieved as follows [17]:

$$\psi^* = 1 - \sqrt{[(1 - T_k(x))^2 + (I_k(x))^2 + (F(x))^2]/3} \quad (3)$$

2.1 SVNS DEMATEL

DEMATEL (Decision Making Trial and Evaluation Laboratory) is a technique developed in 1972 by Fontela and Gabus at the Geneva Research Center of the Battelle Memorial Institute [15]. It is used to analyze the interdependence (relationship or influence) between components, variables, or attributes of a complex system, identify those that are critical, and study their cause-effect relationships, using an impact relationship diagram. DEMATEL is mainly used in complex multi-criteria decision-making processes to analyze the internal relationships between decision criteria.

The steps to apply DEMATEL in its neutrosophic variant are detailed below and can be found in more detail in [16].

Step 1. Identify the influential variables in the eligibility of individuals in asylum applications and immigration processes: Through the application of semi-structured interviews to a representative sample and the generation of ideas through a brainstorming process, a set of relevant factors in the context of eligibility for asylum and immigration is identified. Subsequently, a panel of experts is requested to assess the mutual influence between these factors through paired comparisons using the scoring scale based on linguistic variables, as shown in [13-18-19].

Step 2. Determine the relative importance of the experts in the context of eligibility: The group of experts participating in the evaluation has different levels of experience and knowledge in the field of decision-making related to eligibility for asylum and immigration. As a result, a specific weight is assigned to each expert, which is expressed in terms of linguistic variables and transmitted in the form of neutrosophic numbers (SVNN) for later identification using equation (1).

Step 3. Transform the linguistic evaluations provided by the experts into neutrosophic numbers (SVNN): From the individual evaluation matrices containing crisp values obtained from the experts, individual neutrosophic matrices are constructed for each decision maker. See [13] for further details.

Step 4. Obtain the initial matrix of direct relationships in the form of crisp numbers: To obtain the initial matrix of direct relationships initially presented as crisp numbers, the individual neutrosophic matrices of decision makers are combined, and then they are denoted using equations (2) and (3) respectively. Matrix A shows the initial effects that factor j causes, as well as the initial effects that factor j receives from other factors. The sum of each *i-th* row of matrix A represents the total direct effects that factor *i* transmits to the other factors, and the sum of each *i-j* column of matrix A represents the total direct effects that factor *j* receives from the other factors.

Step 5. Identify the cause-effect relationships between the factors: Based on the aggregate matrix of direct relationships A obtained in step 4, it is possible to calculate the matrix of total relationships T by applying the equations (4 -6), as shown below:

$$D = A * S \quad (4)$$

Where

$$S = \frac{1}{\max_{l \leq i \leq n} \sum_{j=1}^{n} a_{ij}} \quad (5)$$

And

$$T = D(I - D)^{-1} \quad (6)$$

I: is the identity matrix.

The values t_{ij} of the matrix T reflects the direct and indirect interdependence exerted by the element in row i on the element in column j. Indirect interdependence is when one element i can influence another element j through third-party elements in the system. These indirect interdependences arise when the matrix X is raised to successive powers.

Step 6. Obtain the Causal Importance Relationship Diagram. In the stage of obtaining the Causal Importance Relationship Diagram, one should first calculate the vectors R (the sum of the rows of T) and C (the sum of the columns of T). Then, on the horizontal axis of the causal diagram, "Prominence" is defined as the vector R+C. This vector indicates the importance or relevance of each element in the system. The higher the value of R+C, the greater the prominence of the element. A high value of R+C signifies that an element:

- Considerably influences other elements.
- Receives a great influence from other elements.
- It exerts influence and is influenced in a balanced way so that the sum of both concepts is high.

If R+C is low, the element has little "importance" because both types of influence are reduced. On the vertical axis, "Ratio" is defined as the vector R-C. This vector establishes the net influence of each element. If R-C>0, it indicates that the element exerts more influence than it receives. This element would be the "cause" (influential/transmitter) of the influence. If R-C<0, it indicates that the element receives more influence than it emits, so it is considered an "effect" (influenced/receiver). Based on these values, it is possible to create a relationship map (R+C, R-C).[17]

3 Results

Through the application of semi-structured interviews and the brainstorming process, a set of relevant factors in the context of eligibility for asylum and immigration was identified. These factors are considered essential for understanding and evaluating asylum applications and immigration processes. Below is a list of the 10 study variables that emerged as a result of this identification process:

1. Persecution in the country of origin: The presence of political, religious, ethnic, or other types of persecution in the applicant's country of origin is one of the most important factors for asylum eligibility.
2. Integration into the host country: The applicant's ability to integrate into the host country's society, including language proficiency, cultural adaptation, and willingness to contribute to the community.
3. Economic contribution: In some cases, the applicant's ability to contribute economically to the host country, either through employment, investment, or business creation, may be considered.
4. National security: Evaluating potential threats to the host country's national security is an important factor. Authorities must ensure that the applicant does not represent a risk to the country's security.
5. Hosting capacity: The host country's capacity to receive and accommodate new immigrants is a critical factor. This includes considering the availability of resources such as housing, employment, and social services.
6. Relatives in the host country: The existence of close relatives who are already residents or citizens of the host country can be a determining factor in eligibility for immigration.
7. Criminal record: The applicant's criminal record is reviewed, and certain crimes may lead to the denial of asylum or immigration applications.
8. Reasons for application: Specific reasons for seeking asylum or immigration, such as family reunification, pursuit of better economic opportunities, or fleeing natural disasters or conflicts, are also taken into consideration.
9. Health status: The applicant's health status can be a factor, as some medical conditions may require special attention or affect eligibility.
10. Compliance with legal procedures and requirements: The applicant's ability to comply with legal procedures and requirements, such as completing required documentation and following proper procedures, is crucial.

These variables represent key dimensions that influence the eligibility of individuals in asylum applications and immigration processes. The linguistic variable-based scoring scale used by the panel of experts to assess the mutual influence among these factors is a tool that assigns values to influence relationships. This scale is a fundamental component of the evaluation process and is structured into five categories, each with its respective values:

1. "No influence/importance" (0.1, 0.8, 0.9): Indicates that one factor does not exert influence or is not important in relation to another.
2. "Low influence/importance" (0.35, 0.6, 0.7): Denotes a low but significant influence between factors.
3. "Medium influence/importance" (0.5, 0.4, 0.45): Reflects a medium and significant influence level.
4. "High influence/importance" (0.8, 0.2, 0.15): Indicates a high and significant influence.
5. "Very high influence/importance" (0.9, 0.1, 0.1): This represents a very high influence and great importance in the relationship between factors.

The evaluations carried out by the experts are recorded in bidirectional tables using the linguistic values described earlier. These values are subsequently expressed in terms of SVNN (see Table 1) and then transformed using equations 2 and 3 to derive the initial matrix of direct interdependence.

Table 1. Evaluation of the analyzed variables carried out by an expert n. Source: own elaboration.

	V 1	V 2	V 3	V 4	V 5	V 6	V 7	V 8	V 9	V10
V1	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.8; 0.2; 0.15)	(0.9; 0.1; 0.1)	(0.8; 0.2; 0.15)	(0.5; 0.4; 0.45)
V2	(0.8; 0.2; 0.15)	(0.1; 0.8; 0.9)	(0.8; 0.2; 0.15)	(0.8; 0.2; 0.15)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.9; 0.1; 0.1)
V3	(0.1; 0.8; 0.9)	(0.8; 0.2; 0.15)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.8; 0.2; 0.15)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.8; 0.2; 0.15)	(0.9; 0.1; 0.1)
V4	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.8; 0.2; 0.15)	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)
V5	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.8; 0.2; 0.15)	(0.8; 0.2; 0.15)	(0.9; 0.1; 0.1)
V6	(0.5; 0.4; 0.45)	(0.9; 0.1; 0.1)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)
V7	(0.8; 0.2; 0.15)	(0.8; 0.2; 0.15)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)
V8	(0.9; 0.1; 0.1)	(0.1; 0.8; 0.9)	(0.9; 0.1; 0.1)	(0.35; 0.6; 0.7)	(0.8; 0.2; 0.15)	(0.8; 0.2; 0.15)	(0.35; 0.6; 0.7)	(0.1; 0.8; 0.9)	(0.8; 0.2; 0.15)	(0.9; 0.1; 0.1)
V9	(0.35; 0.6; 0.7)	(0.8; 0.2; 0.15)	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)
V 10	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)	(0.8; 0.2; 0.15)	(0.8; 0.2; 0.15)	(0.1; 0.8; 0.9)	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)

Table 2 displays the initial matrix of direct interdependence, providing valuable information about the mutual influence of the variables evaluated in the context of eligibility for asylum and immigration. It is observed that experts 1 and 2 received assessments of "Very High" in terms of importance, indicating that their perceptions and knowledge regarding these variables were considered highly significant in the evaluation process. On the other hand, experts 3 and 4 received assessments of "High" in terms of importance. This implies that, while their opinions are valued, they are not attributed the same level of relevance as experts 1 and 2. These differences in the importance assigned to the experts are due to their specific experience and knowledge in the field of decision-making related to eligibility for asylum and immigration. These findings highlight the importance of considering the weighting of expert opinions when analyzing the interdependence of variables and are essential for making informed decisions in this context.

Table 2. Values associated with the direct relationship matrix of the analyzed variables. Source. own elaboration.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	0.000	0.761	0.542	0.713	0.239	0.644	0.852	0.885	0.636	0.548
V2	0.767	0.000	0.815	0.767	0.239	0.548	0.239	0.377	0.644	0.873
V3	0.239	0.815	0.000	0.548	0.239	0.815	0.377	0.548	0.815	0.873
V4	0.436	0.644	0.404	0.000	0.377	0.525	0.815	0.533	0.377	0.377
V5	0.239	0.807	0.548	0.636	0.000	0.548	0.644	0.815	0.744	0.841

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V6	0.548	0.873	0.785	0.548	0.239	0.000	0.404	0.764	0.548	0.548
V7	0.815	0.815	0.772	0.548	0.548	0.548	0.000	0.503	0.377	0.548
V8	0.885	0.239	0.850	0.377	0.815	0.772	0.377	0.000	0.815	0.857
V9	0.377	0.713	0.764	0.431	0.548	0.458	0.377	0.548	0.000	0.548
V10	0.377	0.764	0.815	0.815	0.239	0.377	0.377	0.533	0.548	0.000

From the initial matrix of direct interdependence, the next step involves normalization to obtain the normalized initial direct relationship matrix D. This is achieved using equations (4) and (5), which allow for the adjustment of interdependence values among the study variables. Additionally, the total direct relationship matrix T is calculated using equation (6). This process is essential for understanding the cause-and-effect relationships between the variables and evaluating their impact in the context of eligibility. The resulting matrices provide a quantitative representation of interactions between factors and are crucial for making informed decisions in this field.

$$T = D(I-D)^{-1} = \begin{bmatrix} 0.65 & 0.96 & 0.93 & 0.84 & 0.52 & 0.81 & 0.72 & 0.86 & 0.84 & 0.89 \\ 0.69 & 0.77 & 0.88 & 0.77 & 0.47 & 0.72 & 0.57 & 0.71 & 0.77 & 0.85 \\ 0.62 & 0.88 & 0.76 & 0.74 & 0.47 & 0.76 & 0.59 & 0.73 & 0.79 & 0.85 \\ 0.58 & 0.77 & 0.74 & 0.58 & 0.44 & 0.64 & 0.59 & 0.66 & 0.65 & 0.70 \\ 0.68 & 0.96 & 0.93 & 0.82 & 0.48 & 0.79 & 0.68 & 0.84 & 0.85 & 0.93 \\ 0.67 & 0.90 & 0.89 & 0.75 & 0.47 & 0.65 & 0.60 & 0.77 & 0.76 & 0.82 \\ 0.73 & 0.93 & 0.92 & 0.78 & 0.54 & 0.76 & 0.57 & 0.77 & 0.77 & 0.85 \\ 0.79 & 0.92 & 1.00 & 0.81 & 0.61 & 0.85 & 0.67 & 0.75 & 0.89 & 0.96 \\ 0.59 & 0.81 & 0.82 & 0.68 & 0.48 & 0.66 & 0.55 & 0.69 & 0.62 & 0.76 \\ 0.59 & 0.83 & 0.83 & 0.73 & 0.44 & 0.65 & 0.55 & 0.68 & 0.71 & 0.67 \end{bmatrix}$$

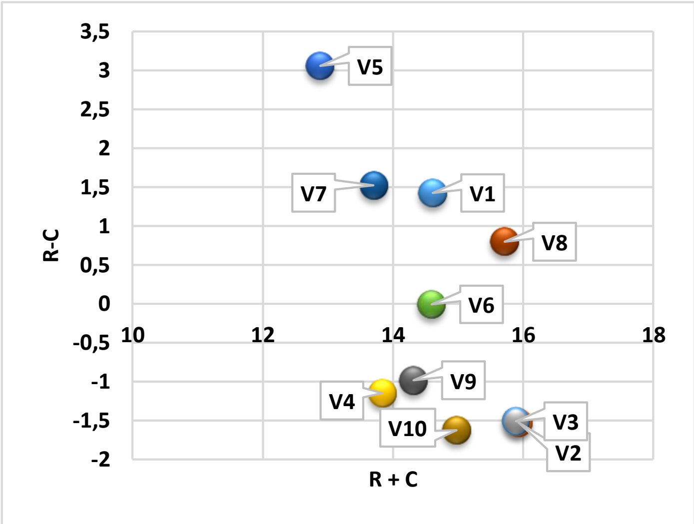
After obtaining the total direct relationship matrix, the next step involves analyzing the direct and indirect effects of the elements identified through the analysis of the prominence and relationship axes for the cause-and-effect group. The results of this analysis are presented in Table 3. These effects are calculated by considering the interaction of factors and their influence on the system, providing crucial information for understanding the dynamics of the studied variables.

Table 3. Level of influence between the variables. Source. own elaboration

Variables	R_i	C_i	$R_i + C_i$	$R_i - C_i$
Persecution in the country of origin	8,016	6,592	14,608	1,424
Integration in the host country	7,199	8,725	15,924	-1,526
Economic contribution	7,186	8,698	15,884	-1,512
National security	6,343	7,493	13,836	-1.15
Hosting capacity	7.97	4.91	12.88	3.06
Relatives in the host country	7.29	7,298	14,588	-0.008
Criminal record	7,612	6,091	13,703	1,521
Reasons for the application	8,255	7,455	15.71	0.8
Health status	6,663	7,648	14,311	-0.985
Compliance with procedures and legal requirements	6,675	8,299	14,974	-1,624

The creation of an influential graph is the final step in applying the DEMATEL model, helping decision-makers identify the most influential variables. In Figure 1, the X-axis contains the values of R + D, and the Y-axis contains the values of R - D. These values are based on Table 3. This graph positions the most influential variables at the highest (upper) level and the least influential factor at the lowest (lower) level.

Figure 1. Causal diagram. Source: own elaboration



The results obtained through the application of the DEMATEL method to assess the mutual influence among variables related to the eligibility of individuals in asylum applications and immigration processes reveal an insightful panorama. Each variable has been evaluated in terms of its relative importance (Ri) and causality (Ci), as well as the sum of both (Ri+Ci) and the difference between them (Ri-Ci).

The variable "Persecution in the country of origin" displays high relative importance (8.016) and significant causality (6.6), resulting in a total score (Ri+Ci) of 14.608. This indicates that persecution in the country of origin exerts a substantial influence on the eligibility of individuals. Furthermore, the difference (Ri-Ci) is positive (1.424), suggesting that this variable has a driving effect in this context.

On the other hand, the variables "Integration in the host country" and "Economic contribution" show similar scores, with a total score (Ri+Ci) of 15.924 and 15.884, respectively. However, both exhibit a negative difference (Ri-Ci), indicating a higher influence received than exerted. This suggests that integration in the host country and economic contribution are factors more influenced by other elements in the system.

The "Hosting capacity" stands out with a high total score (Ri+Ci) of 12.88 and a positive difference (Ri-Ci) of 3.06, implying that this variable exerts a significant influence and is a driving factor in the context of eligibility.

Discussion

The use of the DEMATEL method in conjunction with neutrosophic logic during the research has proven to be of vital importance. This approach provided an effective tool to assess and understand the interdependence and causality relationships among multiple influential factors in the eligibility process for asylum and immigration applications. Through DEMATEL, it became possible to visualize the direct and indirect effects of each factor in the context of a multidimensional and highly complex problem.

Neutrosophic logic, on the other hand, effectively handled and represented the inherent uncertainty and ambiguity in expert assessments in this field. This logic allowed for a more precise description of the levels of influence of each factor, surpassing the limitations of traditional approaches that tend to oversimplify the complexity of factor relationships.

The combination of DEMATEL and neutrosophic logic also proved valuable in identifying and prioritizing the most influential factors in the decision-making process related to eligibility for asylum and immigration. This information was crucial for decision-makers, as it provided them with a deeper and well-founded understanding of which aspects should be considered a priority in the evaluation process.

In retrospect, this research underscores the importance of integrating advanced analytical and logical approaches into decision-making in the field of eligibility for asylum and immigration. The application of the DEMATEL method and neutrosophic logic has demonstrated its effectiveness in addressing multidimensional problems in high-uncertainty contexts, providing a solid foundation for informed and strategic decision-making in a matter of critical importance.

Conclusions

Within the scope of this study, neutrosophic logic was applied to evaluate the variables involved in the eligibility of individuals in asylum and immigration applications. A set of influential variables for the study was identified through the use of semi-structured interviews and brainstorming. Single-valued neutrosophic sets were employed to conduct the corresponding evaluations based on linguistic variables. It was found that factors such as "Persecution in the country of origin" and "Reasons for the application" had a high influence, while factors like "Integration in the host country" and "Economic contribution" had a moderate influence. This provided crucial information for decision-makers, helping them prioritize the most critical aspects of the evaluation process. The results obtained provided a solid foundation for informed and strategic decision-making, contributing to a more efficient and equitable process in the field of eligibility for asylum and immigration. By using neutrosophic logic in combination with the DEMATEL method, a more robust structure and a deeper understanding of the interrelationships between the involved factors were achieved.

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Prof. Dr. Florentin Smarandache, Postdoc, Mathematics Department, University of New Mexico, Gallup, NM 87301, USA, E-mail: smarand@unm.edu.
Dr. Mohamed Abdel-Basset, Faculty of Computers and Informatics, Zagazig University, Egypt, E-mail: mohamed.abdelbasset@fci.zu.edu.eg
Prof. Dr. Maikel Leyva Vazquez, Autonomous Regional University of the Andes (UNIANDES Ambato), Ecuador, E-mail: mleyvaz@gmail.com
Dr. Said Broumi, Laboratory of Information Processing, Faculty of Science Ben M'Sik, University of Hassan II, Casablanca, Morocco, E-mail: s.broumi@flbenmsik.ma

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