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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

Society has become aware of the importance of science and its influence on issues such as health, education, food and energy resources, conservation of the environment, transportation and the media; the conditions that improve the quality of life of the human being.

General education must evolve according to the demands of a progressively unsatisfied society, which requires an intensive development of individual capacities that favor the incorporation into difficult productive processes and the mental flexibility necessary to assume different roles in a dynamic society. In addition, education should encourage the development of a critical and creative capacity that allows influencing the modification of everyday reality.

On one hand, there is a high degree of uncertainty, impreciseness, vagueness, incompleteness, inconsistency, and indeterminacy in Soft Sciences, and on the other hand, Neutrosophic Sciences advance with important tools to contribute to the solution of these social problems.

Neutrosophy is branch of philosophy based on opposites, neutralities and indeterminacy, which arose as an extension of the international movement in science and literature called Paradoxism founded by Florentin Smarandache in the 1980s. Neutrosophy has given birth to many scientific branches, such as Neutrosophic Logic, Neutrosophic Sets, Neutrosophic Probability and Statistics, Neutrosophic Algebraic Structures, and so on; all of them with multiple applications in engineering, computer science, medical research, etcetera.

The main objective of this special issue is to divulge the applicability of the Neutrosophic Theory and to explore the possibilities and advantages of neutrosophic tools, through both the presentation of thorough research and case studies in solving social problems in Latin America.

The best presentations discussed at the III International Congress of Educational Research and University Innovation, turned into papers, show us the capacity for socialization of neutrosophic knowledge and its link with this science of validation and consolidation of scientific knowledge.

This publication with authors from 11 countries that we place in the hands of the international scientific community, constitutes an example of how in Latin America the Neutrosophy is contributing to complex solutions based on the results of scientific research carried out by teachers and students committed to the social responsibility of continuing to progress for the benefit of humanity.

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Neutrosophic Games Applied to Political Situations

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Abstract. Game theory is the branch of applied mathematics dedicated to modeling and resolve conflict situations. This has great application in other sciences such as economics, military sciences, biology, sociology, cybernetics, and political sciences. Conflict situations in politics are common and may reach high degrees of complexity. Opponents tend to change strategies during the course of time; they can cooperate with each other at a certain moment and suddenly take totally opposite positions. In addition, the actions they take at each step can be confusing and ambiguous for the adversary. That is why Neutrosophy can be an adequate theory to model this type of situation. In this paper, we propose a neutrosophic model for non-cooperative games in matrix form that generalizes a previous solution where triangular intuitionistic fuzzy payoffs were used. This generalization allows us to define the indeterminacy membership function, which is not restricted to any condition of dependency between the membership and non-membership functions. Specifically, the elements of the matrix are payoffs of single-valued triangular neutrosophic numbers. The advantage of the neutrosophic solution is that the ambiguity that is typical in political conflicts can be expressed more precisely. The use of the proposed solution is illustrated with two examples.

Keywords: Single-valued triangular neutrosophic number, matrix games, neutrosophic games, political conflicts.

1 Introduction

Game Theory is the branch of applied mathematics that proposes a solution to conflict situations between two or more agents, [1, 2]. This is a part of mathematics much appreciated for its applicability to solving real-life problems. It is common for two or more agents to reach an agreement when negotiating with each other. Each agent wants to obtain the highest possible profit, which produces contradictions between the opposing parties. However, it is essential that they reach an agreement, which should ideally be the fairest one.

The game consists of the pair formed by the set of agents called players, and the set of strategies that are the possible actions or moves that the players can perform. The solution to the game consists of finding the combination of strategies, one for each player, such that there is equilibrium in the gains.

In the so-called pure strategies, a payoff function is defined for each combination of strategies for each player, which determines the players' profits that would emerge from combining the strategies of each of the players. The obtained solution is the optimal value corresponding to one pure strategy per player.

There is not always a solution to game theory problems using pure strategies. On other occasions, it is not convenient to have this type of strategies because they are predictable. That is why mixed strategies are introduced, where each player chooses a strategy according to a probability.

A classic decision method in non-cooperative game theory, or games where the parties do not form coalitions to cooperate, is the minimax method. This method consists in each party determines its optimal strategy considering the highest payoff within the set of strategies with the lowest payoff with respect to the contrary's strategies. Another classical solution is Nash equilibrium, [3].

Basically in game theory it is considered that the players try to carry out actions to obtain the greatest number of their own possible gains, which are modeled with non-cooperative models. There is also, the cooperative game theory, where it is established that the parties form coalitions can negotiate, so as to obtain greater individual gains from jointly negotiating with other parties, [1, 4, 5].

Wide group of sciences use game theory to solve their own problems, some of them are: economics, biology, sociology, psychology, computer science, military science and political science.

In this paper, we emphasize game theory to solve political situations. Politics is usually characterized by high conflict between parties that have different ideologies, often opposite, with certain degrees of power that cannot be overridden by the opposing party, [6-8]. In many political negotiations, there are multiple conditions on each of the parties that can determine high degrees of complexity in the decisions that are made at any time.

In certain moments, the parties may tend towards cooperation, in others towards confrontation. The actions of the parties can be ambiguous, indeterminate and imprecise [9-11]. That is why Neutrosophy is an appropriate theory to deal with this type of situation. Neutrosophy is the branch of philosophy that studies all related to neutralities, where lack of information, contradictions, paradoxes and ambiguity are modeled, [12].

It is in political sciences where neutrosophic games have mainly developed, [6, 7, 13]. In [14] an example may be found of the application of neutrosophic sets, especially offsets, to solve problems of cooperative games using what was called off-uninorms. Also, in [15] it is developed a matrix game approach in a neutrosophic framework, although it is not based on single-valued triangular neutrosophic numbers [16].

There are solutions to cooperative and non-cooperative games that use fuzzy theories, such as fuzzy sets or intuitionistic fuzzy sets, [4, 17]. However, they may be limited in their application to political sciences, because the indeterminacy membership function is not defined independently, and this constitutes a fundamental function to be able to define some situations having degrees of cooperation and non-cooperation, and ambiguity in actions and speeches in political negotiations. Politics may have contradictions between what is said and what is shown. Additionally, we can find an interval-valued solution of matrix games, which includes imprecision and indeterminacy, [18].

This paper aims to extend a solution to non-cooperative games that can be found in [17], to the framework of neutrosophic sets. In the aforementioned solution, a score function is used to de-fuzzify triangular intuitionistic fuzzy payoffs in the so-called matrix games, or games where the payoffs for each pair of strategies, one for each player, are represented with the help of a matrix. The indeterminacy in the intuitionistic fuzzy sets is expressed through the degree of hesitation that depends on the degrees of membership and non-membership of the intuitionistic fuzzy set, which are restricted by the condition that their sum is less than or equal to unity [19]. The advantage of the proposed method is that a membership function of indeterminacy is explicitly defined, in addition to a membership function and a non-membership function, and the three of them are independent of each other. This model better captures the essence of political conflicts.

This paper is structured as follows: Section 1 describes the fundamental elements of game theory and Neutrosophy. Section 2 proposes a neutrosophic method for solving matrix games, including two examples from politics. The paper ends with the conclusions.

2 Preliminaries

In this section, we describe the main concepts needed to understand the proposed method. The first subsection contains the basic concepts of matrix games. The second subsection shows the concepts of Neutrosophy.

2.1 Matrix games

A game consists of a nonempty set of players, denoted by $\mathrm{N} = \{1, 2, \cdots, \mathrm{n}\}$, a set of moves (or pure strategies) available to those players, denoted by $\mathrm{A} = \{\mathrm{A}_1, \mathrm{A}_2, \cdots, \mathrm{A}_\mathrm{p}\}$, and a specification of rewards for each combination of strategies, [1]. In the case where two players are considered, the rewards of the players are represented using a payoff matrix, one player selects the row and the other one the column. The element of the i-th row and the j-th column contains the utility obtained by player I (by rows) when applying the i-th strategy ($i \in \{1, 2, \cdots, p\}$, $p \geq 1$) when player II (by columns) applies the j-th strategy ($j \in \{1, 2, \cdots, q\}$, $q \geq 1$). Let us call $\mathrm{u}_{\mathrm{ij}} = \mathrm{U}(\mathrm{A}_\mathrm{i}, \mathrm{B}_\mathrm{j})$ the payoff, where $\mathrm{U}: \mathrm{A} \times \mathrm{B} \to \mathbb{R}$, A is the set of strategies of player I and B is the set of strategies of player II.

The “maximin” and “minimax” criteria establish that each player should minimize his/her maximum loss:

“Maximin” criterion: player I chooses that his/her minimum possible payoff is the highest.

“Minimax” criterion: player II chooses that the maximum payoff to player I is the lowest possible.

Let us remark that these definitions correspond to a two-person zero sum non-cooperative games, i.e., a matrix game, where the sum of profits of the two players for every pair of strategies is null.

Definition 1 [1]: A *Saddle Point* is the (k, r)-th position of the payoff matrix, where the following condition is satisfied:

$$max_i min_j \mathrm{u}_{\mathrm{ij}} = min_j max_i \mathrm{u}_{\mathrm{ij}}$$

The mixed strategies are defined as pure strategies; each of them is associated with one probability.

Definition 2 [1]:The *mixed strategies* in the game of two players I and II, with strategies $\mathrm{A} = \{\mathrm{A}_1, \mathrm{A}_2, \cdots, \mathrm{A}_\mathrm{p}\}$ for player I and $\mathrm{B} = \{\mathrm{B}_1, \mathrm{B}_2, \cdots, \mathrm{B}_\mathrm{q}\}$ for player II, are defined as the vectors $x = (x_1, x_2, \cdots, x_p) \in [0, 1]^p$ and $y = (y_1, y_2, \cdots, y_q) \in [0, 1]^q$, such that $\sum_{i=1}^{p} x_i = \sum_{j=1}^{q} y_i = 1$. The payoff function of player I by player II is defined as:

$$\mathrm{E}(\mathrm{x}, \mathrm{y}) = \sum_{\mathrm{i}=1}^{\mathrm{p}} \sum_{\mathrm{j}=1}^{\mathrm{q}} \mathrm{x}_\mathrm{i} \mathrm{u}_{\mathrm{ij}} \mathrm{y}_\mathrm{j} = x^T u y, \text{ where } u = (u_{ij})_{1 \leq i \leq p, 1 \leq j \leq q}.$$

Definition 3 [1, 17]: A *Saddle Point* with mixed strategies is the pair of vectors (x^{*}, y^{*}) which satisfies the following condition:

$$min_{y}max_{x}\mathrm{E}(x,y) = max_{x}min_{y}\mathrm{E}(x,y) = \mathrm{E}(x^{*},y^{*}) \qquad (1)$$

2.2 Basic concepts on Neutrosophy

Definition 4: [20-26] 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 $^{-}0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^{+}$.

See that according to Definition 4, $T_A(x), I_A(x), F_A(x)$ 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 5: [20-26] 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 $F_A: U \rightarrow [0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

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 6: [20-26] 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 falsehood membership functions are defined as follows, respectively:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}}, & x = a_2 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_2 < x \leq a_3 \\ 0, & \text{otherwise} \end{cases} \qquad (2)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, & x = a_2 \\ \frac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \text{otherwise} \end{cases} \qquad (3)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a}}, & x = a_2 \\ \frac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \text{otherwise} \end{cases} \qquad (4)$$

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

Definition 7: [20-26] 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:

$$\frac{\tilde{a}}{\tilde{b}}=\begin{cases}\left\langle\left(\frac{a_1}{b_3},\frac{a_2}{b_2},\frac{a_3}{b_1}\right);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\right\rangle, a_3>0\ and\ b_3>0\\ \left\langle\left(\frac{a_3}{b_3},\frac{a_2}{b_2},\frac{a_1}{b_1}\right);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\right\rangle, a_3<0\ and\ b_3>0\\ \left\langle\left(\frac{a_3}{b_1},\frac{a_2}{b_2},\frac{a_1}{b_3}\right);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\right\rangle, a_3<0\ and\ b_3<0\end{cases}$$

6. Multiplication of two triangular neutrosophic numbers:

$$\tilde{a}\tilde{b}=\begin{cases}\langle(a_1b_1,a_2b_2,a_3b_3);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\rangle, & a_3>0\ and\ b_3>0\\ \langle(a_1b_3,a_2b_2,a_3b_1);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\rangle, & a_3<0\ and\ b_3>0\\ \langle(a_3b_3,a_2b_2,a_1b_1);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\rangle, & a_3<0\ and\ b_3<0\end{cases}$$

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,

$$S(\tilde{a})=\frac{1}{8}[a_1+a_2+a_3](2+\alpha_{\tilde{a}}-\beta_{\tilde{a}}-\gamma_{\tilde{a}}) \quad (5)$$

$$A(\tilde{a})=\frac{1}{8}[a_1+a_2+a_3](2+\alpha_{\tilde{a}}-\beta_{\tilde{a}}+\gamma_{\tilde{a}}) \quad (6)$$

They are called the score and accuracy degrees of $\tilde{a}$, respectively.

Definition 8: Let $\tilde{a}$ and $\tilde{b}$ be two SVTNNs. Let us define the order relation denoted by $\preccurlyeq$, such that $\tilde{a}\preccurlyeq\tilde{b}$ if and only if $\mathbf{A}(\tilde{a})\leq\mathbf{A}(\tilde{b})$.

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:

$$\widetilde{A}=\sum_{j=1}^{n}\lambda_j\widetilde{A}_j \quad (7)$$

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

3 Matrix games with single-valued triangular neutrosophic number payoffs

This section introduces the matrix games proposed by the authors, which extends the model in [17] from the intuitionistic fuzzy framework to the neutrosophic framework .

Definition 9: A *SVTNN Matrix Game* is a game whose elements of the payoff matrix are single-valued triangular neutrosophic numbers, as shown below:

$$\begin{array}{c c}
 & \begin{array}{cccc} B_1 & B_2 & \cdots & B_q \end{array}\\
\begin{array}{c} A_1\\ A_2\\ \vdots\\ A_p \end{array} & \begin{pmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \tilde{t}_{1q}\\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \tilde{t}_{2q}\\ \vdots & \vdots & \vdots & \vdots\\ \tilde{t}_{p1} & \tilde{t}_{p2} & \cdots & \tilde{t}_{pq} \end{pmatrix}
\end{array} \quad (8)$$

Where $\tilde{t}_{ij}$ (i = 1,2,…,p; j = 1, 2,…, q) are SVTNNs, which means the payoffs for player I to carry out the strategy A_i when player II carries out the strategy B_j.

This game incorporates the indeterminacy mentioned in [17], but here it is explicitly defined and it is independent.

Definition 10: Let G be a SVTNN Matrix Game whose payoff function is: $\tilde{u}(A_i,B_j)=\langle(s_{1ij},s_{2ij},s_{3ij});\alpha_{s_{ij}},\beta_{s_{ij}},\gamma_{s_{ij}}\rangle$. Then, considering pure strategies we have the saddle point is defined as the (k,r)-th position $\tilde{u}(A_k,B_r)=\langle(s_{1kr},s_{2kr},s_{3kr});\alpha_{s_{kr}},\beta_{s_{kr}},\gamma_{s_{kr}}\rangle=\vee_i\wedge_j\tilde{u}(A_i,B_j)=\wedge_j\vee_i\tilde{u}(A_i,B_j)$.

Let us note that $\vee:=max$ and $\wedge:=min$, according to the order relation $\preccurlyeq$ defined in definition 8.

Definition 11: Let G be a SVTNN Matrix Game whose payoff function is: $\tilde{u}(A_i,B_j)=\langle(s_{1ij},s_{2ij},s_{3ij});\alpha_{s_{ij}},\beta_{s_{ij}},\gamma_{s_{ij}}\rangle$. Then, considering mixed strategies $x=(x_1,x_2,\cdots,x_p)$ and $y=(y_1,y_2,\cdots,y_q)$, we have the expected payoff of player I by player II is defined by Equation 9:

$$\widetilde{E}(x,y)=\sum_{i=1}^{p}\sum_{j=1}^{q}x_i\tilde{u}_{ij}y_j=x^T\tilde{u}y \quad (9)$$

Where $\tilde{u}=(\tilde{u}_{ij})_{1\leq i\leq p,1\leq j\leq q}$.

In such a situation, player I chooses x so as to maximize his/her expectation and player II chooses y so as to minimize player II's maximum expectation, thus it is calculated by formula 10:

$$min_y max_x \widetilde{\mathrm{E}}(x,y) = max_x min_y \widetilde{\mathrm{E}}(x,y) = \widetilde{\mathrm{E}}(x^*,y^*) \qquad (10)$$

Where, (x^*,y^*) is the *saddle point* of the game and $\widetilde{\mathrm{E}}(x^*,y^*)$ is the solution of the game.

For simplicity, we consider another approach defining the expected payoff as a crisp value based on the accuracy degree, which is a score function, as follows:

$$\tilde{E}_{\mathbf{A}}(x,y) = \sum_{i=1}^{p}\sum_{j=1}^{q} \mathrm{x_i}\mathbf{A}(\tilde{u}_{ij})\mathrm{y_j} = x^T\mathbf{A}(\tilde{u})y \qquad (11)$$

The saddle point of the matrix game with $\tilde{E}_{\mathbf{A}}(x,y)$ is (x^*,y^*) satisfying conditions in Equation 12.

$$min_y max_x \tilde{E}_{\mathbf{A}}(x,y) = max_x min_y \tilde{E}_{\mathbf{A}}(x,y) = \tilde{E}_{\mathbf{A}}(x^*,y^*) \qquad (12)$$

Where, $\tilde{E}_{\mathbf{A}}(x^*,y^*)$ is the solution of the game and $\mathrm{A}(\cdot)$ is the accuracy degree shown in Equation 6.

Next, we use two examples to illustrate the application of this neutrosophic game solution in political situations.

Example 1 (A voter problem): [17]

Two major political parties, denoted by A and B are involved in an election, where the total number of voters is constant, thus, when the number of voters increases for A, then the number of voters for B decreases and vice versa. Let us suppose A has two strategies, which are the following:

A_1: Giving importance in door-to-door campaigning and carrying their ideology and issues to people.

A_2: Cooperating with other small political parties to reduce secured votes of the opposition.

Whereas, party B has these two strategies:

B_1: Campaigning by celebrities and big rallies.

B_2: Making lot of promises to the people.

Chief voting agents have to forecast the results of these strategies in the future, thus, there is uncertainty and indeterminacy in the possible results, which are approximates. Payoff matrix contains the following SVTNNs:

$$\begin{array}{cc} & \begin{array}{cc} \mathrm{B}_1 & \mathrm{B}_2 \end{array} \\ \begin{array}{c} \mathrm{A}_1 \\ \mathrm{A}_2 \end{array} & \begin{pmatrix} \langle(4,6,9);0.5,0.1,0.3\rangle & \langle(5,7,8);0.6,0.1,0.2\rangle \\ \langle(4,7,8);0.4,0.4,0.3\rangle & \langle(3,5,6);0.5,0.3,0.2\rangle \end{pmatrix} \end{array}$$

This matrix game means that, for example, when party A performs strategy A_1 and party B performs strategy B_1 the results is that A gains approximately 6×10^5 votes whose values may change in the interval $(4\times10^5, 9\times10^5)$, with 0.5 degree of truthiness, 0.3 degree of falsehood and 0.1 degree of indeterminacy.

An equivalent crisp matrix of payoffs is obtained by calculating the accuracy degree with Equation 6:

$$\begin{array}{cc} & \begin{array}{cc} \mathrm{B}_1 & \mathrm{B}_2 \end{array} \\ \begin{array}{c} \mathrm{A}_1 \\ \mathrm{A}_2 \end{array} & \begin{pmatrix} 6.4125 & 6.75 \\ 5.4625 & 4.20 \end{pmatrix} \end{array}$$

Considering the maximin and minimax criteria we have one equilibrium point, (2,1) with solution 5.4625 or from the original payoff matrix $\langle(4,7,8);0.4,0.4,0.3\rangle$. Thus, the optimal solution for party A is to cooperate with other small political parties and they will get a number of voters in the interval $(4\times10^5, 8\times10^5)$.

Example 2 : [7]

Two Asian countries, India and Pakistan have a territorial dispute over Jammu and Kashmir since 1947. Both countries should achieve an accordance to finish this historical conflict. There are three strategies S_1, S_2, or S_3 to resolve this difference. The neutrosophic payoff matrix is the following:

$$\begin{array}{ccc} & & \text{Pakistan} \\ & & \begin{array}{ccc} \mathrm{S}_1 & \mathrm{S}_2 & \mathrm{S}_3 \end{array} \\ \text{India} & \begin{array}{c} \mathrm{S}_1 \\ \mathrm{S}_2 \\ \mathrm{S}_3 \end{array} & \begin{pmatrix} \langle(0,0,0);0.50,0.50,0.50\rangle & \langle(-3,-2,-1);0.40,0.65,0.60\rangle & \langle(1,2,3);0.40,0.65,0.60\rangle \\ \langle(1,2,3);0.40,0.65,0.60\rangle & \langle(0,0,0);0.50,0.50,0.50\rangle & \langle(-3,-2,-1);0.40,0.65,0.60\rangle \\ \langle(-3,-2,-1);0.40,0.65,0.60\rangle & \langle(1,2,3);0.40,0.65,0.60\rangle & \langle(0,0,0);0.50,0.50,0.50\rangle \end{pmatrix} \end{array}$$

The crisp matrix game after applying accurate degree is the following:

$$\begin{array}{ccc} & & \text{Pakistan} \\ & & \begin{array}{ccc} \mathrm{S}_1 & \mathrm{S}_2 & \mathrm{S}_3 \end{array} \\ \text{India} & \begin{array}{c} \mathrm{S}_1 \\ \mathrm{S}_2 \\ \mathrm{S}_3 \end{array} & \begin{pmatrix} 0 & -1.7625 & 1.7625 \\ 1.7625 & 0 & -1.7625 \\ -1.7625 & 1.7625 & 0 \end{pmatrix} \end{array}$$

This game has not a pure strategy solution, thus, the optimal mixed strategy is $x^* = y^* = \left(\frac{1}{3}, \frac{1}{3}, \frac{1}{3}\right)$. Therefore, $\widetilde{\mathrm{E}}(x^*, y^*) = \langle\left(-\frac{2}{3}, 0, \frac{2}{3}\right); 0.40, 0.65, 0.60\rangle$.

Conclusion

This paper presents a new neutrosophic solution to matrix games, which can be applied in any real life problem. Specifically, it is recommendable to use this solution in political situations, where ambiguity of the parties is usual, as well as their changes of strategies during the time span. Here, the payoff matrix is defined using single-valued triangular neutrosophic numbers, which are de-neutrosophied with a score function. The solution extends another one defined for intuitionistic fuzzy payoffs, however, in this approach, indeterminacy is independent, and so it is a more accurate solution for matrix game theory. Two examples of political situations illustrate the applicability of the solution in politics. Future works will study to extend this neutrosophic approach to bimatrix games [27] and Nash equilibrium points will be also considered, [1, 3].

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An Exploration of Wisdom of Crowds using Neutrosophic Cognitive Maps

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Abstract. The wisdom of crowds (WOC) is a theory where it is believed that a multitude of people, unknown to each other and not experts in some subject, can reach more accurate conclusions on this subject than each of them would achieve individually; it could even have more accuracy than the result that a group of experts would obtain. This theory can be used to obtain information from the individual knowledge of an inexperienced crowd, including knowledge on complex phenomena. In this paper, the complex phenomenon is represented with the help of Neutrosophic Cognitive Maps (NCM), which allow us to capture the cause-effect relations among the concepts according to each of the individuals' judgments. In this case, a dynamic processing of the results is carried out. The NCMs are aggregated following the WOC principles using an aggregation algorithm, which is based on the Fuzzy Negative-Positive-Neutral (NPN) logic. The advantage of using NCM is that indeterminacy is included in the modeling, thus individuals can express their opinions more reliably.

Keywords: Wisdom of crowds, fuzzy cognitive map, neutrosophic cognitive map, fuzzy NPN logic.

1 Introduction

The Wisdom of Crowds is a theory introduced by James Surowiecki in his book "The Wisdom of Crowds: Why the Many are Smarter than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations", [1]. The book proposes the thesis that the opinion's aggregation of the multitude's members that are non-experts on a subject will have a more accurate result than that of each of the members has individually; it could even be more exact than the opinion obtained by a few experts.

The explanation that is usually given to this fact is that the bias committed by one person is annulated by the bias of another, [2-4]. A much-cited example corresponds to Francis Galton's experience at a cattle fair in his county. In the example, a crowd accurately deduced the weight of an ox when their individual estimates were averaged (and the average was closer to the true weight of the ox than the estimates separately from most of the crowd and closer than any of the livestock experts' estimates).

This thesis is debated in the book through a large number of examples from the field of economics and psychology, and where it is not hidden that on some occasions group decisions can fail, as is the case with the collective analysis of market bubbles. This is because not every crowd meets the conditions necessary to get to a sufficiently approximate result. Participants need to meet certain conditions, such as: (1) Independence, which means every individual makes a judgment on his/her own, such that each individual does not discuss or even does not have knowledge on the others' opinions. (2) Diversity, which means the judgments are sufficiently different each other with respect to their perspectives, (3) Decentralization, which means that for aggregating the individual results, every member has the same weight, [3].

This theory can be applicable not only to cases such as the weighing of an ox at a fair, but also to arrive at analysis of complex phenomena. For example, [5, 6] shows the application of the WOC theory in the study of stakeholder crowds' knowledge of social-ecological systems. It is known that this type of problem involves complex interactions between human systems and natural systems, where there are different dimensions to the same problem, such as sociological, economic, ecological, cultural, among others, so that holistic knowledge of the phenomenon is difficult to capture. In [6] they experimentally demonstrated that the WOC can be used to generate collective knowledge from the knowledge of stakeholders on this issue, where preferably none of them is an expert.

The individual knowledge of each stakeholder is represented using Fuzzy Cognitive Maps (FCM), which is a tool for representing knowledge based on cause-effect relationships of two or more factors related to the phenomenon being studied. The dynamic study of FCM allows us to reach an equilibrium point using a sequence of results dependent on a discrete time variable. There can also be instability, which occurs when the sequence does not converge to any point, and in this case, the result cannot be used.

FCMs were introduced by Kosko [7]. These are directed graphs, where the nodes represent concepts and the edges represent the relationships between two concepts. In Cognitive Maps [8], each edge has a weight associated with it (-1 which means an inverse total relationship, 0 means that there is no relationship, 1 means that the two concepts are directly and totally related). For Kosko, these weights take values in the interval [-1, 1]. FCMs have been generalized to Neutrosophic Cognitive Maps (NCM), some of them are analyzed statically and others dynamically, [9-15]. The idea of the NCM is to add to the weights -1, 0, 1, the value I that represents indeterminacy.

The WOC is an approach of great interest to sociology, which has also been generalized to the field of Neutrosophy with the so-called Neutrosociology [16, 17]. This paper aims to introduce a theoretical tool based on Neutrosophy, especially NCM to represent the knowledge of each individual, and a method to apply WOC as a way to obtain collective knowledge. In FCM and NCM, the usual set of truth values [0, 1] is extended to the set [-1, 1]. This semantic is related to the bipolar fuzzy sets that have also been extended to the field of Neutrosophy with the bipolar neutrosophic sets [18-24]. This type of bipolar sets have been extended to the offsets [25], where operators such as the offuninorms have been defined, [26].

In this paper, we use NCMs as a way of representing the individual knowledge of the crowd members. The individual results are aggregated satisfying the WOC conditions and converted into a single FCM with the help of an aggregation algorithm, which is based on the Fuzzy Negative-Positive-Neutral (NPN) logic. Fuzzy NPN logic extends the range of truth values [0, 1] to logical relations represented as ordered pairs of truth values in [-1, 1], [18, 27, 28]. This logic contains operators that are used in FCM and are based on some rules specially designed to perform calculations with FCM. Fuzzy NPN logic can be considered a type of bipolar neutrosophic set, since the individual can express his/her opinion indeterminately in the form of an interval, with a minimum value that can be negative and a maximum value that can be positive.

The contribution of this paper is that for the first time is offered a tool to obtain knowledge on complex phenomena through the use of NCM and WOC. The potentialities of the Fuzzy NPN logic are also used. Even though we employ an iterative algorithm for calculating the equilibrium point, the Pool2 algorithm [29] is also recommendable to get to the result of a collective knowledge. The advantage over the proposal shown in [30] is that the NCM allow us to include indeterminacy in the knowledge representation.

This article is structured into the following sections. Section 2 recalls the main concepts of Neutrosophy, NCM, and Fuzzy NPN logic; Section 3 introduces the tools and arguments that should be used in an NCM-based WOC method. Conclusions are shown in the last section.

2 Preliminaries

This section summarizes the main concepts needed to develop the method that we propose. First, in subsection 2.1 we describe the Neutrosophic Cognitive Map theory, which is processed by a dynamic method. Subsection 2.2 exposes the definitions and main elements of Fuzzy NPN logic.

2.1 Neutrosophic Cognitive Maps

Definition 1: [31] Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow]^-0, 1^+[$, which satisfy the condition $^-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3^+$ for all x∈X. $u_A(x), r_A(x)$ and $v_A(x)$ are the membership functions of truthfulness, indeterminacy and falseness of x in A, respectively, and their images are standard or non-standard subsets of $]^-0, 1^+[$.

Definition 2: [31] Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is a set of the form:

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

Where $u_A, r_A, v_A : X \rightarrow [0,1]$, satisfy the condition $0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ for all x∈X. $u_A(x), r_A(x)$ and $v_A(x)$ denotes the membership functions of truthfulness, indeterminacy and falseness of x in A, respectively. For convenience a *Single-Valued Neutrosophic Number* (SVNN) will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$ and satisfy $0 \leq a + b + c \leq 3$.

Other important definitions are related to the graphs, [14, 31].

Definition 3: [9, 11, 12, 14, 23] A *neutrosophic graph* is a graph containing at least one indeterminate edge, which is represented by dotted lines.

Definition 4: [9, 11, 12, 14, 23] A *neutrosophic directed graph* is a directed graph containing at least one indeterminate edge, which is represented by dotted lines.

Definition 5: [9, 11, 12, 14, 23] A *Neutrosophic Cognitive Map* (NCM) is a neutrosophic directed graph, whose nodes represent concepts and whose edges represent causal relationships among the edges.

If $C_1, C_2, \ldots, C_k$ are k nodes, each of the C_i $(i = 1, 2, \ldots, k)$ can be represented by a vector $(x_1, x_2, \ldots, x_k)$ where $x_i \in \{0, 1, I\}$. $x_i = 0$ means that the node C_i is in an activated state, $x_i = 1$ means that the node C_i is in a deactivated state and $x_i = I$ means that the node C_i is in an indeterminate state, in a specific time or in a specific situation.

If C_m and C_n are two nodes of the NCM, an edge directed from C_m to C_n is called a *connection* and represents the causality from C_m to C_n. Each node in the NCM is associated with a weight within the set $\{-1, 0, 1, I\}$. If α_{mn} denotes the weight of the edge C_mC_n, $\alpha_{mn} \in \{-1, 0, 1, I\}$ then we have:

$\alpha_{mn} = 0$ if C_m has no effect on C_n,

$\alpha_{mn} = 1$ if an increase (decrease) in C_m produces an increase (decrease) in C_n,

$\alpha_{mn} = -1$ if an increase (decrease) in C_m produces a decrease (increase) in C_n,

$\alpha_{mn} = I$ if the effect of C_m on C_n is indeterminate.

Definition 6: [9, 11, 12, 14, 23] A NCM having edges with weights in $\{-1, 0, 1, I\}$ is called *Simple Neutrosophic Cognitive Map*.

Definition 7: [9, 11, 12, 14, 23] If $C_1, C_2, \ldots, C_k$ are the nodes of a NCM. The *neutrosophic matrix* $N(E)$ is defined as $N(E) = (\alpha_{mn})$, where α_{mn} denotes the weight of the directed edge C_mC_n, such that $\alpha_{mn} \in \{-1, 0, 1, I\}$. $N(E)$ is called the *neutrosophic adjacency matrix* of the NCM.

Definition 8: [9, 11, 12, 14, 23] Let $C_1, C_2, \ldots, C_k$ be the nodes of a NCM. Let $A = (a_1, a_2, \ldots, a_k)$, where $a_m \in \{-1, 0, 1, I\}$. A is called *instantaneous state neutrosophic vector* and means a position of on-off-indeterminate state of the node in a given instant.

$a_m = 0$ if C_m is deactivated (has no effect),

$a_m = 1$ if C_m is activated (has an effect),

$a_m = I$ if C_m is indeterminate (its effect cannot be determined).

Definition 9: [9, 11, 12, 14, 23] Let $C_1, C_2, \ldots, C_k$ be the nodes of a NCM. Let $\overrightarrow{C_1C_2}$, $\overrightarrow{C_2C_3}$, $\overrightarrow{C_3C_4}$,…, $\overrightarrow{C_mC_n}$ be the edges of the NCM, then the edges constitute a *directed cycle*.

The NCM is called *cyclic* if it has a directed cycle. It is *acyclic* if it has not a directed cycle.

Definition 10: [9, 11, 12, 14, 23] A NCM containing cycles is said to have *feedback*. When there is feedback in the NCM, it is a *dynamic system*.

Definition 11: [9, 11, 12, 14, 23] Let $\overrightarrow{C_1C_2}$, $\overrightarrow{C_2C_3}$, $\overrightarrow{C_3C_4}$,…, $\overrightarrow{C_{k-1}C_k}$ be a cycle. When C_m is activated and its causality flows through the edges of the cycle and it is the cause of C_m itself, then the dynamic system circulates. This is fulfilled for each node C_m with $m = 1, 2, \ldots, k$. The equilibrium state for this dynamic system is called the *hidden pattern*.

Definition 12: [9, 11, 12, 14, 23] If the equilibrium state of a dynamic system is a single state, then it is called a *fixed point*.

An example of a fixed point is when a dynamic system starts by being activated by C_l. If it is assumed that the NCM sits on C_l and C_k, i.e. the state remains as $(1, 0, \ldots, 0, 1)$, then this vector of neutrosophic state is called *fixed point*.

Definition 13: [9, 11, 12, 14, 23] If the NCM is established with a neutrosophic state-vector that repeats itself in the form:

$A_1 \to A_2 \to \cdots \to A_m \to A_1$, then the equilibrium is called a *limit cycle* of the NCM.

Method to determine the Hidden Patterns

Let $C_1, C_2, \ldots, C_k$ be the nodes of the NCM with feedback. Assume that E is the associated adjacency matrix. A hidden pattern is found when C_l is activated and a vector input $A_1 = (1, 0, 0, \ldots, 0)$ is given. The data must be passed to the neutrosophic matrix $N(E)$, which is obtained by multiplying A_1 by the matrix $N(E)$.

Let $A_1N(E) = (\alpha_1, \alpha_2, \ldots, \alpha_k)$ with the threshold operation of replacing α_m by 1 if $\alpha_m > p$ and α_m by 0 if $\alpha_m < p$ (p is a suitable positive integer) and α_m is replaced by I if this is not an integer. The resulting concept is updated; vector C_1 is included in the updated vector by transforming the first coordinate of the resulting vector into 1.

If $A_1N(E)\rightarrow A_2$ is assumed then $A_2N(E)$ is considered and the same procedure is repeated. This procedure is repeated until a limit cycle or fixed point is reached.

Definition 14: [32-34] A *neutrosophic number* N is defined as a number in the form of:

$$N = d + I \quad (2)$$

Where d is called *determinate part* and I is called *indeterminate part*.

Given $N_1 = a_1 + b_1I$ and $N_2 = a_2 + b_2I$ two neutrosophic numbers, some operations between them are defined as follows:

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

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

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

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

2.2 Fuzzy NPN logic

Fuzzy NPN logic is a generalization of the NPN logic, which consists of 6-valued semantic containing the following values, -1 (negative), 1 (positive), 0 (neutral or unrelated), (-1, 0) (negative or neutral), (0, 1) neutral or positive, (-1, 1) (negative or positive/negative, neutral, or positive).

An NPN fuzzy value pair is represented in the form of (x, y), where $x \in [-1, 0]$ and $\in [0, 1]$.

Three logical operations between one or two fuzzy NPN values are the following:

$$NEG(x, y) = (NEG(y), NEG(x)) \quad (3)$$

$$(x, y) * (u, v) = \left(\min(x * u, x * v, y * u, y * v), \max(x * u, x * v, y * u, y * v)\right) \quad (4)$$

$$(x, y)OR(u, v) = \left(\min(x, u), \max(y, v)\right) \quad (5)$$

When these operators are restricted to the crisp domain, they intuitively correspond to the rules shown in Table 1.

A)	Friend’s friend is friend
B)	Friends enemy is enemy
C)	Friend’s neutral friend is neutral
D)	Enemy’s enemy is friend
E)	Enemy’s friend is enemy
F)	Enemy’s neutral friend is neutral
G)	Neutral’s friend is neutral
H)	Neutral’s neutral friend is neutral
I)	Neutral’s enemy is neutral
J)	IF a neutral’s friend is a friend’s enemy. THEN he/she is an enemy or neutral
K)	IF a friend’s friend is another friend’s enemy. IF a friend’s friend is an enemy’s friend, or IF an enemy’s enemy is another enemy’s friend, THEN he/she might be a friend or an enemy

Table 1: Some production rules related to crisp NPN logic. Source [18, 27, 28].

Some important identities of Fuzzy NPN logic are summarized in Table 2.

Law	AND form (*)	OR (+) form
Identity law	$1(x, y) = (x, y)$	undefined
Null law	$0(x, y) = 0$	$(-1,1) + (x, y) = (-1,1)$
Idempotent law	undefined	$(x, y) + (x, y) = (x, y)$
Commutative law	$(x, y)(u, v) = (u, v)(x, y)$	$(x, y) + (u, v) = (u, v) + (x, y)$
Associative law	$\left((x, y)(u, v)\right)(w, z) = (x, y)\left((u, v)(w, z)\right)$	$\left((x, y) + (u, v)\right) + (w, z) = (x, y) + \left((u, v) + (w, z)\right)$
Distributive law	undefined	$(x, y)\left((u, v) + (w, z)\right) = (x, y)(u, v) + (x, y)(w, z)$

Table 2: Some logical identities in Fuzzy NPN logic. Source [27].

3 NCM and WOC

This section introduces the method for combining WOC and NCMs.

First, the crowd must be selected, such that it satisfies the conditions of Independence and Diversity. The larger the size of the crowd the best is the result. Because we are dealing with a complex phenomenon, the completely non-expert crew is not desirable, instead of that a "stakeholder" crowd can be selected, which are not expert peoples, with certain degree of experience with respect to the subject they are analyzing.

Other measure to take into account is to select a group of people having different point of views from the subject. For example, if the subject is the effectiveness of certain medication, the crowd can be formed by patients being treated with this drug, some physicians not experts in medicaments, and so on. On the other hand, the opinion of every one of them must be collected individually without any discussion among the members; moreover, the members of the crowd should not know each other.

A moderator informs to each crowd's member $G = \{g_1, g_2, \cdots, g_m\}$ the set of concepts $C = \{C_1, C_2, \dots, C_k\}$ he/she is dealing with. Each g_i $(i = 1, 2, \dots, m)$ assigns a value $e_{pq}^i \in \{-1, 0, 1, I\}$ $(p, q = 1, 2, \dots, k)$ to the edge which connects the two nodes p and q.

The algorithm contains two counter functions defined by equations 6 and 7:

$$f_-(e_{pq}^i) = \begin{cases} -1, \text{if } e_{pq}^i = -1 \text{ or } I \\ 0, \quad \text{otherwise} \end{cases} \quad (6)$$

$$f_+(e_{pq}^i) = \begin{cases} 1, \text{if } e_{pq}^i = 1 \text{ or } I \\ 0, \quad \text{otherwise} \end{cases} \quad (7)$$

Here we consider $I = [-1, 1]$, thus, it is included for aggregating both negative as well as positive values. The aggregated NCM is represented with the adjacency matrix $M = (M_{pq})$ such that $M_{pq} = \left(f_L(e_{pq}), f_U(e_{pq})\right)$ that is the ordered pair where:

$$f_L(e_{pq}) = \frac{\sum_{i=1}^m f_-(e_{pq}^i)}{m} \quad (8)$$

$$f_U(e_{pq}) = \frac{\sum_{i=1}^m f_+(e_{pq}^i)}{m} \quad (9)$$

This new cognitive map is a FCM with a pair of values corresponding to the Fuzzy NPN logic representation. Let us remark that every member of the crowd is equally weighted, thus Decentralization principle is complied with. Then, the HTC algorithm [29] is applied, with the effect of obtaining more negative value for $f_L(e_{pq})$ and more positive value for the $f_U(e_{pq})$ for each edge e_{pq} in the new FCM. The pseudo-code of this algorithm is the following [30]:

Given M defined like above, convert M to M' by representing each element as a pair with a lower boundary and upper boundary $M_{pj} = (a, b)$:

1) DO q = l TO k
2) DO p =1 TO k
3) IF $M_{pq} = (x, y)$ AND $(x, y) \neq (0, 0)$ THEN
4) DO j = 1 TO k
   IF $M_{qj} = (u, v)$, THEN
   $M'_{qj} = (\min(a, x * u, x * v, y * u, y * v), \max(b, x * u, x * v, y * u, y * v))$
5) END
6) END
7) END

Where the operator * is defined for $x, y \in [-1, 1]$ as follows:

$$x * y = \text{sign}(x) * \text{sign}(y) * (|x| * |y|) \quad (10)$$

The effect of this algorithm implies the satisfaction of the desirable condition of the WOC, which states that the dissidence of criteria is welcome.

For $M'_{pq} = \left(M'_{pq}(1), M'_{pq}(2)\right)$ we form a new matrix M''_{pq} applying the maximum effect, which means that if $M'_{pq}(2) \geq \left|M'_{pq}(1)\right|$ we have $M''_{pq} = M'_{pq}(2)$, else $M''_{pq} = M'_{pq}(1)$.

The equilibrium point is calculated with the formula 11.

$$A_p^t = F\left(\sum_{q=1,q\neq p}^{k} A_q^{t-1} W_{pq} + A_p^{t-1}\right) \quad (11)$$

Where, A_p^t is the value of node C_p at step t, A_p^{t-1} is the value of node C_p at step t-1, A_q^{t-1} is the value of node C_q at step t-1, W_{pq} is the weight of the interconnection between C_p and C_q, i.e., M''_{pq}. F is the threshold function; in this case, we use the sigmoid function, see Equation 12.

$$F(x) = \frac{1}{1+e^{-x}} \quad (12)$$

The previous method of convergence is simple, it can be substituted with others like Pool2 algorithm [29], and that introduced in [30].

Let us illustrate our approach with a simple hypothetical example, nevertheless in future works we use a real-life example as an experimental proof of the validity of the proposed method.

Example 1:

First, we would like to make some reflections about the method. We have to pay attention about the satisfaction of every condition of WOC. For example, the problem on migrant construction workers in West Bengala, India who are HIV carriers [11] is a complex problem with social, economical, human-rights dimensions. However, almost every citizen has an opinion on this subject, thus a crowd with a large size can be selected, where they have a variety of criteria about very controversial subjects like immigration or sexual diseases are.

In this example we select a hypothetical case with three nodes (k = 3) $C = \{C_1, C_2, C_3\}$ and the size of the crowd is of 200 members. Tables 3, 4, 5, and 6 summarize the number of members which selected -1, 0, 1, I, respectively, as the connection between every C_p and C_q, $(p, q = 1, 2, 3)$.

	C_1	C_2	C_3
C_1	89	52	5
C_2	85	129	21
C_3	3	34	40

Table 3: Number of crowd's members who evaluated as -1 the edges C_pC_q.

	C_1	C_2	C_3
C_1	14	55	23
C_2	4	14	2
C_3	77	44	65

Table 4: Number of crowd's members who evaluated as 0 the edges C_pC_q.

	C_1	C_2	C_3
C_1	67	79	84
C_2	98	19	32
C_3	20	58	56

Table 5: Number of crowd's members who evaluated as 1 the edges C_pC_q.

	C_1	C_2	C_3
C_1	30	14	88
C_2	13	38	145
C_3	101	64	39

Table 6: Number of crowd's members who evaluated as I the edges C_pC_q.

Then, calculating M with Equations 6 and 7, later applying HTC algorithm and finally calculating M'' we have the matrix summarized in Table 7.

	C_1	C_2	C_3
C_1	0.60500	0.61000	0.52030
C_2	0.60500	0.61000	0.53985
C_3	0.60500	0.61000	0.47500

Table 7: Matrix M'' of the example.

Calculating the iterative process using Equation 9, individually activating every one of the three nodes, i.e., starting with $x_0 = (1, 0, 0)$, $y_0 = (0, 1, 0)$, and $z_0 = (0, 0, 1)$, after 10 iterations we obtain $x \approx y \approx z = (0.93155, 0.93249, 0.91154)$.

Conclusion

In this paper, we propose a method where the wisdom of crowds' theory is used to obtain knowledge from complex issues represented individually in the form of neutrosophic cognitive maps. To apply the method, the principles of Independence and Diversity proposed by the WOC must be complied with. Within the method, the decentralization recommended in the WOC is guaranteed. The novelty of the method consists in representing the individual knowledge of the members of the crowd with the help of NCMs; this allows each individual to include indeterminacy in the knowledge representation. The aggregation is carried out with the help of the Fuzzy Negative-Positive-Neutral (NPN) logic, which naturally allows calculating with the symbol I, to obtain a FCM. A way to perform dynamic calculations is also developed by means of a recursive method. In future works, we will explore other methods, such as Pool2. Additionally, future studies will carry out experiments on the use of this proposal in real life problems, the results of which will be compared with other methods using experts, to test the validity of the authors' proposal.

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Evaluating Strategies of Continuing Education for Academics Supported in the Pedagogical Model and Based on Plithogenic Sets

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Abstract. The preparation with which students graduate in the global environment and become university teachers, reveals that little time is devoted to the content of some disciplines related to the educational act. Therefore, they graduate with the contents that they poorly learned. Throughout their schooling, there is no adequate program on how to develop a teaching that guarantees the learning of university students. That is why continuous training programs are needed to pledge the training of these teaching professionals to confront the new challenges of Ecuadorian higher education. The purpose of this research is to determine and rank the strategies of continuous training for university teachers, proposed and evaluated by four experts. For this purpose, we use Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method, in the Plithogenic framework. Plithogenic sets generalize crisp, fuzzy, intuitionistic fuzzy, and neutrosophic sets, and have been applied successfully in decision-making problems. For the first time this method is applied in the pedagogical area.

Keywords: Higher education, continuing education, pedagogical performance, pedagogical model, VIKOR, plithogenic sets.

1 Introduction

Education by extension, continuing education or continuous training are terms that comprise a spectrum of activities and theoretical-practical learning programs, which take place after compulsory or regulated training, such as secondary, high school, or university education, [1]. Among the range of programs, there are courses developed for non-traditional students, forms of training without an academic degree, job training, personal training courses, whether in person or at distance, self-directed education, such as courses through Internet interest groups, personal research activities, internships focused on problem solving, language courses, among others.

Usually the continuing education students have a certain educational or professional level and want to improve it or obtain official recognition for their training or simply continue and deepen their education. Continuing education activities will depend on the acceptance of a regulatory body. In most cases, it requires the approval of a continuing education provider. However, the existence of online educational platforms and virtual courses transcend traditional geographical barriers and allow students to obtain quality continuing education from the comfort of their home, at work and even on mobile devices. The shift in continuing education towards virtualization has been motivated by the busyness of individuals' daily lives, lack of time, and the poverty of locally available educational resources.

Continuous training is necessary because there is a very competitive world environment due to the current speed of change and innovation in technology, rigidity of business structures and work organization, globalization of markets, and strong competitiveness.

The training of teachers in higher education currently requires a new stance that cannot be dissociated from the political, economic and social situation, marked by the incessant growth of State investment in educational infrastructures and in the formulation of the new Ecuadorian educational policy.

This is about evaluating not only the growth in offers in the management and development of inter-institutional projects for teaching. It also requires in higher education, as in the other instructional subsystems, to develop continuous training in accordance with the social, cultural and political context, which is the main goal of every educational phenomenon.

Scientific and technological advances and new models of production are factors that occur on a global scale and impose a serious reflection by the political entities about the types of organization and the operation of the higher education system. Within the challenges of that reality, the trends are related to:

• The implementation of educational reforms to increase the quality of the educational process. Chinchilla's position is recognized in this field, who refers to the "... need for a change in the curriculum of university majoring.", [2].

• The reengineering of university substantive processes in each management that reflects on the certification and accreditation of universities (plans and programs). In this sense, other researchers such as Campoverde have stated that: "… the improvement of the pedagogical professional performance of teachers should be a reflection of university certification…", [3].

• The curricular reformulation also makes evident the imperativeness of continuous training for teachers and managers, seeking to address the scientific and technological dimensions, for a sustainable and humanistic educational process.

• The development of didactic, communicative, investigative, technological, professional and human competences that show synergy in all the constant disciplines in the curricular programs. That agrees with Oramas who offers a system of competences of university teachers for medical courses, which is a "... system of knowledge, skills and values in the modes of professional performance.", [4].

In higher education, this analysis encourages a critical and complex reflection on the approach made to the continuous training of university teachers and authorities, which promotes the improvement of their pedagogical performance and raises the quality of teaching; this is the main goal of this work.

In this paper, different strategies of continuous training for teachers of higher education in Ecuador are studied. In this regard, a theory known as Plithogeny recently emerged from Neutrosophy. Plithogeny is the genesis or origination, creation, formation, development, and evolution of new entities from dynamics and organic fusions of contradictory and/or neutrals and/or non-contradictory multiple old entities, [5]. Plithogeny pleads for the connections and unification of theories and ideas in any field. "Entities" mean the "knowledge" in various fields, such as soft sciences, hard sciences, arts and letters theories, among others.

While Neutrosophy only deals with the triad (<A>, <neut A>, <anti A>), where A is an item or a concept, Plithogeny is responsible for obtaining new objects from old ones represented by other triads (<B>, <neut B>, <anti B>) or simply <C> or <D>, so that there may be partial or total contradictions between them, which when dynamically interacting with each other create a new object.

A plithogenic set P is a set whose elements are characterized by one or more attributes, and each attribute may have many values, [5-10]. Each attribute value v has a corresponding (fuzzy, intuitionistic fuzzy, or neutrosophic) degree of appurtenance d(x,v) of the element x, to the set P, with respect to some given criteria, [11]. In order to obtain a better accuracy for the plithogenic aggregation operators, a (fuzzy, intuitionistic fuzzy, or neutrosophic) contradiction (dissimilarity) degree is defined between each attribute value and the dominant (most important) attribute value.

Additionally we use the Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR), which is a multi-criteria decision-making method that focuses on the criteria evaluation with respect to others, where the main idea of the method consists in assuming that the compromise is acceptable to resolve conflicts, [12-14]. In this method, each evaluation is compared against the best and worst ideal evaluations. This method has been used with plithogenic sets for hospital medical care systems evaluation, [15-18].

In this paper, we evaluate strategies for the continuous training of higher education teachers. This is a very useful and unprecedented way to make decisions in the university context of Ecuador. There are several papers covering to use Neutrosophy and Plithogeny in decision-making [7, 19-23], and pedagogical situations, [24, 25].

This paper is split into the following sections: section 2 contains a brief overview of the basic concepts of VIKOR and plithogenic sets. In section 3, we describe the results of the study of the strategies that can be applied in higher education for the continuous training of teachers, according to four experts' opinions who evaluate five alternatives based on eight criteria. Section 4 presents the conclusions.

2 Basic concepts

This section contains the basic concepts of plithogenic sets in subsection 2.1 and VIKOR method in subsection 2.2.

2.1 Plithogenic sets

Definition 1. ([5]) A *plithogenic set* (P, A, V, d, c) is a set P that includes numerous elements described by a number of attributes $A = \{\alpha_1, \alpha_2, \dots, \alpha_m\}$, $m \geq 1$, which has values $V = \{v_1, v_2, \dots, v_n\}$, for $n \geq 1$. For V there are two main features attributes values, they are the *appurtenance degree function* $d(x, v)$ of the element x, with respect to some given criteria, and the *contradiction* (*dissimilarity*) *degree function* $c(v, D)$ which is the one that exists between each attribute value and the most important (dominant) one.

Given A, a non-empty set of uni-dimensional attributes $A = \{\alpha_1, \alpha_2, \ldots, \alpha_m\}$, $m \geq 1$, and let $\alpha \in A$ be an attribute with its value spectrum the set S, where S can be defined as a finite discrete set, $S = \{s_1, s_2, \ldots, s_l\}$ $l \in [1, \infty)$, or infinitely countable set $S = \{s_1, s_2, \ldots\}$, or infinitely uncountable (continuum) set $S = (a, b)$, $S = (a, b]$, $S = [a, b)$, or $S = [a, b]$.

Definition 2. ([5]) The *degree of appurtenance* is defined for fuzzy, intuitionistic fuzzy, or neutrosophic degree of appurtenance to the plithogenic set. See expression 1 below:

$$\forall x \in P, d: P \times V \to \mathcal{P}([0,1]^z) \qquad (1)$$

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

Definition 3. ([5]) The attribute value *contradiction degree function* is defined as follows:

$$c: V \times V \to [0,1] \qquad (2)$$

Such that $c(v_1, v_2)$ represents the dissimilarity between two attribute values v_1 and v_2, and satisfies the following axioms:

- $c(v_1, v_1) = 0$, the contradiction degree between the attribute values and itself is zero,
- $c(v_1, v_2) = c(v_2, v_1)$.

Definition 4. Given a plithogenic set (P, A, V, d, c), a *Plithogenic Neutrosophic Aggregation Operator* is defined in Equation 3:

$$(a_1, a_2, a_3)\mathrm{Aggr_p}(b_1, b_2, b_3) = \Big(\bar{c}(a_1 \wedge_F b_1) + (1 - \bar{c})(a_1 \vee_F b_1), \tfrac{1}{2}[a_1 \wedge_F b_1 + a_1 \vee_F b_1], \bar{c}(a_1 \vee_F b_1) + (1 - \bar{c})(a_1 \wedge_F b_1)\Big) \qquad (3)$$

Where $\bar{c} \in [0,1]$, $\wedge_F$ is a t-norm and $\vee_F$ is a t-conorm.

It is a *Plithogenic Neutrosophic Intersection* when $\bar{c} = 1$ and it is a *Plithogenic Neutrosophic Union* when $\bar{c} = 0$, [5]. This aggregator is more accurate than both the n-norms and n-conorms between neutrosophic sets.

A plithogenic neutrosophic set can be converted into a crisp value using the following formula, [15]:

$$\mathcal{S}(T, I, F) = \frac{1}{3}(2 + T - I - F) \qquad (4)$$

2.2 The VIKOR method

One fundamental formula of the VIKOR method is the L_p-metric. Let us denote by $A = \{A_1, A_2, \cdots, A_J\}$ the set of alternatives and $C = \{c_1, c_2, \cdots, c_n\}$ the set of criteria. If f_{ij} denotes the j-th alternative measured against the i-th criterion. Then, the L_p-metric is used as follows, [13, 14]:

$$L_{pj} = \left\{\sum_{i=1}^{n}\left[w_i\left(f_i^* - f_{ij}\right)/\left(f_i^* - f_i^-\right)\right]^p\right\}^{1/p} \qquad (5)$$

Where $1 \leq p \leq \infty$; $j = 1, 2, \cdots, J$, $i = 1, 2, \cdots, n$, f_i^* and f_i^- are the best and the worst values of criteria, respectively. If c_i is a beneficial criteria, then $f_i^* = \max_j(f_{ij})$ and $f_i^- = \min_j(f_{ij})$. In contrast, if c_i is non-beneficial criteria, then $f_i^* = \min_j(f_{ij})$ and $f_i^- = \max_j(f_{ij})$. w_i is the weight of the i-th criterion expressing its importance.

Next, for decision making, indexes S_j (maximum group utility) and R_j (minimum individual regret of the opponent) are calculated using L_{1j} and $L_{\infty j}$, respectively through Equations 6 and 7.

$$S_j = \sum_{i=1}^{n}\left[w_i\left(f_i^* - f_{ij}\right)/\left(f_i^* - f_i^-\right)\right] \qquad (6)$$

$$R_j = max_i\left[w_i\left(f_i^* - f_{ij}\right)/\left(f_i^* - f_i^-\right)\right] \qquad (7)$$

Then, the concordance index is calculated using Equation 8:

$$Q_j = v\left[\frac{S_j - S^*}{S^- - S^*}\right] + (1 - v)\left[\frac{R_j - R^*}{R^- - R^*}\right] \qquad (8)$$

Where $S^- = \max_j S_j$, $S^* = \min_j S_j$, $R^- = \max_j R_j$, $R^* = \min_j R_j$, and v is the weight of strategy of maximum group utility, usually it is fixed as 0.5.

Finally, we sort the alternatives A_j according to the values of Q_j in descending order, where alternative having the minimum Q is the best one. Then, for alternative selection, two additional conditions should be satisfied.

Condition 1 (acceptable advantage):
If A^1 and A^2 are the first and the second alternatives, respectively in the order, then this condition is:
$\mathrm{Q}(A^1) - \mathrm{Q}(A^2) \geq \frac{1}{\mathrm{J}-1}$

Condition 2 (acceptable stability):
As the ranking of Q, A^1 must be the superior in both, the ranking of S and R. In case that one condition is not satisfied, a set of alternatives is proposed:

- If condition 2 is not satisfied, then A^1 and A^2 are compromise solutions;
- If condition 1 is not satisfied, then A^1, A^2,…, A^J are compromise solutions, where A^J is determined by the following equation:

$\mathrm{Q}(A^J) - \mathrm{Q}(A^1) < \frac{1}{\mathrm{J}-1}$.

In [15] there is a solution obtained with VIKOR method using plithogenic sets. They define linguistic terms for assessing the weights of criteria and the classification terms, as in Tables 1 and 2, respectively.

Linguistic expressions	**The plithogenic number of all expressions (T, I, F)**
Low significance (LS)	(0.10, 0.70, 0.80)
Equal significance (ES)	(0.30, 0.40, 0.80)
Robust significance (RS)	(0.50, 0.40, 0.60)
Very robust significance (VRS)	(0.70, 0.30, 0.10)
Absolute significance (AS)	(0.90, 0.10, 0.10)

Table 1: Semantic expressions for the significance weights of criteria. Source [15].

Linguistic expressions	**Plithogenic number (T, I, F)**
Very poor (VP)	(0.10, 0.75, 0.85)
Poor (P)	(0.25, 0.60, 0.80)
Medium poor (MP)	(0.40, 0.70, 0.50)
Medium (M)	(0.50, 0.40, 0.60)
Medium Good (MG)	(0.65, 0.30, 0.45)
Good (G)	(0.80, 0.10, 0.30)
Very Good (VG)	(0.95, 0.05, 0.05)

Table 2: Linguistic expressions for rendering classification of substitutions. Source [15].

This method contemplates a matrix where the k-th evaluator assesses the J alternatives according to the n criteria as follows:

$$\widetilde{\mathrm{M}}_{\mathrm{k}} = \begin{array}{c} \\ Contradiction\ degrees \\ A_1 \\ A_2 \\ \vdots \\ A_J \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_n \end{array} \\ \begin{bmatrix} cd_1 & cd_2 & \cdots & cd_n \\ \widetilde{\mathrm{X}}_{11\mathrm{k}} & \widetilde{\mathrm{X}}_{12\mathrm{k}} & \cdots & \widetilde{\mathrm{X}}_{1\mathrm{nk}} \\ \widetilde{\mathrm{X}}_{21\mathrm{k}} & \widetilde{\mathrm{X}}_{22\mathrm{k}} & \cdots & \widetilde{\mathrm{X}}_{2\mathrm{nk}} \\ \vdots & \vdots & \cdots & \vdots \\ \widetilde{\mathrm{X}}_{\mathrm{J1k}} & \widetilde{\mathrm{X}}_{\mathrm{J2k}} & \cdots & \widetilde{\mathrm{X}}_{\mathrm{Jnk}} \end{bmatrix} \end{array} \tag{9}$$

Where $\widetilde{\mathrm{X}}_{\mathrm{jik}} = (\mathrm{T}_{\mathrm{jik}}, \mathrm{I}_{\mathrm{jik}}, \mathrm{F}_{\mathrm{jik}})$ $(\mathrm{j} = 1,2, \dots, \mathrm{J})(\mathrm{i} = 1,2, \dots, \mathrm{n})$ is the evaluation given by the k-th expert about the j-th alternative evaluated according to the i-th criterion. These values are obtained from Table 2.
On the other hand, experts evaluate every criterion according to matrix in Equation 10.

$$\widetilde{\mathrm{N}} = \begin{array}{c} \\ Contradiction\ degrees \\ E_1 \\ E_2 \\ \vdots \\ E_m \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_n \end{array} \\ \begin{bmatrix} cd_1 & cd_2 & \cdots & cd_n \\ \widetilde{\mathrm{X}}_{11} & \widetilde{\mathrm{X}}_{12} & \cdots & \widetilde{\mathrm{X}}_{1\mathrm{n}} \\ \widetilde{\mathrm{X}}_{21} & \widetilde{\mathrm{X}}_{22} & \cdots & \widetilde{\mathrm{X}}_{2\mathrm{n}} \\ \vdots & \vdots & \cdots & \vdots \\ \widetilde{\mathrm{X}}_{\mathrm{m1}} & \widetilde{\mathrm{X}}_{\mathrm{m2}} & \cdots & \widetilde{\mathrm{X}}_{\mathrm{mn}} \end{bmatrix} \end{array} \tag{10}$$

Here, $\widetilde{X}_{ki}$ is the evaluation of the k-th expert on the importance of the i-th criterion. The values are obtained from the linguistic terms in Table 1 and $\widetilde{X}_{ki}$ are their equivalent plithogenic numbers.

Then, the algorithm to calculate the best alternative is the following:

1. Select the set of experts $E = \{E_1, E_2, \cdots, E_m\}$, the set of criteria $C = \{c_1, c_2, \cdots, c_n\}$, and the set of alternatives $A = \{A_1, A_2, \cdots, A_J\}$.
2. Each expert evaluates the criteria according their importance using the linguistic terms in Table 1, then their associated plithogenic numbers are used to form matrix $\widetilde{N}$.
   The elements of each column of $\widetilde{N}$ are aggregated using formula 3 and cd_i.
   Then, each obtained value is converted into a crisp number using formula 4, let us call them w_i.
   Next, normalize each w_i as $\widetilde{w}_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$. Subsequently, $\widetilde{w}_i$ are used as weights in the formulas.
3. Each expert evaluates each alternative against the criteria and matrices $\widetilde{M}_k$ are obtained, where their elements are those in Table 2, such that the linguistic terms are converted into their equivalent plithogenic numbers shown in the table.
   Aggregate matrices $\widetilde{M}_k$ in a matrix $\widetilde{M}$, where $\widetilde{M}(j,i) = \mathrm{Aggr}_{p,k}\widetilde{M}_k(j,i)$.
   $\widetilde{M}(j,i)$ is converted into a crisp matrix using Equation 4 for all its elements, let us call it M.
4. Apply crisp VIKOR method, i.e., calculate S_j, R_j, and Q_j, using $\widetilde{w}_i$ for the weights and the elements of M, fixing v. We recommend to use $v = 0.5$.
5. Sort the alternatives following the steps of the classical VIKOR method. Thus, the best alternative can be selected.

3 Best alternative for continuing education

This section analyzes and selects the best alternative for continuing education in the Ecuadorian universities. For this purpose, we apply the algorithm explained in section 2, where VIKOR method is used combined with plithogenic sets, as proposed in [15].

Four experts were selected, they are denoted by $E = \{E_1, E_2, E_3, E_4\}$, thus m = 4. The criteria to evaluate alternatives are the following:

c_1: Economical feasibility,

c_2: Technical feasibility,

c_3: Correspondence with the pedagogical model of the Ecuadorian higher education centers,

c_4: Cost,

c_5: Profitability,

c_6: Predicted pedagogical results,

c_7: Social, economic and political impact of the alternative in case of successful result, and

c_8: Availability of qualified teachers.

Whereas the alternatives (strategies) are the following:

A_1: Not to perform continuous education, the regular education is sufficient.

To perform continuous education that is associated with the following programs:

A_2: Diploma course in pedagogical sciences,

A_3: Program of educational improvement at distance,

A_4: Training program in organization and administration for work teams, and

A_5: Program of doctoral training at distance.

Table 3 summarizes the assessment of the criteria by the four experts.

Expert\Criteria	**c_1**	**c_2**	**c_3**	**c_4**	**c_5**	**c_6**	**c_7**	**c_8**
Contradiction Degrees	1/10	1/20	1/10	1/10	1/10	0	0	1/10
E_1	VRS	VRS	VRS	RS	VRS	VRS	VRS	RS
E_2	ES	VRS	ES	RS	LS	VRS	RS	LS
E_3	AS	RS	LS	RS	AS	AS	RS	ES
E_4	VRS	VRS	RS	ES	LS	VRS	RS	RS

Table 3: Importance of the criteria assessed by the four experts and their contradiction degrees.

We aggregate the results shown in Table 3 for all the experts using formula 3 and c_is, next we convert the obtained vector into a crisp vector using Equation 4, and finally we normalize it. The results are the following:

$\widetilde{w}_1 = 0.13999$, $\widetilde{w}_2 = 0.13751$, $\widetilde{w}_3 = 0.11322$, $\widetilde{w}_4 = 0.10999$, $\widetilde{w}_5 = 0.11763$, $\widetilde{w}_6 = 0.14399$, $\widetilde{w}_7 = 0.13383$, and $\widetilde{w}_8 = 0.10384$.

Now, experts evaluate the alternatives against the criteria using the linguistic terms in Table 2. The results are summarized in Tables 4-7.

Alternative\Criteria	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
Contradiction Degrees	1/10	1/20	1/10	1/10	1/10	0	0	1/10
A_1	VG	VG	VG	VG	VP	M	P	VG
A_2	G	G	VG	G	VG	VG	VG	G
A_3	MG	MG	VG	MG	VG	VG	VG	G
A_4	G	G	G	G	G	VG	VG	G
A_5	G	G	VG	G	G	VG	MG	M

Table 4: Alternatives assessed against the criteria by expert 1.

Alternative\Criteria	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
Contradiction Degrees	1/10	1/20	1/10	1/10	1/10	0	0	1/10
A_1	VG	VG	G	G	P	P	P	G
A_2	VG	G	VG	VG	G	G	VG	G
A_3	M	M	G	MG	G	VG	VG	VG
A_4	G	G	VG	VG	G	G	VG	G
A_5	VG	G	G	G	G	G	M	M

Table 5: Alternatives assessed against the criteria by expert 2.

Alternative\Criteria	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
Contradiction Degrees	1/10	1/20	1/10	1/10	1/10	0	0	1/10
A_1	M	G	MG	G	P	P	P	VG
A_2	G	VG	G	VG	VG	G	VG	G
A_3	MG	MG	G	G	G	VG	VG	G
A_4	VG	VG	G	G	G	G	VG	VG
A_5	G	VG	G	G	G	VG	MG	MG

Table 6: Alternatives assessed against the criteria by expert 3.

Alternative\Criteria	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
Contradiction Degrees	1/10	1/20	1/10	1/10	1/10	0	0	1/10
A_1	VG	VG	G	G	P	VP	VP	VG
A_2	VG	VG	VG	VG	VG	VG	VG	VG
A_3	M	G	G	G	G	G	VG	VG
A_4	VG	VG	G	MG	MG	G	G	G
A_5	G	G	G	G	G	G	M	M

Table 7: Alternatives assessed against the criteria by expert 4.

Table 8 contains the values of matrix M defined in step 3 of the algorithm. Before we aggregated the associated elements of matrices $\widetilde{\mathrm{M}}_{\mathrm{k}}$ to obtain $\widetilde{\mathrm{M}}$ using $\widetilde{\mathrm{M}}(\mathrm{j},\mathrm{i}) = {}_{\mathrm{k}=1}^{4}\mathrm{Aggr}_{\mathrm{p}}\widetilde{\mathrm{M}}_{\mathrm{k}}(\mathrm{j},\mathrm{i})$, then, the crisp values are obtained through formula 4.

Alternative\Criteria	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
A_1	0.94510	0.97658	0.92375	0.94440	0.46028	0.59016	0.50337	0.97693
A_2	0.97027	0.97684	0.97316	0.97693	0.97693	0.97698	0.98333	0.96637
A_3	0.78517	0.89715	0.94440	0.91470	0.94440	0.97498	0.98333	0.97027
A_4	0.97403	0.97684	0.94440	0.89808	0.89028	0.96817	0.97498	0.95020
A_5	0.94440	0.96051	0.94440	0.93816	0.93816	0.97281	0.84466	0.76852

Table 8: Matrix M of alternatives according to the criteria.

Thus, the results of S and R are obtained through Equations 6 and 7, respectively:
$S_1 = 0.5759448$, $S_2 = 0.0080519$, $S_3 = 0.4416774$, $S_4 = 0.2145537$, and $S_5 = 0.3230270$.
$R_1 = 0.1439900$, $R_2 = 0.0052624$, $R_3 = 0.1399900$, $R_4 = 0.1099900$, and $R_5 = 0.1038400$.
Hence, the values of Q through Equation 8 are:
$Q_1 = 1$, $Q_2 = 0$, $Q_3 = 0.86737$, $Q_4 = 0.55927$, and $Q_5 = 0.63261$.
Sorting the alternatives in descending order according to Q, we have $A_1 \succ A_3 \succ A_5 \succ A_4 \succ A_2$. Therefore A_2 is the best one.
Checking the satisfaction of the two conditions, we have:

$Q(A_4) - Q(A_2) = 0.55927 \geq \frac{1}{5-1} = 0.25$, then the condition of acceptable advantage is satisfied.

The condition of acceptable stability is also satisfied, A_2 is the best alternative with respect to S, R and Q.

Conclusion

This paper contains the investigation on continuing education in the Ecuadorian higher education centers. This aims to select the best strategy for continuous training in pedagogical sciences of the postgraduate professionals who are teaching in the universities and colleges around the country. For this purpose, we used the VIKOR method in the framework of plithogenic sets, which has had a good performance applied in the medical management decision-making. Four specialists assessed five strategies according to eight criteria. The best strategy among those related to continuing education is "to perform the diploma course in pedagogical sciences", whereas the worst option is to "do not perform any continuous education". These conclusions are particularly useful to design the pedagogical models in Ecuadorian higher education. For the first time this method is used to select strategies in the area of pedagogical sciences, especially in continuing education.

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Neutrosophic DEMATEL to Prioritize Risk Factors in Teenage Pregnancy

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Abstract: Care during pregnancy is a task of high importance for the health system. In Ecuador, special importance has been given to pregnant teenagers. However, there are various factors that influence pregnancy and in many cases it is not possible to prioritize their care. This research aims to develop a model to prioritize the factors that influence teenage pregnancy. The model operates using the neutrosophic DEMATEL method for the study of cause and effect in complex situations. The method implements as a principle the modeling of neutrality using neutrosophic numbers and allows evaluation through the use of linguistic terms, which is a natural form of evaluation for humans.

Keywords: DEMATEL; Neutrosophic Numbers; teenage pregnancy; risk factors.

1. Introduction

Starting to have sexual activity at an early age often leads to early pregnancies. Teenage pregnancy has been increasing in recent years [1]. Studies have registered that the maternal mortality rate in Ecuador continues to be high, approximately between 500 and 700 women die each year due to complications related to pregnancy [2]. Avoiding perinatal complications associated with teenage pregnancy constitutes a challenge for the Public Health system [3, 4]. Recent research has identified aspects related to teenage pregnancy that range from the psychological to the social [5, 6].

For the gestation process in adolescents, the influence of a set of critical factors determine the success of pregnancy [7]. Quantifying compliance with these factors would allow continuous evaluation and recommendation to the pregnant woman. Processes of this nature have been covered by science using Artificial Intelligence techniques to model uncertainty[8]. A critical factor is represented by a degree of compliance, a degree of neutrality, and a degree of uncertainty. In this context, the representation of the fulfillment of critical factors can be modeled using neutrosophic numbers[9].

This research aims to develop a model for the prioritization of risk factors in adolescent pregnancy. The model operates using the DEMATEL method that includes the calculation with neutrosophic sets [10-12]. Indeterminacy is part of daily life, which is why the neutrosophic DEMATEL allows the study of complex cause-effect relationships, which includes indeterminacy and the use of linguistic terms, which is the natural form of communication for human beings.

This article is structured in several sections. In the Materials and Methods section, we describe the structure of the proposed model from the implementation of a neutrosophic DEMATEL. Next, the Results section is developed; in which the proposed method is implemented in a case study, thereby demonstrating the applicability of the method proposed in the previous section. Finally, the Conclusions and References are presented.

2. Preliminaries

This section describes the main definitions that make up the theoretical references on the object of study; such as the neutrosophic sets. We also make a description of the Neutrosophic Single Value Sets[13, 14] and the Neutrosophic Triangular Single Value Numbers[15, 16].

2.1 Definitions

Definition 1. Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow \,]^-0, 1^+[$, which satisfy the condition $-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3+$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denotes the membership functions to true, indeterminate and false of x in A, respectively, and their images are standard or non-standard subsets of $]^-0, 1^+[$ (see [17],[18]).

Definition 2. Let X be a universe of discourse. A *Single Value 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 $v_A(x)$ denotes the membership functions of true, indeterminate and false of x in A, respectively. For convenience, a *Single Value Neutrosophic Number* (SVNN) will be expressed as A = (a, b, c), where a, b, c $\in$ [0,1] and satisfies $0 \leq a + b + c \leq 3$ (see [17],[19]).

Definition 3. A *Triangular Single Value Neutrosophic Number* (TSVNN), which is denoted by: $\tilde{a} = \langle (a_1, a_2. a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a CN over $\mathbb{R}$, whose membership functions of truthfulness, indeterminacy, and falsehood are defined below (see [17],[20]):

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}}, & x = a_2 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_2 < x \leq a_3 \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, & \\ \frac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \end{cases} \tag{3}$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a}}, & \\ \frac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \end{cases} \tag{4}$$

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

Definition 4. 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 TSVNN and λ is any non-zero real number. Then the following operations are defined:

Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_3, a_2 - b_2, a_3 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
Inversion: $\tilde{a}^{-1} = \langle ({a_3}^{-1}, {a_2}^{-1}, {a_1}^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, donde$a_1, a_2, a_3 \neq 0$.

Product by a scalar:

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

Division of two TSVNN:

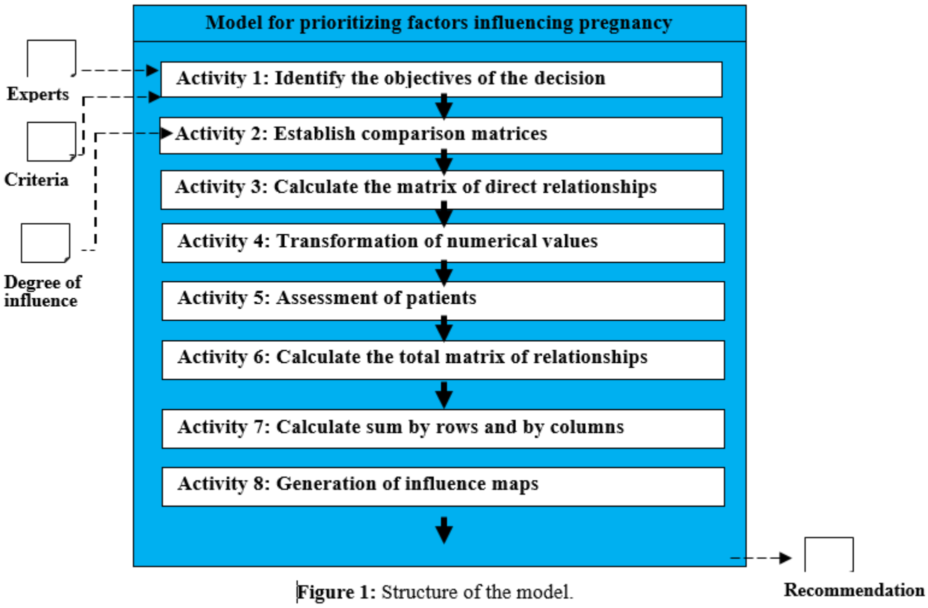

Figure 1: Structure of the model.

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \left\langle\left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\right\rangle, a_3 > 0 \;\; y \;\; b_3 > 0 \\ \left\langle\left(\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\right\rangle, a_3 < 0 \;\; y \;\; b_3 > 0 \\ \left\langle\left(\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\right\rangle, a_3 < 0 \;\; y \;\; b_3 < 0 \end{cases}$$

Multiplication of two TSVNN:

$$\tilde{a}\tilde{b} = \begin{cases} \langle(a_1 b_1, a_2 b_2, a_3 b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_3 > 0 \;\; y \;\; b_3 > 0 \\ \langle(a_1 b_3, a_2 b_2, a_3 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_3 < 0 \;\; y \;\; b_3 > 0 \\ \langle(a_3 b_3, a_2 b_2, a_1 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_3 < 0 \;\; y \;\; b_3 < 0 \end{cases}$$

Where, $\wedge$ is a t-norm and $\vee$ is a t-conorm.

A t-norm is an operator T: $[0, 1]^2 \rightarrow [0, 1]$ such that it satisfies the following axioms for all a, b, c and d in [0, 1]:

1. T(0,0) = 0, T(a,1) = a, (Boundary conditions),
2. T(a,b) ≤ T(c,d) if a ≤ c and b ≤ d (Monotony)
3. T(a,b) = T(b,a) (Commutativity)
4. T(a,T(b,c)) = T(T(a,b),c) (Associativity)

A t-conorm is an operator S: $[0, 1]^2 \rightarrow [0, 1]$ such that it satisfies the following axioms for all a, b, c and d in [0, 1]:

1. S(1,1) = 1, S(a,0) = a, (Boundary conditions),
2. S(a,b) ≤ S(c,d) si a ≤ c y b ≤ d (Monotony)
3. S(a,b) = S(b,a) (Commutativity)
4. S(a,S(b,c)) = S(S(a,b),c) (Associativity)

To convert TSVNN into real numerical values, the following formulas are applied, known as Score Index and Precision Index, respectively:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{5}$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (6)$$

3. Materials and Methods

The proposed model is structured in a workflow to prioritize the factors that influence teenage pregnancy. It is based on the DEMATEL Neutrosophic method[21], which will adapt to triangular and non-trapezoidal neutrosophic numbers [17]. Figure 1 shows a general diagram of the operation of the proposed model.

Activity 1. Identify the objectives of the decision: compilation of the relevant information present in the problem. It consists of:

1. Selection of experts and decision-makers who have experience in the field under study. Let us denote the experts by $E = \{E_1, E_2, \ldots, E_k\}$ ($k \geq 1$).
2. Identify the relevant criteria that characterize the problem. They will be denoted by $C = \{C_1, C_2, \ldots, C_m\}$ ($m \geq 2$).

Activity 2. Establish comparison matrices: forming the comparison matrices by pairs of relevant criteria. The experts emit the k comparison matrices by pairs of criteria, with order m×m. For this, each expert must give a value to each criterion compared to another, in the form of TSVNN, evaluating according to the values shown in Table 1. The value of the element X_{ij} measures how much the factor F_i directly influences the factor F_j, where $X_{ij} = \tilde{0}$ if i = j. Table 1 shows the evaluation scales to measure the degree of influence between the factors.

Linguistic Term	Corresponding Unique Triangular Neutral-To-Value Number
No influence	$\tilde{0} = \langle(0,0,0); 0{,}50;\ 0{,}50;\ 0{,}50\rangle$
Low influence	$\tilde{1} = \langle(0,1,2); 0{,}30;\ 0{,}75;\ 0{,}70\rangle$
Medium influence	$\tilde{2} = \langle(1,2,3); 0{,}80;\ 0{,}15;\ 0{,}20\rangle$
High influence	$\tilde{3} = \langle(2,3,4); 0{,}90;\ 0{,}10;\ 0{,}10\rangle$
Very high influence	$\tilde{4} = \langle(4,4,4); 1{,}00;\ 0{,}00;\ 0{,}00\rangle$

Table 1. Linguistic terms that describe the relationship between two factors or criteria and their equivalent in TSVNN.

Activity 3. Calculate the matrix of direct relationships as the sum of the k comparison matrices and then divide by k, that is, the arithmetic mean of the previous matrices, where the operations between TSVNN of sum and product by the scalar 1/k. This matrix is called $A = (A_{ij})_{mxm}$.

Activity 4. Transformation of numerical values using the formula of Equations 5 or 6.

Activity 5. A is normalized by dividing it by $s = \max\left(\max_{1\leq i\leq m} \sum_{j=1}^{m} a_{ij}, \max_{1\leq j\leq m} \sum_{i=1}^{m} a_{ij}\right)$, it will be called A_N.

Activity 6. Calculate the total matrix of relationships using the following formula:

$$T = A_N(I - A_N)^{-1} \quad (7)$$

Where I is the identity matrix of order m, the superscript -1 means inverse.

Activity 7. Calculate sum by rows and by columns of $T = (T_{ij})_{mxm}$. The sum by rows is denoted by D and the sum by columns is denoted by R. That is, $D = \left[\sum_{i=1}^{m} T_{ij}\right]_{1xm}$ y $R = \left[\sum_{j=1}^{m} T_{ij}\right]'_{mx1}$. Where the apostrophe indicates the matrix transposition.

Activity 8. Generation of relationship influence maps. For this, we calculate (R+D) called "Prominence" that measures the degree of central role that the factor or criterion plays within the system. While (R-D) is called "Ratio" and represents the effect that the factor or criterion produces in the system.

1. If rj-cj>0 the factor or criterion Cj is located in the group of causes,
2. If r_j-c_j<0 the factor or criterion C_j is located in the group of effects.

The pairs (R+D, R-D) can be represented graphically to give decision-makers a graphic idea about the system.

4. Results

This section presents the results of this research. It was carried out using data obtained from pregnant teenagers admitted at the Gynecology and Obstetrics service of Alfredo Noboa Montenegro Hospital in Guaranda, Ecuador. The study followed the sequence described in the model.

Three independent subject experts are selected, who issue their evaluations on the risk factors influencing adolescent pregnancy. The factors determined were those referred in [22] and that we reproduce below:

F_1: Individual factors.
F_2: Psychological factors.
F_3: Family factors.
F_4: Social factors.
F_5: Cultural factors.

Tables 2, 3, 4 show the comparison matrices by pairs of criteria according to the evaluations issued by Experts 1, 2, 3 respectively. Table 5 contains the results of the aggregation using the arithmetic mean of the TSVNN shown in Tables 2, 3, 4. *Min* was used as t-norm and *max* as t-conorm.

All the calculations carried out in this article were made with Octave 4.2.1, which is a free software that uses the MATLAB language, and facilitates the calculation with matrices, see [17].

Factor	F_1	F_2	F_3	F_4	F_5
F_1	$\tilde{0}$	$\tilde{2}$	$\tilde{4}$	$\tilde{0}$	$\tilde{2}$
F_2	$\tilde{4}$	$\tilde{0}$	$\tilde{4}$	$\tilde{0}$	$\tilde{0}$
F_3	$\tilde{2}$	$\tilde{4}$	$\tilde{0}$	$\tilde{1}$	$\tilde{1}$
F_4	$\tilde{2}$	$\tilde{3}$	$\tilde{2}$	$\tilde{0}$	$\tilde{4}$
F_5	$\tilde{3}$	$\tilde{1}$	$\tilde{2}$	$\tilde{4}$	$\tilde{0}$

Table 2. Evaluation carried out by Expert 1 by pairs of factors on the degree of direct influence of the row factor on the column factor.

Factor	F_1	F_2	F_3	F_4	F_5
F_1	$\tilde{0}$	$\tilde{1}$	$\tilde{3}$	$\tilde{0}$	$\tilde{3}$
F_2	$\tilde{2}$	$\tilde{0}$	$\tilde{4}$	$\tilde{0}$	$\tilde{0}$
F_3	$\tilde{2}$	$\tilde{3}$	$\tilde{0}$	$\tilde{2}$	$\tilde{2}$
F_4	$\tilde{2}$	$\tilde{3}$	$\tilde{2}$	$\tilde{0}$	$\tilde{3}$
F_5	$\tilde{3}$	$\tilde{1}$	$\tilde{2}$	$\tilde{4}$	$\tilde{0}$

Table 3. Evaluation carried out by Expert 2 by pairs of factors on the degree of direct influence of the row factor on the column factor.

Factor	F_1	F_2	F_3	F_4	F_5
F_1	$\tilde{0}$	$\tilde{2}$	$\tilde{4}$	$\tilde{0}$	$\tilde{2}$
F_2	$\tilde{3}$	$\tilde{0}$	$\tilde{2}$	$\tilde{0}$	$\tilde{0}$
F_3	$\tilde{4}$	$\tilde{4}$	$\tilde{0}$	$\tilde{2}$	$\tilde{1}$
F_4	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{0}$	$\tilde{4}$
F_5	$\tilde{2}$	$\tilde{3}$	$\tilde{3}$	$\tilde{4}$	$\tilde{0}$

Table 4. Evaluation carried out by Expert 3 by pairs of factors on the degree of direct influence of the row factor on the column factor.

Factor	F_1	F_2	F_3	F_4	F_5
F_1	$\tilde{0}$	$\tilde{1}$	$\tilde{3}$	0	$\tilde{2}$
F_2	$\tilde{3}$	$\tilde{0}$	$\tilde{3}$	$\tilde{0}$	$\tilde{0}$
F_3	$\tilde{2}$	$\tilde{3}$	$\tilde{0}$	$\tilde{2}$	$\tilde{1}$
F_4	$\tilde{2}$	$\tilde{3}$	$\tilde{2}$	$\tilde{0}$	$\tilde{3}$
F_5	$\tilde{2}$	$\tilde{2}$	$\tilde{2}$	$\tilde{4}$	$\tilde{0}$

Table 5. Arithmetic mean of factor pairwise expert evaluations of the degree of direct influence of the row factor on the column factor.

Table 6. contains the total matrix of relations T, calculated after successively finding the elements of the matrix in Table 5, the precision index of the elements with Equation 6. It is then normalized as indicated in activity 5 of the model, and finally Equation 7 is applied.

Factor	F_1	F_2	F_3	F_4	F_5
F_1	0	0,15625	0,34375	0	0,21875
F_2	0,28125	0	0,3125	0	0
F_3	0,25	0,34375	0	0,15625	0,125
F_4	0,21875	0,28125	0,21875	0	0,34375

F5	0,25	0,15625	0,21875	0,375	0

Table 6. Matrix of total relations.

From the matrix of total relations we have that D = [1,0000; 0,9375;1,09375;0,53125;0,6875; 4,2500] and R = [0,71875; 0,59375; 0,8750; 1,0625; 1], see activity 7 of the model.

The vector R+D = [1,718751,53125 1,96875 1,59375 1,6875] , while R-D = [-0,28125 -0,34375 -0,21875 0,53125 0,3125]. See also Figure 2, where the pairs (R+D, R-D) are plotted.

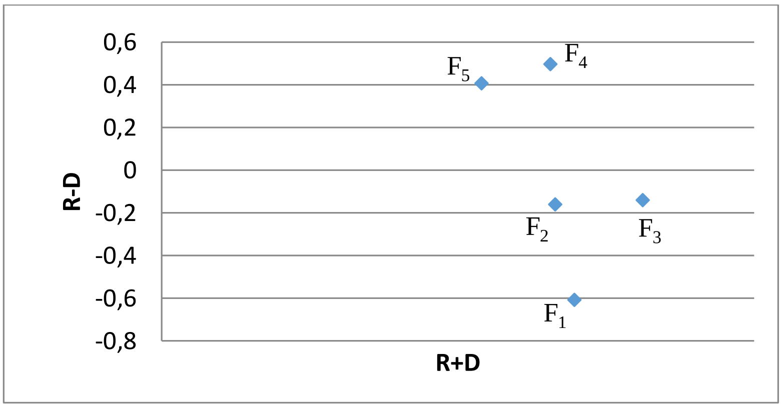

Figure 2. Graphical representation of the pairs (R + D, R-D). Each pair has a legend associated with the factor it represents.

From Figure 2 we can notice that factors 4 and 5 are the main cause of the other factors.

Conclusions

This investigation implemented a model to prioritize the factors that influence teenage pregnancy. The model based its inference process on the method known as DEMATEL neutrosophic for the study of cause and effect. The use of neutrosophic sets allowed the inclusion of uncertainty, indeterminacy and the use of linguistic terms. The evaluation of three experts was reviewed and the most important factors for the case under study were identified. As a result of the research, a case study was implemented based on data obtained from pregnant adolescents admitted at the Gynecology and Obstetrics service of Alfredo Noboa Montenegro Hospital in Guaranda, Ecuador, from which it was possible to demonstrate the applicability of the presented proposal.

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A Trialist Perspective of the Labor Inclusion of Indigenous People in Ecuador through PESTEL and Neutrosophic Cognitive Maps

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Abstract. The purpose of this research was to determine from a trialist perspective what factors currently affect the labor inclusion of people from indigenous cultures in Ecuadorian society and to propose strategies for their mitigation. A broad and generic analysis is carried out to assess whether the norms and the social reality evident in the country effectively adhere to each other. We used a fusion of PESTEL method and Neutrosophic Cognitive Maps, since during the mathematical exercise that endorses the analysis, indeterminacy is incorporated into the modeling of the causal relationships between the factors analyzed. Finally, the figure of indigenous labor inclusion is declared as an unfinished topic. Therefore, the priority factor to consider is the establishment of policies favoring the employment of indigenous people. As a solution, this paper ends with the proposal of compliant strategies to promote improvements in this area.

Keywords: labor inclusion; indigenous people; trialism; PESTEL analysis; neutrosophic cognitive maps.

1 Introduction

Trialist theory or trialism within the legal world is a legal theory developed by the German jurist Werner Goldschmidt [1]. It is also known as legal three-dimensionalism. It states that the legal world consists of three dimensions: facts (conduct or human behavior), norms (descriptions and logical captures of behaviors) and values (justice carried out through evaluations of men's behaviors). By nature, they integrate with each other, since it is the value of justice that allows the conduct and norms to be integrally judged. This is the reason why any branch of legal science must reflect this quality called three-dimensionality, which must not only reflect a certain trialist distribution, but should also show integration. Because of this, many conceptions can be considered three-dimensional in this broad sense: all natural law and a good part of Anglo-Saxon legal realism [2, 3].

Due to the nature of the aforementioned dimensions, we may say that there is a metaphysical union to prevent their political-methodological separation. Therefore, for its application it is necessary to start from the fusion principle of these two spaces. All this without decoupling from the concept of legal space [1, 2, 4]. One of the applications of trialism is the analysis of social phenomena through a formula that demonstrates integration between dimensions from an organic perspective, since "law is not just a set of rules that are established to regulate social behavior, but a complex totality that is called the "Legal World"[1]. [2] declares that, due to the origin and importance given to three-dimensionalism applied to an event within this context, it is necessary to carry out an exhaustive investigation of all the variables inherent to each of the dimensions of the trialist perspective.

From this perspective, the social reality of Ecuador is precisely analyzed. A reality in which takes place a historical-cultural event imposed by the rootedness of its idiosyncrasy: the categorization of people in what today is known as "Independent National States", where inequality, social inequality, racism and discrimination persist. Which contrasts with the premises of "Good living", the fundamental pillar of the Ecuadorian Constitution [5].

Currently, indigenous peoples and nations are the most affected, along with the afro-descendant population, called niggers. In this sense, much of the work of the public or private function, in the Ecuadorian territory there is evidence of the absence of indigenous people who hold positions in such entities. In this framework, the State has the obligation to identify those social groups having special difficulties to share with others on equal terms and thus give an effective guarantee of labor inclusion for this group of people.

Therefore, the main problem object of this study is the insertion of the indigenous population in the Ecuadorian labor environment. A glance at this topic, applying the trialist perspective, exposed that today equality is not applied; there is discrimination for jobs in areas with a greater amount of indigenous culture. The three-dimensional approach showed that the presence of these people practicing in a position is practically null, which is why this vulnerable sector must receive asymmetric, spontaneous participation and equity justice in order to shed legal certainty. The State has the mission of building equal national policies for all. However, researchers are obliged to provide solution strategies to identify, determine, correct and help those social groups and give an effective guarantee of a labor inclusion for this group of people. Then, due to the origin and essential importance of this topic, it was urgent to pay attention to it, so we decided to carry out this study with the objective: to determine what factors affect the labor inclusion of people from indigenous cultures in Ecuadorian society in the topicality and propose strategies to mitigate them[6].

The aforementioned is based on the idea that if we determine the factors that affect the problem and offer a hierarchy according to its negative impact, then we may propose strategies to the State of Ecuador in order to favor the incursion of so-called niggers into the environment of the country. In accordance with this approach, it is essential to study the situation using comprehensive strategic analysis techniques endorsed in mathematical methods compatible with the trialist perspective, to fulfill the stated objective. As well as the following specific objectives:

1. To characterize in an integral way the micro and macro-environment of the problem.
2. To determine the factors that affect the occurrence of the proposed phenomenon.
3. Rank the factors by their level of incidence based on a comprehensive mathematical model that transforms the linguistic results into mathematical ones and includes the notion of indeterminacy.
4. Propose strategies based on the results of the study and the interpretative capacity of the data.

After reviewing the bibliography and consulting several authors [7], we decided to apply the neutrosophic PESTEL analysis, due to its versatility in factor research. PESTEL is a strategic analysis technique to determine the external environment that affects the following factors: namely political, economic, sociocultural, technological, ecological and legal. It consists of determining the forces that affect the specific environment: sector, employment market, target groups, competition, among others. It is a technique to analyze business and determine the context in which it moves, in turn, allows the design of strategies to defend, take advantage of or adapt to anything that affects the sector [8]. The categories under consideration are:

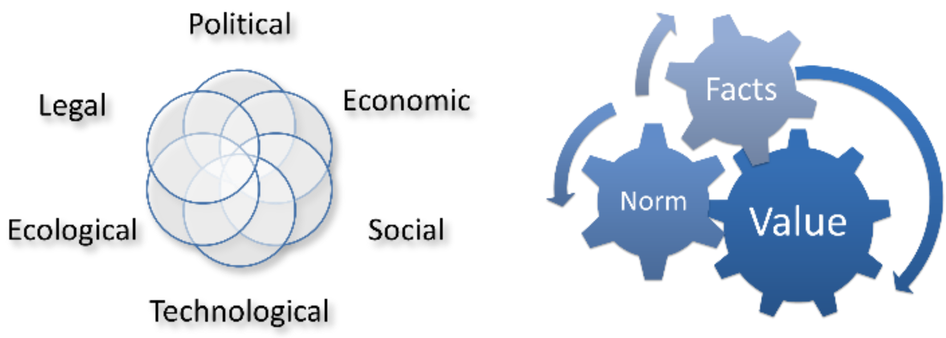

Figure 1. Representations of PESTEL analysis and Trialist Perspective. Source: own elaboration

Due to the need to establish a mathematical model of the linguistic terms that PESTEL offers as an output (factors), indeterminacies my occur and an answer must be required. The theory of Neutrosophy proposed by Florentin Smarandache, for the treatment of neutralities, generalizes clear and fuzzy set theories [9], where indeterminacies are supported. Neutrosophy is a useful theory that is increasing its number of applications in many fields. In this case, the inclusion of this theory enriches the possibilities of the PESTEL analysis, mainly due to two reasons: firstly, the addition of the notion of indeterminacy and, secondly, the possibility of calculating using linguistic terms [10]. That is why, we decided to opt for a fusion of both techniques and to run the study through the use of neutrosophic PESTEL, that is, the combination of PESTEL analysis with neutrosophic cognitive maps [11].

It is necessary to clarify that the problem under study is based on the interrelation shown by six aspects of the technique that integrate the trialist vision. In this way, a greater capacity for interpretation of the results is that it facilitates and contributes to the correlation between the characteristics of the study factors. Currently, [12-14] considers that the theory of Neutrosophy has significantly improved the techniques, tools and sharp methods, being an example its joint use with TOPSIS, VIKOR, ANP and DEMATEL.

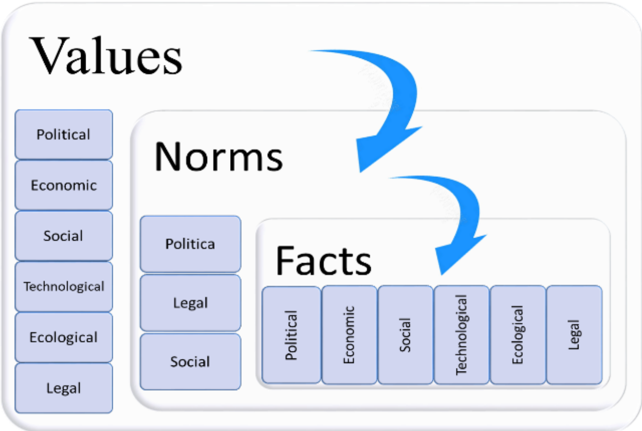

Figure 2. Trialist perspective fusion with neutrosophic PESTEL. Source: own elaboration.

After analyzing the previous discourse, it was necessary to apply the following theoretical methods to write this paper[15]:

- Analysis and Synthesis of the information obtained from the literature review, both international and national, of the specialized documentation, as well as the experience of observers and actors consulted to develop logical and valid conclusions, as well as a set of premises and/or positions generated by relevant actors within the social system, ethnic groups and their labor incursion.
- Systemic - structural for the development of the analysis through its decomposition into the elements that comprise it. It was possible to determine that there are countless unfavorable situations that contribute to the unemployment of indigenous cultures with unavoidable economic effects.
- Hermeneutic to make a comparative interpretation of the legislation applicable to the subject in question.

Based on the previously mentioned, the study is structured as follows: a second section where the basic concepts necessary to achieve the solution of this problem are briefly and compactly described; a third section to describe the results of the application of neutrosophic PESTEL in solving the posed problem. Finally, we state the conclusions reached after executing the analysis and the bibliography that allowed the development of this paper.

2 Materials and methods

Starting from the previous elements, in this particular work the use of Neutrosophic Cognitive Maps (NCMs) is proposed considering the advantages that this technique offers compared to other soft-computing techniques, in terms of interpretability, scalability, aggregation of knowledge, dynamism and its ability to represent feedback and indeterminacy relationships [16].

Neutrosophic Cognitive Maps (NCMs) were introduced by [17] in 2003. NCMs is an integration of the Fuzzy Cognitive Maps (FCM) introduced by Kosko in 1986 and the Neutrosophic Sets introduced by Smarandache in 1995 [18]. This technique overcomes the inability of traditional techniques to represent indeterminacy [19]. The inclusion of indeterminacy establishes that neutrality and ignorance are also forms of uncertainty. [18] declares that FCM constitutes a technique that has received increasing attention due to its possibilities for representing causality. Below is a set of definitions necessary for working with NCMs:

First, let us formally reproduce the original definition of neutrosophic logic as shown in [20].

Definition 1. Let N = {(T, I, F): T, I, F∈ [0,1]}[21] be a *neutrosophic set of evaluation*. v:***P***→N is a mapping of a group of propositional formulas into N, i.e., each sentence p∈ ***P*** is associated to a value in N, as it is exposed in the Equation 1, meaning that p is T% true, I% indeterminate and F% false.

$$v(p) = (T, I, F) \quad (1)$$

Hence, the neutrosophic logic is a generalization of fuzzy logic, based on the concept of Neutrosophy according to [9, 22].

Definition 2. (See [21, 23]) Let K be the ring of real numbers. The ring generated by K∪I is called a *neutrosophic ring* if it involves the indeterminacy factor in it, where I satisfies $I^2 = I$, I+I = 2I and in general, I+I+...+I = nI, if k∈K, then k.I = kI, 0I = 0. The neutrosophic ring is denoted by K(I), which is generated by K∪I, i.e., K(I) = <K∪I>, where <K∪I> denotes the ring generated by K and I.

Definition 3. A *neutrosophic matrix* is a matrix $A = [a_{ij}]_{ij}$ i =1, 2, …, m and j = 1, 2, …, n; m, n≥1, such that each $a_{ij} \in K(I)$, where K(I) is a neutrosophic ring, see [24].

Let us observe that an element of the matrix may have the form a+bI, where a and b are real numbers, while I is the indeterminacy factor. The usual operations of neutrosophic matrices can be extended from the classical matrix operations.

For example, $\begin{pmatrix} -1 & I & 5I \\ I & 4 & 7 \end{pmatrix}\begin{pmatrix} I & 9I & 6 \\ 0 & I & 0 \\ -4 & 7 & 5 \end{pmatrix} = \begin{pmatrix} -21I & 27I & -6+25I \\ -28+I & 49+13I & 35+6I \end{pmatrix}$.

Additionally, a *neutrosophic graph* is a graph that has at least one indeterminate edge or one indeterminate node [20, 25]. The *neutrosophic adjacency matrix* is an extension of the adjacency matrix in classical graph theory. $a_{ij} = 0$ means nodes i and j are not connected, $a_{ij} = 1$ means that these nodes are connected and $a_{ij} = I$ means the connection is indeterminate (whether they are connected or not is unknown). Fuzzy set theory does not use such notions.

On the other hand, if the indetermination is introduced in a cognitive map as it is referred in [26], then this cognitive map is called a *neutrosophic cognitive map*, which is especially useful in the representation of causal knowledge [9, 27]. It is formally defined in Definition 4.

Definition 4. A *Neutrosophic Cognitive Map* (NCM) is a neutrosophic directed graph with concepts like policies and events as nodes and causalities or indeterminacies as edges. It represents the causal relationship between concepts.

Neutrosophic Cognitive Maps are used in this paper, in accordance to the proposed objective, to include an indeterminate framework in the PESTEL analysis. The proposed framework is shown in Figure 3.

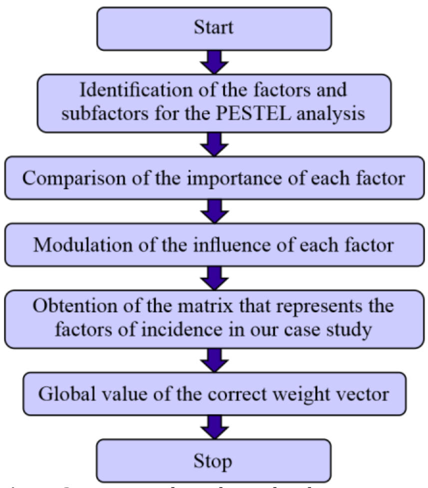

Figure 3. Framework to obtain the characteristics analyzed in each factor of the PESTEL model based on neutrosophic cognitive maps.

Neutrosophic cognitive maps are a generalization of fuzzy cognitive maps. Fuzzy cognitive maps are introduced by Axelrod, see [21], where nodes represent concepts or variables in a particular area of study and arcs indicate either positive or negative influences, considered as causal relationships. They have been applied in numerous areas, especially in supporting decision-making and in the analysis of complex systems as it is referred in [28]. Static analysis in a cognitive neutrosophic map focuses on the selection of the most important concepts, characteristics or factors in the modeled system [25].

The framework proposed in Figure 3 guides the process to obtain the characteristics of each of the factors analyzed with the PESTEL model. Integrated structure factors corresponding to a PESTEL analysis and characteristics are modeled using neutrosophic cognitive maps, which contributes to obtain quantitative information of the characteristics of factor analysis.

The measures described below are used in the proposed model, they are based on the absolute values of the adjacency matrix [26]:

- Outdegree (v_i) is the sum of the row elements in the neutrosophic adjacency matrix. It reflects the strength of the outgoing relationships (c_{ij}) of the variable.

$$od(v_i) = \sum_{i=1}^{n} c_{ij} \qquad (2)$$

- Indegree (v_i) is the sum of the column elements. It reflects the strength of relations (c_{ij}) outgoing from the variable.

$$id(v_i) = \sum_{i=1}^{n} c_{ji} \qquad (3)$$

- Total centrality (total degree $td\ (vi)$), is the sum of the indegree and the outdegree of the variable.

$$td(v_i) = od(v_i) + id(v_i) \qquad (4)$$

The static analysis is applied using the adjacency matrix, taking into consideration the absolute value of the weights [25]. Static analysis in Neutrosophic Cognitive Maps (NCM), see [27], initially contains the neutrosophic number of the form (a + bI, where I = indetermination) [29]. It requires a process of de-neutrosophication as proposed in [26], where I ∈ [0, 1] and it is replaced by their maximum and minimum values.

Finally, we work with the average of the extreme values, calculated using Equation 5, which is useful to obtain a single value. This value contributes to the identification of the characteristics to be attended, according to the factors obtained with the PESTEL model, for our case study.

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \qquad (5)$$

Then,

$$A \succ B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2} \qquad (6)$$

3 Results

Once the state of the art of the elements under analysis has been examined, we carry out the extraction of potential factors (variables) applying the following process approach:

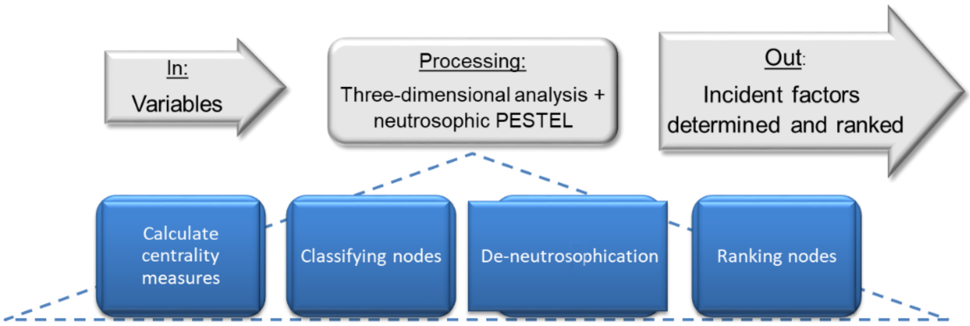

Figure 4. Process approach to data processing with PESTEL merged with neutrosophic cognitive maps. from the three-dimensional perspective. Source: own elaboration

The following table shows the factors and characteristics of the PESTEL model obtained for the analysis:

Dimension	Factor	State
Political	**Establishment of policies favoring indigenous employment (p1)**	• Article 33 of the Constitution of the Republic of Ecuador, declares the right to work, so it becomes a social duty that the government should materialize. Even though the regulations protect and favor these groups of people, in reality their employment rights are undermined. • There are no policies to favor the employment of the indigenous community, obliging companies, regardless of their type, to hire non-white people. Rather, the so-called niggers are undermined. • There is no perceived political interest in establishing parameters in the labor code to consider or favor inclusion, because there is a tendency for the legislator not to limit himself to explain what is happening, but rather to worry about what should be accomplished.
Economic	**Possession of wealth (e1)**	• There is predominance of possession of wealth in people who define themselves as white persons. The primacy of poverty phenomenon is defined as a ratio of 5/10 (45%) in those who call themselves white and 7/10 (55%) in those who call themselves black, non-white.
Social	**Perception of rights in the population**	• The right to work is perceived as a moral and ethical responsibility of Ecuadorian society to guarantee that each citizen has a job, or an activity that generates remuneration in exchange for a provision of a

	(s1)	service, as long as it is not against good customs. • There are no constitutional principles applied to companies, so in practice the access of indigenous people to public or private jobs is very low. • The jobs and employers keep the representatives of the indigenous communities socially confined, restricting them mostly to agricultural work. • At popular level, discriminatory terms such as non-whites or self-proclaimed blacks are ingrained, arising white supremacy. • Marginality imposed by white groups. • Self-recognition and respect of idiosyncrasy in self-defined indigenous or non-white people. According to a census, nine out of ten people define themselves as indigenous.
Technological	**Technical knowledge (t1)**	• Self-proclaimed non-white people do not have technical and/or technological knowledge that demonstrates the universalization of society. Which does not allow a rising professional quarry with the annual promotions of technical careers of the members of indigenous communities who are increasingly illiterate every day because they do not perceive the need to be formally employed in the cities.
Ecological	**Impact of climate change (ec1)**	• The phenomenon of climate change has affected indigenous communities largely dependent on agriculture as a mean of subsistence. This establishes a trend towards migration to cities and the preference for technical careers. Agricultural sustainability, once centered on the forces acting in society, is affected by migration and other social phenomena.
Legal	**Rights (l1)**	• The rights enshrined in the Carta Magna of the Republic of Ecuador, specifically in Article 33, considers work not only as a Right. • In the same way, article 11, numeral 2, declares that all people are equal and have the same rights, duties and opportunities, these being understood as indigenous, foreign, etc. It is emphasized that no one may be discriminated for the sake of ethnicity, place of birth, age, sex, gender identity, cultural identity, marital status, language, religion, ideology, affiliation, etc. • In the Labor Code, the consideration of inclusion as an obligation of public or private companies is not explicitly stated.

Table 1. Diagnosis of variables and interrelation matrix between dimensions, factors and their current condition. Source: own elaboration.

These factors called variables will be denoted by alphanumeric codes (p1, e1, s1, t1, ec1, l1), following the preceding order in the table. There is a group of experts who evaluate the causal relationships between the six variables with neutrosophic numbers. Using an average of the experts' evaluations, we obtained an adjacency matrix and the graph who represents it:

$$E = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 0.4 & 0.9 \\ 1 & 1 & 0 & 1 & 0.9 & 0 \\ 0 & 0 & 0.8 & 0 & 0.7 & 0 \\ 0 & 0.7 & 0.9 & 1 & 0 & 0 \\ 1 & 0.8 & 0.9 & 0.6 & 0 & 0 \end{bmatrix}$$

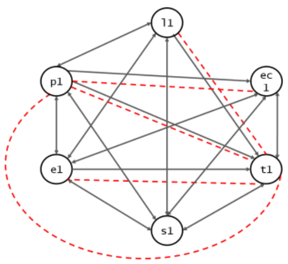

Figure 5. Adjacency matrix and the Neutrosophic Cognitive Map on the causal relationships between the factors identified in the PESTEL (decision nodes).

$$N(E) = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 0.4 & 0.9 \\ 1 & 1 & 0 & 1 & 0.9 & 0 \\ I & I & 0.8 & 0 & 0.7 & I \\ I & 0.7 & 0.9 & 1 & 0 & 0 \\ 1 & 0.8 & 0.9 & 0.6 & 0 & 0 \end{bmatrix} \quad E = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 0.4 & 0.9 \\ 1 & 1 & 0 & 1 & 0.9 & 0 \\ 0.5 & 0.5 & 0.8 & 0 & 0.7 & 0.5 \\ 0.5 & 0.7 & 0.9 & 1 & 0 & 0 \\ 1 & 0.8 & 0.9 & 0.6 & 0 & 0 \end{bmatrix}$$

	td
p1	1.8
e1	1.66
s1	1.7
t1	1.52
ec1	1.22
l1	1.14

Figure 6. Neutrosophic, de-neutrosophied adjacency matrix and the means of the extreme values corresponding to the NCM.

In accordance with the aforementioned, we can partially conclude:

- When p1 is activated, all the other nodes are activated, which means that the establishment of policies favoring indigenous employment will cause all the other problems identified in the other vertices. It will have an optimistic influence due to the causal relationship with positive indices (if p1 increases then e1, s1, t1, ec1, l1 will increase in the same way).
- The relationships with p1 and the rest of the nodes is bidirectional, therefore we can confirm the causal relationship in both directions and magnitude.
- If e1 it is activated, we can verify that there is a strong causal relationship also with the rest of the nodes, but not in both directions, unlike p1.
- It is evident that there is an indeterminacy relationship between t1 and e1.

Result: the order of importance of the factors is: $\mathrm{p}_1 \succ \mathrm{e}_1 \succ \mathrm{s}_1 \succ \mathrm{t}_1 \succ \mathrm{ec}_1 \succ 1$

Priority factor to analyze: Establishment of policies favoring indigenous employment.

Strategies to consider:

- No.1: Consider a reform to the Labor Code, which establishes a minimum percentage of indigenous people who must be hired in relation to all the workers established on the payroll, both in the public and private sectors.
- No. 2: Implement an ordinance regulating indigenous jobs.

Conclusions

After the analysis of the factors determined from a trialist perspective fused with the neutrosophic PESTEL technique, we can say that:

- Indeterminacy is incorporated into the modeling of the causal relationships between the factors analyzed, where neutrosophic science is an active part in decision-making.
- The labor inclusion of indigenous people in Ecuador is a vague and inconclusive issue since, given the reality and despite the existence of norms that protect indigenous communities, they do not achieve their objective and consequently no plans or actions have been created to give a timely response to the real needs of the community. Despite the existence of regulations and government plans in a broad and generic sense, it is important to consider vertical awards with greater emphasis on plans with areas of special action (local or provincial) for indigenous labor inclusion.
- The work carried out in most of the indigenous culture is agricultural; therefore, free access to education is important for communities with difficult access to it, mainly in provinces where there is a greater concentration of indigenous communities.
- The priority factor to analyze is the establishment of policies favoring indigenous employment, and strategies that are consistent with making improvements in this area.

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Delphi Validation of Educational Talks on the Treatment of First Premolars Vertucci Type III

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Abstract. Endodontics is the science and art that treats the tooth and periapical tissue from a morphological, structural, physiological and pathological point of view, combining knowledge to comprehensively treat the tooth and surrounding tissues. Because of endodontics comprises the root canal treatment, sufficient knowledge of the internal root anatomy is required. However, this knowledge is not always taught with sufficient quality with respect to some teeth such as the upper first premolars with Vertucci type III classification, due to the complexity involved in this content. At the Faculty of Medical Sciences of Universidad Regional Autónoma de los Andes (UNIANDES) in Ecuador, it is proposed to hold a group of talks on these issues. This research aims to validate educational talks on the treatment of Vertucci type III first premolars. For this purpose, the Neutrosophic Delphi method is applied, which is an extension of Delphi method to the neutrosophic framework. Delphi method allows a group of experts to reach a consensus on a topic of research, in this case on the proposed talks. Neutrosophy is included to incorporate the indeterminacy that exists in experts' evaluation, as well as the use of linguistic terms to perform the evaluations, which is more appropriate when it comes from subjective evaluations carried out by humans.

Keywords: Neutrosophic Delphi, first premolar, Vertucci type III, Endodontics, educational talks.

1 Introduction

The term endodontics comes from the two Greek voices "endo" which means "inside" and "odonto" which relates to a tooth. Endodontics is the science and art that treats the tooth and periapical tissue from a morphological, structural, physiological and pathological point of view, combining knowledge to comprehensively treat the tooth and surrounding tissues. Considered as a branch of Dentistry that is responsible for the treatment of the dental vascular-nervous complex, as well as the etiology, diagnosis and prevention of different lesions that affect the pulp and periradicular level, [1, 2].

Under an internal conceptualization, endodontics requires sufficient elements to achieve its objectives. It is necessary to know all the small details that escape the human eye, through the meticulous and priority study of the external and internal morphology, managing to combine both, to obtain enough knowledge when treating pulp alterations and their repercussions on the periapical tissues and thus prevent future endodontic failures, and to offer better treatments to the patient. It acts directly and indirectly, including the removal of the dental pulp.

Briefly, endodontics is the way to remove infected tissue, which includes nerves and blood vessels, from the inside of the tooth and replace it with an inert material, in such a way that the infection is eliminated. Therefore, the removal of dental pulp and bacterial content is carried out to reach a healthy tooth.

This research will be based on the Vertucci classification that describes the internal root anatomy of upper premolars, taking into account type III, [3]. It can be observed with the help of the dental diaphanization technique that consists of making the soft tissues of the dental organ transparent in order to observe its internal anatomy, [4].

A premolar tooth is any tooth that erupts in the space left by a temporary molar. There are a total of 8 premolars, 4 in the mandible and 4 in the maxilla, two on each side respectively. They are the teeth that are immediately before the molars. Its function in chewing is fine grinding. They are not present in children. The upper premolars have a pentagonal crown with a greater vestibulopalatine dimension than the mesiodistal one. They have two cusps: vestibular, larger and quadrangular in shape, and palatal, which is smaller. The upper first premolar contacts mesially the upper canine and distally the upper second premolar, [2].

Figure 1 represents the location of the premolars:

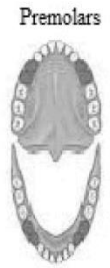

Figure 1: Graphical representation of the teeth. Premolars are in dark color. Source: Internet.

Figure 2 shows the dental morphology of the upper first premolar.

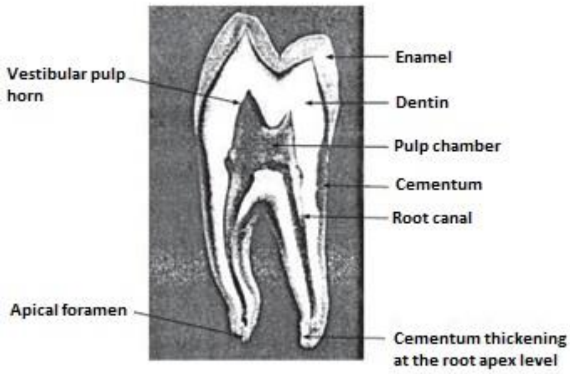

Figure 2: Dental morphology of the upper first premolar. Source [1].

For a correct classification, an adequate general knowledge of the dental organs is needed, for this reason the professional must have not only a wide knowledge of the entire pulp cavity and of the internal root anatomy, but also of variations according to the age, systemic disorders, ethnic differences, race, etc. Such ignorance can generate a future failure in endodontic treatment.

Currently, the lack of knowledge of the upper first premolar anatomy at the time of conducting root canal treatment leads to its failure. This is not only due to the aforementioned ignorance, but also because of the complementary methods conventionally used such as radiographic examination do not fully help us to determine the possibility of variations that the upper first premolar may present in its internal anatomy.

The purpose of this research is to validate talks designed at the Universidad Regional Autónoma de los Andes (UNIANDES) in the Faculty of Medical Sciences, on the treatment and prevalence of upper first premolars with Vertucci type III classification. The talks aim to distinguish the possible variations and thus to obtain an optimal result in the root canal treatment, therefore they will allow a better preparation of the students regarding this treatment that requires a previous training of the endodontist.

These talks will be validated with the support of Delphi method, especially Neutrosophic Delphi, [5-7]. Delphi method is a structured communication technique, developed as an interactive systematic prediction method and based on a panel of experts, [8-16]. Its objective is to achieve a consensus based on discussion among experts. It is a repetitive process. It relies on the elaboration of a questionnaire that has to be answered by the experts. Once the information is received, another questionnaire derived from the previous one is carried out to be answered again. However, one limitation is that consensus among specialists may take time; therefore the convergence of this technique may be slow.

Neutrosophic Delphi extends the Delphi technique to the neutrosophic framework. This technique comprises the indeterminacy, which is typical in decision-making[17, 18]. Sometimes, experts do not know, are not sure, are indifferent or have no information in part of the subject they will make a decision. Here, due to the complexity of the decision to make, experts do not have the complete certainty about their evaluations. Moreover, the subject itself can be confuse to any specialist not enough trained. Hence, the way to design high quality didactic talks on this subject is a challenge to the academics.

This paper is structured into the following sections. Section of materials and methods, contains the main concepts of endodontics and neutrosophic Delphi. Section of results, contains the results of applying neutrosophic Delphi method to design the aforementioned talks. Final section shows the conclusions.

2 Materials and Methods

This section is split into two subsections. The first one contains some important concepts of endodontics and the Vertucci classification. In subsection 2.2, we explain the main concepts of neutrosophic Delphi.

2.1 Previous concepts of Endodontics

The pulp chamber is the internal space of the tooth that is in its coronary area. It is completely covered by dentin and houses the dental pulp, which may present the variations already mentioned above. It is oval, irregular and flattened in a mesio-distal direction. The pulp chamber is made up of the following structures, [1, 2]:

• Chamber roof

It occurs in the incisal or occlusal direction with variations due to the external anatomy so that the pulp horns are thus formed.

• Chamber soil

It will present itself in a rectangular form, especially in the posterior or multiradicular dental organs; otherwise, it occurs in the single-rooted teeth, which can only be differentiated by a slight narrowing that occurs at the cervical level.

• Side walls

They are named the same way as in the case of external anatomy, the free walls are generally concave. Its angles are rounded.

•Shape

It can be considered cubic in shape, with six faces called mesial, distal, buccal, palatine-lingual, ceiling and floor. The faces are not flat, but are generally concave and convex.

•Volume

It depends on the different variations that the dentin presents, whether due to reparative processes or another cause. Also according to age, the older the patient the more pulp chamber gradually reduce in size.

Since various authors do not fully determine an exact concept of root canals, we here refer to them as the means of union between the pulp chamber, the vascular-nervous complex and the dental support anatomy.

The radicular anatomy of this dental organ consists of two canals; the vestibular is the most visible at the time of treatment. The roots of these teeth appear in three fundamental forms:

1. Simple roots: a tooth with a single root.
2. Forked roots. It occurs as two separate roots.
3. Fused roots. They constitute roots that are fused.

According to Vertucci, it is classified into eight types. The first five types are the following:

• Type I: a single canal that runs from the pulp chamber to the dental apex.

• Type II: two canals that start from the pulp chamber and join to the end in a single canal near the dental apex.

• Type III: start and end two separate root canals.

• Type IV: initiates a single root canal that runs through the root to finish in a division before reaching the dental apex.

• Type V: initiates and ends three separate root canals.

Figure 3 contains the classification and percentage of types of canals found in the upper first premolar. Figure 4 represents Vertucci classification.

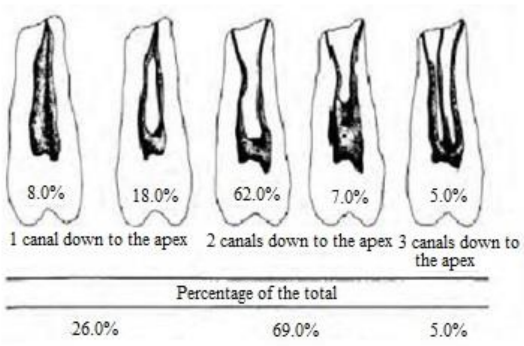

Figure 3: Classification and percentage of type of canals found in the upper first premolar. Source [1].

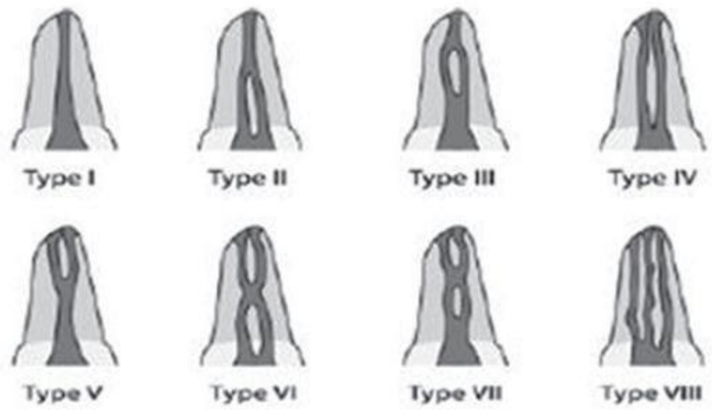

Figure 4: Graphical representation of the Vertucci classification. Source [1].

2.2 Neutrosophic Delphi method

This subsection contains a description of Delphi method, as well as the main concepts of Neutrosophy [19, 20] needed to apply the neutrosophic Delphi technique.

Delphi method is a structured communication technique; it is an interactive method for prediction, [8-16]. A group of experts evaluates the subject. They must achieve a consensus after a repetitive process of discussions. Questionnaires are answered by experts per iteration, in such a way that the information that is yielded from one questionnaire is used to create the next questionnaire.

Finally, the person responsible for the study will reach its conclusions from the statistical analysis of the obtained data.

Delphi is based on:

- Anonymity of the participants,
- Repeatability and controlled feedback,
- Group response in statistical form,
- Process

Before starting Delphi, a series of previous tasks are carried out, such as:

- Define the context and the time horizon in which we want to make the forecast on the subject under study.
- Select the panel of experts and get their commitment to collaborate. The chosen people must not only be highly knowledgeable about the subject on which the study is carried out, but must also present a plurality in their approaches. This plurality should avoid the appearance of biases in the information available on the panel.
- Explain to the experts what the method is about. In order to obtain reliable forecasts, as the experts will always know what is the objective of each of the processes required by the methodology.

A group of terms is usually used in this technique:

- Questionnaire: Document that is sent to the experts, including the results of previous circulations.
- Panel: Group of experts that takes part in Delphi.

The core of Delphi technique is a group of questionnaires. The first questionnaire can include questions worded in general form. In each subsequent phase, the questions become more specific because they are formed with the answers to the previous questionnaire.

Delphi technique comprises at least three phases:

1. A questionnaire is sent to a group of experts.
2. A summary of the first phase is prepared.
3. A summary of the second phase is prepared.

Three phases are generally recommended, but more phases can be used, as in the case of the Delphi study of security management.

The number of participating experts may vary from just a few to more than 100, depending on the scope of the issue. A range of 15-30 is recommended for a focal issue. As long as more experts participate, costs will also rise as well as the coordination required for the technique.

Below we explain some basic concepts of Neutrosophy [21-23].

Definition 1: ([24-28]) 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 $^{-}0\leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^{+}$.

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: ([24-28]) The *Single-Valued Neutrosophic Set* (SVNS) 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 $F_A: U\rightarrow[0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

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

Definition 3: ([24-28]**)** 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 falsehood membership functions are defined below, respectively:

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

$$I_{\tilde{a}}(x) = \begin{cases} \dfrac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, & x = a_2 \\ \dfrac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \text{otherwise} \end{cases} \tag{2}$$

$$F_{\tilde{a}}(x) = \begin{cases} \dfrac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a}}, & x = a_2 \\ \dfrac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \text{otherwise} \end{cases} \tag{3}$$

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

Definition 4: ([24-28]) 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:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle\left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, a_3 > 0 \ and\ b_3 > 0 \\ \langle\left(\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, a_3 < 0 \ and\ b_3 > 0 \\ \langle\left(\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, a_3 < 0 \ and\ b_3 < 0 \end{cases}$$

6. Multiplication of two triangular neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1b_1, a_2b_2, a_3b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 > 0 \text{ and } b_3 > 0 \\ \langle (a_1b_3, a_2b_2, a_3b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 < 0 \text{ and } b_3 > 0 \\ \langle (a_3b_3, a_2b_2, a_1b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 < 0 \text{ and } b_3 < 0 \end{cases}$$

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,

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (4)$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (5)$$

They are called the score and accuracy degrees of ã, respectively.

Let $\{\tilde{A}_1, \tilde{A}_2, \cdots, \tilde{A}_n\}$ be a set of n SVTNNs, where $\tilde{A}_j = \langle (a_j, b_j, c_j); \alpha_{\tilde{a}_j}, \beta_{\tilde{a}_j}, \gamma_{\tilde{a}_j} \rangle$ (j = 1, 2, …, n), then the *weighted mean of the SVTNNs* is calculated with the following Equation:

$$\tilde{A} = \sum_{j=1}^{n} \lambda_j \tilde{A}_j \quad (6)$$

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

Two scales of measurement used in the method are summarized in Tables 1 and 2, see [6, 29, 30].

Linguistic terms	**SVTNN**
Extremely unimportant (EU)	$\langle (0,0,1); 0.00, 1.00, 1.00 \rangle$
Not very important (NVI)	$\langle (0,1,3); 0.17, 0.85, 0.83 \rangle$
Not important (NI)	$\langle (1,3,5); 0.33, 0.75, 0.67 \rangle$
Medium (M)	$\langle (3,5,7); 0.50, 0.50, 0.50 \rangle$
Important (I)	$\langle (5,7,9); 0.67, 0.25, 0.33 \rangle$
Very important (VI)	$\langle (7,9,10); 0.83, 0.15, 0.17 \rangle$
Extremely important (EI)	$\langle (9,10,10); 1.00, 0.00, 0.00 \rangle$

Table 1: Importance weight as linguistic variables and their associated SVTNN. Source: [6].

Linguistic term	**SVTNN**
Very low (VL)	$\langle (0,0,1); 0.00, 1.00, 1.00 \rangle$
Medium low (ML)	$\langle (0,1,3); 0.17, 0.85, 0.83 \rangle$
Low (L)	$\langle (1,3,5); 0.33, 0.75, 0.67 \rangle$
Medium(M)	$\langle (3,5,7); 0.50, 0.50, 0.50 \rangle$
High (H)	$\langle (5,7,9); 0.67, 0.25, 0.33 \rangle$
Medium high (MH)	$\langle (7,9,10); 0.83, 0.15, 0.17 \rangle$
Very high (VH)	$\langle (9,10,10); 1.00, 0.00, 0.00 \rangle$

Table 2: Linguistic terms for evaluations associated with SVTNN. Source: [6].

3 Results

This section explains the design of educational talks on the treatment of first premolars Vertucci type III at the Faculty of Medical Sciences of UNIANDES, Ecuador. Twenty specialists were selected as experts to make the decision on this subject. Among them, there are academics that teach Endodontics in some faculties of the country, specialists in dental diaphanization technique, specialists in didactic, and some administrators of Medical Sciences in some universities of the country.

One professor of the Faculty with great experience and knowledge on the subject was selected as the moderator. He is the only one who knows the identity of experts, and he communicates with every one of them by e-mail. The first questions of the survey are general and the last ones are particulars. The first questionnaire corresponding to the first phase of the design is the following:

1. About the audience
   1.1. How many students per talk do you think is the optimal number?
   1.2. What group of students do you think is the most suitable to receive the talks? Why?
2. On the structure of the talks
   2.1. How many talks do you think are necessary to be effective?
   2.2. In your opinion, what is the weekly frequency that the talks should have to be effective?
   2.3. How many talks per year do you think should be held?
   2.4. How many hours do you think each talk should be?

2.5. Should the talks contain practical exercises and how would they be applied?
2.6. What is the ratio of theory to practice that these talks would need?
2.7. Assuming that the talks are classified into introductory talk(s), topic development talks and concluding talk(s), what do you think is the content that cannot be missing in each of these structures? How many talks do you think are appropriate for each part of the proposed structure?

3. About the specialists who should do the talks
   3.1. What should be the minimum scientific and teaching categories of the teachers who do the talks?
4. Location conditions where to hold the talks
   4.1. Under what material conditions should the talks take place?
5. Ways of evaluating the quality of the talks
   5.1. What is the most appropriate way that you consider the quality of the talks should be evaluated?
   - No need to be evaluated.
   - Evaluating the teacher who teaches them.
   - Evaluating the students who receive the talks.
   - Assessing both, teachers and students
6. Content of the talks
   6.1. Do you think that the topic of internal root anatomy of upper first premolars should be covered? In what talk and to what degree of complexity?
   6.2. Do you consider it is necessary to introduce talks on clearing as a learning method to reinforce the internal study of dental organs? In what way, theoretical or practical?
   6.3. Do you consider that instrumentation techniques should be generalized in all dental organs in the talks?
   6.4. Do you think that the issue of the use of tomography in complex cases to locate ducts should be addressed?
   6.5. Do you consider that the use of periapical radiography should be explained to ensure accurate detection of the ducts?
   6.6. Do you think that the topic of canal preparation in the upper first premolar should be covered?

Each of the questions belongs to a topic that is specified in each previously written index, which are items from 1 to 6. Each sub-item contains the question asked to the specialists. As we can see, the questions asked are open in order to design the most popular variants within the answers.

Additionally, each of the experts was asked to evaluate items 1 to 6 on their importance in the EU, NVI, NI, M, I, VI, EI linguistic scale that appears in Table 1, which will be relevant in the second phase of the design.

The moderator sends the questionnaire to the experts. Previously, they were informed about the objective and importance of this study and they have given their approval to participate in the design. Once the questionnaires have been completed, the moderator analyzes the answers, which are diverse, and elaborates the possible designs of the talks, grouping the closest proposals, and then asking to the same specialists who select from these proposals which one they prefer. Additionally, as an advanced step, we have the results of the evaluation of the experts about each of the previous items; these results are summarized in Table 3.

Linguistic terms/Item	**1**	**2**	**3**	**4**	**5**	**6**
Extremely unimportant (EU)	0	0	0	0	0	0
Not very important (NVI)	0	0	0	0	1	0
Not important (NI)	0	0	0	4	10	0
Medium (M)	0	0	0	6	7	0
Important (I)	1	3	0	9	1	0
Very important (VI)	2	15	1	1	1	0
Extremely important (EI)	17	2	19	0	0	20

Table 3: Frequency of assessment (in every cell) with linguistic terms (by row) of every item number (by column). Source: Authors.

Each linguistic term in Table 3 was associated with its respective SVTNN in Table 1 and with the help of Equation 5, they were converted to a single numerical value. Then, we calculated the mean of these numerical values for each item, according to the results of Table 3. These results were the weights assigned to each item according to its importance, which were normalized and the following result was obtained:

$w_1 = 0.207608$, $w_2 = 0.179736$, $w_3 = 0.212793$, $w_4 = 0.110873$, $w_5 = 0.074600$, and $w_6 = 0.214390$. Where, w_i represents the weight of item i = 1, 2, 3, 4, 5, 6.

According to the results of the survey, the moderator determined that there are mainly three types of talks, each of which summarizes the idea of a subgroup within the expert group. These educational talks designs are denoted by C_1, C_2, C_3. Which were forwarded to each expert with the intention of re-evaluating them. The new questionnaire with closed questions is explained below. Now consisting of six points, one for each item. Some details are omitted to maintain the simplicity of this exposition.

Note that for each item there are given options denoted by (a), (b), and (c). (a) corresponds to C_1, (b) to C_2 and (c) to C_3.

1. About the audience:
   (a) It must be a graduate group. In the widest possible number of students to receive it each time.
   (b) It must be a group of high degree college students. With a small number of students receiving it every time.
   (c) It must be a group of middle degree college students. With a small number of students receiving it each time.
2. On the structure of the talks
   (a) There should be few talks with a large number of hours of duration (approximately 8 hours per meeting), in a short weekly frequency (about three weekly), for a period of 15 days (six in total). A talk should be included having at least one practical activity.
   (b) There should be an average amount of talks in total (between 10 and 15), with a small amount of hours per talk (3 hours), spaced in time (no more than 2 per week). At least three practical talks should be included.
   (c) Idem that (b).
3. About the specialists who should do the talks
   (a) Minimum must have a PhD or MSc with more than 10 years of experience.
   (b) Idem that (a).
   (c) At least teachers of the subject of Endodontics, who receive special preparation.
4. Conditions for talks
   (a) Specialized classrooms with computers connected to the internet and Wi-Fi, as well as laboratories where to perform the practices.
   (b) The classrooms where regularly students receive their classes.
   (c) Idem that (b).
5. Ways of evaluating the quality of the talks
   (a) It is enough to evaluate the students with a simple theoretical and practical examination at the end of the talks, as a last activity.
   (b) Only students should be evaluated.
   (c) No evaluation is required.
6. Content of the talks
   (a) The talks should include all the proposed content in depth.
   (b) The talks should include all the proposed contents in a didactic way, which is more motivational than to achieve a deep knowledge of the topic.
   (c) Idem that (b).

The moderator forwards these three proposals to the experts and asks them to evaluate sub-items (a), (b), and (c), using the linguistic terms in Table 2, answering the question of how successful the expert evaluates option (a), (b) or (c) as a proposal for talks, in the linguistic scale VL, ML, L, M, H, MH, and VH.

For each expert's answers, the linguistic values were converted into their respective SVTNN, and then they were converted into numerical values using expression 5. $O_{ij(a)}$, $O_{ij(b)}$, and $O_{ij(c)}$ denote the numerical values representative of options (a), (b), and (c) within item i = 1, 2, 3, 4, 5, 6, evaluated by expert j = 1, 2,..., 20.

$O_{ij} = \frac{O_{ij(a)}+O_{ij(b)}+O_{ij(c)}}{3}$ is calculated.

A threshold value was set to $th = 2$ to determine that there is agreement between experts.

The standard deviation between j values of O_{ij} was calculated using formula (7).

$$\sigma_i = \sqrt{\frac{1}{19}\sum_{j=1}^{20}\left(O_{ij} - \bar{O}_i\right)^2} \quad (7)$$

Where $\overline{O}_i = \frac{\sum_{j=1}^{20} O_{ij}}{20}$.

If $\sigma_i > th$ there is no enough consensus among experts on item i, therefore a next round is necessary. Although it is more inefficient, this research considered passing to the next round for all items in case at least one of them satisfies $\sigma_i > th$, since there is a close relationship between options (a), (b) and (c) within the different items.

In case of agreement, evaluate each option by $O_{(a)} = \frac{\sum_{j=1}^{20}\sum_{i=1}^{6} w_i O_{ij(a)}}{20}$, $O_{(b)} = \frac{\sum_{j=1}^{20}\sum_{i=1}^{6} w_i O_{ij(b)}}{20}$, and $O_{(c)} = \frac{\sum_{j=1}^{20}\sum_{i=1}^{6} w_i O_{ij(c)}}{20}$. The option (a), (b), or (c) with the highest value is selected.

If there is no consensus, the moderator sends the results of each round to each of the experts, including on which items there was consensus and which did not. Experts are asked to reconsider their responses.

Table 4 summarizes the standard deviation using formula 7, for each round and item, according to experts' assessments.

Round/Item	**1**	**2**	**3**	**4**	**5**	**6**
First	1.3472	1.4608	1.7842	2.0269	2.2711	1.8687
Second	1.3472	1.4608	1.7842	1.8272	2.1870	1.7999
Third	1.3472	1.4608	1.7842	1.7708	1.8395	1.7999

Table 4: Standard deviations for each round and item. Source: Authors.

According to the results in Table 4, items 4 and 5 did not satisfy the condition $\sigma_i \leq 2$, thus, two more rounds were needed to fulfill the condition of agreement. The results were $O_{(a)} = 4.1804$, $O_{(b)} = 5.4703$, and $O_{(c)} = 5.6817$.

Therefore, design denoted by C_3 is the one preferred by experts.

Conclusion

This paper validates educational talks on the treatment of first premolars Vertucci type III at the Faculty of Medical Sciences at Universidad Regional Autónoma de los Andes. Twenty experts expressed their opinions about the characteristics of the talks, using the neutrosophic Delphi technique. The first phase consisted in interviewing experts with open questions about the talks. The second phase contained closed questions on three possible designs proposed from the results of the first phase. Three rounds were necessary to obtain a final consensus, which is that the talks should be addressed to students of middle courses of the Faculty, with few students receiving it each time, between 10 and 15, with a small amount of hours per talk, spaced in time, and at least three practical talks should be included. Neutrosophic Delphi, allowed us to deal with the indeterminacy of decision-making and to evaluate based on linguistic terms rather than numbers. This subject is important in a dentists' curriculum, but it has a high degree of difficulty, thus, these talks will positively influence the quality of future specialists' practices.

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Risk Factors Prioritization for Chronic Obstructive Pulmonary Disease

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Abstract: Lung diseases represent one of the main causes of death in the world. Making an opportune diagnosis would improve the quality of life of patients. A set of factors intervene in the diagnostic process that significantly impact the evolution of the disease. However, there is uncertainty to determine which factors promote the development of lung disease. The present research aims to propose a method for prioritizing risk factors for chronic obstructive pulmonary disease. The method uses a multi-criteria approach where uncertainty is modeled using neutrosophic numbers. The proposed method is implemented in a case study at Alfredo Noboa Montenegro Hospital. The result is the prioritization of the factors whose mitigation would favor the reduction of lung disease.

Keywords: Pulmonary diseases; diagnosis; neutrosophic numbers.

1. Introduction

Chronic obstructive pulmonary disease is an inflammatory pathology that constitutes a major public health problem and one of the main causes of mortality [1, 2] in Ecuador and in the world. In recent years, this phenomenon has shown a constant growth. It has become the fourth cause of death worldwide [3].

Chronic obstructive pulmonary disease is a preventable and treatable condition that creates persistent airflow limitation that is generally progressive and associated with an enhanced chronic inflammatory response to noxious particles or gases in the airways and lung [4, 5]. This disease is one of the leading causes of morbidity and mortality worldwide and generates an economic and social burden that is both substantial and growing [6, 7].

Inhalation of harmful particles, such as tobacco smoke and biomass fuels, cause inflammation that may become a chronic condition and induce the destruction of parenchymal tissue and alter the normal repair and defense mechanisms. These pathological changes cause structural modifications and narrowing of the small airways [8, 9]. Destruction of the lung parenchyma by inflammatory processes leads to the loss of the alveolar attachments to the small airways and decreases the elastic recoil of the lung; so, these changes decrease the ability of the airways to remain open during expiration [10, 11].

The alarming prevalence figures for obstructive pulmonary disease [12-14], have motivated this investigation. The main objective is to develop a method for the prioritization of risk factors for chronic obstructive pulmonary disease. The method uses a multi-criteria approach where the uncertainty is modeled using neutrosophic numbers.

The investigation is structured in several sections, so that each one contributes to reach the previously defined objective. The Preliminaries section describes the main characteristics of chronic obstructive pulmonary disease and identifies the risk factors associated with this condition. The Materials section proposes the method for prioritizing risk factors for chronic obstructive pulmonary disease and describe each of the activities in which it is structured. In the Results section, the proposed method is implemented in a case study at Alfredo Noboa Montenegro Hospital, where the important results obtained demonstrate the need for an early diagnosis of the disease and the applicability of the method.

To carry out the research, we decided to make a cross-sectional study. With this research design we determined the total of cases reported with a diagnosis of chronic obstructive pulmonary disease in the sample obtained from patients of the internal medicine unit at Alfredo Noboa Montenegro hospital, and the prevalence of this pathology under study. The review of the medical records made it possible to identify the clinical factors that influenced the development of this pathology and to analyze the role of the risk factors that most affect chronic obstructive pulmonary disease and whose prioritization is the object of study in this research.

2. Preliminaries

This section provides a description of the main elements associated with the problem. A study of lung diseases is carried out as the basis of this investigation. Subsequently, the main risk factors that affect chronic obstructive pulmonary disease are identified for prioritizing risk factors.

2.1. Pulmonary diseases

Chronic obstructive pulmonary disease is not a single disease, but a general concept that designates various chronic lung ailments that limit the flow of air in the lungs. Therefore, it is classified as Chronic Bronchitis and Emphysema [15].

Chronic bronchitis is inflammation of the main airways in the lungs that continues for a long time or that comes back repeatedly. The main cause is smoking. Secondhand smoke may also cause chronic bronchitis, which is worsened by environmental pollution, infection, and allergies [16]. It is considered to be chronic when symptoms persist for more than 90 days a year for two consecutive years, as long as it is not due to a localized bronchopulmonary disease. Smoking is the most common cause of chronic bronchitis and there is no precondition for gender, age or ethnicity. Up to 5% of the population can be affected, and it tends to occur more in women and people over 45 years of age [17, 18].

Pulmonary emphysema is a disease that produces the enlargement of the pulmonary alveoli permanently, damaging them in such a way that they become obstructed and decrease respiratory function [19, 20]. The loss of elasticity causes the airways to narrow, as a consequence your body does not receive the oxygen it needs. This pathology usually appears as a sequel to bronchitis and asthma. Smoking is the most common cause for its appearance. Emphysema is mainly a disease of people over 40 years of age and is more frequent in men than in women, although the increase in the incidence of women has been notable in recent years.

The chronic inflammatory process, ischemia, and limitation of physical activity are associated with this disease, along with the adverse effects of the drugs used in its treatment, produce systemic effects such as cachexia or muscle atrophy. Concomitant diseases such as hypertension or diabetes mellitus influences the clinical status of patients with chronic obstructive pulmonary disease and worsens the prognosis, increasing the risk of developing lung cancer [21, 22]. The prevalence and impact of this disease on the population is expected to increase due to aging and the rise of the smoking rates of the population, both in developed and underdeveloped countries. The worldwide prevalence in the general population is estimated at around 1% and in those over 40 years at 10%.

2.2. Risk factors for chronic obstructive pulmonary disease

Identifying the risk factors that significantly affect lung diseases is the basis for improving the quality of life of patients. Pulmonary diseases have a multifactorial origin and develop due to the interaction of different risk factors, such as: genetic factors, bronchial reactivity and environment [23].

Each risk factor has a set of associated measurement indicators that determine the incidence criteria for medical diagnosis. The risk factors for chronic obstructive pulmonary disease identified from the implemented research design are listed below:

1. Smoking: considered the most important risk factor for the development of chronic obstructive pulmonary disease. The risk increases depending on the number of cigarettes smoked, the age of start, and the time they have been smoking, with tobacco smoke being the main cause [24].
2. Genetic factors: the deficiency of alpha-1-antitrypsin stands out, which is a protein that protects the lungs from damage. That is why its deficit is associated with the early and accelerated development of emphysema and decrease in lung function.
   It should be analyzed primarily in young patients with chronic obstructive pulmonary disease; especially if they are not smokers [25].

3. Bronchial reactivity: this factor is associated with the risk of developing chronic obstructive pulmonary disease, since people affected by bronchial reactivity usually present bronchial obstruction [26].
4. Lung growth: people with incomplete lung development have reduced lung function, and consequently a higher risk of developing chronic obstructive pulmonary disease. Lung growth disturbances are often associated with events during pregnancy [18, 19].
5. Passive smoking: passive and continuous exposure to tobacco smoke may cause respiratory symptoms, increase in acute respiratory diseases and worsening lung function, which in the future may trigger the development of chronic obstructive pulmonary disease [12, 13, 27, 28].
6. Respiratory infections: severe respiratory infections have been associated with decreased lung function. These infections generally occur in childhood and may cause damage to the airways; and in adult life cause the appearance of chronic obstructive pulmonary disease.
7. Nutrition: malnutrition is an unfavorable factor in the evolution of this disease. Lack of vitamin C and E and magnesium decrease protection against the development of chronic obstructive pulmonary disease.
8. Atmospheric pollution: it contributes to the load of inhaled particles, which produces a greater number of exacerbations, causing an irritating effect in the airways, which conditions greater bronchoconstriction and pulmonary hypersecretion.
9. Exposure to toxins: it manifests itself mainly during the combustion of garbage, exposure to chemicals, combustion at home (wood stove).
10. Demographic factors: the review of medical records showed that demographic elements (Urban, Rural) influence the development of chronic obstructive pulmonary disease; because patients in rural areas have a higher exposure to biomass and work mostly in agriculture, which exposes them to inhalation of chemicals and insecticides.
11. Socioeconomic level: The risk of developing chronic obstructive pulmonary disease is inversely related to socioeconomic position, in such a way that it is more frequent in depressed social classes, due to the fact that they present a greater number of risk factors that are associated with the development of the illness such as: alcohol, smoking, more frequent childhood infections, overcrowding, poor nutrition.
12. Pathological background: various studies have confirmed that the development of chronic obstructive pulmonary disease may be associated with pathological elements such as arterial hypertension, diabetes mellitus, hypothyroidism, hyperthyroidism, among others.
13. Others (age, family history of chronic obstructive pulmonary disease): aging produces an increase in respiratory symptoms and therefore a decrease in lung function, which leads to a future development of the pathology. In the family history are genetic factors and most likely passive smoking that is suffered by the children of the patient with chronic obstructive pulmonary disease, the same ones who may have a predisposition to smoke in the future.

The identification of risk factors for chronic obstructive pulmonary disease shows that there is no single cause that provoke this pathology, it is rather the consequence of various risk factors. The problem lies in the fact that the clinical manifestations of this pathology such as dyspnea, chronic cough, production of profuse and sometimes purulent expectoration, are of a progressive nature, becoming persistent or evident with effort. Chronic obstructive pulmonary disease is a slowly progressive disease that, with proper treatment and compliance with it, the patient can lead a life without complications.

2.3. Neutrosophic multicriteria decision analysis.

Multi-criteria decision-making problems allow uncertainty to be modeled through fuzzy logic, initially introduced by Zadeh [29]. It allows you to model knowledge in a more natural way. The basic idea is the notion of the membership relation that takes truth values in the interval [0,1].

The introduction of the *Intuitionistic Fuzzy Set* (IFS) as a universe with a generalization of fuzzy sets have been defined by K. Atanassov in [30]. In IFS, in addition to the degree of membership $(\mu_A(x) \in [0,1])$ of each element $x \in X$ to a set A, a degree of non-membership $v_A(x) \in [0,1]$, as considered, such as shown in equation 1:

$$\forall x \in X \mu_A(x) + v_A(x) \leq 1 \quad (1)$$

The *Neutrosophic Set* (NS) introduced the degree of indeterminacy (i) as an independent component [31]. The truth value in the neutrosophic set is the following [32, 33]:

Let N be a set defined as: $N = \{(T, I, F): T, I, F \subseteq [0,1]\}$ a neutrosophic evaluation n is a mapping of the set of propositional formulas to N, that is, for each p we have:

$$v(p) = (T, I, F) \quad (2)$$

The *Single Valued Neutrosophic Set* (SVNS) [34, 35] was developed to facilitate real world applications of the set theoretic and neutrosophic set operators. An SVNS is a special case of a neutrosophic set proposed as a generalization of intuitionistic fuzzy sets to treat incomplete information [36-38].

The single value neutrosophic numbers (SVN number) are denoted by $A = (a, \text{b}, c)$, where, [0,1] and $a, b, c \in [0,1]$ and $a + b + c \leq 3$ [39]. In real world problems, we can sometimes use linguistic terms like "good", "bad" to get preferences about an alternative, and we cannot use some numbers to express qualitative information. Some classic multicriteria decision models have been adapted to Neutrosophy, for example, AHP, TOPSIS and DEMATEL [40-42].

3. Materials and Methods

This section describes the structure and operation of the method to assess risk factors for chronic obstructive pulmonary disease. The method consists of eight activities: reference framework, collection of parameters, selection of preferences, calculation of the degree of consensus, control, generation, evaluation of alternatives and classification of risk factors. It is based in previous works on consensus in neutrosophic environments [43-45] . Figure 1 shows the structure of the method.

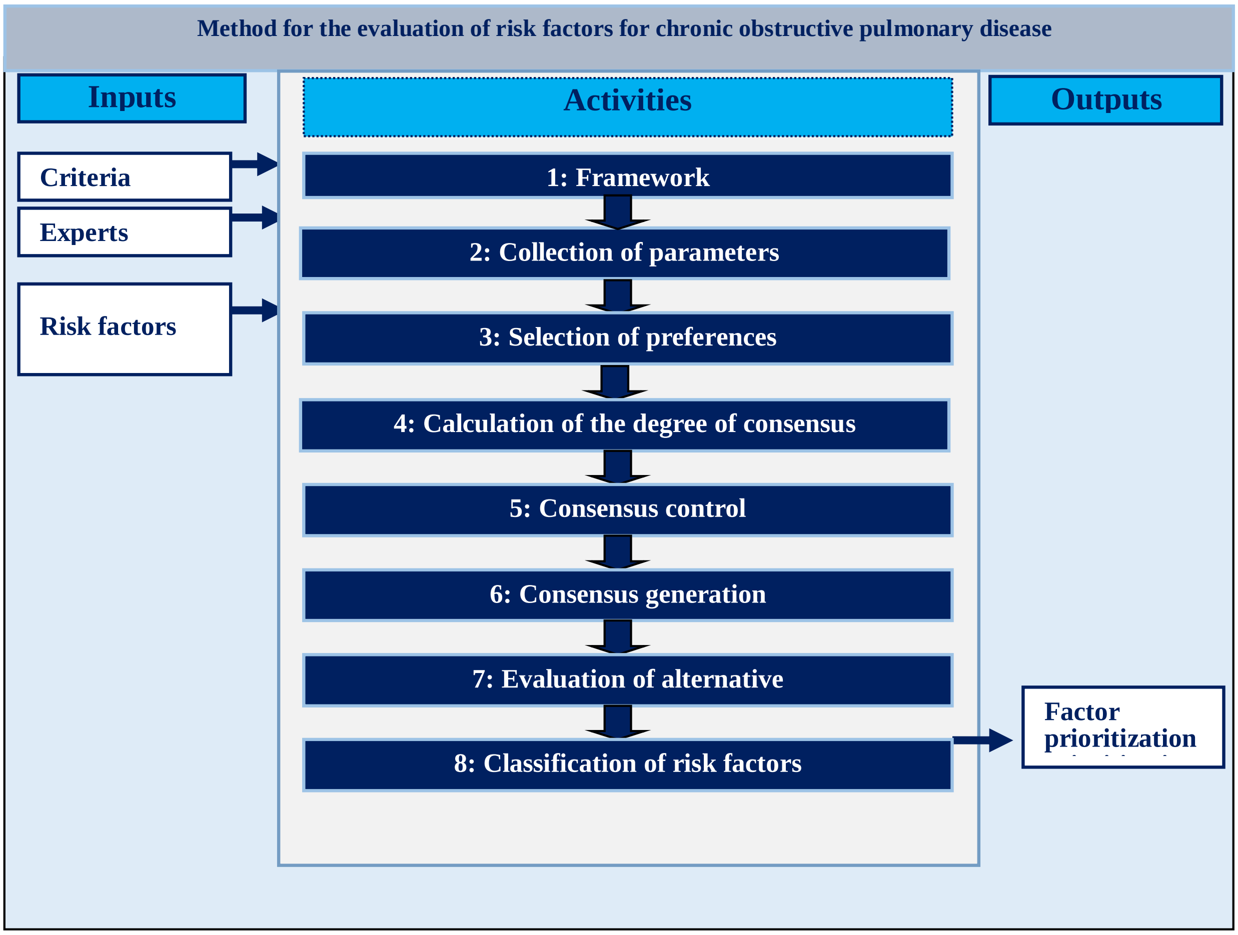

Figure 1. General diagram of how the method works.

The main activities involved in the proposed method are described below. Each activity describes the main elements that are managed.

Activity 1: Framework. This activity defines the evaluation framework for the decision problem of prioritizing risk factors for chronic obstructive pulmonary disease. The frame is set in such a way that:

$C = \{c_1, c_2, .. c_n\}, n \geq 2$, is the set of criteria that represent risk factors for chronic obstructive pulmonary disease.

$E = \{e_1, e_2, .. e_k\}, k \geq 2$, is the set of experts involved in the process.

$X = \{x_1, x_2, .. x_m\}, m \geq 2$, is the finite set of patients to be diagnosed.

Criteria and experts could be grouped. The group of experts will provide the evaluations of the decision problem. The main criteria that represent risk factors for chronic obstructive pulmonary disease according to [23]. Figure 2 shows the identified factors.

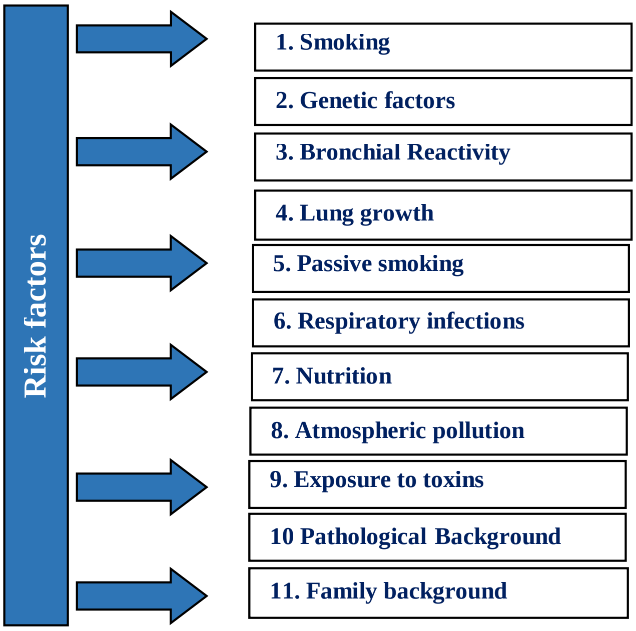

Figure 2. Risk factors for chronic obstructive pulmonary disease.

Activity 2: collection of parameters**.** The granularity of the linguistic term is selected. Parameters are brought together to control the consensus process: consensus threshold μ ∈ [0,1] and MAXROUND ∈ N to limit the maximum number of discussion rounds. The acceptability threshold $\varepsilon \geq 0$, is also collected, to allow a margin of acceptability to avoid generating unnecessary recommendations.

Activity 3: selection of preferences. For each expert, their preference is compiled using the chosen set of linguistic terms.

In this activity, each e_k expert, provides the evaluations using evaluation vectors:

$$U^k = (v_1, i = 1, .. n, j = 1, .. m) \tag{3}$$

The evaluation, v_i^k provided by each expert e_k for each criterion c_i of each alternative X_j, is expressed by SVN numbers.

Activity 4: calculation of the degree of consensus. The degree of standardized collective consensus is calculated in a range of values [0,1].

For each pair of experts, $e_k, e_t (k < t)$ s a similarity vector is determined

$$SM_{kt} = (sm_i^{kt}), sm_i^{kt} \in [0,1] \tag{4}$$

is calculated:

$$sm_i^{kt} = 1 - \left(\frac{1}{3} \sum_{j=1}^{n} \left\{ \left(|t_i^k - t_i^t| \right)^2 + \left(|i_i^k - t_i^t| \right)^2 + \left(|f_i^k - t_i^t| \right)^2 \right\} \right)^{\overline{2}} \tag{5}$$

$$(i, 2, .., m)$$

A consensus vector $CM = (cm_i)$ is obtained by adding similarity values:

$$cm_i = OAG_1(SIM_i) \tag{6}$$

Where OAG_1 is an aggregation operator, $SIM_i = \left\{sm_i^{12}, sm_i^{1m}, .., sm_i^{(m-1)m}\right\}$ representing all pairs of experts determines the similarity in their opinion on the preference between (v_i, v_j) and cm_i is the degree of consensus reached by the group in their opinion. Finally, a degree of general consensus is calculated:

$$cg = \frac{\sum_{i=1}^{n} cv_i}{n} \tag{7}$$

Activity 5: consensus control**.** The degree of consensus cg is compared with the consensus threshold (μ). If $cg \geq \mu$, the consensus process ends; otherwise, the process requires additional discussion. The number of rounds is compared to the MAXROUND parameter to limit the maximum number of discussion rounds.

Activity 6: consensus generation. When$cg < \mu$, the experts must modify the preference relationships to make their preferences close to each other and increase the degree of consensus in the next round. The consensus generation begins to compute the collective preferences w^c. This collective preference model is calculated by adding the reference vector of each expert:

$$w^c = OAG_2(v^1, .. v^m) \tag{8}$$

Where: OAG_2 is an aggregation operator and $v \in U$. After that, a proximity vector (PP^k) is obtained between each of the expert e_k and w^c. The proximity values, $pp_{ij}^k \in [0,1]$ are calculated as:

$$pp_{ij}^k = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(\left|t_i^k - t_i^c\right|\right)^2 + \left(\left|i_i^k - t_i^c\right|\right)^2 + \left(\left|f_i^k - t_i^c\right|\right)^2\right\}\right)^{\overline{2}} \tag{9}$$

Subsequently, preference relationships to change (CC) are identified. The preference relationship between the criteria c_i and c_j with a degree of consensus, below the defined (μ) is identified:

$$CC = \{w_i^c | cm_i| < \mu\} \tag{10}$$

Then, depending on the CC, those experts who should change their preference are identified. To calculate an average proximity pp_i^A, the proximity measures are added.

$$pp^A = OAG_2(pp^1, .., pp_i^m) \tag{11}$$

Where OAG_2 is an SVN aggregation operator.

e_k experts whose $pp_i^k < pp_i^A$ are advised to modify their preference ratio W_i^k.

Finally, the direction rules are checked to suggest the direction of the proposed changes. A threshold $\varepsilon \geq 0$ has been established to avoid generating an excessive number of unnecessary tips.

DR 1: If $v_i^k - w_i^c < -\varepsilon$ then e_k should increase its value of the preference relation v_i.

DR 2: If $v_i^k - w_i^c < -\varepsilon$ then e_k should decrease its value of the preference relation v_i.

DR 3: If $-\varepsilon \leq v_i^k - w_i^c \leq -\varepsilon$ then e_k must not modify the value of the preference relation v_i.

Steps 3 through 6 are repeated until the consensus reaches the maximum number of rounds.

Activity 7: evaluation of alternatives. The objective of this activity is to obtain a global evaluation for each alternative. Taking into account the previous phase, an evaluation is calculated for each alternative, using the selected resolution process that allows managing the information expressed in the decision frame.

In this case, the alternatives are classified according to the single value neutrosophic weighted average aggregation operator (SVNWA):

$$F_w(A_1, A_2, .., A_n,) = \langle 1 - \prod_{j=1}^{n}\left(1 - T_{Aj}\right)^{j}, \prod_{j=1}^{n}\left(I_{Aj}(x)\right)^{wj}, \prod_{j=1}^{n}\left(F_{Aj}(x)\right)^{wj}\rangle \tag{12}$$

Where $W = (w_1, w_2, , .. w_n)$ is the weight vector of $A_j(j = 1,2, , .., n)$, $w_n \in [0,1]$ and $\sum_j^n w_j$.

Activity 8: classification of risk factors. In this activity, the alternatives are ranked and the best scoring function is chosen [29]. According to the scoring and precision functions of the SVN sets, a sort order of the set of alternatives can be generated [46]. Selecting the options with the highest score.

To order alternatives a scoring function is used [35]:

$$s(V_j) = 2 + T_i + F_j - I_j \tag{13}$$

Additionally, a precision function is defined:

$$a(V_j) = T_i - F_j \tag{14}$$

So

1. Si

   a. $a(V_j) = a(V_i)$, then V_j are equal, denoted by $V_j = V_i$.

   b. $a(V_j) < a(V_i)$, then V_j is less than V_i, denoted by $V_j < V_i$.

3. Si $s(V_j) < s(V_i)$, then V_j is less than V_i, denoted by $Vj < Vi$.

   a. Si $a\ (Vj)\ < a\ (Vi)$, then V_j is less than V_i, denoted by $V_j < V_i$.

   b. Si a $(Vj)\ =\ a\ (Vi)$, then V_j and V_i are equal, denoted by $Vj\ =\ Vi$.

Another option is to use the scoring function proposed in [47]:

$$s(V_j) = (1 + T_j - 2F_j - I_j)/2 \tag{15}$$

where $s(V_j)\ \in\ [-1,1]$.

According to the classification method of the SVN scoring function[48, 49], the classification order of the set of risk factors for chronic obstructive pulmonary disease can be generated and the alternatives can be prioritized.

4. Results

To demonstrate the applicability of the proposed method, we decided to conduct a case study, taking as a reference a patient admitted to the intensive care unit at Alfredo Noboa Montenegro Hospital in Ecuador. In this study, we had the collaboration of three experts $E = \{e_1, e_2, e_3\}, n = 3$ from which their preferences are determined. To increase the way in which the input data is interpreted, a set of linguistic terms with cardinality nine is used (Table 1).

Linguistic terms	**SVNSs**
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0,15,0.20)
Good (G)	(0.70,0.25,0.30)
Medium good (MG)	(0.60,0.35,0.40)
Medium (M)	(0.50,0.50,0.50)
Medium bad (MB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 1. Linguistic terms used to provide the assessments [47].

The scope of the consensus process is defined by eleven criteria $C = \{c_1, c_2, .., c_{11}\}$ shown in Table 2.

Node	**Description**
c_1	Smoking
c_2	Genetic factors
c_3	Bronchial reactivity
c_4	Lung growth
c_5	Passive smoking
c_6	Respiratory infections
c_7	Nutrition

c_8	Atmospheric pollution
c_9	Exposure to toxins
c_{10}	Pathological background
c_{11}	Family background

Table 2. Criteria for prioritizing risk factors for chronic obstructive pulmonary disease.

The parameters used in this case study are shown in Table 3.

Consensus threshold	$\mu = 0{,}9$
Maximum number of discussion rounds	MAXROND =10
Acceptability threshold	$\varepsilon = 0.1$

Table 3. Defined parameters.

Initially, experts provide the following preferences:

	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}
E1	B	M	B	VG	G	G	G	B	G	M	B
E2	VG	G	G	G	G	G	G	VG	G	G	VG
E3	VB	VG	M	G	VG	VG	G	VB	VG	VG	VG

Table 4. Preference Round 1

First round

Similarity vectors are obtained.

s^{12}=[0,9226; 0,9221; 0,95; 0,5807; 0,9702; 0,9707; 0,9707; 0,6807; 0,9204; 0,9606; 0,9606]

s^{13}=[0,9402; 0,9414; 0,7424; 0,62; 0,9802; 0,9707; 0,7825; 0,8752; 0,9608; 0,9604; 0,9204]

s^{23}= [0,9204; 0,9704; 0,9414; 0,7234; 0,9428; 0,9406; 0,9207; 0,896; 0,9554; 0,9402; 0,9606]

The consensus vector obtained is CV = [0,9277; 0,9446; 0,8779; 0,6413; 0,9644; 0,9606; 0,8913 0,8173; 0,9455; 0,9537; 0,9472]. Finally, a degree of general consensus is calculated: cg = 0.8974

Since cg 0.6848 <μ 0.9, the generation of tips is activated.

The collective preferences are calculated using the SVNWA operator, in this case giving the same importance to each expert W^c =[(0,80; 0,15; 0,20)(0,65; 0,50; 0,50)(0,5; 0,50;0,50)(0,70; 0,25; 0,30) (0,70; 0,25; 0,30)(0,70; 0,25; 0,30)(0,70; 0,25; 0,30)(0,60;0,40;0,40)(0,70; 0,25; 0,30)(0,6; 0,40;0,40) (0,60;0,40;0,40)]

The proximity vectors are calculated k

pp_1=[0,92; 0,92; 0,95; 0,58; 0,97; 0,97; 0,97; 0,68; 0,92; 0,96; 0,96]

pp_2=[0,94; 0,94; 0,94; 0,62; 0,98; 0,97; 0,78; 0,87; 0,96; 0,96; 0,92]

pp_3=[0,92; 0,97; 0,94; 0,72; 0,94; 0,94; 0,92; 0,89; 0,95; 0,94; 0,96]

Then the exchange preferences (CC) are identified.

$CC = \{w_i^c | cm_i| < 0.9\}$= w_4, w_8

The average proximity for this value is calculated as follows:

$pp_4^A = 0.6413, pp_8^A = 0.8173$

The proximity values for each preference expert w_4, w_8 as follows:

$pp_4^1 = 0.611, pp_8^1 = 0.979$
$pp_4^2 = 0.9605,\ \ pp_8^2 = 0.8462$
$pp_4^3 = 0.9682\ \ pp_8^3 = 0.8566$

The preference sets to change are: $\{v_4, v_8\}$
According to the DR1 rule, experts are required to increase the following ratios: v_4^1
According to the DR2 rule, experts are required to decrease the following relationships: v_8^2,
and according to rule DR3, these relationships should not be changed: v_8^3

Second round

In accordance with the previous advice, the experts implemented changes and the new preferences obtained are shown in table 5.

	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}
E1	B	M	B	G	G	G	G	B	G	M	B
E2	VG	G	G	G	G	G	G	B	G	G	VG
E3	VB	VG	M	G	VG	VG	G	B	VG	VG	VG

Table 5. Round 2 Preferences.

Similarity vectors are again obtained:
s^{12}=[0,9226; 0,9221; 0,95; 0,9207; 0,9702; 0,9707; 0,9707; 0,9207; 0,9204; 0,9606; 0,9606]
s^{13}=[0,9402; 0,9414; 0,7424; 0,962; 0,9802; 0,9707; 0,7825; 0,9652; 0,9608; 0,9604; 0,9204]
s^{23}= [0,9204; 0,9704; 0,9414; 0,9472; 0,9428; 0,9406; 0,9207; 0,9406; 0,9554; 0,9402; 0,9606]
The consensus vector CV = [0,9277; 0,9446; 0,8779; 0,94; 0,9644; 0,9606; 0,8913; 0,94 0,9455; 0,9537; 0,9472; 0,9357]
Finally, a degree of general consensus is calculated: cg=0.9357
Since cg = 0.93>μ = 0.9, the desired level of consensus is reached.
From the result obtained, we concluded that the prioritized risk factors were $C = c_1, c_{10}, c_8, c_9$ respectively, which correspond to smoking, family history, air pollution and genetic factors.

Conclusions

The proposed method consists of eight activities, includes automatic search mechanisms for areas of conflict and recommendations to experts to bring their preferences closer. A study was carried out from which it was possible to show that the prevalence of chronic obstructive pulmonary disease in the population selected for the study was high and the prevalent risk factors are smoking, family history, primary education, air pollution and genetic factors. The implementation of the proposed method allowed the prioritization of risk factors.

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Neutrosophic Scale to Measure Psychopathic Personalities Based on Triple Refined Indeterminate Neutrosophic Sets

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Abstract. The psychopathic personality is the disorder of the personality characterized by antisocial behavior, lack of empathy and cruelty of the individual. This type of personality is not simple to diagnose. It is not possible to differentiate with certainty a psychopathic individual from one who is not. One measure to evaluate psychopathy is the Triarchic Psychopathy Measure (TriPM), consisting of three sub-scales that measure boldness, meanness, and disinhibition. This measure uses a Likert-type scale with 4-points. However, due to the complexity that characterizes measuring this type of personality, TriPM may be inaccurate, because four points are used instead of five. Therefore, the scale consisting of true, mostly true, mostly false, and false was modified to a new one with five elements, where indeterminacy is added. Another contribution of this paper is that the four numerical elements are replaced by a scale based on Triple Refined Indeterminate Neutrosophic Sets, where the person instead of measuring the item having a single numerical value with 100% of certainty, uses five elements with certainty between 0% and 100%. Accuracy is essential in this topic, where indeterminacy is present since psychopathy definition. Additionally, the method is illustrated with an example. Psychopathy evaluation is very important in forensic psychology, since these individuals can be involved in criminal acts.

Keywords: Triple Refined Indeterminate Neutrosophic Sets; Likert scale; psychopathic personality; Triarchic Psychopathy Measure.

1 Introduction

Psychopathy or psychopathic personality is an antisocial personality disorder[1]. Despite the popular myths about this term, scientifically there is no consensus on how to unequivocally differentiate a psychopathic person from one who is not. Two people evaluated as psychopathic do not necessarily have the same behavior. That is why the most accurate term is that of a "more or less psychopathic" person. Therefore, this type of personality is not easy to classify, which represents a challenge for the researcher who studies these individuals, [2, 3].

Some common characteristics in this personality type are its marked antisocial behavior, reduced empathy and remorse, and its uninhibited character. Psychopaths have their own code of behavior that contradicts socially accepted codes, they do not feel guilty when they transgress the social rules[4], they only feel injured when their own rules are affected.

These people know the social codes and can go unnoticed by most people; although with the pass of time their characteristics may emerge. That makes diagnosis even more difficult to achieve.

Two leading scientists who have studied this topic were Robert Hare and Hervey Cleckley. Hare created its own Psychopathy Check List, [5]. For Cleckley, psychopaths have the following characteristics, [3]:

- Superficial charm and intelligence,
- Absence of delusions or other signs of non-rational thinking,
- Absence of nervousness or psychoneurotic manifestations,
- Poor reliability,

• Falsehood or insincerity,
• Lack of remorse and shame,
• Antisocial behavior for no good reason,
• Poor judgment and difficulty learning from experience,
• Pathological self-centeredness and lack of empathy,
• Generalized poverty in the main affective relationships,
• Specific loss of intuition,
• Insensitivity in general interpersonal relationships,
• Extravagant and unpleasant behavior under the influence of alcohol and sometimes without it,
• Rarely complete suicide threats,
• Impersonal, frivolous and unstable sexual life,
• Inability to follow any life plan,

On the other hand, for Hare these personalities are characterized by:

• Great verbal ability and superficial charm,
• Exaggerated self-esteem,
• Constant need to obtain stimuli and tendency to boredom,
• Tendency to lie pathologically,
• Malicious and manipulative behavior,
• Lack of guilt or any kind of remorse,
• Frivolous affectivity, with a superficial emotional response,
• Lack of empathy. Cruelty and insensitivity,
• Parasitic lifestyle,
• Lack of control over behavior,
• Promiscuous sex life,
• History of behavior problems since childhood,
• Lack of realistic long-term goals,
• Impulsive attitude,
• Irresponsible behavior,
• Pathological inability to accept responsibility for their own actions,
• History of many short-term marriages,
• Trend toward juvenile delinquency,
• Revocation of parole,
• Versatility for criminal action.

The origin of a psychopathic personality cannot be clearly determined. Genetic and environmental factors, such as child abuse, are believed to contribute to its development. People of antisocial or alcoholic parents are at higher risk. Men have been more affected than women have. Prisons go a long way toward developing this condition in people. People who have a habit of setting fire, mistreating animals and even losing control of the urethral sphincter during childhood are linked to the development of the antisocial personality.

There are a large number of scales to measure psychopathy, [6-8]. This measurement is important, especially from the legal point of view, where it is necessary to determine whether the accused of a crime has psychopathic characteristics. It has also been determined that the non-criminal population can contain this type of people, who can commit infractions that are not detected. This article will be based on the scale called Triarchic Psychopathy Measure (TriPM) which consists of 58-items self-report inventory of psychopathy, [9, 10]. TriPM is divided into three sub-scales, each of which measures *boldness*, defined as the nexus of high dominance, low anxiousness, and venturesomeness; *meanness*, reflecting tendencies toward callousness, cruelty, predatory aggression, and excitement seeking; and *disinhibition*, reflecting tendencies toward impulsiveness, irresponsibility, oppositionality, and anger/hostility.

TriPM is based on 4-points (mostly false, false, mostly true, true) Likert-type scale, [11]. This type of scale has limitations for two reasons; firstly, it would lack a neutral element that is central in the scale that means indeterminacy. The second limitation is related to the intrinsic nature of Likert-type scales, which are numerical and only offer a single option with 100% of certainty. This is an important limitation in cases of psychopathies, which is characterized by the difficulty of measurement.

The proposal we carry out is based on Neutrosophy, [12, 13]. Neutrosophy is the branch of philosophy that studies all related to neutralities, due to the lack of information, contradictory information, paradoxical and imprecise information, among others. That is why Neutrosophy can serve to measure the degree of psychopathy, whose manifestations are characterized by indeterminacy[14]. One contribution of this paper is that for the first time Neutrosophy is used to measure psychopathies. On the other hand, the Likert scale is extended to a 5-point scale based on the Triple Refined Indeterminate Neutrosophic Set (TRINS), [15, 16], where instead of the three elements of the Single-Valued Neutrosophic Sets[17, 18], there are two more elements, the indeterminacy leaning toward truth membership and the indeterminacy leaning toward false membership. So, greater measurement accuracy is obtained.

Neutrosophy, especially TRINS, have been used successfully to measure personality traits, [15, 16]. Additionally there is the so-called Neutrosophic Psychological Theory, [19-22], which is also called Neutropsyche. Neutrosophic Psychological Theory is defined as the psychological theory[23] that studies the soul or spirit using Neutrosophy and neutrosophic theories. It is based on triadic neutrosophic psychological concepts, procedures, ideas, and theories of the form (<A>, <neutA>, <antiA>), such as (positive, neutral, negative), and so on. Neutropsychic means of or having to do with the neutropsyche.

This paper structured into the following sections: Section of Materials and methods, contains the concepts related to Neutrosophy and TRINS. The next section includes the proposal made in this article on the measurement of psychopathic personality with the combination of TriPM questionnaire and a neutrosophic scale. An example is also offered. This paper ends with the conclusions.

2 Materials and methods

This section contains the main concepts related to Neutrosophy[24] that we use in this paper, especially Triple Refined Indeterminate Neutrosophic Sets.

Definition 1 ([15, 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 $T_A: U \to [0,1]$, $I_A: U \to [0,1]$, and $F_A: U \to [0,1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

Definition 2 ([25-30])**:** The *refined neutrosophic logic* is defined such that: a truth T is divided into several types of truths: $T_1, T_2, \ldots, T_p$, I into various indeterminacies: $I_1, I_2, \ldots, I_r$ and F into various falsehoods: $F_1, F_2, \ldots, F_s$, where all $p, r, s \geq 1$ are integers, and $p + r + s = n$.

Definition 3 ([15, 16])**:** Consider X to be a set of points (objects) with generic entities in X denoted by x. A *Triple Refined Indeterminate Neutrosophic Set* (TRINS) A in X is considered as truth membership function $T_A(x)$, indeterminacy leaning toward truth membership function $I_{T_A}(x)$, indeterminacy membership function $I_A(x)$, indeterminacy leaning toward falsehood membership function $I_{F_A}(x)$, and falsehood membership function $F_A(x)$. Each membership function has a weight $w_m \in [0,5]$ associated with it. For each generic element $x \in X$, there are:

$$T_A(x), I_{T_A}(x), I_A(x),\ I_{F_A}(x), F_A(x) \in [0,1],\ w_T\ (T_A(x)), w_{I_T}(I_{T_A}(x)), w_I\ (I_A(x)), w_{I_F}(I_{F_A}(x)), w_F(F_A(x)) \in [0,5]$$

and

$$0 \leq T_A(x) + I_{T_A}(x) + I_A(x) + I_{F_A}(x) + F_A(x) \leq 5.$$

Therefore, a TRINS A can be represented by $A = \{\langle x;\ T_A(x), I_{T_A}(x), I_A(x),\ I_{F_A}(x), F_A(x)\rangle | x \in X\}$.

Definition 4 ([15, 16])**:** Consider a TRINS A, its complement is denoted by $c(A)$ and is defined as

1. $T_{c(A)}(x) = F_A(x)$,
2. $I_{T_{c(A)}}(x) = 1 - I_{T_A}(x)$,
3. $I_{c(A)}(x) = 1 - I_A(x)$,
4. $I_{F_{c(A)}}(x) = 1 - I_{F_A}(x)$,
5. $F_{c(A)}(x) = T_A(x)$.

For all *x* in X.

Definition 5 ([15, 16])**:** A TRINS A is contained in another TRINS B, $A \subseteq B$, if and only if

1. $T_A(x) \leq T_B(x)$,
2. $I_{T_A}(x) \leq I_{T_B}(x)$,
3. $I_A(x) \leq I_B(x)$,
4. $I_{F_A}(x)(x) \leq I_{F_B}(x)$,
5. $F_A(x) \geq F_B(x)$.

For all x in X.

Definition 6 ([15, 16])**:** The union of two TRINSs A and B is a TRINS C, denoted as $C = A \cup B$, whose truth membership, indeterminacy leaning toward truth membership, indeterminacy membership, indeterminacy leaning toward falsehood membership and falsehood membership functions are associated to A and B according to:

1. $T_C(x) = \max(T_A(x), T_B(x))$,

2. $\mathrm{I}_{\mathrm{T}_\mathrm{C}}(\mathrm{x}) = \max(\mathrm{I}_{\mathrm{T}_\mathrm{A}}(\mathrm{x}), \mathrm{I}_{\mathrm{T}_\mathrm{B}}(\mathrm{x}))$,
3. $\mathrm{I}_\mathrm{C}(\mathrm{x}) = \max(\mathrm{I}_\mathrm{A}(\mathrm{x}), \mathrm{I}_\mathrm{B}(\mathrm{x}))$,
4. $\mathrm{I}_{\mathrm{F}_\mathrm{C}}(\mathrm{x}) = \max(\mathrm{I}_{\mathrm{F}_\mathrm{A}}(\mathrm{x}), \mathrm{I}_{\mathrm{F}_\mathrm{B}}(\mathrm{x}))$,
5. $\mathrm{F}_\mathrm{C}(\mathrm{x}) = \min(\mathrm{F}_\mathrm{A}(\mathrm{x}), \mathrm{F}_\mathrm{B}(\mathrm{x}))$.

Definition 7 ([15, 16])**:** The intersection of two TRINSs A and B is a TRINS C, denoted as $\mathrm{C} = \mathrm{A} \cap \mathrm{B}$, whose truth membership, indeterminacy leaning toward truth membership, indeterminacy membership, indeterminacy leaning toward falsehood membership and falsehood membership functions are associated to A and B according to:

1. $\mathrm{T}_\mathrm{C}(\mathrm{x}) = \min(\mathrm{T}_\mathrm{A}(\mathrm{x}), \mathrm{T}_\mathrm{B}(\mathrm{x}))$,
2. $\mathrm{I}_{\mathrm{T}_\mathrm{C}}(\mathrm{x}) = \min(\mathrm{I}_{\mathrm{T}_\mathrm{A}}(\mathrm{x}), \mathrm{I}_{\mathrm{T}_\mathrm{B}}(\mathrm{x}))$,
3. $\mathrm{I}_\mathrm{C}(\mathrm{x}) = \min(\mathrm{I}_\mathrm{A}(\mathrm{x}), \mathrm{I}_\mathrm{B}(\mathrm{x}))$,
4. $\mathrm{I}_{\mathrm{F}_\mathrm{C}}(\mathrm{x}) = \min(\mathrm{I}_{\mathrm{F}_\mathrm{A}}(\mathrm{x}), \mathrm{I}_{\mathrm{F}_\mathrm{B}}(\mathrm{x}))$,
5. $\mathrm{F}_\mathrm{C}(\mathrm{x}) = \max(\mathrm{F}_\mathrm{A}(\mathrm{x}), \mathrm{F}_\mathrm{B}(\mathrm{x}))$.

Let *A* and *B* be two TRINS in a finite universe of discourse, $\mathrm{X} = \{\mathrm{x}_1, \mathrm{x}_2, \dots, \mathrm{x}_\mathrm{n}\}$, which are denoted by:

$A = \{\langle \mathrm{x};\ \mathrm{T}_\mathrm{A}(\mathrm{x}), \mathrm{I}_{\mathrm{T}_\mathrm{A}}(\mathrm{x}), \mathrm{I}_\mathrm{A}(\mathrm{x}),\ \mathrm{I}_{\mathrm{F}_\mathrm{A}}(\mathrm{x}), \mathrm{F}_\mathrm{A}(\mathrm{x})\rangle | \mathrm{x} \in \mathrm{X}\}$ and $B = \{\langle \mathrm{x};\ \mathrm{T}_\mathrm{B}(\mathrm{x}), \mathrm{I}_{\mathrm{T}_\mathrm{B}}(\mathrm{x}), \mathrm{I}_\mathrm{B}(\mathrm{x}),$ $\mathrm{I}_{\mathrm{F}_\mathrm{B}}(\mathrm{x}), \mathrm{F}_\mathrm{B}(\mathrm{x})\rangle | \mathrm{x} \in \mathrm{X}\}$,

Where $\mathrm{T}_\mathrm{A}(\mathrm{x}_\mathrm{i}), \mathrm{I}_{\mathrm{T}_\mathrm{A}}(\mathrm{x}_\mathrm{i}), \mathrm{I}_\mathrm{A}(\mathrm{x}_\mathrm{i}),\ \mathrm{I}_{\mathrm{F}_\mathrm{A}}(\mathrm{x}_\mathrm{i}), \mathrm{F}_\mathrm{A}(\mathrm{x}_\mathrm{i}), \mathrm{T}_\mathrm{B}(\mathrm{x}_\mathrm{i}), \mathrm{I}_{\mathrm{T}_\mathrm{B}}(\mathrm{x}_\mathrm{i}), \mathrm{I}_\mathrm{B}(\mathrm{x}_\mathrm{i}),\ \mathrm{I}_{\mathrm{F}_\mathrm{B}}(\mathrm{x}_\mathrm{i}), \mathrm{F}_\mathrm{B}(\mathrm{x}_\mathrm{i}) \in [0, 1]$, for every $\mathrm{x}_\mathrm{i} \in$ X. Let w_i (i = 1,2,...,n) be the weight of an element x_i (i = 1,2,...,n), with $\mathrm{w}_\mathrm{i} \geq 0$ (i = 1, 2,..., n) and $\sum_{i=1}^{n} \mathrm{w}_\mathrm{i} = 1$.

The *generalized TRINS weighted distance* is defined as follows, [15, 16]:

$$d_\lambda(A, B) = \left\{\frac{1}{5}\sum_{i=1}^{n} w_i \left[|\mathrm{T}_\mathrm{A}(\mathrm{x}_\mathrm{i}) - \mathrm{T}_\mathrm{B}(\mathrm{x}_\mathrm{i})|^\lambda + \left|\mathrm{I}_{\mathrm{T}_\mathrm{A}}(\mathrm{x}_\mathrm{i}) - \mathrm{I}_{\mathrm{T}_\mathrm{B}}(\mathrm{x}_\mathrm{i})\right|^\lambda + |\mathrm{I}_\mathrm{A}(\mathrm{x}_\mathrm{i}) - \mathrm{I}_\mathrm{B}(\mathrm{x}_\mathrm{i})|^\lambda + \left|\mathrm{I}_{\mathrm{F}_\mathrm{A}}(\mathrm{x}_\mathrm{i}) - \mathrm{I}_{\mathrm{F}_\mathrm{B}}(\mathrm{x}_\mathrm{i})\right|^\lambda + |\mathrm{F}_\mathrm{A}(\mathrm{x}_\mathrm{i}) - \mathrm{F}_\mathrm{B}(\mathrm{x}_\mathrm{i})|^\lambda\right]\right\}^{1/\lambda} \quad (1)$$

Where $\lambda > 0$.

The generalized TRINS weighted distance $d_\lambda(A, B)$ for $\lambda > 0$ satisfies the following properties:

1. $d_\lambda(A, B) \geq 0$,
2. $d_\lambda(A, B) = 0$ if and only if $\mathrm{A} = \mathrm{B}$,
3. $d_\lambda(A, B) = d_\lambda(B, A)$,
4. If $A \subseteq B \subseteq C$, C is a TRINS in X, then $d_\lambda(A, C) \geq d_\lambda(A, B)$ and $d_\lambda(A, C) \geq d_\lambda(B, C)$.

Definition 8 ([15, 16])**:** Let A_j (j = 1,2,...,m) be a collection of m TRINS, then the *TRINS distance matrix* $\mathrm{D} = \left(\mathrm{d}_{\mathrm{ij}}\right)_{\mathrm{m}\times\mathrm{m}}$,where $\mathrm{d}_{\mathrm{ij}} = d_\lambda\left(\mathrm{A}_\mathrm{i}, \mathrm{A}_\mathrm{j}\right)$ is the generalized TRINS distance between A_i and A_j and satisfies the following:

1. $\mathrm{d}_{\mathrm{ij}} \in [0, 5], \forall \mathrm{i}, \mathrm{j} = 1,2, \dots, \mathrm{m}$;
2. $\mathrm{d}_{\mathrm{ij}} = 0$ if and only if $\mathrm{A}_\mathrm{i} = \mathrm{A}_\mathrm{j}$;
3. $\mathrm{d}_{\mathrm{ij}} = \mathrm{d}_{\mathrm{ji}}$ for all $\mathrm{i}, \mathrm{j} = 1,2, \dots, \mathrm{m}$.

Definition 9 ([15, 16])**:** The *generalized Triple Refined Indeterminate Neutrosophic weight* is defined as follows:

$$w(A) = \sum_{i=1}^{n}\left\{w_T\left(\mathrm{T}_\mathrm{A}(\mathrm{x}_\mathrm{i})\right) + w_{\mathrm{I}_\mathrm{T}}\left(\mathrm{I}_{\mathrm{T}_\mathrm{A}}(\mathrm{x}_\mathrm{i})\right) + w_\mathrm{I}\left(\mathrm{I}_\mathrm{A}(\mathrm{x}_\mathrm{i})\right) + w_{\mathrm{I}_\mathrm{F}}\left(\mathrm{I}_{\mathrm{F}_\mathrm{A}}(\mathrm{x}_\mathrm{i})\right) + w_F\left(\mathrm{F}_\mathrm{A}(\mathrm{x}_\mathrm{i})\right)\right\} \quad (2)$$

Where, $w_T, w_{\mathrm{I}_\mathrm{T}}, w_\mathrm{I}, w_{\mathrm{I}_\mathrm{F}}, w_F$ denote the weights of every membership.

3 Neutrosophic TriMP measure

This section proposes a new TriMP measure based on a 5-points Likert type scale using TRINS. Below are the original questions corresponding to the three subscales about boldness, meanness and disinhibition, see [9]:

Boldness Scale items:

1. I'm optimistic more often than not.
2. I have no strong desire to parachute out of an airplane.
3. I am well-equipped to deal with stress.
4. I get scared easily.

5. I'm a born a leader.
6. I have a hard time making things turn out the way I want.
7. I have a knack for influencing people.
8. I function well in new situations, even when unprepared.
9. I don't think of myself as talented.
10. I'm afraid of far fewer things than most people.
11. I can get over things that would traumatize others.
12. It worries me to go into an unfamiliar situation without knowing all the details.
13. I can convince people to do what I want.
14. I don't like to take the lead in groups.
15. It's easy to embarrass me.
16. I stay away from physical danger as much as I can.
17. I don't stack up well against most others.
18. I never worry about making a fool of myself with others.
19. I'm not very good at influencing people.

Meanness Scale items:

1. How other people feel is important to me.
2. I would enjoy being in a high-speed chase.
3. I don't mind if someone I dislike gets hurt.
4. I sympathize with others' problems.
5. I enjoy a good physical fight.
6. I return insults.
7. It doesn't bother me to see someone else in pain.
8. I enjoy pushing people around sometimes.
9. I taunt people just to stir things up.
10. I don't see any point in worrying if what I do hurts someone else.
11. I am sensitive to the feelings of others.
12. I don't have much sympathy for people.
13. For me, honesty really is the best policy.
14. I've injured people to see them in pain.
15. I sometimes insult people on purpose to get a reaction from them.
16. Things are more fun if a little danger is involved.
17. I don't care much if what I do hurts others.
18. It's easy for me to relate to other people's emotions.
19. It doesn't bother me when people around me are hurting.

Disinhibition Scale items:

1. I often act on immediate needs.
2. I've often missed things I promised to attend.
3. My impulsive decisions have caused problems with loved ones.
4. I have missed work without bothering to call in.
5. I jump into things without thinking.
6. I've gotten in trouble because I missed too much school.
7. I have good control over myself.
8. I have taken money from someone's purse or wallet without asking.
9. People often abuse my trust.
10. I keep appointments I make.
11. I often get bored quickly and lose interest.
12. I have conned people to get money from them.
13. I get in trouble for not considering the consequences of my actions.
14. I have taken items from a store without paying for them.
15. I have a hard time waiting patiently for things I want.
16. I have lost a friend because of irresponsible things I've done.
17. Others have told me they are concerned about my lack of self-control.
18. I have robbed someone.
19. I have had problems at work because I was irresponsible.
20. I have stolen something out of a vehicle.

The new method consists in adapting each question, in a way that the person has the opportunity to pick between choices <A> and <anti A> with five degrees of accuracy. Always, <A> represents a no psychopathic trait of the personality, and <anti A> a psychopathic trait. Some examples of these changes are illustrated below:

The first question of boldness, which says "I'm optimistic more often than not", is substituted by:

Boldness	**Q1**	I'm pessimistic	1	2	3	4	5	I'm optimistic

This new scheme has different shades of evaluations. 1 represents a degree of "pessimism", 2 represents a degree of "leaning toward pessimism", 3 represents a degree of uncertainty and indeterminacy about "pessimism and optimism", 4 represents a degree of "leaning toward optimism", and 5 represents "optimism".

Question 2 of boldness can be adapted in the following way:

Boldness	**Q2**	I have no strong desire to parachute out of an airplane	1	2	3	4	5	I have strong desire to parachute out of an airplane

Now, the scale is interpreted as the degrees of "to have no strong desire", "leaning toward to have no strong desire", uncertainty and indeterminacy about "to have not and to have strong desire", "leaning toward to have strong desire", and "to have strong desire".

Boldness	**Q3**	I am not well-equipped to deal with stress	1	2	3	4	5	I am well-equipped to deal with stress

The scale is interpreted as the degrees of "not to be well-equipped", "leaning toward not to be well-equipped", uncertainty and indeterminacy about "not to be well-equipped and to be well-equipped", "leaning toward to be well-equipped", "to be well-equipped".

The last example is:

Boldness	**Q4**	I get scared easily.	1	2	3	4	5	I don't get scared easily.

The scale is interpreted as the degrees of "to get scared easily", "leaning toward to get scared easily", uncertainty and indeterminacy about "to get scared and to not get scared easily", "leaning toward to not get scared easily", "to not get scared easily".

One drawback of this new method with respect to the precedent one is that the former is more complex, this is the necessary disadvantage to obtain more accuracy. However, this accuracy is required because of the difficulty to capture precisely a psychopathic personality. Moreover, the complexity of the questionnaire can be dissipated if it is coded and supported with an electronic device, like a personal computer.

Let us denote with $\mathrm{Q_{Bi}}$ (i = 1, 2,…,19) the question with index i to measure boldness, $\mathrm{Q_{Mi}}$ (i = 1, 2,…,19) the question with index i to measure meanness, and $\mathrm{Q_{Di}}$ (i = 1, 2,…, 20) the question with index i to measure disinhibition. On the other hand, let us denote with $\mathrm{R_{Bi}}$ the answer to $\mathrm{Q_{Bi}}$ in form of TRINS, $\mathrm{R_{Mi}}$ the answer to $\mathrm{Q_{Mi}}$, and $\mathrm{R_{Di}}$ the answer to $\mathrm{Q_{Di}}$.

The steps to evaluate psychopathy are the following:

1. The person answers the questions using the new scale. This step may needs of the help of a specialist. Thus, $\mathrm{R_{Bi}}$, $\mathrm{R_{Mi}}$, and $\mathrm{R_{Di}}$ are obtained. To make the evaluation easier, the specialist may indicate to the person to evaluate each point of the scale (from 1 to 5) in a value from 0 to 10, then, this value is divided by 10 and the TRINS is obtained.

2. The average of $\mathrm{R_{Bi}} = \langle \mathrm{T(R_{Bi}),\ I_T(R_{Bi}), I(R_{Bi}), I_F(R_{Bi}), F(R_{Bi})} \rangle$, $\mathrm{R_{Mi}} = \langle \mathrm{T(R_{Mi}),\ I_T(R_{Mi}), I(R_{Mi}), I_F(R_{Mi}), F(R_{Mi})} \rangle$, and $\mathrm{R_{Di}} = \langle \mathrm{T(R_{Di}),\ I_T(R_{Di}), I(R_{Di}), I_F(R_{Di}), F(R_{Di})} \rangle$ are calculated with formulas in Equation 3:

$$\overline{R}_B = \langle \frac{\sum_{i=1}^{19} T(R_{Bi})}{19}, \frac{\sum_{i=1}^{19} I_T(R_{Bi})}{19}, \frac{\sum_{i=1}^{19} I(R_{Bi})}{19}, \frac{\sum_{i=1}^{19} I_F(R_{Bi})}{19}, \frac{\sum_{i=1}^{19} F(R_{Bi})}{19} \rangle$$
$$\overline{R}_M = \langle \frac{\sum_{i=1}^{19} T(R_{Mi})}{19}, \frac{\sum_{i=1}^{19} I_T(R_{Mi})}{19}, \frac{\sum_{i=1}^{19} I(R_{Mi})}{19}, \frac{\sum_{i=1}^{19} I_F(R_{Mi})}{19}, \frac{\sum_{i=1}^{19} F(R_{Mi})}{19} \rangle \quad (3)$$
$$\overline{R}_D = \langle \frac{\sum_{i=1}^{20} T(R_{Di})}{20}, \frac{\sum_{i=1}^{20} I_T(R_{Di})}{20}, \frac{\sum_{i=1}^{20} I(R_{Di})}{20}, \frac{\sum_{i=1}^{20} I_F(R_{Di})}{20}, \frac{\sum_{i=1}^{20} F(R_{Di})}{20} \rangle$$

3. The index to measure the psychopathic personality is calculated with formula 4:
$$PI = \overline{R}_B \cap \overline{R}_M \cap \overline{R}_D \quad (4)$$

4. To obtain a unique crisp value, calculate $w(PI)$, the generalized Triple Refined Indeterminate Neutrosophic weight with Equation 2, thus, $dp = round\left(\frac{w(PI)}{3}\right)$ indicates the degree of phychopathy of the person in the following scale:

$$\begin{Bmatrix} dp \leq 1\text{: Non psychopathic personality} \\ dp = 2\text{: leaning toward non psychopathic personality} \\ dp = 3\text{: Indeterninacy on psychopathic and non psychopathic personality} \\ dp = 4\text{: leaning toward psychopathic personality} \\ dp = 5\text{: psychopathic personality} \end{Bmatrix}$$

Example 1:

This example serves to illustrate the applicability of the neutrosophic TriMP scale in a hypothetical case. Tables 1, 2 and 3, summarize the responses of a hypothetical person about boldness, meanness, and disinhibition, respectively.

Question	$\mathbf{R_{Bi}}$
Q1	$\langle 0.30, 0.10, 0.60, 0.00, 0.00 \rangle$
Q2	$\langle 0.10, 0.50, 0.\ 40, 0.00, 0.00 \rangle$
Q3	$\langle 0.30, 0.30, 0.40, 0.00, 0.00 \rangle$
Q4	$\langle 0.40, 0.60, 0.00, 0.00, 0.00 \rangle$
Q5	$\langle 0.00, 0.00, 0.40, 0.30, 0.30 \rangle$
Q6	$\langle 0.20, 0.50\ 0.30, 0.00, 0.00 \rangle$
Q7	$\langle 0.00, 0.00, 0.10, 0.20, 0.70 \rangle$
Q8	$\langle 0.50, 0.20, 0.30, 0.00, 0.00 \rangle$
Q9	$\langle 0.60, 0.40, 0.00, 0.00, 0.00 \rangle$
Q10	$\langle 0.00, 0.00, 0.30, 0.30, 0.40 \rangle$
Q11	$\langle 0.00, 0.00, 0.40, 0.40, 0.20 \rangle$
Q12	$\langle 0.10, 0.60, 0.20, 0.10, 0.00 \rangle$
Q13	$\langle 0.30, 0.40, 0.20, 0.10, 0.00 \rangle$
Q14	$\langle 0.00, 0.00, 0.30, 0.30, 0.40 \rangle$
Q15	$\langle 0.20, 0.40, 0.40, 0.00, 0.00 \rangle$
Q16	$\langle 0.00, 0.00, 0.00, 0.70, 0.30 \rangle$
Q17	$\langle 0.40, 0.60, 0.10, 0.00, 0.00 \rangle$
Q18	$\langle 0.30, 0.30, 0.40, 0.10, 0.00 \rangle$
Q19	$\langle 0.00, 0.50, 0.50, 0.00, 0.00 \rangle$

Table 1: Responses to the questionnaire about boldness.

Question	$\mathbf{R_{Mi}}$
Q1	$\langle 0.00, 0.20, 0.10, 0.30, 0.40 \rangle$
Q2	$\langle 0.00, 0.40, 0.20, 0.30, 0.00 \rangle$
Q3	$\langle 0.00, 0.00, 0.10, 0.60, 0.00 \rangle$
Q4	$\langle 0.00, 0.00, 0.30, 0.60, 0.30 \rangle$
Q5	$\langle 0.00, 0.20, 0.20, 0.60, 0.00 \rangle$
Q6	$\langle 0.00, 0.20, 0.70, 0.1, 0.00 \rangle$
Q7	$\langle 0.00, 0.00, 0.1, 0.50, 0.50 \rangle$
Q8	$\langle 0.10, 0.10, 0.20, 0.70, 0.00 \rangle$
Q9	$\langle 0.40, 0.50, 0.10, 0.00, 0.00 \rangle$

Q10	$\langle 0.30, 0.60, 0.10, 0.00, 0.00\rangle$
Q11	$\langle 0.00, 0.10, 0.10, 0.20, 0.70\rangle$
Q12	$\langle 0.00, 0.30, 0.20, 0.50, 0.00\rangle$
Q13	$\langle 0.00, 0.00, 0.70, 0.30, 0.10\rangle$
Q14	$\langle 0.00, 0.30, 0.10, 0.50, 0.00\rangle$
Q15	$\langle 0.00, 0.10, 0.50, 0.40, 0.00\rangle$
Q16	$\langle 0.20, 0.10, 0.20, 0.50, 0.00\rangle$
Q17	$\langle 0.60, 0.20, 0.20, 0.00, 0.00\rangle$
Q18	$\langle 0.00, 0.50, 0.20, 0.30, 0.00\rangle$
Q19	$\langle 0.10, 0.60, 0.30, 0.20, 0.00\rangle$

Table 2: Responses to the questionnaire about meanness.

Question	$\mathbf{R_{Di}}$
Q1	$\langle 0.20, 0.50, 0.30, 0.00, 0.00\rangle$
Q2	$\langle 0.20, 0.60, 0.20, 0.00, 0.00\rangle$
Q3	$\langle 0.30, 0.30, 0.40, 0.00, 0.00\rangle$
Q4	$\langle 0.00, 0.40, 0.10, 0.50, 0.00\rangle$
Q5	$\langle 0.00, 0.30, 0.50, 0.20, 0.00\rangle$
Q6	$\langle 0.10, 0.20, 0.50, 0.20, 0.00\rangle$
Q7	$\langle 0.00, 0.00, 0.30, 0.20, 0.40\rangle$
Q8	$\langle 0.00, 0.40, 0.20, 0.40, 0.00\rangle$
Q9	$\langle 0.00, 0.00, 0.40, 0.10, 0.40\rangle$
Q10	$\langle 0.00, 0.00, 0.00, 0.60, 0.40\rangle$
Q11	$\langle 0.00, 0.10, 0.30, 0.50, 0.20\rangle$
Q12	$\langle 0.30, 0.40, 0.30, 0.10, 0.00\rangle$
Q13	$\langle 0.00, 0.50, 0.20, 0.20, 0.10\rangle$
Q14	$\langle 0.00, 0.00, 0.50, 0.50, 0.00\rangle$
Q15	$\langle 0.00, 0.10, 0.60, 0.30, 0.00\rangle$
Q16	$\langle 0.30, 0.70, 0.00, 0.00, 0.00\rangle$
Q17	$\langle 0.00, 0.00, 0.60, 0.40, 0.00\rangle$
Q18	$\langle 0.20, 0.50, 0.30, 0.00, 0.00\rangle$
Q19	$\langle 0.30, 0.30, 0.50, 0.00, 0.00\rangle$
Q20	$\langle 0.30, 0.50, 0.20, 0.30, 0.00\rangle$

Table 3: Responses to the questionnaire about disinhibition.

Then, we have when applying Equation 3 that $\overline{\mathrm{R}}_{\mathrm{B}} = \langle 0.19474, 0.28421, 0.27895, 0.13158, 0.12105\rangle$, $\overline{\mathrm{R}}_{\mathrm{M}} = \langle 0.089474, 0.231579, 0.242105, 0.347368, 0.105263\rangle$, and $\overline{\mathrm{R}}_{\mathrm{D}} = \langle 0.110000, 0.290000, 0.320000, 0.225000, 0.075000\rangle$. From Equation 4, $\mathrm{PI} = \langle 0.089474, 0.231579, 0.242105, 0.131580, 0.121050\rangle$, thus, from Equation 2 we have $\mathrm{dp} = round(2.4105) = 2$, therefore, the personality of this person is classified as "leaning toward non psychopathic personality".

Conclusion

To diagnose a psychopathic personality is complex, due to the indeterminacy of its definition, thus, an accurate evaluation is essential to measure this type of personality. Additionally, this assessment is important in forensic psychology in offenders and non-offenders persons. Triarchic Psychopathy Measure is a 4-point Likert-type measure to self-evaluation based on a questionnaire and three subscales of boldness, meanness, and disinhibition. This paper proposes a new measure, which uses Triple Refined Indeterminate Neutrosophic Sets. The advantage of this new technique is that it is more accurate than the original, because we propose a 5-point scale, and additionally the neutrosophic Likert allows us to select the five options with a degree of certainty, instead of only one option with a 100% of certainty. The output of the method is a value belonging to a 5-point classification, in a comprehensible way for the person and the specialist. With this new scale, the person can widely express its feelings and thoughts, which can be conditioned by the ambiance of the location where the test is carried out. Finally, we illustrated with a hypothetical example how to use the method.

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Selection of Experts to Validate a Research Proposal Using a Neutrosophic Method

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Abstract. The regulation and relocation of tolerance centers has remained a current and important issue in Ecuador. As a proposal to solve this situation, we elaborated a Project of Municipal Ordinance to relocate the tolerance centers. We propose the use of expert criteria to validate the application of the proposed project in the city of Tulcan, Ecuador. For the selection of the experts, we made use of the neutrosophic theory, with single value neutrosophic sets (SVNS) associated to linguistic variables. The use of SVNS allowed us to evaluate the level of theoretical and practical knowledge of the experts in the subject under study, and their suitability to analyze it, taking into account the weight that the experts assigned themselves. As a main result, the proposed project was validated, obtaining a "Very relevant" general evaluation.

Keywords: Experts method; knowledge level; neutrosophic theory; tolerance centers.

1 Introduction

The regulation and relocation of tolerance centers has remained a current and important issue in Ecuador, due to the lack of attention from different government entities, which has caused the inappropriate use of these spaces to proliferate, affecting the increase in crime and the welfare of other inhabitants of the town. This has been an issue of interest to both the civilian population and local governments, who are the ones who must provide solutions to the community[1].

Centers of tolerance exist in many countries of the world, but they must comply with the regulations established for this type of place. They allow the legal prostitution of adults, and the people who engage in this activity are subject to a commitment with the health department, which obliges them to undergo permanent medical examinations to ensure that they are not infected by HIV and other sexually transmitted infection. In addition, they are given free condoms, to avoid as much as possible these places to be sources of infection and contagion [2].

Since the centers of tolerance are places where alcohol is sold, and narcotic substances are consumed, these places often trigger physical, psychological and sexual violence in the city of Tulcan, province of Carchi. Tolerance centers must be immediately relocated in order to solve this social problem. It is indispensable to design an ordinance with the corresponding regulations in order to protect the safety and the best interest of the children who live in the houses next to these tolerance centers. Such centers cause fear and insecurity to all their neighbors, violating their rights guaranteed in The Good Living by the Decentralized Autonomous Government of the Municipality of Tulcan[3].

This way, the principle of the best interest of the child is being violated, which goes against the guarantee of Good Living for this vulnerable social group, due to the lack of design and approval of an ordinance that regulates the relocation of the tolerance centers in the canton of Tulcán[4, 5].

For this reason, the author has elaborated a Project of Municipal Ordinance to relocate the tolerance centers, which is reproduced below:

DRAFT ORDINANCE FOR THE RELOCATION OF TOLERANCE CENTERS IN THE CANTON OF TULCÁN, PROVINCE OF CARCHI

Article 1. Object. The present ordinance has as object, to establish the norms and the legal minimum requirements, that will govern for the regulation, control and sanction, to guarantee its fulfillment, in the implantation of fixed structures, for the operation of the sites of diversion and tolerance, within which it includes the activity of the sexual commerce, which will be relocated in the canton Tulcan, territory and jurisdiction of the Decentralized Autonomous Municipal Government of Tulcan, considered as Zone of Urban Expansion, in the Plan of Development and Territorial Ordering.

Article 2. Scope. This ordinance will act in accordance with other laws and regulations issued for purposes related to it, guaranteeing citizens and the rights of children and adolescents and other urban centers for an orderly and sustained development, the provisions of this ordinance, would apply throughout the territory of Canton Tulcan.

Article 3. Subjects. Natural or legal persons, national or foreign, public or private, in general of the establishments that have their respective permits, shall be subject to these provisions.

Article 4. General Conditions for the Implantation and Relocation of the Centers of Tolerance. Of the premises for the work of sexual activity and related to the canton of Tulcan, necessarily must comply with the conditions of zoning, use and occupation of land and space of green areas, evacuation of rainwater and sewage and so on; in relations of compatibility with the ordinance that regulates the Use and Occupation of land, as equipment for public services, as a line of transport, water, electricity, telephone, electric lighting service, internet etc., taking into account as a category, infrastructure, sectorial type and regulations related to the work to be developed, as well as comply with the general conditions required.

Article 5. Prohibitions of Tolerance Centers. All tolerance centers that develop their sexual activity, due to human development or expansion, will be prohibited. They will be relocated to less than 200 to 300 meters from the cantonal urban zone, with the prohibition of regulating their work activity, close to: gardens, schools, colleges, sports or activity parks where children and adolescents are found, who will be totally prevented from working in establishments near these places, by the Decentralized Autonomous Municipal Government of the Canton of Tulcan, after a technical report of inspection of urban expansion in which the radius of 200 to 300 meters around the urban zone is respected.

Article 6. Particular Conditions for the Relocation of the Tolerance Centers. The premises or establishments dedicated to sexual activity, which at the date of approval of this Ordinance and are operating in the urban areas and urban expansion of Canton Tulcan, which do not affect with a visual impact to the transient community, even if they are in closed sites with isolation of 100 to 200, meters of populated areas will continue to operate in the site where they are located, and provided that its location is safe and has not been implemented on slopes or sites of high risk.

The time that all these premises located as tolerance centers have for their relocation as of one year from the date of approval of this Ordinance, except for some complication of natural order or force majeure for which an extension of three months is granted; for such effect the municipal administration will lend the facilities that were the case in function of the fulfillment of this disposition.

It must be taken into account that no permit will be allowed or extended for the operation of those premises dedicated to sexual activity, which after the approval of this provision continue working within the urban and peripheral perimeter, which will be closed permanently by the municipal administration of the canton of Tulcan.

Article 7. Conditions of Visual, Landscape, Hygienic and Sound Impact Taking into consideration the following conditions:

a) For the improvement of the ornament of the canton and the operation of the complex center of tolerance they will have to maintain the entire complex clean and hygienic, keeping a minimum impact in case of producing some sinister.
b) At the same time, the tolerance centers and each one of the different premises or establishments that operate in the complex are protected by this ordinance with their portals or porches in addition to the surroundings must be suitable in accordance with this municipal ordinance.
c) In case of emergency, there will be no obstacle to their evacuation. The garbage or waste generated by the premises and complex itself will be collected in waste deposits with classification.
d) The sound generated by the tolerance centers in general within the complex, shall not exceed decibels of noisy or strident impact that contaminates the surrounding environment and affects the health of those who come to these sites, noise, vibrations and disproportionate sounds are prohibited.
e) If there is any infringement of criminal law, regardless of whether it is recorded inside or outside the premises, the owner of the site who feels affected shall file the corresponding complaint with the competent authorities for the case.
f) In those establishments where the sex trade and the sale of alcoholic beverages are carried out, infrared cameras are used to capture and record any incident that may occur in the establishment.

Article 8. Operation. The operation permits will have the validity determined by the Municipal Administration of the Decentralized Autonomous Government, taking into consideration what is established by article 4 of the present ordinance.

Article 9. Jurisdiction and Competence. The Mayor of the Decentralized Autonomous Government of the Canton of Tulcan, and the other authorities within its jurisdiction in accordance with the control exercised, have jurisdiction and competence to know, sanction and resolve the violations of this ordinance.

Article 10. Sanctions. In the event of failure to comply with this Ordinance by the owners within the period assigned in accordance with Article 5 of this Ordinance, in an unjustified manner, the local authorities shall proceed to relocate the premises and establishments of the sex trade and the sale of alcoholic beverages, in a coercive manner to the site to be assigned after informing the intendant of the Decentralized Autonomous Government of the Canton of Tulcán.

Article 11. Validity. The present ordinance will become effective as of its approval without prejudice of its promulgation in the Official Registry.

Hence, the objective of this investigation is to validate the project of municipal ordinance to regulate the relocation of the centers of tolerance in the city of Tulcan by means of the experts' criterion.

Previous investigations

At a Latin American level, the work carried out in Colombia at Universidad del Valle, under the title "Female sex work, a comparative analysis of two night clubs in the city of Cali", has been found to have a background, establishing the need to change the centers of tolerance and relocate them outside the urban center, due to the insecurity they generate [6].

At the national level, there is the undergraduate work of [2] "Sex work and labor rights" where he analyzes the legal problems involved in sex work in centers of tolerance.

On the other hand, [7] in his work "The Municipal Public Policy against Street Sex Work and the use of Public Space in Urban Regenerated Areas, case La 24 de Mayo" deals with the life of the sex workers and the mechanisms of regulation of the use of public space.

2 Methods

We used neutrosophic theory to make the selection of the experts, based on their self-evaluation of their level of theoretical and practical knowledge in the subject, as well as evaluation of the weight of theoretical knowledge in relation to practical knowledge.

Neutrosophy, which was proposed by Smarandache[4, 8, 9] for the treatment of neutralities, has formed the basis for a series of mathematical theories that generalize classical and diffuse theories such as neutrosophic sets and neutrosophic logic [10, 11].

The original definition of truth value in the neutrosophic logic is shown below:

Set N = {(T, I, F): T, I, F ⊆ [0, 1]} n, a neutrosophic valuation is a mapping of a group of propositional formulas to N, and for each p statement you have:

$$v(p) = (T, I, F) \tag{1}$$

Neutrosophic set theory starts from classical set theory and fuzzy set theory, adding a membership function to the set μ generally defined as an x-number between 0 and 1 (the interval [0.1], instead of the classical binary membership defined in the set {0.1}. Thus, we introduce the concept of a neutrosophic set associated to a certain linguistic value, defined by a word, adjective or linguistic label $\mathcal{A}$, [12, 13].

A neutrosophic set A is defined as a membership function that links the elements of a domain or universe of discourse X with elements of the interval [0,1]: A: X→[0,1]. For each neutrosophic set a belonging or inclusion function μA(x) is defined, which represents the degree to which a value for the variable x is included in the concept represented by the label A. The closer A(x) is to the value 1, the greater the membership of the object x to the set A. The values of membership vary between 0 (no belonging at all) and 1 (total belonging) so that a neutrosophic set is a class of objects with continuous degrees of membership [14].

The use of single-value neutral sets (SVNS) allows the use of linguistic variables, which increases the possibility of interpretation in recommendation models and the use of indetermination [15-17].

Let X be a universe of discourse, a SVNS A over X has the following form:

$$A = \{\langle x, u_a(x), r_a(x), v_a(x)\rangle : x \in X\}d \tag{2}$$

Where

$$u_a(x): X \to [0,1], r_a(x): X \to [0,1]\ y\ \ v_a(x): X \to [0,1]$$

With

$0 \le u_a(x), r_a(x), v_a(x) \le 3, \qquad \forall\, x \in X$

The intervals $u_a(x), r_a(x)$ and $v_a(x)$ denote the memberships to true, indeterminate and false of x in A, respectively.

The first step for the selection of the experts was a pre-selection of 30 lawyers from the Municipality of Tulcán, Province of Carchi. The pre-selection was based on the years of experience in the profession (more than five years) and the willingness to participate in the study.

These attorneys were explained the problems previously analyzed and were asked to qualitatively evaluate their level of theoretical and practical knowledge (understood as that acquired through the practical exercise of their profession) in the subject analyzed, according to the categories suggested in Figure 1)[18-20]

.

Evaluate your level of knowledge in the topic to be addressed according to the following categories *Extremely high (EH), Very very high (VVH), Very high (VH), High (H), Medium high (MH), Medium (M), Medium low (ML), Low (L), Very low (VL), Very very low(VVL) y Extremely low (EL)*	
Level of theoretical knowledge	
Level of practical knowledge (knowledge acquired through the practical exercise of your profession)	
Evaluate on a scale of 1 to 100 the weight you give to theoretical knowledge in relation to practical knowledge, for the analysis of the subject in question	
Weight of theoretical knowledge	

Figure 1. Questionnaire applied for the evaluation of the knowledge levels of experts and the weight of theoretical knowledge. Source: Authors' elaboration

They were also asked to evaluate what weight they would grant, on a scale of 1 to 100, to the theoretical knowledge in relation to practical knowledge, for the analysis of the subject in question.

This value was divided by 100 and the difference was found to be 1, to know the value given to practical knowledge. In other words, the sum of the two weights is equal to 1. Thus, the averages of the weights given were established as *wt* (weight of the theoretical knowledge level) and *wp* (weight of the practical knowledge level).

For the processing of these self-evaluations, we propose the association of the linguistic terms to the SVN numbers shown in table 1.

LINGUISTIC TERM	**EVALUATION**	**SVN NUMBERS**
Extremely High	EH	(1; 0; 0)
Very Very High	VVH	(0.9, 0.1, 0.1)
Very High	VH	(0,8; 0,15; 0,20)
High	H	(0.70,0.25,0.30)
Medium High	MH	(0,60; 0,35; 0,40)
Medium	M	(0,50; 0,50; 0,50)
Medium Low	ML	(0,40; 0,65; 0,60)
Low	L	(0.30,0.75,0.70)
Very Low	VL	(0,20; 0,85; 0,80)
Very Very Low	VVL	(0.10,0.90,0.90)
Extremely Low	EL	(0; 1; 1)

Table 1. Linguistic terms used. Source: Authors' elaboration

To aggregate the assessments of theoretical and practical knowledge given by the experts in order to determine their level of total knowledge in the subject, the single-value weighted average (SVNWA) was used, which is defined as[21]:

$$F_w(A_1, A_2, \dots, A_n) = \langle 1 - \prod_{j=1}^{n}\left(1 - T_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(I_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(F_{A_j}(w)\right)^{w_j} \rangle \quad (3)$$

Where:

$W = (w_1, w_2, \dots, w_n)$ is vector of $A_j(j = 1,2, \dots, n)$ such that $w_n \in [0,1]$ y $\sum w_j = 1$.

Once the aggregations were obtained, the score function was used to obtain a unique value for the expert evaluation [22]:

$$s(V_j) = 2 + T_j - F_j - I_j \tag{4}$$

With this value, a qualitative evaluation of each expert was obtained by taking the possible score (from 0 to 3) and was divided by 11 (according to the number of language terms used, thus obtaining the intervals to classify the scores, as shown in Table 2.

LINGUISTIC TERM	EVALUATION	SCORING INTERVALS
Extremely Low	EL	[0 - 0,270)
Very Very Low	VVL	[0,27 - 0,55)
Very Low	VL	[0,55 - 0,81)
Low	L	[0,81 - 1,09)
Medium Low	ML	[1,09 - 1,36)
Medium	M	[1,36 - 1,63)
Medium High	MH	[1,63 – 1,90)
High	H	[1,90 – 2,18)
Very High	VH	[2,18 – 2,45)
Very Very High	VVH	[2,45 – 2,72)
Extremely High	EH	[2,72 – 3]

Table 2. Intervals for evaluation of the expert's level of knowledge according to score function value Source: Authors' elaboration

With this evaluation, the experts were selected according to the chosen criteria. In this case, the experts with "Very very high" and "Very high" level of knowledge.

These selected experts were surveyed to validate the Municipal Ordinance Project previously presented, with the format shown in figure 2.

Mark with an X the rating given to the Draft Municipal Ordinance presented for the relocation of the Tolerance Centers in the Canton of Tulcan, according to the following categories *Very Relevant (VR), Quite Relevant (QR), Relevant (R), Not very Relevant (NVR) and Not Relevant (NR)*						
	Criteria to be evaluated	VR	QR	R	NVR	NR
1	It has consistency in its writing					
2	It has a commitment to legality					
3	It corresponds to the constitutional principles of Ecuador					
4	Attributes a greater responsibility in the location and control of these tolerance centers, to the competent authorities of the Decentralized Autonomous Municipal Government of Tulcan					
5	It allows to guarantee the Good Living to the inhabitants of Tulcan					
6	Protect the rights of children and adolescents of Tulcan					
7	It is appropriate given the problems presented					
8	It has feasibility for practical application					

Figure 2. Questionnaire applied to experts for the validation of the Draft Municipal Ordinance. Source: Author's elaboration

Once the survey was applied, the cut-off points and their respective indicator scales were calculated using the inverse standard normal values. This was done by approximating the closest value of the cumulative probability Standard Normal curve.

Finally, the N-P value was estimated, obtained as the difference of the limit value minus the average value of each statement, and the relevance of each statement was determined through the comparison of the N-P value of each statement with the cut-off points and range limits of each of the categories.

3 Results

The results of the evaluations of the experts' level of theoretical and practical knowledge are shown in table 3.

EXPERT	LEVEL OF THEORETICAL KNOWLEDGE	LEVEL OF PRACTICAL KNOWLEDGE
1	MH	MH
2	VVH	MH
3	M	MH
4	ML	L
5	H	VVH
6	VL	L
7	H	H
8	MH	MH
9	ML	ML
10	MH	ML
11	MH	ML
12	ML	M
13	VH	H
14	MH	M
15	MH	MH
16	H	VH
17	MH	ML
18	VH	VVH
19	L	VL
20	H	MH
21	MH	H
22	MH	M
23	L	VL
24	H	VVH
25	H	H
26	H	VH
27	ML	H
28	MH	VH
29	MH	H
30	M	MH

Table 3. Self-evaluation of experts on their level of theoretical and practical knowledge on the subject. Source: Authors' elaboration

Then, the weights of the levels of theoretical and practical knowledge (w_t y w_p) for the analysis of the topic were determined, according to the average of the values given by the experts. The result was that $w_t=0,3$ y $w_p=0,7$. As we can see, the experts considered that for the analysis of the topic in question, the experience obtained through the exercise of the profession has a greater weight.

With these results, the aggregation of the evaluations in both fields was done using the SVNWA operator (table 4).

EXPERT	AGGREGATION
1	(0,6 ; 0,35 ; 0,35)
2	(0,74 ; 0,24 ; 0,24)
3	(0,57 ; 0,39 ; 0,39)
4	(0,33 ; 0,72 ; 0,72)
5	(0,86 ; 0,13 ; 0,13)
6	(0,27 ; 0,78 ; 0,78)

7	(0,7 ; 0,25 ; 0,25)
8	(0,6 ; 0,35 ; 0,35)
9	(0,4 ; 0,65 ; 0,65)
10	(0,47 ; 0,54 ; 0,54)
11	(0,47 ; 0,54 ; 0,54)
12	(0,47 ; 0,54 ; 0,54)
13	(0,73 ; 0,21 ; 0,21)
14	(0,53 ; 0,45 ; 0,45)
15	(0,6 ; 0,35 ; 0,35)
16	(0,77 ; 0,17 ; 0,17)
17	(0,47 ; 0,54 ; 0,54)
18	(0,88 ; 0,11 ; 0,11)
19	(0,23 ; 0,82 ; 0,82)
20	(0,63 ; 0,32 ; 0,32)
21	(0,67 ; 0,28 ; 0,28)
22	(0,53 ; 0,45 ; 0,45)
23	(0,23 ; 0,82 ; 0,82)
24	(0,86 ; 0,13 ; 0,13)
25	(0,7 ; 0,25 ; 0,25)
26	(0,77 ; 0,17 ; 0,17)
27	(0,63 ; 0,33 ; 0,33)
28	(0,75 ; 0,19 ; 0,19)
29	(0,67 ; 0,28 ; 0,28)
30	(0,57 ; 0,39 ; 0,39)

Table 4. Aggregation results Source: Author's elaboration

From the aggregations, the score per expert was obtained and his qualitative evaluation for the analysis of the topic, taking into account the intervals of score by categories of evaluation determined previously, as shown in table 5.

expert	level of knowledge on the subject	
	Score	***Evaluation***
1	1,85	MH
2	2,231844896	VH
3	1,755084364	MH
4	0,944785412	L
5	2,590283946	VVH
6	0,764081225	VL
7	2,15	H
8	1,85	MH
9	1,15	ML
10	1,397605594	M
11	1,397605594	M
12	1,402835157	M
13	2,254240204	VH

14	1,615489831	M
15	1,85	MH
16	2,373419178	VH
17	1,397605594	M
18	2,640836424	VVH
19	0,64415305	VL
20	1,94975318	H
21	2,069363957	H
22	1,615489831	M
23	0,64415305	VL
24	2,590283946	VVH
25	2,15	H
26	2,373419178	VH
27	1,928322722	H
28	2,314129843	VH
29	2,069363957	H
30	1,755084364	MH

Table 5. Qualitative evaluations of the level of knowledge of the experts in the subject according to score. Source: Author's elaboration

Finally, the experts with "Very Very High" and "Very High" level of knowledge were selected, for a total of eight experts.

The results of the application of the survey to these eight experts were as follows (figure 3):

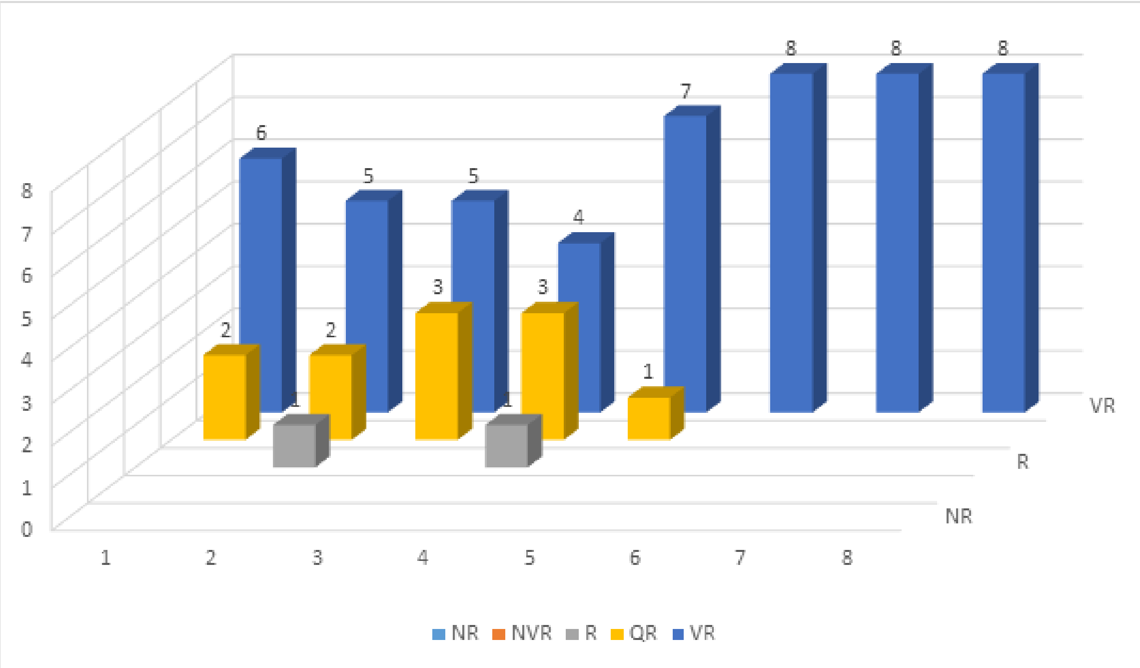

Figure 3. Results of expert survey application (absolute frequency). Source: Authors' elaboration

The majority score for each category to be evaluated was "Very relevant", being this total in questions 6, 7 and 8, while in questions 1 to 5 some scores were also obtained as "Relevant" and "Quite relevant", but in a smaller proportion.

When analyzing the image of the relative frequencies, the respective cut-off points and the N-P values (table 6), of each analyzed category, we found that all are in the range of "Very Relevant".

CRITERIA	Image of the relative cumulative frequencies						
	NR	NVR	R	QR	VR	Average	N-P
1	-3,500	-3,500	-3,500	-0,674	3,500	-1,535	-0,072
2	-3,500	-3,500	-1,150	-0,319	3,500	-0,994	-0,613
3	-3,500	-3,500	-3,500	-0,319	3,500	-1,464	-0,143
4	-3,500	-3,500	-1,150	0,000	3,500	-0,930	-0,677
5	-3,500	-3,500	-3,500	-1,150	3,500	-1,630	0,023
6	-3,500	-3,500	-3,500	-3,500	3,500	-2,100	0,493
7	-3,500	-3,500	-3,500	-3,500	3,500	-2,100	0,493
8	-3,500	-3,500	-3,500	-3,500	3,500	-2,100	0,493
Cut-off Points	-3,500	-3,500	-2,913	-1,620	3,500	-1,607	

Table 6. Images by the Standard Inverse Normal Curve, Cut-off Points, and N-P values Source: Author's elaboration

We then can conclude that the evaluations provided by the members of the panel of experts validate the proposal of the Municipal Ordinance Project of the Centers of Tolerance of the canton of Tulcan.

Conclusions

In this paper the use of expert criteria to validate the application of the proposed project in the city of Tulcan, Ecuador is presented. For the selection of the experts, we made use of single value neutrosophic sets (SVNS) associated to linguistic variables. The use of Neutrosophy for the selection of experts, allowed a more accurate evaluation of them in terms of the level of knowledge in the topic addressed, by making a detailed qualitative self-assessment of their levels of theoretical and practical knowledge and taking into account the weight they gave to these two levels.

The Project of Municipal Ordinance of the Centers of Tolerance of the canton of Tulcan presented was validated with a qualification of "Very relevant" in all the evaluated criteria.

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Neutrosophic Analytic Hierarchy Process for the Control of the Economic Resources Assigned as Alimony

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Abstract: Currently, the right to food for children and adolescents is constituted as the duty imposed and recognized by the Law to provide the necessary resources for integrity protection. The control of the economic resources assigned as alimony represents a sensitive task to be insured by The State. This investigation proposes a solution to the posed problem through the implementation of a method for the control of the economic resources assigned as alimony. The method we recommend operates through a multicriteria approach with the use of the Neutrosophic Analytic Hierarchy Process.

Keywords: Alimony; Neutrosophy; Neutrosophic Analytic Hierarchy Process; Control of economic resources.

1. Introduction

The right to food is focused on the protection and guarantee of rights. It is established by the current Organic Code for Children and Adolescents. It is convenient to highlight the intimate relationship between the right to food and the right to life, and the development of children and adolescents [1], [2], [3]. The Organic Code of Children and Adolescents states in its Article 1: “the integral protection that The State, society and the family must guarantee to all children and adolescents living in Ecuador, in order to achieve their integral development and the full enjoyment of their rights, within a framework of freedom, dignity and equity” [4], [5].

The State sets an alimony that allows the subsistence of the children and adapts to the reality of economic income [6], [7], [8]. The problem lies in the absence of a rule that regulates the use of the money given as alimony. Sometimes, the person in charge of the care and protection of the child or adolescent uses this resource in expenses that do not correspond to the essence of the alimony, letting aside priority needs of the child or adolescent [9], [10].The control of the economic resources assigned as alimony represents a social problem to solve.

In the 1980s, the international movement called Paradoxism [11], based on the occurrence of contradictions in science and literature, was founded by Smarandache, who then extended it to Neutrosophy, based on contradictions and their neutrals. Using this approach, new extension to classical decision methods have been proposed such as the Neutrosophic Analytic Hierarchy Process (NAHP) [12, 13].

In this research, we develop a method for the control of the economic resources assigned as alimony through a multi-criteria approach with the use of the NAHP. This method allows us to rank four criteria according to four experts’ assessments.

This paper has the following structure: section 2 contains the main concepts of Neutrosophy, section 3 describes the NAHP technique and the procedure we will follow to make the decision. In section 4 we make the calculus. At the end, we present the conclusion.

2. Preliminaries

This section makes an approximation of the main concepts associated with the problem domain. In addition, we describe the different concepts that facilitate the understanding of the research. We also make a description of the food rights of girls, boys and adolescents in Ecuador. The Neutrosophic Analytic Hierarchy Process is appropriate to represent uncertainty in decision-making problems.

2.1 The Food Law of children and adolescents in Ecuador.

The non-existence of a regulation to control the economic resources assigned as alimony, is opposed to the best interests of the child typified in article 11 of the Organic Code of Children and Adolescents [14], [15].

The legal duty to provide food in Ecuador has been introduced many years ago, and at the moment in the Constitution of the Republic it is mentioned in its article 11, numeral 9 that the highest duty of The State is to respect and enforce the rights enshrined in the Constitution [16], [17]. In accordance with this provision, it must be understood that the main duty of The State is to ensure respect for all rights, especially those in which priority care groups such as children and adolescents are involved. Those rights are in full accordance with the provisions of article 44 of the Constitution of the Republic of Ecuador that declares: “The State, society and the family will promote as a priority the integral development of children and adolescents, and will ensure the full exercise of their rights; the principle of their best interests will be met and their rights will prevail over that of other people”.

2.2 The Neutrosophic Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was proposed by Thomas Saaty in 1980 [18]. It is one of the most widespread methods to solve multi-criteria decision-making problems.

This technique models the problem that leads to the establishment of a hierarchy representative of the associated decision-making scheme [19, 20]. This hierarchy presents, at the upper level, the goal pursued in solving the problem and, at the lower level, the different alternatives from which a decision must be taken. The intermediate levels detail the set of criteria and attributes considered [21], [22].

AHP is a method that selects alternatives based on a series of criteria or hierarchical variables, which usually have contradictions between them. In this hierarchical structure, the final objective is at the highest level, and the criteria and sub-criteria at the lower levels. Figure 1 shows the hierarchical structure of AHP [23], [24].

In a typical hierarchy the highest level locates the decision making problem. The elements that affect decision-making are represented at the intermediate level. At the lowest level appear the decision options or alternatives [25], [26], [27].

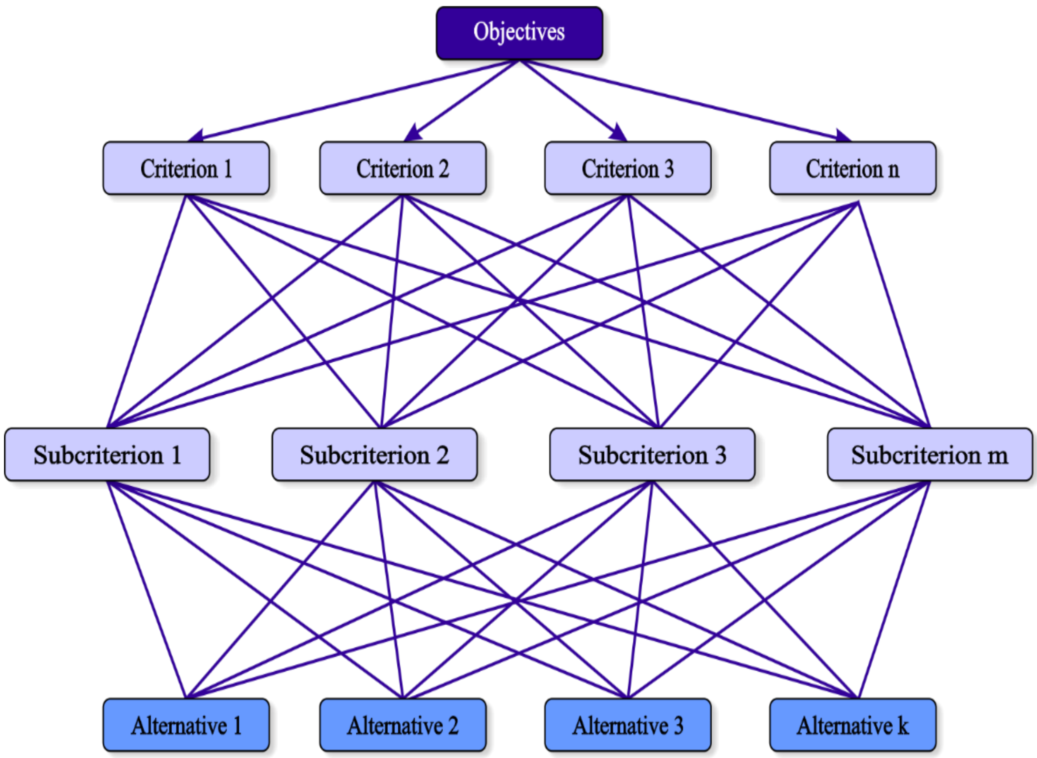

Figure 1. Scheme of a generic tree representing an Analytic Hierarchy Process.

Once the hierarchical structure is defined, the criteria of each group of the same hierarchical level are compared and the direct pairwise comparison of the alternatives with respect to the criteria of the lower level. For this, we used pairwise comparison matrices with a Fundamental Scale [28].

The comparison of the different alternatives with respect to the criteria of the lower level of the hierarchical structure, such as the comparison of the different criteria of the same hierarchical level generates a square matrix, known as the decision matrix.

The Neutrosophic Analytic Hierarchy Process (NAHP) extends the AHP method to a neutrosophic environment [12]. Neutrosophic set does not only mean truth-membership and falsehood-membership but also considers indeterminacy which is very common in real life situations like the control of the economic resources assigned as alimony[13]. This method is based on the Single-Valued Neutrosophic (SVNN) number, the main definitions on Neutrosophy related to this concept are given below:

Definition 1 [29]: 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]. $^-0$ and 1^+ belong to the set of hyper-real numbers.

Definition 2 [30],[20]: 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 $F_A: U \to [0, 1]$. $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

The Single Valued Neutrosophic (SVN) number 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]): 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 falsehood membership functions are defined as follows:

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

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

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

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

Definition 3 [32]: 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:

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

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

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 $a_1, a_2, a_3 \neq 0$.

Multiplication by a scalar number:

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

Division of two triangular neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \left\langle \left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \right\rangle, a_3 > 0 \ \ and \ \ b_3 > 0 \\ \left\langle \left(\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \right\rangle, a_3 < 0 \ \ and \ \ b_3 > 0 \\ \left\langle \left(\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \right\rangle, a_3 < 0 \ \ and \ \ b_3 < 0 \end{cases}$$

Multiplication of two triangular neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1b_1, a_2b_2, a_3b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 > 0 \ \ and \ \ b_3 > 0 \\ \langle (a_1b_3, a_2b_2, a_3b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 < 0 \ \ and \ \ b_3 > 0 \\ \langle (a_3b_3, a_2b_2, a_1b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 < 0 \ \ and \ \ b_3 < 0 \end{cases}$$

Where $\wedge$ is a t-norm and $\vee$ is a t-conorm.

3. Proposal of a method for the control of the economic resources assigned as alimony

The method is structured in three stages: input, processing and output of information. The input stage feeds the method selection criteria, subsequently; in the processing stage the multi-criteria evaluation is implemented. The output stage visualizes the inference proposed by the method as a result of the evaluation process. The method operates based on a Neutrosophic Analytic Hierarchy Process. Figure 2 shows the general structure of the proposed method.

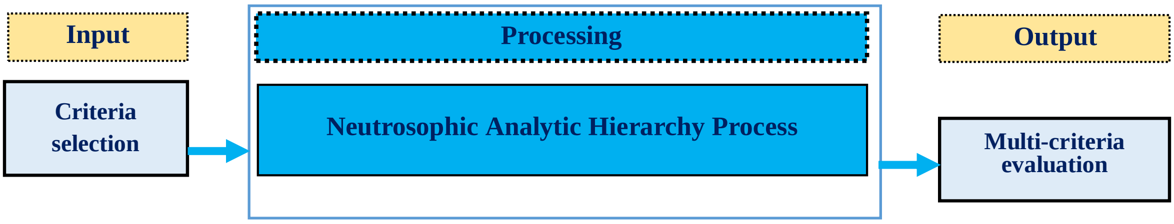

Figure 2. General structure of the proposed method.

Once the evaluation criteria have been identified, the method performs a process of comparison between criteria[33], [33]. The levels of importance or weights associated with each criteria are established [34-36]. They are estimated by means of pairwise comparisons between each criterion. This comparison is carried out using a scale, as expressed by the equation (1) [37], [38].

$$S = \left\{\frac{1}{9}, \frac{1}{8}, \frac{1}{7}, \frac{1}{6}, \frac{1}{5}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, 1,2,3,4,5,6,7,8,9\right\} \tag{1}$$

In the case of n attributes, the pairwise comparison of the element i with the element j is placed in the aij position of the matrix A of pairwise comparisons, as shown in equation (2).

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \tag{2}$$

The reciprocal values of these comparisons are obtained from the comparison process [39]. The values obtained are placed in the a_{ji} position of A, in order to preserve the consistency of the judgment [40-42]. The decision process must compare the relative importance of an element with respect to a second, using the 9 point scale shown in table 1.

Matrix $\tilde{A}$ must satisfy the condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, based on the operator of aggregation for converting neutrosophic triangular numbers into crisp numbers, there are two indexes defined in [43], they are the so-called score and accuracy indexes, respectively, see Equations 5 and 6:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{3}$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \tag{4}$$

For item 1 that was rated with strong dominance over item 2, this relationship is expressed as a result in position a_{12}, by placing a 5 in that position and reciprocally in a_{21} we placed a 1/5.

Saaty 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	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$ $\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$ $\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$ $\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

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

On the other hand, Saaty established that Consistency Index (CI) should depend on λmax, the maximum Eigenvalue of the matrix. He defined the equation

$$\mathrm{CI} = \frac{\lambda_{\max} - \mathrm{n}}{\mathrm{n} - 1} \quad (5)$$

where n is the order of the matrix. Additionally, he defined the Consistency Ratio (CR) through equation CR = CI/RI, where RI is given in Table 2.

.

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

Table 2. RI associated to every order

If CR≤0.1 we can consider that experts' evaluation is sufficiently consistent and hence we can proceed to use AHP [44-46].

AHP aims to score criteria, sub-criteria and alternatives, and to rank every alternative according to these scores [33, 47]. For more details about this technique [27], [34], [36] can be consulted.

AHP can also be used in group assessment. In such a case, the final value is calculated by the weighted geometric mean, see Equations 5 and 6.

$$\bar{\mathrm{x}} = \left(\prod_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{x}_{\mathrm{i}}^{\mathrm{w}_{\mathrm{i}}}\right)^{1/\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{w}_{\mathrm{i}}} \quad (6)$$

If expert's weights sum up one, i.e. $\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{w}_{\mathrm{i}} = 1$., Equation 5 converts to Equation 6,

$$\bar{\mathrm{x}} = \prod_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{x}_{\mathrm{i}}^{\mathrm{w}_{\mathrm{i}}} \quad (7)$$

4. Implementation of the method for the control of the economic resources assigned as alimony

The main elements on which the implementation is based are described below.

To obtain the information, the proposed method uses a multi-expert multi-criteria approach.

In this step, the group of experts involved in the decision-making problem participates as defined below:

$E = \{e_1, e_2, e_3, e_4\}$

The set of criteria that characterize the control of the economic resources assigned as alimony in the decision-making problem is identified so that:

$C = \{c_1, c_2, .., c_m\}, m \geq 2, \forall c_m \notin \emptyset, 1 \leq m \leq i$

As a result, the proposed evaluation criteria are:

c_1: The sustenance is guaranteed in favor of the pensioner.

c_2: Minimum accommodation conditions are guaranteed.

c_3: At least socially appropriate clothing is guaranteed.

c_4: An adequate education is guaranteed.

The evaluation process is described below:

The four matrices are obtained in pairs corresponding to the criteria of each expert who intervened in the process. The matrices obtained are summarized in Tables 3, 4, 5 and 6. Note that the values are expressed in correspondence with the scale given in Table 1, using linguistic values. We make reference to the number assigned to the criterion and not to the description in words.

Criteria	c_1	c_2	c_3	c_4
c_1	$\tilde{1}$	$\tilde{3}$	$\tilde{5}$	$\tilde{5}$
c_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$
c_3	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{2}$
c_4	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$

Table 3. Matrix resulting from the comparison of the criteria given by expert e_1.

The weight vector of the criteria is:

$$W_F = \begin{bmatrix} 0.554805 \\ 0.240180 \\ 0.117195 \\ 0.087820 \end{bmatrix}$$

Where CR = 0.016680.

Criteria	c_1	c_2	c_3	c_4
c_1	$\tilde{1}$	$\tilde{3}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$
c_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{9}^{-1}$	$\tilde{9}^{-1}$
c_3	$\tilde{7}$	$\tilde{9}$	$\tilde{1}$	$\tilde{2}^{-1}$
c_4	$\tilde{5}$	$\tilde{9}$	$\tilde{2}$	$\tilde{1}$

Table 4. Matrix resulting from the comparison of the criteria given by expert e_2.

The weight vector of the criteria is:

$$W_F = \begin{bmatrix} 0.080247 \\ 0.038968 \\ 0.399124 \\ 0.481660 \end{bmatrix}.$$

Where CR = 0.039495.

Criteria	c_1	c_2	c_3	c_4
c_1	$\tilde{1}$	$\tilde{3}$	$\tilde{2}$	$\tilde{5}^{-1}$
c_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{5}^{-1}$
c_3	$\tilde{2}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{7}^{-1}$
c_4	$\tilde{5}$	$\tilde{5}$	$\tilde{7}$	$\tilde{1}$

Table 5. Matrix resulting from the comparison of the criteria given by expert e_3.

The weight vector of the criteria is defined as:

$$W_F = \begin{bmatrix} 0.167695 \\ 0.120590 \\ 0.071251 \\ 0.640464 \end{bmatrix}$$

Where CR = 0.069705.

Criteria	c_1	c_2	c_3	c_4
c_1	$\tilde{1}$	$\tilde{4}$	$\tilde{2}$	$\tilde{4}$
c_2	$\tilde{4}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$
c_3	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$
c_4	$\tilde{4}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$

Table 6. Matrix resulting from the comparison of the criteria given by expert e_4.

The weight vector of the criteria is:

$$\bar{W}_F = \begin{bmatrix} 0.32187 \\ 0.16259 \\ 0.20867 \\ 0.30688 \end{bmatrix}$$

Table 5 summarizes the priority vector of the four criteria by using the geometric mean with weights w_i = ¼, see Equation 10, and later it was normalized. The results are shown in Table 7.

Criterion	priority vector	Ranking
c_1	0.32187	1
c_2	0.16259	4
c_3	0.20867	3
c_4	0.30688	2

Table 7. Criteria priority vectors and final order.

According to the results shown in Table 7, the criteria are ordered by priority level as follows: $c_1 \succ c_4 \succ c_2 \succ c_3$. This means that the highest incidence is represented by the criterion “The sustenance is guaranteed in favor of the pensioner”.

Conclusions

This investigation evaluated the control of the economic resources assigned as alimony. The research used the Neutrosophic Analytic Hierarchy Process technique. A group decision process approach is developed using mean as aggregation operator of individual assessments.

The research was applied for the evaluation of the control of the economic resources assigned as alimony. Criteria are prioritized and sorted based on group evaluation who determined to give more importance to “The sustenance is guaranteed in favor of the pensioner”. Future work will concentrate on developing a consensus process and using linguistic information based on 2-tuples representation. The obtained result is useful for improving the performance of the assignment of alimony. To model with NAHP allowed us to include the indeterminacy, which is typical in every decision-making.

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Analysis of Crimonogenic Factors in Femicide Crimes

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Abstract. Femicide in Ecuador is one of the cruelest manifestations of power exercised over women. Actions have been executed, but they are still insufficient. Therefore, it is necessary to study the factors that cause its high level of incidence. By doing so, we intend to provide the government with a tool that makes it possible to focus some measures in order to reduce and/or eradicate it. The objective of this research is to analyze these factors through neutrosophic cognitive maps. This technique is chosen because of the advantages it offers compared to other soft-computing techniques, in terms of interpretability, scalability, aggregation of knowledge, dynamism and its ability to represent feed-back and indeterminacy relationships. This way, decision-making by the government will be facilitated by hierarchizing the incidence factors, launching new strategies to eradicate femicide and to protect the right to life.

Keywords: femicide; factors; hierarchization and interrelation; neutrosophic cognitive maps

1 Introduction

Femicide in Ecuador is one of the cruelest manifestations of power exercised over women. For decades, violence against women has been a totally imperceptible problem for society, a product of machismo, supported by inequality and inequity regarding women in the everyday world. Discrimination against women has placed her as a simple object of control and submission to men. This subordination is attributed to gender relations, where the roles of men and women are played according to the social construct of each society [1-3].

It is necessary to clarify that in this investigation, the subject of femicide will be addressed because, although it is related to feminicide, the first one is defined by [2] in page 7 as follows: "*Femicide* seeks to denounce the violent death of a woman because of her condition as a woman and demand that these deaths be stopped". As shown in figure 1.

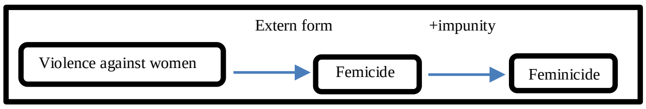

Figure 1. Process of delimitation and relation of the concepts femicide/feminicide. Source:[2]

It is a current problem that affects society, since it is stated that approximately 600 children and young people between 2014 and 2019 have been orphaned due to this act, where the right to life is deprived, just because of being a woman. Likewise, about 625 women died from this form of sexist violence in the same date interval.[4, 5]. From March 12 to May 20 at the national level, Ecu911 has reckoned 17,964 cases, about 257 per day. The Judiciary has attended 2,469 cases of violence against women nationwide between March-May 2020, about 41 hearings were held every day[1, 6, 7].

Therefore, given the increasing frequency of this social problem, the state is obliged to protect the life of women. Actions against the establishment of the human rights of Ecuadorian women such as the right to life and the philosophy of Good Living. Certain measures have been established, such as the creation of the Integral Organic Criminal Code (IOCC) and the Integral Organic Law for the Prevention and Eradication of Gender Violence Against Women, both in response to protests initiated by various women's movements. But they are still insufficient, therefore, the Ecuadorian State must improve its legal framework [4, 8-12] based on accurate studies of the phenomenon, so that these measures respond to core problems.

It is a problem that has been accepted by society and classified as normal, which is characterized by the invisibility of its presence in couples' relationships throughout history. According to statistics carried out by the National Institute of Statistics and Censuses, in its first survey on gender violence in Ecuador, it indicates that 60.6% of Ecuadorian women have experienced some type of violence without differences between rural or urban areas[2, 3]. In addition, it has been proposed that for the analysis of the phenomenon, it is important to take into account that the aggressor might be or not of the same gender, as well as those indirectly affected by the aggression, like: parents, children, siblings, relatives[13].

Due to the incidence of several factors, we decided to carry out a review of the literature and then we extracted the following statements that constitute the main characteristics of the factors. [2-5, 10, 13, 14]:

- They refer to them as risk factors or factors that favor victimization, which are nothing more than the conditions that favor the act or make it susceptible to its occurrence.
- Most of them are classified into endogenous and exogenous factors (classification that will be used in this investigation to achieve a better interpretation of the analyzed phenomenon), but others prefer to classify them as temporary or permanent or according to their predispositions (bio-physiological, social and psychological).
- The victim-causing factor should not be confused with a victim-causing cause, because the factor is something that favors victimization, while the cause is what produces victimization.
- Endogenous factors: factors of the individual inherent to the person, the best known are those of a biological nature that make a person prone to being the victim of an attack (age, ethnicity, weakness, disease, disability). In this regard, the following are vitally important:
  - Age, since there is a predisposition to crime and related punishments, for example: in the crime of rape there are ages where this crime is more frequent, but there are other rates in which a number of ages with a lower proportion of the same act is registered.
  - Ethnicity: it is taken into consideration when the crime typology is violent or urban in nature, where behind the aggression there is usually a xenophobic motive. These factors bring together subjective considerations.
  - Psychological and psychiatric factors, this includes assumptions such as depression, phobias, etc., although some authors include the alcoholism of the victim with a factor under consideration. The volitional sphere is included (refers to the will), for example, in the crime of domestic violence, people who are especially vulnerable and identified as victims are: women, children and the elderly, this has been determined according to statistical studies of victimization based on complaints.
  - Another factor is the cognitive one, it refers to the fact that there is a minorization in the mental processes, this leads to the individual being more easily victimized, for example a person with hearing impairment or reduced attention span and especially when the intelligence and memory are limited, such as people with oligophrenia.
  - Exogenous factors: those that are outside the individual and are changing (marital status, economic level, origin, profession, victim space and time, schooling, family, social status, etc.). The most relevant ones are explained below:
  - Marital status: refers to whether the victim is single, married, widowed, separated, divorced, etc.
  - Economic level: interesting both by excess and by default according to the criminal typology, it is a factor that in practice frequently occurs.
  - Provenance: basically refers to whether the victim is national or foreign.
  - The profession: there are certain groups that are more likely to be victims, for example: taxi drivers, gas station employees, prostitutes, etc.).
  - Victim space and time: all victimization takes place in a specific space and time. There are certain areas more criminogenic than others and certain time intervals, according to hours, weather conditions, seasons of the year, etc., in which there is a greater risk of being victimized.
  - "Victim time": refers to the seasons of the year. In spring, there are more sexual assaults, while in summer and on vacations, mistreatment towards the love partner increases, etc.
  - Schooling: basically refers to whether the victim is in school or not and, if so, what level.
  - The family: refers to whether it is structured or not.

It is important to highlight that in the case of endogenous factors, learning plays an essential role in victim prevention, that is, the best way to prevent crime is to act directly on the victim. In criminology the theory of opportunity is described, it basically states that for the crime to be generated, there must be three elements, first, there must be a predisposed criminal, second, there must be a suitable victim and third there must be an absence of control, when these three elements occur, the crime is automatically generated. Therefore, preventing crime is complicated, because the subject is free to act, it is the subject who decides the time and place (how, where and when); what can be done is to act promoting preventive measures. In cases of absence of control, some measures can be taken, such as: installing security cameras.

Based on the foregoing, it can be said that there is a need to study the factors that affect acts of femicide in Ecuador. Once their incidence and characterization have been determined, measures can be taken aimed at reducing and/or eradicating the phenomenon. The aforementioned is based on the idea that, if the factors that affect the problem are determined and a negative impact hierarchy is presented, strategies may be proposed to the State of Ecuador in order to favor the non-occurrence of femicide in the country. According to this approach, it is essential to study the situation using comprehensive strategic analysis techniques endorsed in compatible mathematical techniques to fulfill the objective set.

After a review of the bibliography and consultation of several authors [15-30], it is decided that, due to its versatility in factor research, the neutrosophic cognitive maps will be chosen from the theory of Neutrosophy proposed by Florentin Smarandache, for the treatment of neutralities, which generalizes theories [29, 31], of number of its applications in many fields[31-33]. In this case, sharp sets, where the indeterminacies have support. Neutrosophy is a useful theory that is increasing. The inclusion of this theory enriches the possibilities of the analysis, mainly due to two reasons: firstly, the addition of the notion of indeterminacy and, secondly, the possibility of calculating using linguistic terms [15, 23, 34-37].

The decision to apply the neutrosophic cognitive maps for this analysis lies in the fact that it is a way of representing knowledge through a directed graph. Each vertex of the graph represents a concept and each edge the causal relationship between the concepts represented by the vertices that it connects. Additionally, each edge is associated with a real value in the interval (-1, 1), where a negative value means that there is an inverse relationship between the concepts and a positive value means that the relationship is direct. The value measures the strength of the relationship. This method has been used successfully in social studies [15, 17-23, 25-27, 29, 30, 38-41]. In this article, Neutrosophic Cognitive Maps (NCMs) are applied to represent the causal relationships between the causal factors of femicide [25, 26, 42-44]. This way, the following are set out as specific objectives to be developed in this paper:

1. Determine and characterize the factors that influence the occurrence of femicide in Ecuador.
2. Model the current situation of factors in Ecuador using the neutrosophic cognitive maps.
3. Propose strategies based on the results of the study.

Based on the above-mentioned, this document is structured as follows: a second section where the basic concepts necessary to achieve the solution of this problem are briefly described; a third section to expose the results of the application of neutrosophic cognitive maps in the solution of the studied problem. Finally, we present the conclusions reached after executing the analysis and the bibliographic references of the consulted sources.

2 Materials and methods

To fulfill the proposed specific objectives, it was necessary to apply the following theoretical methods for the elaboration of this paper:

- Analysis and synthesis of the information obtained from the literature review, both international and national, of specialized documentation, as well as the experience of observers and actors consulted to develop logical and valid conclusions, as well as a set of premises and/or positions generated by relevant actors within the social system, ethnic groups and their incursion into work.
- Systemic - structural for the development of the analysis through its decomposition into the elements that comprise it.
- Hermeneutic to carry out a comparative interpretation of the legislation applicable to the subject in question.

In this particular investigation, the use of Neutrosophic Cognitive Maps (NCMs) is proposed considering the advantages that this technique offers compared to other soft-computing techniques, in terms of interpretability, scalability, aggregation of knowledge, dynamism and its ability to represent feedback and indeterminacy relationships [30, 45-47]. NCMs were introduced by [48] in 2003. NCMs is an integration of the Fuzzy Cognitive Maps (FCMs) introduced by Kosko in 1986 and the Neutrosophic Sets (NSs) introduced by Smarandache in 1995 [15]. 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. [15] exposes that FCMs constitute a technique that has received increasing attention due to its possibilities for representing causality. The following is a set of definitions necessary for working with NCMs. Firstly, let formally expose the original definition of neutrosophic logic as it is shown in [25].

Definition 1. Let N =[15, 18, 20-26, 29, 30] [22] be a neutrosophic set of evaluation. v: P→N is a mapping of a group of propositional formulas into N, i.e., each sentence p∈ ***P*** is associated to a value in N, as it is exposed in Equation 1, meaning that p is T% true, I% indeterminate and F% false.

$\mathrm{v}\,(\mathrm{p}) = (\mathrm{T}, \mathrm{I}, \mathrm{F})$ (1)

Hence, the neutrosophic logic is a generalization of fuzzy logic, based on the concept of Neutrosophy according to [24, 29].

Definition 2. (See[22, 23]) Let K be the ring of real numbers. The ring generated by K∪I is called a neutrosophic ring if it involves the indeterminacy factor 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∪I, i.e., 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 aij∈K (I), where K (I) is a neutrosophic ring, see [26].

Let us observe that an element of the matrix can have the form a + bI, where “a” and “b” are real numbers, whereas I is the indeterminacy factor. The usual operations of neutrosophic matrices can be extended from the classical matrix operations.

For example, $\begin{pmatrix} -1 & \mathrm{I} & 5\mathrm{I} \\ \mathrm{I} & 4 & 7 \end{pmatrix}\begin{pmatrix} \mathrm{I} & 9\mathrm{I} & 6 \\ 0 & \mathrm{I} & 0 \\ -4 & 7 & 5 \end{pmatrix} = \begin{pmatrix} -21\mathrm{I} & 27\mathrm{I} & -6+25\mathrm{I} \\ -28+\mathrm{I} & 49+13\mathrm{I} & 35+6\mathrm{I} \end{pmatrix}$

Additionally, a *neutrosophic graph* is a graph that has at least one indeterminate edge or one indeterminate node [20, 25]. The neutrosophic adjacency matrix is an extension of the adjacency matrix in classical graph theory. aij = 0 means nodes i and j are not connected, aij = 1 means that these nodes are connected and aij = I, that means the connection is indeterminate (unknown if it is or if not). Fuzzy set theory does not use such notions.

On the other hand, if the indetermination is introduced in a cognitive map as it is referred in [19], then this cognitive map is called a neutrosophic cognitive map, which is especially useful in the representation of causal knowledge [18, 29]. It is formally defined in Definition 4.

Definition 4. A Neutrosophic Cognitive Map (NCM) is a neutrosophic directed graph with concepts like policies, events, among others, as nodes and causalities or indeterminate ones 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 [19]:

- Outdegree (v_i) is the sum of the row elements in the neutrosophic adjacency matrix. It reflects the strength of the outgoing relationships (c_{ij}) of the variable.

$od(v_i) = \sum_{i=1}^{n} c_{ij}$ (2)

- Indegree (v_i) is the sum of the column elements. It reflects the strength of relations (c_{ij}) outgoing from the variable.

$id(v_i) = \sum_{i=1}^{n} c_{ji}$ (3)

- Total centrality (total degree $td\ (vi)$), is the sum of the indegree and the outdegree of the variable.

$td(v_i) = od(v_i) + id(v_i)$ (4)

Static analysis is applied using the adjacency matrix, taking into consideration the absolute value of the weights [20]. Static analysis in Neutrosophic Cognitive Maps (NCM), see [18], initially contains the neutrosophic number of the form (a + bI, where I = indetermination) [17]. It requires a process of de-neutrosophication as proposed in [19], where I ∈ [0, 1] and it is replaced by their values maximum and minimum.

Finally, we work with the average of the extreme values, which is calculated using Equation 5, which is useful to obtain a single value as it is referred in [16]. This value contributes to the identification of the characteristics to be attended, according to the factors obtained, for our case study.

$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2}$ (5)

Then,

$A \succ B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2}$ (6)

Finally, the variables are classified according to the following criteria:

a) *Transmitting variables* are those with $\mathrm{od}(\mathrm{v_i}) > 0$ and $\mathrm{id}(\mathrm{v_i}) = 0$.
b) *Receiving variables* are those with $\mathrm{od}(\mathrm{v_i}) = 0$ and $\mathrm{id}(\mathrm{v_i}) > 0$.
c) *Ordinary variables* satisfy at the same time $\mathrm{od}(\mathrm{v_i}) \neq 0$ and $\mathrm{id}(\mathrm{v_i}) \neq 0$.

3 Results

Once the state of the art of the studied elements has been analyzed, we proceed to the extraction of potential factors (variables) applying the following process approach, which is present in each of the specific objectives determined in the introduction and which are listed in this part as sub-headings:

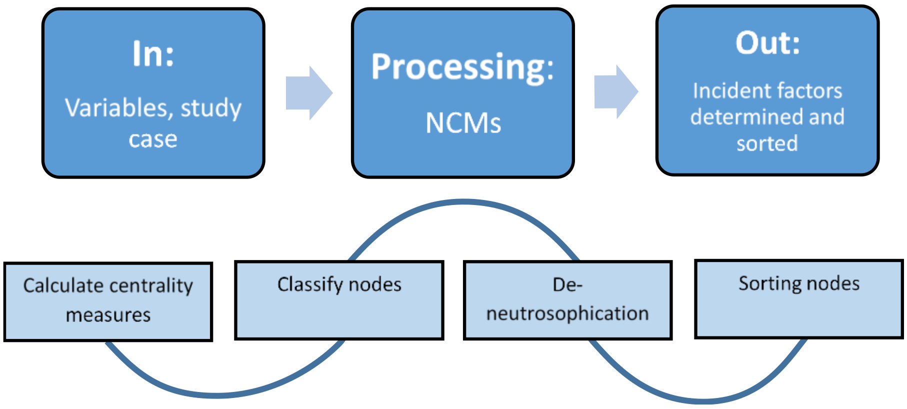

Figure 2. Information processing with NCMs. Source: self-made.

3.1. Factors that influence the occurrence of femicide in Ecuador:

A. Physical state of the victim (includes age): there is generally a predominance of physically defenseless people or people who do not put up significant resistance to the aggression. The number of underage girls raped and murdered by their stepfathers due to similar causes is increasing. Statistical studies register that the age range in women where there is a greater probability of being victims is between 31 and 40 years old and in second place between 35 and 20 years, so that the highest rate is centered on 35 years. Today during the COVID-19 quarantine, there is an increase in girls raped and murdered.

B. Ethnicity-Environment: there is a predominance of the victimization index in urban and suburban areas.

C. Personal living conditions: in this aspect the family environment, the power relationship, economic conditions, level of education were included. This scourge is more prevalent where there is economic dependence on women, lack of family financial support and social isolation. In the field of social, public, political and private life exercised by couples, families, co-workers, and different forms of socio-individual interaction, in social life under subordination exercised towards women, incest, etc. There is an increase in the number of cases where the victims are married or accompanied under consensual unions not formally legalized where there is a presumption of adultery or bigamy, as well as dysfunctional families with intrafamily violence even in the children.

D. Profession: a low incidence is defined in economically independent women with the occupation of a socially relevant job. In general, this type of women invests in their personal security and shows dominant traits of low susceptibility to victimization.

E. Cognitive factors: belief of endless love or feelings of infatuation, emotional dependence, excessive fear of partner abandonment, attributional errors, post-traumatic disorder, depression, feelings of helplessness and hopelessness, use of violence with children, low perception of risk. Personality with a high level of introversion and introspection, manipulable and dependent. Many are already victims of previous attacks, of various kinds and origins. The perpetrator often induces self-flagellation.

F. Strength of the legislation and advice: there is a gradual increase in complaints since the previous five-year period due to the strengthening of the legislation, the information and support of assistance from the state to the victims this helps to increase the complaints. Because there is increasing social awareness regarding this crime. In April, the website of the Prosecutor's Office was enabled to report these attacks online. At the national level, 164 judicial units are currently enabled to hear cases. In that city they attend under telephone call modality, meaning that, when there is a flagrancy, the Prosecutor's Office contacts the person in charge of the unit and immediately enables attention.

3.2. Modeling of femicide factors using neutrosophic cognitive maps.

They will be called variables/factors to facilitate their processing and will be denoted according to the letter that identifies them in 3.1 (A, B, C, D, E, F). They will be subjected to a group to the criteria of a group of experts that will evaluate the causal relationships between the eight previous variables with linguistic terms equivalent to neutrosophic numbers. For its representation in the NCM, an average of the evaluations of the experts was used. From them, a neutrosophic adjacency matrix[49] and the graph that represents it was obtained, where the indeterminacies are highlighted:

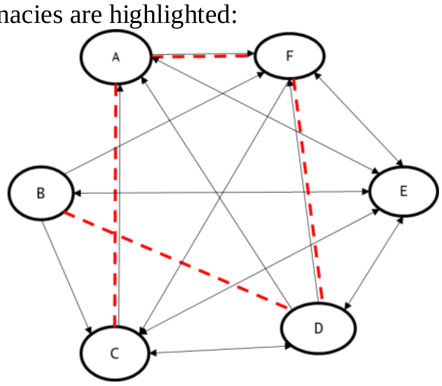

Figure 3. NCMs. Source: self made

	A	B	C	D	E	F
A	0	I	0.5 + I	0	1	0.6 + I
B	0	0	0.4	0	0.7	0.3
C	1	0	0	0.9	1	0
D	0.3	I	0.9	0	1	0.8
E	1	1	1	1	0	1
F	0.8	0	0.8	I	0.9	0

Table 1. Neutrosophic Adjacency Matrix. Source: self made

	A	B	C	D	E	F
A	0	0	0.108696	0	0.217391	0.1304348
B	0	0	0.086957	0	0.152174	0.0652174
C	0.21739	0	0	0.195652	0.217391	0
D	0.06522	0	0.195652	0	0.217391	0.173913
E	0.21739	0.217391	0.217391	0.217391	0	0.2173913
F	0.17391	0	0.173913	0	0.195652	0

Table 2. De-neutrosophication of the Matrix. Source: self made

Table 3 contains the Outdegree, Indegree, Total Degree and classification values of each variable according to the application of the formulas set forth in Definition 4 of section 2 of this paper.

Factors	Outdegree	Indegree	Total Degree	Classification
A	0.45652174	0.673913	1.130434783	Ordinary
B	0.30434783	0.2173913	0.52173913	Ordinary
C	0.63043478	0.7826087	1.413043478	Ordinary
D	0.65217391	0.4130435	1.065217391	Ordinary
E	1,08695652	1	2,086956522	Ordinary
F	0.54347826	0.5869565	1.130434783	Ordinary

Table 3. Outdegree, indegree, total degree values by factors and their classification. Source: self made

From the calculation carried out, it can be said that:

- There are indeterminate relationships, of which its level of influence cannot be specified, but it is stated that in general the established relationships are positive, so they are directly proportional to each other.
- The variables, when classified as ordinary, have a double relationship and according to what is stated in figure 3, this relationship is directly proportional. Although some of them do not show interrelationships with the others such as A and B, as shown by their centrality index.
- The factors are ranked as follows:
  - E Cognitive factors
  - C Personal living conditions
  - A Physical state of the victim (includes age)
  - F Strength of legislation and advice
  - D Profession
  - B Ethnicity-Environment
- Provenance is not a serious problem to be analyzed, since its causal influence or dependence on the rest of the factors was not verified.
- It can be verified the fact that, if there is a policy of criminal punishment and strong methods of reporting and counseling, they can be largely avoided, since mothers and relatives will be advised and protected by law. As with the strengthening of punishments, the perpetrators will be judged, with the “burden” of their action falling on them.

3.3. Propose strategies based on the results of the study.

- Consider conducting psychological evaluations with the help of social workers, support groups in the most affected communities
- Implement rigorous laws that imply penalties of greater legislative strength.
- Promote gyms and sports clubs, where it helps the development of the physical and mental state of girls and boys, which promote awareness of culture, sports and good living by achieving a physical state of balance. In the same way, integrate the family in these practices.
- Consider that, due to the relationship between the nodes, jointly strengthen the factors: Personal living conditions, Cognitive factors and Strength of legislation and advice, a synergy could be achieved with a positive impact on the mitigation and future elimination of this factor.

Conclusions

After analyzing the determined factors, it can be said that:

- The indeterminacy is incorporated into the modeling of the causal relationships between the analyzed factors, where neutrosophic science is an active part and a person who makes decisions. As well as it is verified that the neutrosophic cognitive maps accurately evaluate verbal judgments under an environment of uncertainty.
- It was possible to determine and characterize the factors with the highest incidence in the occurrence of femicides, achieving the mathematical modeling of the phenomenon by applying the neutrosophic cognitive maps. Which served to illustrate the causal relationships of this factor.
- Policies should be aimed at improving and promoting positive impacts on cognitive factors, personal living conditions, physical condition of the victim (including age) and the strength of legislation and advice. Attention should also be paid to policies that enact good economic conditions that increase the level of schooling and favor personal living conditions. Age is a priority factor, so special attention must be paid since girls/elderly women are an easy target for this type of crime.

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Study on the Level of Knowledge in Dental Medical Emergencies of Dentistry Students through Neutrosophic Values

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Abstract. This research carries out an analysis of the level of knowledge in dental medical emergencies of tenth semester dentistry students at Universidad Regional Autónoma de los Andes UNIANDES, during the academic period April-August 2019, related to the reception of first aid courses. For this purpose, we made use of the neutrosophic theory, through the application of the single valued neutrosophic set (SVNS) associated to linguistic variables to evaluate the students' answers to the applied questionnaire. As a main result, we obtained a negative evaluation of the level of knowledge of dental medical emergencies for the students who have not received the first aid course.

Keywords: single valued neutrosophic set; aggregation operator; scoring function; dental medical emergencies

1 Introduction

Medical emergencies occur relatively frequently in the dental office [1] either as medical or dental emergencies. They can be triggered by stress or the administration of medications such as local anesthetics [2], which can cause episodes of syncope and hyperventilation [3], especially in adult patients with pre-existing pathologies.

It is therefore essential that dentistry students and professionals have the basic knowledge to ensure the initial diagnosis and management, to prevent the occurrence of fatal complications [4]. It is considered an emergency to those unpredictable risk situations that affect the patient's life and therefore require immediate attention. There are triggers factors such as stress , therapeutic and pharmacological management[5].

Advances in the field of health have generated a longer life expectancy in patients, so that today the professional in dentistry is already caring for elderly patients with systemic diseases that increase the incidence of emergency situations in the dental office [2].

Effective management of an emergency situation in the dental office is responsibility of the dentist, who must be able to diagnose the signs and symptoms and control them properly. If this is achieved, the professional will be able to provide a more complete and safe treatment[6]

When a medical emergency arises at the dental office, the dentist must be a competent professional, so it is essential to have basic knowledge to make a proper initial diagnosis and management of dental medical emergencies.

Preparation for medical emergencies is related to the training capacity of university centers and to the continuous updating of the professionals. That is why the objective of this investigation is to determine the impact of the first aid courses in the level of knowledge of dental medical emergencies of tenth semester students at Universidad Regional Autónoma de los Andes UNIANDES.

2 Description of previous research

Although there are few studies that evaluate the level of training of dental students in a medical emergency, the scientific search reports some research works as a background, such as:

Casco & Jacquett [7] determined the level of knowledge of fifth and sixth year students of the School of Dentistry of the Pierre Fauchard Autonomous University of Paraguay on the management of medical emergencies that may occur during dental consultations, by applying a survey concluding that the level of knowledge was unfavorable by 56%.

Díaz & Castañeda [8] applied a 20-questions questionnaire with topics of diagnosis of dental medical emergencies, first aid and pharmacological management, and concluded that the level of knowledge of dental medical emergencies of the students of the seventh and ninth semesters of Dentistry at Universidad Privada Antonio Guillermo Urrello, Cajamarca, Peru, is bad, with 66.3%.

Torres [9] determined the level of knowledge about the management of dental emergencies such as, management of dental-alveolar trauma, infectious processes, hemorrhages and pain, through the application of a structured questionnaire to the students of the Dentistry Clinic "Luis Vallejos Santoni" at Universidad Andina del Cusco, concluding that their level of knowledge is predominantly regular.

Villena [10] in his research work about medical emergencies during dental consultation of fifth and sixth year students of dentistry at Universidad Nacional de Trujillo, 2013, by applying a survey of 20 questions concluding that the level of knowledge is low in 65.3%, medium 34.7%, not reporting high level.

In Ecuador, Rodriguez [11] determined the level of knowledge about dental medical emergencies during dental outpatient visits among students of the School of Dentistry at the UCE, using a survey made up of 26 closed questions, concluding that the level of knowledge was better among ninth-semester students than eighth-semester ones.

In his thesis "Protocols for dental medical emergencies more frequent in the central zone of the country", Paredes [12] used a questionnaire with questions about dental medical emergencies to make protocols.

In this work, we propose the use of neutrosophic theory to evaluate the level of knowledge of students in dental medical emergencies.

Neutrosophy, which was proposed by Smarandache for the treatment of neutralities, has prepared the basis for a series of mathematical theories that generalize the classical and fuzzy theories such as the neutrosophic sets and the neutrosophic logic [13-15] .

The original definition of truth value in the neutrosophic logic is shown below [16]:

Let $N = \{(T, I, F): T, I, F \subseteq [0,1]\}$ n, a neutrosophic valuation is a mapping of a group of propositional formulas to N, and for each p statement you have

$v(p) = (T, I, F)$ (1)

Neutrosophic sets theory starts from classical sets theory and fuzzy sets theory, adding a membership function to the set μ generally defined as an x-number between 0 and 1 (the interval [0.1], instead of the classical binary membership defined in the set {0.1}. Thus, we introduce the concept of a neutrosophic set associated to a certain linguistic value, defined by a word, adjective or linguistic label A, [17-19].

It can be said that a neutrosophic set A is defined as a membership function that links or matches the elements of a domain or universe of discourse X with items in the [0,1] range: $A: X \rightarrow [0,1]$ [18, 20-22]. For each neutrosophic set, a $\mu A(x)$ membership or inclusion function is defined, which represents the degree to which a value for the variable x is included in the concept represented by the label A. The closer A(x) is to the value 1, the greater is the membership degree of the object x to the set A. The values of membership vary between 0 (no belonging at all) and 1 (total membership) so that a neutrosophic set is a class of objects with continuous degrees of membership [16, 23].

3 Methods

To demonstrate the impact that first aid courses have, students were given a diagnosis of their knowledge in the detection and treatment of medical and dental emergencies.

The population we studied were all the tenth semester dentistry students during the period April-August, 2019 at Universidad Regional Autónoma de los Andes UNIANDES. Since the population is less than 100 people (only 24 students), it was not required to calculate the sample size. Therefore, 100% of the students from the tenth semester who met the inclusion and exclusion criteria were taken into account. In this case these criteria were based on the students' availability to participate in the study. Four students out of 24, did not participate, so the sample was made up of 20 students[24-26].

For the collection of information, a 26 question questionnaire was applied to the students. The first two questions were designed as closed question, to characterize the student as to whether he or she had received a first aid course and whether it was theoretical or practical. The remaining questions were open, ten of which were focused on testing the students' knowledge on diagnosis and fourteen on testing the students' knowledge about the treatment of dental medical emergencies.

The questionnaire we applied was adapted from the scientific article “Level of knowledge about the management of medical emergencies of the fifth and sixth year students of the School of Dentistry at Facultad de Odontología of Universidad Autónoma del Paraguay Pierre Fauchard”, published by Casco and Jaquett [7] and shown below.

Questionnaire

Have you participated in a first aid course?
If yes, please clarify whether it was theoretical or practical.
What is an emergency situation for you?

What medical emergency has the clinical signs of sudden loss of consciousness, disappearance of carotid pulses, heart sounds, severe mucocutaneous paleness and cyanosis?

What is the medical emergency for clinical signs of loss of consciousness, pallor, sweating, and decreased pulse?

What are the main clinical signs for diagnosing a seizure syndrome?

What medical emergency is presented with a picture of seizures, tachycardia, hypotension, increased breathing rate, nausea, and vomiting?

What clinical signs in a patient can orient our diagnosis towards a severe anaphylaxis during the dental consultation?

When a patient goes through a picture of diastolic blood pressure greater than 120 mm hg, headache, eye injuries (bleeding, exudates), hematuria and seizures, what can be diagnosed?

What can be treated the clinical signs of the presence of strong abdominal pain, vomiting, tachypnea, and when the glucometer registers values higher than 200mg/dl of blood glucose?

What can be diagnosed when the picture begins with a productive cough accompanied by bronchospasm, intense dyspnea, intercostal muscle retractions (pulling) and cyanosis of the lip and nail base mucosa?

What clinical signs in a patient can orient our diagnosis towards an acute airway obstruction during the dental consultation?

If a vasovagal syncope is present in the patient, it is recommended to place him/her in the Lemburg Train or anti-shock position. What does this position consist of?

In hypertensive emergencies, what is the therapeutic behavior that we should follow?

With respect to laboratory tests, what are the normal values of coagulation time and bleeding time?

Hyperventilation syndrome appears when the anxious patient begins to breathe rapidly, abnormally eliminating co2. What should you do in this case?

What measures would you take if the patient suffers an acute airway obstruction in your practice?

How would you counteract critical hyperglycemia in a patient's office?

What behavior would you adopt if your patient begins to suffer from a seizure syndrome in your dental care?

In a severe situation of local anesthetic poisoning, what type of medication would you administer to your patient to counteract his or her main clinical sign (seizure)?

What steps would you take in a situation of anaphylaxis in your patient?

What type of medication would you administer to your patient if an acute asthmatic crisis occurs during your patient's care in the dental office?

What are the normal values of breathing rate in a healthy patient?

If a patient breathes in a foreign body while sitting in a dental chair and begins to cough and have difficulty breathing, what steps should be taken to treat this emergency?

If while in the office waiting room, a patient begins to experience tachycardia, dizziness, palpitations, malaise, chest tightness, blood pressure of 150/110 hg, what is happening to him/her?

In a picture of oral bleeding, what signs and symptoms will give us reference that an adult patient lost a blood volume of approximately 650cc to 1000cc in an oral surgery?

For the analysis of the results, three experts (specialists in dentistry who teach first aid courses at UNIANDES) were asked to qualitatively evaluate each response. For this purpose, we proposed the use of single valued neutral sets (SVNS) which allow the use of linguistic variables and increase the interpretability in the recommendation models and the use of indeterminacy [16, 27].

Let X be a universe of discourse, a SVNS A over X has the following form:

$$A = \{\langle x, u_a(x), r_a(x), v_a(x)\rangle : x \in X\}d \qquad (2)$$

Where

$$u_a(x): X \to [0,1], r_a(x): X \to [0,1] \quad and \quad v_a(x): X \to [0,1]$$

With
$0 \leq u_a(x), r_a(x), v_a(x) \leq 3, \quad \forall \; x \in X$

The intervals $u_a(x), r_a(x)$ y $v_a(x)$ denote the memberships to true, indeterminate and false from *x* in *A*, respectively.

In order to obtain the experts' ratings in the evaluation models, we propose the use of the associated linguistic terms SVN numbers as shown in table 1.

LINGUISTIC TERM	SVN NUMBERS
EXCELLENT	(1; 0; 0)
VERY GOOD	(0,8; 0,15; 0,20)
GOOD	(0,60; 0,35; 0,40)
REGULAR	(0,50; 0,50; 0,50)

REGULAR TENDING TO BAD	(0,40; 0,65; 0,60)
BAD	(0,20; 0,85; 0,80)
VERY BAD	(0; 1; 1)

Table 1. Linguistic terms used. Source: Author's elaboration

To aggregate the assessments given by the experts in each question in order to determine the level of knowledge of each student in the fields of diagnosis and treatment of dental medical emergencies, we used the single-valued weighted neutrosophic mean (SVNWA) proposed by Ye [28]and defined as follows:

$$F_w(A_1, A_2, \dots, A_n) = \langle 1 - \prod_{j=1}^{n}\left(1 - T_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(I_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(F_{A_j}(w)\right)^{w_j} \rangle \quad (3)$$

Where:

$W = (w_1, w_2, \dots, w_n)$ is the vector of $A_j (j = 1,2, \dots, n)$ such that $w_n \in [0,1]$ y $\sum w_j = 1$.

In this case it was assumed that all questions have the same weight in both fields, that is, w_j is equal to 0,10 for questions 3 to 12 and equal to 0,07 for questions 13 to 26. The scoring function was then used to determine each student's level of knowledge in dental medical emergencies in general.

Once the aggregations were obtained, the score function was used to sort the evaluations and to obtain a unique value of assessment in each field by student:

$$s(V_j) = 2 + T_j - F_j - I_j \quad (4)$$

With this value it was possible to obtain a qualitative evaluation of each student by field taking the possible range of scores (from 0 to 3) and divided by 7 (according to the amount of linguistic terms used, which yielded the intervals to classify the scores, as shown in Table 2

SCORING INTERVALS	EVALUATION	LINGUISTIC TERM
[0 - 0,429)	VB	Very bad
[0,429 - 0,857)	B	Bad
[0,857 - 1,286)	RB	Regular tending to bad
[1,286 - 1,714)	R	Regular
[1,714 - 2,143)	G	Good
[2,143 - 2,571)	VG	Very good
[2,571 - 3]	E	Excellent

Table 2. Intervals for student evaluation according to score function value. Source: Author's elaboration

From these results, the hierarchical clustering algorithm with Ward link and Euclidean distance measurement was used. With the implementation of the Orange 3.26 package[29], grouping students according to their evaluations in both fields and characterizing the group in general according to their level of knowledge in dental medical emergencies and the influence of the first aid courses received.

4 Results

The results of the experts' assessments by questions on diagnosis and treatment of dental medical emergencies are shown in Tables 3 and 4.

STUDENT	EVALUATION BY QUESTIONS									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	R	B	B	RB	B	RB	B	RB	RB	R
2	VG	B	B	VG	VG	B	B	B	VG	B
3	R	R	R	B	RB	B	R	B	RB	R
4	B	VG	VG	B	B	VG	B	VG	B	VG
5	RB	RB	B	R	RB	B	RB	RB	R	RB
6	RB	B	RB	RB	RB	RB	RB	B	R	R
7	RB	RB	RB	B	RB	RB	R	RB	B	R
8	RB	B	R	RB	R	RB	RB	RB	RB	RB

9	VG	B	VG	B	VG	VG	VG	B	B	B
10	B	RB	RB	R	RB	B	B	RB	RB	RB
11	B	B	B	R	R	RB	R	B	RB	B
12	R	RB	B	B	B	RB	R	RB	B	R
13	B	B	VG	B	VG	VG	B	B	VG	B
14	R	B	B	B	R	RB	B	B	R	B
15	VG	B	VG	B	VG	B	VG	B	VG	VG
16	B	B	B	VG	B	B	VG	B	B	VG
17	B	R	R	B	B	R	R	B	B	B
18	B	RB	B	R	R	RB	B	RB	RB	RB
19	B	B	VG	VG	B	VG	VG	B	VG	VG
20	B	RB	B	B	R	RB	B	RB	B	R

Table 3. Expert evaluation criteria for diagnostic questions. Source: Author's elaboration

STUDENT	**EVALUATION BY QUESTIONS**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	RB	RB	RB	B	B	R	R	R	RB	B	R	RB	R	B
2	G	VG	VG	VG	VG	G	VG	G	G	VG	VG	VG	VG	VG
3	R	R	G	RB	R	R	R	R	R	R	R	R	RB	R
4	G	G	VG	VG	G	VG	G	VG	VG	VG	VG	G	G	G
5	RB	G	G	R	RB	G	G	G	G	G	G	RB	G	G
6	G	R	R	R	G	G	RB	RB	G	G	R	R	R	G
7	R	RB	R	R	RB	G	RB	R	G	R	RB	RB	RB	R
8	G	R	RB	RB	R	R	G	R	R	R	G	R	R	G
9	G	G	G	G	G	G	VG	G	G	G	VG	VG	VG	VG
10	R	RB	G	G	RB	R	G	RB	RB	RB	R	G	R	R
11	R	RB	B	R	RB	R	RB	R	B	B	RB	R	R	R
12	RB	B	R	R	B	B	B	B	B	B	RB	B	R	RB
13	G	VG	VG	VG	G	G	VG	VG	G	VG	VG	G	VG	VG
14	B	RB	R	B	RB	RB	R	R	RB	RB	R	RB	RB	B
15	G	VG	G	VG	VG	G	G	G	G	VG	VG	G	VG	VG
16	G	G	G	G	VG	VG	G	VG	G	G	G	VG	VG	VG
17	R	RB	G	R	G	R	G	RB	RB	R	R	RB	R	RB
18	R	R	RB	R	G	R	R	G	G	R	RB	RB	RB	RB
19	VG	G	VG	G	G	G	VG	G	G	VG	G	VG	G	VG
20	R	R	G	RB	RB	RB	G	R	G	R	R	RB	RB	R

Table 4. Expert evaluation criteria for treatment questions. Source: Author's elaboration

We may observe that the evaluations by questions oscillated between Bad and Very Good, without any rating of Excellent or Very Bad in both fields.

The results of the aggregation from the SVNWA operator on diagnosis and treatment of dental medical emergencies are shown in Table 5.

STUDENT	**AGGREGATION**	
	Diagnosis	**Treatment**
1	(0,73; 0,218; 0,27)	(0,356; 0,677; 0,644)
2	(0,392; 0,634; 0,608)	(0,398; 0,627; 0,602)
3	(0,611; 0,353; 0,389)	(0,499; 0,496; 0,501)
4	(0,536; 0,441; 0,464)	(0,463; 0,552; 0,537)
5	(0,339; 0,705; 0,661)	(0,469; 0,542; 0,531)
6	(0,754; 0,193; 0,246)	(0,483; 0,522; 0,517)
7	(0,495; 0,504; 0,505)	(0,717; 0,229; 0,283)

8	(0,497; 0,499; 0,503)	(0,535; 0,443; 0,465)
9	(0,524; 0,461; 0,476)	(0,507; 0,483; 0,493)
10	(0,534; 0,445; 0,466)	(0,703; 0,243; 0,297)
11	(0,628; 0,329; 0,372)	(0,717; 0,229; 0,283)
12	(0,637; 0,324; 0,363)	(0,369; 0,664; 0,631)
13	(0,499; 0,494; 0,501)	(0,481; 0,521; 0,519)
14	(0,506; 0,486; 0,494)	(0,667; 0,286; 0,333)
15	(0,66; 0,292; 0,34)	(0,703; 0,243; 0,297)
16	(0,42; 0,602; 0,58)	(0,414; 0,615; 0,586)
17	(0,381; 0,651; 0,619)	(0,651; 0,309; 0,349)
18	(0,676; 0,278; 0,324)	(0,494; 0,502; 0,506)
19	(0,645; 0,313; 0,355)	(0,65; 0,304; 0,35)
20	(0,499; 0,494; 0,501)	(0,486; 0,515; 0,514)

Table 5. Aggregation of assessments in the fields of diagnosis and treatment. Source: Author's elaboration

From the aggregations, the score per student was obtained along with it the qualitative evaluation, as shown in table 6.

STUDENT	**DIAGNNOSIS**		**TREATMENT**	
	Score	***Evaluation***	***Score***	***Evaluation***
1	1,015	RB	1,1403	RB
2	2,144	VG	2,3213	VG
3	1,557	R	1,4838	R
4	2,205	VG	2,2052	VG
5	1,388	R	1,7034	R
6	1,388	R	1,6217	R
7	1,388	R	1,4209	R
8	1,309	R	1,5682	R
9	2,205	VG	2,1168	G
10	1,431	R	1,5027	R
11	1,001	RB	1,2311	RB
12	1,056	RB	0,9235	RB
13	2,144	VG	2,2846	VG
14	0,944	RB	1,1497	RB
15	2,262	VG	2,2052	VG
16	2,079	G	2,1622	VG
17	1,722	G	1,4738	R
18	1,463	R	1,4738	R
19	2,262	VG	2,1622	VG
20	1,603	R	1,4738	R

Table 6. Qualitative evaluations according to score. Source: Author's elaboration

When analyzing these results, the prevalence of the evaluations of Regular in both fields is evident, this is more easily observed in the graph shown in figure 1.

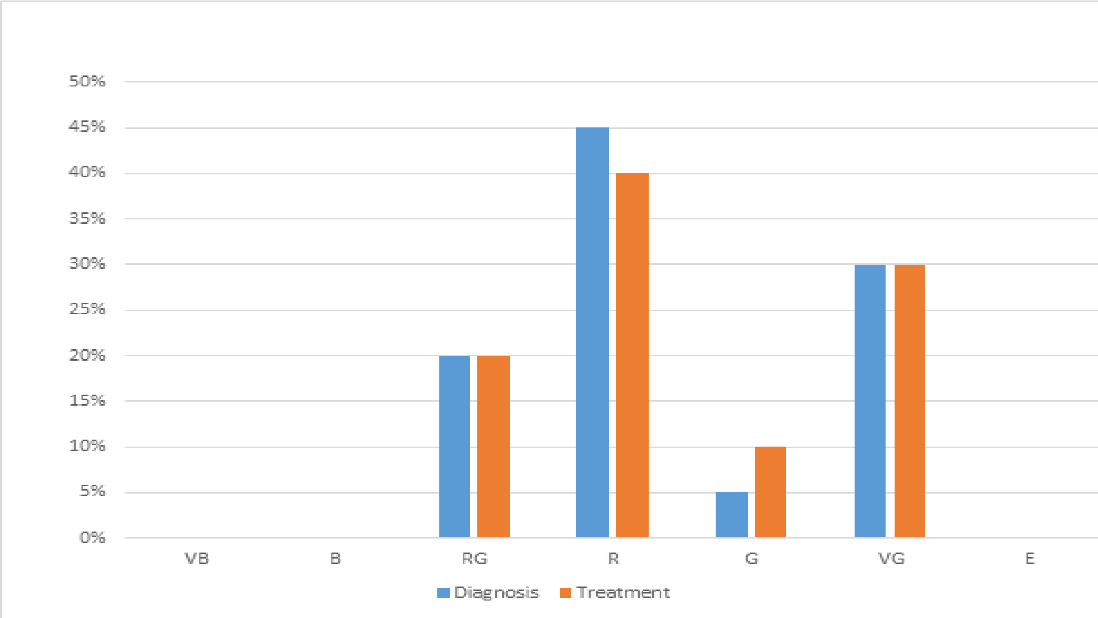

Figure 1. Relative Frequencies of the evaluations. Source: Authors

By applying the hierarchical clustering algorithm, the results of questions 1 and 2 of the questionnaire were added, about whether the student had received the first aid course and thus determine its impact on the evaluations obtained. As a result, we can observe two clusters, as shown in figure 2.

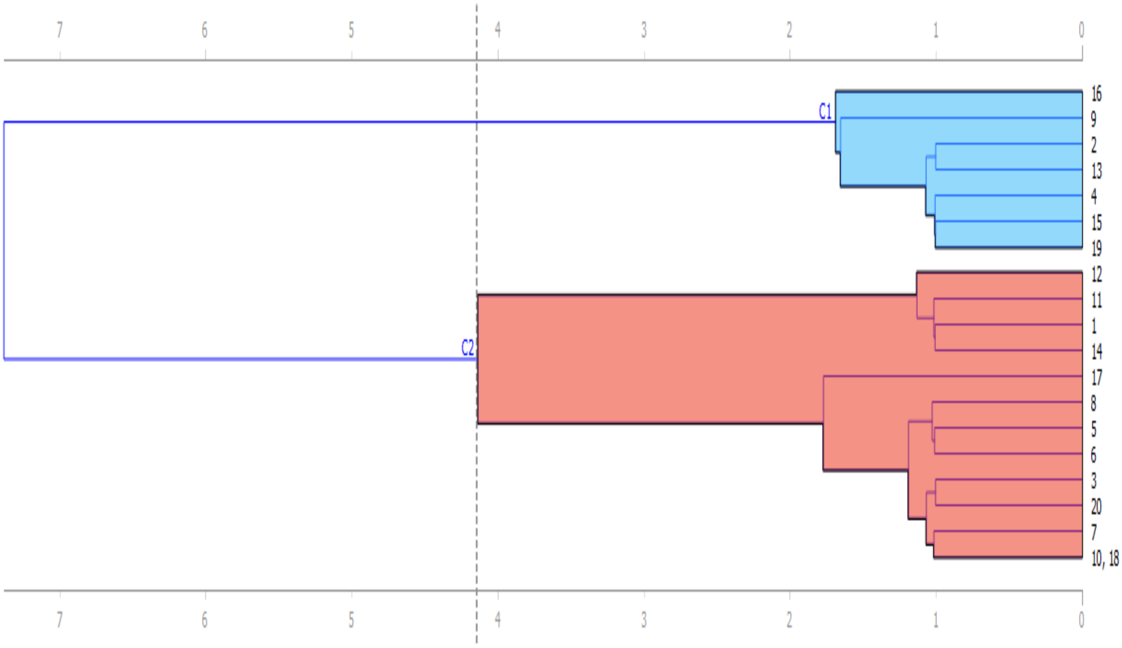

Figure 2. Hierarchical Clustering Dendogram. Source: Author's elaboration

The first cluster (C1, in blue on the image) is formed by 7 students (35% of the total) with 6 VG (86%) and 1 G (14%) evaluations in both diagnosis and treatment. All these students received the first aid course.

The second cluster (C2, in red on the image) is formed by 13 students (65% of the total) with respective evaluations expressed in (number of students, %) of; G (1, 8%), R (8, 62%) and BR (4, 30%) in diagnosis and R (9, 69%) and BR (4, 31%) in treatment. Of these students, only one had received the first aid course.

For a graphical representation of the group's situation on the students' level of knowledge in medical-dental emergencies in general and its relation to the first-aid course, the scatter plot shown in Figure 3 was obtained.

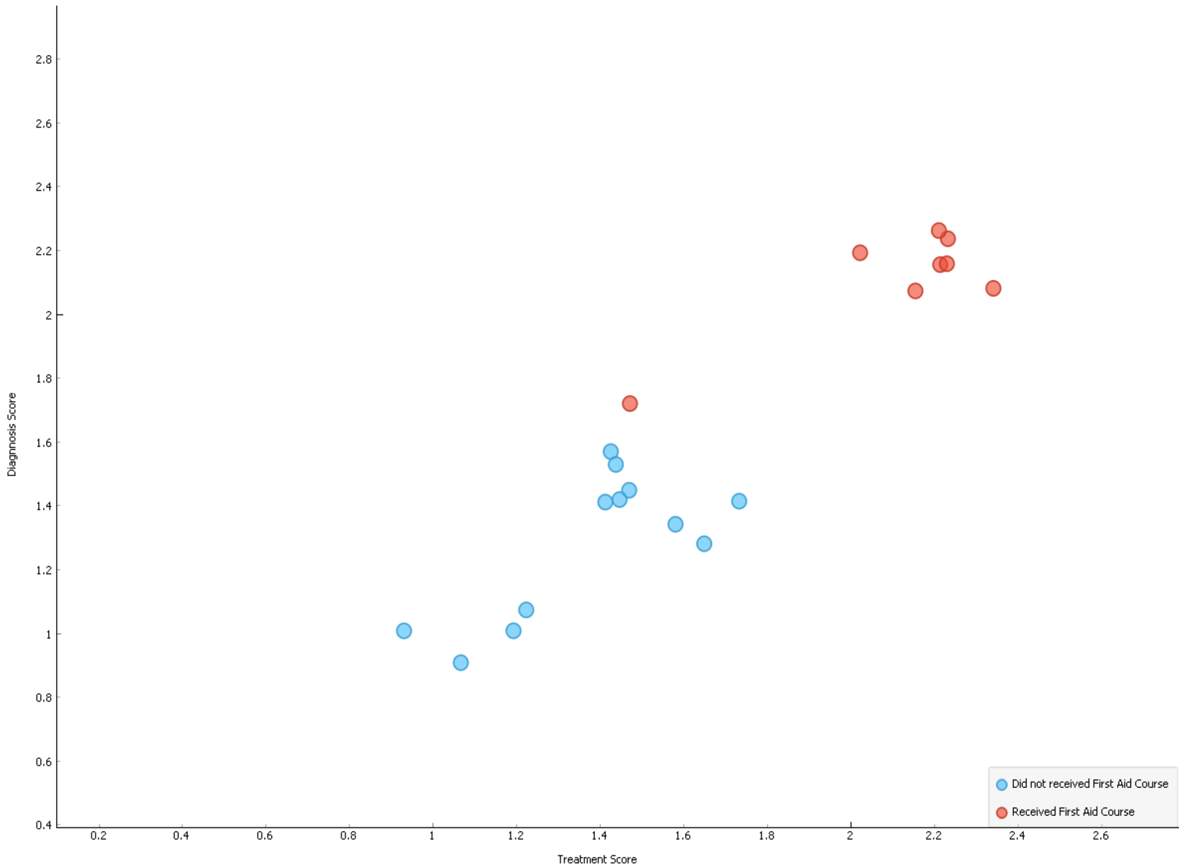

Figure 3. Scatter plot for treatment score vs. diagnosis score. Source: Author's elaboration

As can be seen, the students who received the first aid course, got the highest evaluations in both fields, except for one student who, despite having received the course, obtained an R in the diagnosis. This shows an effectiveness of 88% for the course on the level of knowledge in medical-dental emergencies.

Conclusions

There are few studies that certify the level of preparation of the student of dentistry in medical-dental emergencies, and the few investigations carried out show a deficient knowledge causing imminent risk of the patient's life and legal problems for the professional.

With the use of the single-value neutral sets, it was possible to associate linguistic terms to the experts' evaluation of the open questions of the applied questionnaire, making their quantification more reliable.

We also obtained that the level of knowledge of dental medical emergencies in the students of the tenth semester of UNIANDES, during the academic period April August 2019, has a majority negative valuation in 65%, with similar evaluations in the fields of diagnosis and treatment.

Only 40% of the students have taken the first aid course, which evidences the lack of interest to take such courses. However, from the results obtained, it is evident that this course has a positive influence on the level of knowledge in dental medical emergencies.

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Neutrosophic Case-Based Reasoning Method to Determine the Profitability of the Tourism Sector in the City of Riobamba

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Abstract: The tourism sector represents an area of vital importance for the economic growth of developing countries. The City of Riobamba in Ecuador, constitutes a reference tourist destination for the region. Quantifying the profitability of the tourism sector allows enhancing the places that represent economic objectives. This investigation proposes a case-based reasoning method to determine the profitability of the tourism sector. It bases its operation on Neutrosophy to represent uncertainty. The proposed method has been implemented to determine the profitability of the tourism sector in the City of Riobamba. After applying the method we reached to the conclusion that it constitutes a highly profitable area.

Keywords: case-based reasoning; Neutrosophy; Cost effectiveness; Tourism sector, SVNN

1. Introduction

Nowadays, tourism sector represents one of the highest income areas for the economies. In countries such as Ecuador, its growth has been enhanced, located in third place in non-oil exports [1], [2]. Each region has touristic destinations that characterize it [3], [4]. Riobamba is known as a passing city that has several places and tourist areas that make of it an interesting city [5], [6].

The existing parishes in Riobamba contribute positively to economic profitability due to the performance of the tourist activity [7], [8]. However, the little publicity given about the tourist offers puts tourists in a clear position of absolute confusion [9].

Economically, the classic modalities of tourism generate multiplier effects on the incomes and the native wealth of the tourist zones[10]. In the case of rural tourism, the effect is no different and it also stimulates the growth of other economic sectors through the creation of direct and indirect sources of employment [11], [12].

Although tourism can be considered as a heterogeneous product, the tourism sector is largely price sensitive, due to the great competition that exists between destinations. The consumer has a considerable range of choice where to choose from. Quantifying the profitability of the tourism sector allows enhancing the places that represent key economic objectives.

Based on the situation described above, the objective of this research is to develop case-based reasoning method to determine the profitability of the tourism sector.

2. Preliminaries

This section introduces the main theoretical references on the object of study and the different concepts that facilitate the understanding of the research. We also present a description of tourism in the city of Riobamba, located in Chimborazo province. SVN numbers are used to represent uncertainty in decision-making problems and, finally, a modeling of the uncertainty is carried out using a case-based reasoning method.

2.1. Tourism in the city of Riobamba, Chimborazo province

Riobamba is a wonderful city that has very beautiful touristic places and a wide culture, history and tradition. It has superimposed natural disasters like earthquakes. Riobamba is declared as "the railway capital" of Ecuador, it is one of the first heritage cities, considered the first city for having the first Catholic church and the first Olympic stadium [13], [14]. It represents a historical destination for being the city where the first Constitution of Ecuador was signed [15], [16].

In the communities of San Juan, they believe that their livelihood continues to come from the sowing of agricultural products and the management and grazing of sheep and cattle. The income from milk is low, less than half of a minimum wage. However, thanks to different support programs, both from the State and NGOs, there is a variety of additional income, the main one is the Socio Bosque program [17], which generally provides more income at the family level than agriculture itself. Additionally, there is income from handicrafts and tourism [18], [19], the latter being the object of analysis of this research.

2.1. Neutrosphic case-based reasoning

The profitability of the tourism sector can be modeled as a multi-criteria decision-making problem [20], so that it complies with [21]:

A set of profitability criteria $R = \{R_1, \ldots R_n\}, n \geq 2$;

So that they are evaluated to the set of alternatives that represent the tourist sectors

$I = \{I_1, \ldots I_m\}, m \geq 2$

The profitability is made up of the group of criteria that determine the profitability of the tourism sector [22] strongly influenced by hotel impact on the community [23].

The case-based reasoning methodology consists of solving new problems by reusing past experience using a similarity function to retrieve close cases [24]. Case-based reasoning is one of the preferred method for uncertain decision in complex and dynamic situations. In this paper, we apply this method to multi-criteria evaluation of profitability with an indeterminacy environment.

Indeterminacy could be modeled by neutrosophic theory proposed by Smarandache [25].

Definition 1. ([26, 27]) Let U be a space of points (objects), with a generic element in U denoted by x. A Single-Valued Neutrosophic Set (SVNS) A in U is characterized by a truth-membership function TA, an indeterminacy-membership function IA and a falsehood-membership function FA. TA(x), IA(x) and FA(x)$\in$[0,1]. It can be written as A = {< x, (TA(x), IA(x), FA(x)) >: x $\in$ U; TA(x), IA(x), FA(x)$\in$[0, 1]}.

There is no restriction on the sum of TA(x), IA(x) and FA(x), thus, 0≤TA(x) +IA(x)+FA(x) ≤3.

For convenience, a Single-Valued Neutrosophic Number (SVNN) is represented by (a, b, c), where a, b, c $\in$ [0, 1] and 0≤a+b+c ≤3. In this paper, a linguistic scale is associated with SVNN and used to give assessment in a more natural way; similarity metrics are used for neutrosophic case-based reasoning[28] .

3. Materials and Methods

This section describes the operation of the method to determine the profitability of the tourism sector. The fundamental elements that characterize the proposal are presented to facilitate its understanding.

The method to determine the profitability of the tourism sector is designed to assess its behavior, it is expressed through three basic activities: input, management and information output. Figure 1 shows a general scheme of the proposed method.

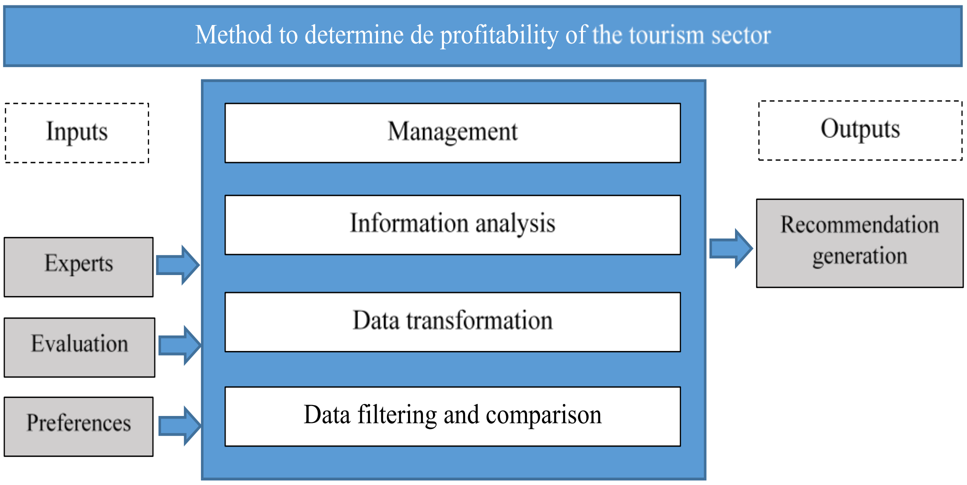

Figure 1. Scheme with the workflow of the proposed method.

The method to determine the profitability of the tourism sector was designed through a workflow composed of three activities that in its integration determine the proposed inference. Below is a description of the proposed activities.

Activity 1 information analysis

To nourish the operation of the proposed method, the sources of information are identified and subsequently stored in databases for further transformation and analysis. This activity uses the empirical organizational knowledge base. It consists of the collection of historical information on the behavior of the tourism sector.

Supported by Neutrosophy, an interpretability of the data is obtained, SVNS sets are used because they allow the use of linguistic variables [29] [30]. The evaluation criteria are expressed through a universe of discourse that is denoted as (X) [31, 32]. Where the Single Valued Neutrosophic Set is defined as A over X, which is an object of the form shown in equation 2.

$$A = \{\langle x, uA(x), rA(x), vA(x)\rangle : x \in X\}d \quad (2)$$

Where: (x)X → [0,1], rA(x) → [0,1], vA(x) → [0,1]; with 0 ≤uA(x)+ rA(x)+ vA(x): ≤ 3 for all x ∈ X. The interval (x), rA (x) and vA (x) denotes the membership to true, indeterminate and false of x in A, successively. The value of the Neutrosophic set A is expressed as shown in equation 3.

$$A = (a, b, c) \quad (3)$$

Where: a, b, c ∈ [0,1], a+b+c ≤ 3

Activity 2 data transformation

Each data describes the characteristics of the sector from Neutrosophic numbers [33], [34],[35],[29] . It has $A^* = (A_1^*, A_2^*, \ldots, A_n^*)$ a vector of SVN numbers, such that: $A_j^* = (a_j^*, b_j^*, c_j^*)$, j=(1,2, … , n), $B_i = (B_{i1}, B_{i2}, \ldots, B_{im})$ (i = 1,2, … , m), it has m vectors of n SVN numbers.

Such that that $B_{ij} = (a_{ij}, b_{ij}, c_{ij})$($i$ = 1,2, … , m), (j = 1,2, … , n), B_i and A^* obtained by equation 4:

$$d_i = \left(\frac{1}{3}\sum_{i=1}^{n}\left\{\left(|a_{ij}-a_j^*|\right)^2+\left(|b_{ij}-b_j^*|\right)^2+\left(|c_{ij}-c_j^*|\right)^2\right\}\right)^{\frac{1}{2}} \quad (4)$$

(i = 1,2,3… , m)

The similarity average is used to obtain the Euclidean distance as expressed in equation 5.

$$F_{a_i} = \{v_1^j, \ldots, v_k^j, \ldots v_l^j\}, j = 1, \ldots n \quad (5)$$

Calculation allows to obtain the measure of the alternative A_i, from the similarity, the method must look for which of the data are closest to the solution set S_i, through the neighborhood you get an order of the alternatives. The smaller the neighborhood the greater the similarity will be [36] ,[34] ,[37].

Activity 3 Data filtering and comparison

The activity consists in evaluating the behavior of the indicators for a given activity. The linguistic scale S, $V_k^j \in S$. is used for this purpose

Where: $S = \{S_1, , S_g\}$ representing the set of linguistic labels to evaluate the characteristics of the C_k sectors.

The evaluation is considered the preference of the process from which they are obtained:

$$P = \{P_1, \ldots P_e\},$$

The values obtained are compared with the previously stored data, a comparison process is carried out using the Euclidean distance as expressed in equation (6).

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

The S function determines the similarity between the values of the stored data and the preferences obtained by comparing the entire existing neighborhood [30, 35].

Information output: Generation of recommendations

After obtaining the similarity, the process of recommendations is executed. Recommendations are made from stored data. It consists of generating an order on the similarity neighborhood.

The best result will be the one that meets the needs that characterize the indicator.

4. Application of the Neutrosophic Method to determine the profitability of the tourism sector

The proposed method was tested to determine the profitability of the tourism sector in the City of Riobamba. An evaluation of two other alternatives was carried out, which were compared with the City of Riobamba. The objective was to make an evaluation and comparison of the indicators to determine the profitability of the tourism sector. Results are represented by alternatives I, so that:

$I = \{i_1, i_2, i_3\}$
i_1: Canton of Babahoyo.
i_2: Canton of Quevedo.
i_3: Canton of Riobamba.

Valued from the set of characteristics C that describe the profitability according to [38], such that:
$C = \{c_1, c_2, c_3, c_{4,} c_5, c_6, c_7, c_{8,}\}$,
Where:
C_1: Index of income and expenses for the hotel service.
C_2: Economic impact of the hotel service in the locality.
C_3: Customer satisfaction index with hotel service.
C_4: Representativeness index of the hotel service in the locality.
C_5: Index of water consumption by rooms occupied days.
C_6: Index of energy consumption by rooms occupied days.
C_7: Number of complaints and claims.
C_8: Hotel competitiveness index in the tourist destination.

From the set of linguistic labels presented in table 1 [33], defined as:

Linguistic term	SVN numbers
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0,15,0.20)
Good (G)	(0.70,0.25,0.30)
Moderate good (MG)	(0.60,0.35,0.40)
Medium (M)	(0.50,0.50,0.50)
Moderate bad (MB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very Very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 1. Language terms used.

The comparison expression shown in (7) is obtained from the application of the method, this data is stored in the case base for further analysis.

$$P_e = \{VVG, G, MG, VG, VVG, G, MG, VG\} \quad (7)$$

After processing the data, its filtering provides a systematic mapping for each alternative object of analysis. Figures 2, 3 and 4 present distances to each criterion in a bar graph.

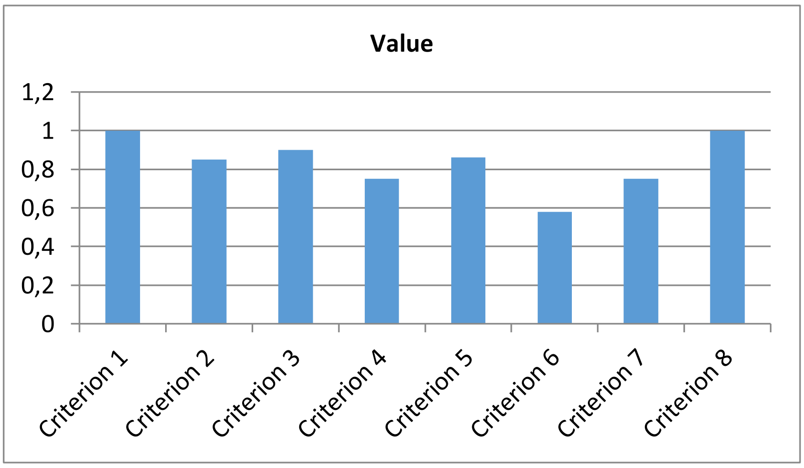

Figure 2. Individual criterion distances for Babahoyo Canton.

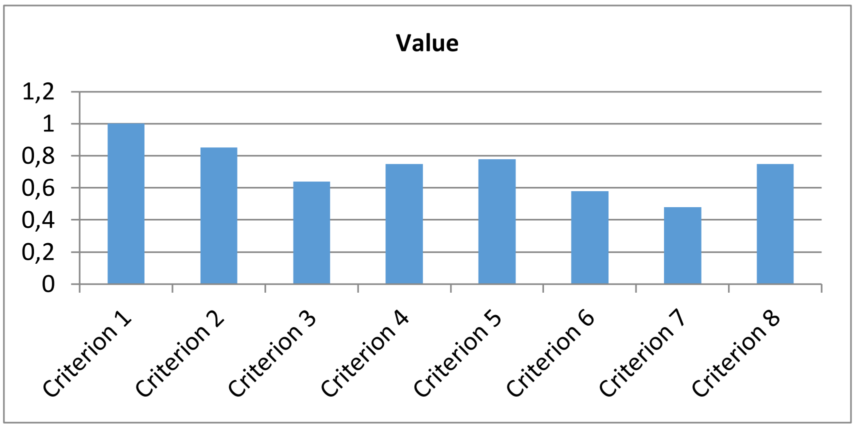

Figure 3. Individual criterion distances for Quevedo Canton .

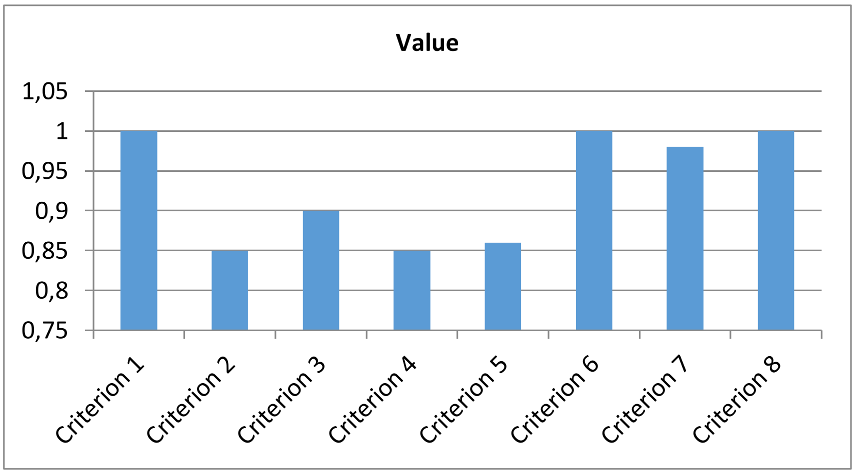

Figure 4. Individual criterion distances for Riobamba Canton.

Once the map of the alternatives was obtained, we proceeded to calculate the similarity. Results are shown in Table 2.

a_1	a_2	a_3
0.45	0.85	0.72

Table 2. Similarity between the characteristics and the profile of the tourism sector.

Based on the analysis of the results, the alternative ordering process is carried out. From that process, the alternative object of attention is visualized. Expression 8 shows the result of the resulting ordering.

$$\{a_2, a_3, a_1\} \tag{8}$$

After ordering, the method recommends the alternative (a_3) which correspond to the City of Riobamba. The recommended alternative has in the case base an evaluation of the profitability valued as "Very good". The analyzed case goes on to take part in the base of cases with a ¨Very good¨ assessment for similarity. Processing lead us to determine that the case under study constitutes a feasible result for its strengthening.

Conclusions

The contribution presented to determine the profitability of the tourism sector was based on the use of Single Valued Neutrosophic Set Numbers through expressions of linguistic terms. The method developed follows a workflow through 3 activities that make up its integral management using case-based reasoning theory.

In order to test of the proposed method, we made an assessment of three cantons to evaluate and determine the touristic profitability in order to enhance their attention. The inference of the method was obtained through the criteria that characterize the profitability and they populated the knowledge base that improves learning for later functioning.

As a general result, we concluded that the City of Riobamba is quantified with a profitability index valued as Very good. Future work will concentrate on extending the model with more historical data and new similarity metrics.

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Experts' Selection for Neutrosophic Delphi Method. A Case Study of Hotel Activity

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Abstract. This investigation aims to model experts' selection for neutrosophic Delphi method. The phase of selecting experts is essential to obtain adequate results in Delphi method, thus this phase deserves a major attention. The proposed method considers the complexity of the subject, according to experts' criteria to fix the number of experts necessary to apply the neutrosophic Delphi method. Single-valued triangular neutrosophic numbers are used to measure experts' self-evaluations and the weights of expertise criteria. Neutrosophy allows us to include indeterminacy, which is typical in any decision-making problem, as well as the calculation based on linguistic terms. Hotel activity serves as a case study for illustrating the applicability of the method in a real life situation.

Keywords: Neutrosophic logic, neutrosophic Delphi method, expert selection process, intellectual capital.

1 Introduction

Among the qualitative methods, Delphi is one of the most widely used in scientific researches. This method is applied to solve many types of problems. Among them, we may find the topic identification in a research, to elaborate instruments for the analysis and collection of information, thus, it is broadly applied in social sciences [1].

Scientific literature reports that this method has been used in different fields like, economy [2], where it was introduced for the first time, as a predictive tool of technological aspects and also as a validation system for information collection tools. Its popularity can be verified in [3], where about 500 publications containing this are reckoned up to the year 1974.

Delphi method is a prospective, expert-based method [4, 5] which is defined as a systematic iterative process aimed to obtain opinions and, if possible, consensus, of a group of experts [6], considering experts those specialist who have a close relationship on the issue, sector, technology or object of investigation [6]. This methodology is appropriate to obtain information from experts based on their knowledge and their ability to analyze the consulted items. It becomes suitable especially in areas of knowledge, which are usually complex, dynamic, ambiguous and lacking of information, [4].

Delphi technique was developed in 1950 by the RAND Corporation of Santa Monica, California [7] with the goal to investigate the impact of technology in the war. The name is derived from the Oracle of Delphi, which was a popular oracle dedicated to the god Apollo in ancient Greece, inspired by its application as a prospective technique [1].

There are several ways of applying Delphi method [3], e.g., with one or two iterations depending on the degree of agreement between the panelists. During this procedure, after every round, panelists' responses are qualitatively and quantitatively analyzed. Usually they are statistically processed by using medians and confidence intervals. Delphi method aims to achieve as much as possible the consensus among the panelists. Empirically, variance of the panelists' responses for each round is used to measure consensus.

Currently, there are several variants of Delphi method rather than the classical one. Each type has its pros and cons based on the field of application [8]. The different changes of this technique have caused significant criticism, which negatively affects its reliability and validity. Selecting a Delphi method variant depends on the problem object of study. This selection depends on the algorithm's characteristics, the number of rounds, anonymity, feedback, sampling, and analysis, among other aspects, [8]. The criteria or opinions issued by experts constitute the examining aspect of the technique, which may be affected by some variables associated with the specialists involved in the research. The indicators to be considered are: years of experience, qualification, and knowledge referred to the problem to study.

This investigation aims to describe a procedure for experts' selection for neutrosophic Delphi method, which is exemplified with hotel activity. This is a real-life case applied to tourism management, specifically to measure intellectual capital in one of the hotels of Meliá Group in Cuba.

Expert criterion occupies a significant place between the methods of empirical research in the sciences [9-12], based on the consultation of people who have deep knowledge about the object of study. There is consent that collective judgment exceeds the insignificant sum of individual results. The available information is continually more opposed than that available to the most qualified participants [3], and of course, when working with a group of experts, one of the main underlying premises is the assumption that a large number of expert judgments are required to adequately deal with any problem. Although generally a face-to-face exchange between the members of the group would be inefficient or impossible due to the cost and time needed for all parties to meet.

In literature, there is no consensus regarding the different methods for choosing experts, such as the selection of individuals, the choice of the best method to use for a particular problem situation although in the state of the art, the method of the greatest application has been the so-called Delphi method [4]. There are other methods applicable to the solution of organizational problems, among which stand out the methods of individual aggregates, the Nominal Group technique and the Group Consensus method. The prediction capacity of the Delphi method is based on the systematic use of an intuitive judgment exposed by a group of experts. The quality of the results is mainly due to the care taken in the preparation of the questionnaire and in the election of the consulted experts.

For the authors, an expert is the individual or group of people or organizations capable of offering conclusive assessments for a particular problem. They are who make recommendations regarding their fundamental moments, with a maximum of competence. In this regard, it is important that prior to considering a work group, the principal investigator or facilitator studies experts' universe linked to the subject. They have to examine and then select the most competent experts.

Neutrosophy is the branch of philosophy related to neutralities. Neutralities are produced by a lack of information, contradictions, the unknown, inconsistencies, and so on, in human's information and knowledge. One component of decision-making is indeterminacy. Neutrosophic logic contains three elements, one of truthfulness, another of indeterminacy, and a third one of falseness. The three are independent from each other.

Using neutrosophic experts' selection for neutrosophic Delphi method guarantees to take into account the uncertainty and indeterminacy we deal with when this phase is carried out. We based our solution on the neutrosophic Delphi method introduced in [13, 14]. Here we generalize to the neutrosophic framework the first phase of the implementation of the well-known modified Delphi method, in a version elaborated by Kaufmann and Gil Aluja in [15] known as Fuzzy-Delphi. In this version, expert theory is incorporated as a valuable tool, which allows us to aggregate the opinion of several experts so that it is transformed into a single truly representative opinion of all of them, that allows to perform the measurement of intellectual capital [16]. The advantage over fuzziness is that neutrosophic framework explicitly contains indeterminacy, thus the results are more accurate than fuzzy theory[17]. We have to highlight the application of a neutrosophic Delphi method for evaluating scientific research proposals that can be read in [14].

The intellectual capital in hotel activity [18] is used as a real case study for applying the proposed neutrosophic method, due to the importance of this subject; this example illustrates well the applicability of the method.

This paper is divided into the following structure. The section of materials and methods contains the main concepts of Neutrosophy, as well as some important aspects of Delphi method. Next section is dedicated to introduce the expert selection method for the neutrosophic Delphi we propose, and to illustrate it with a case study. Finally, last section announces the conclusions of the paper.

2 Materials and Methods

This section describes the preliminaries on Delphi method in subsection 2.1, whereas the main concepts of Neutrosophy are described in subsection 2.2.

2.1 Preliminaries on Delphi method

Delphi method allows expert groups to be consulted on a wide range of possible future developments in their respective fields of action.

The main characteristics of the original Delphi method are the following:

Anonymity: There should be no physical contact between the participants, but the survey administrator can identify each participant and their responses.

Iteration: It can handle as many rounds as necessary.

Controlled feedback: the total results of the previous round are not delivered to the participants, only a selected part of the information circulates.

Statistical results: the group response can be presented statistically (mean and dispersion degree).

Delphi method has the following phases:

1. The group of experts that will design the questionnaire is formed.
2. Participants (experts and non-experts in the specific topic of the survey) are selected.
3. The questionnaire is circulated among the participants (First Round).
4. The answers are analyzed, and the necessary clarifications can be requested from the participants and a second questionnaire is prepared.
5. The second questionnaire is circulated among the participants, and they can re-evaluate their opinion in the light of the other participants´ opinions.
6. Many Rounds as necessary can be carried out until it is noticed that opinions have been consolidated.
7. Finally, the information is summarized and presented, indicating the average values and their dispersion, and it is analyzed by expert groups.

Table 1 summarizes the main variants of Delphi method, classified by their purpose, from the point of view of experts' participation and methodologies.

Delphi variant	Purpose	Experts participation	Methodology
Classical	To collect opinions and seek consensus.	Experts are selected based on the objectives of the research.	The elaborated instrument is sent by regular mail during the development of each planned round. In the first round, a qualitative analysis is carried out, the rest of rounds are concluded with a quantitative type analysis.
Modified	The purpose depends on the research, e.g., to predict and to seek group consensus.	Experts are selected based on the objectives of the research.	The elaborated instrument is sent by regular mail during the development of the first three rounds. The pre-selected articles in the specialized literature on the subject should be analyzed in both, their theoretical and practical content.
Decision	To make decisions and forecast.	Decision makers, with high hierarchical position/expertise.	From the elaborated instrument, experts' decisions are issued, and this result is sent by regular or electronic mail, after the rounds of application of the method.
Policy	To generate contrasting views on policy and possible solutions.	Policy makers qualified to suggest different alternatives.	The elaborated instrument is sent by email and it is analyzed in group meetings during the different rounds necessary to apply the method.
Real time	To elicit opinion and seek consensus in real time rather than postal.	Experts are selected based on the research goals and are available in the assigned time.	The elaborated instrument is analyzed according to the answers received on the same date and place. The first qualitative round is opened, and the rest of the rounds are concluded with their quantitative analysis.
Online	The purpose depends on the research, e.g., to predict and to seek group consensus.	Experts are selected based on the objectives of the research.	In the elaborated instrument, the conduct of the participants is reviewed via online contact, by means of chat rooms or web forms. The first round is opened in its qualitative analysis and the rest of them are concluded in its quantitative analysis.

Table 1: .List of Delphi variants and their purposes. Source: adapted from [8].

Some advantages of Delphi method are:

• It allows obtaining information on points of view in very broad or very specific topics.
• The analysis horizon can be varied.
• It allows the participation of a large number of people, without chaos.

Some disadvantages of Delphi method are:

• It has a high cost due to the amount of people and resources it requires.
• Its execution time can be quite long, from the formulation period to obtain the final results.
• It requires massive participation for the results to have statistical significance. However, the group must have a high degree of correspondence with the topics to be covered in the exercise.
• A critical part of the method is the questions in the questionnaire.

2.2 Main concepts of Neutrosophy

Definition 1: [19-23] 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 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: ([19-23]) 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 $F_A: U \to [0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

The *Single-Valued Neutrosophic number* (SVNN) [24] is expressed by $N = (t, i, f)$, such that $0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Definition 3: [19-23] 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 falsehood membership functions are defined as follows, respectively:

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

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

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

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

Definition 4: [19-23] 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:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \left\langle \left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \right\rangle, a_3 > 0 \textit{ and } b_3 > 0 \\ \left\langle \left(\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \right\rangle, a_3 < 0 \textit{ and } b_3 > 0 \\ \left\langle \left(\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \right\rangle, a_3 < 0 \textit{ and } b_3 < 0 \end{cases}$$

6. Multiplication of two triangular neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1b_1, a_2b_2, a_3b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 > 0 \textit{ and } b_3 > 0 \\ \langle (a_1b_3, a_2b_2, a_3b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 < 0 \textit{ and } b_3 > 0 \\ \langle (a_3b_3, a_2b_2, a_1b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 < 0 \textit{ and } b_3 < 0 \end{cases}$$

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,

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{4}$$

$$\mathbf{A}(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (5)$$

They are called the score and accuracy degrees of $\tilde{a}$, 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:

$$\widetilde{A} = \sum_{j=1}^{n} \lambda_j \widetilde{A}_j \quad (6)$$

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

Two scales of measurement used in the method are summarized in Tables 2 and 3, see [14].

Linguistic terms	SVTNN
Extremely unimportant (EU)	$\langle (0,0,1); 0.00, 1.00, 1.00 \rangle$
Not very important (NVI)	$\langle (0,1,3); 0.17, 0.85, 0.83 \rangle$
Not important (NI)	$\langle (1,3,5); 0.33, 0.75, 0.67 \rangle$
Medium (M)	$\langle (3,5,7); 0.50, 0.50, 0.50 \rangle$
Important (I)	$\langle (5,7,9); 0.67, 0.25, 0.33 \rangle$
Very important (VI)	$\langle (7,9,10); 0.83, 0.15, 0.17 \rangle$
Extremely important (EI)	$\langle (9,10,10); 1.00, 0.00, 0.00 \rangle$

Table 2. Importance weight as linguistic variables and their associated SVTNN. Source: [14].

Linguistic term	SVTNN
Very low (VL)	$\langle (0,0,1); 0.00, 1.00, 1.00 \rangle$
Medium low (ML)	$\langle (0,1,3); 0.17, 0.85, 0.83 \rangle$
Low (L)	$\langle (1,3,5); 0.33, 0.75, 0.67 \rangle$
Medium(M)	$\langle (3,5,7); 0.50, 0.50, 0.50 \rangle$
High (H)	$\langle (5,7,9); 0.67, 0.25, 0.33 \rangle$
Medium high (MH)	$\langle (7,9,10); 0.83, 0.15, 0.17 \rangle$
Very high (VH)	$\langle (9,10,10); 1.00, 0.00, 0.00 \rangle$

Table 3: Linguistic terms for evaluations associated with SVTNN. Source: [14].

3 Results

In this paper, the proposed procedure is exposed in detail. The *Competence Coefficient* (K) determines the experts' competence, which can be calculated by different procedures according to [25], such as the ones listed below:

- Based on the *Knowledge Coefficient* (Kc) and the *Coefficient of Argumentation* (Ka) in this procedure, the experts' competence is determined by the competence coefficient (K), to measure their level of knowledge about the problem and with the sources that allow us to argue these criteria (Ka), [26].
- From the *Coefficient of Theoretical Knowledge* and the *Coefficient of Practical Knowledge*.

In the procedure for the selection of experts, we considered three fundamental stages as described in Table 4:

Stages	Subject content
Stage 1: Preparation of experts' list	In the elaboration of the experts' list, a study is carried out on their quality and their workplace is also considered, as well as their real possibility of collaboration. Internal experts (belonging to the organization) and external experts (belonging to academic or business institutions) may be included in the list.
Stage 2: To fix the number of experts	With respect to this stage, the number of experts should be less or equal to (nα), where α is a numeric value included in the interval [0.1, 1], while parameter n represents the number of elements to measure in the study. According to the proposition that appears in [16] α is defined by the principal investigator, however in this paper we propose to aggregate expert's opinion for obtaining α, despite the other way is not rejected. After defining n, it is multiplied by the selected α, resulting in the number of experts to choose.
Stage 3: Experts issue their consent to participate in the investigation	During this stage, official invitation is sent to explain the pursued goal and what the work consists of; they have to fill the questionnaire about personal data and the competence they have. Once the response is obtained, the final experts' list is determined, after which the specialists are informed about their inclusion in the experts' opinion.

Table 4: .Structure of the proposed procedure for experts' selection. Source: The authors.

Considering the subject of study, it is important to judge the complexity of the knowledge with regard to the research problem, as shown in Table 5.

Very complex or not sufficiently-known topic	Moderately complex or sufficiently known topic	Simple or well-known topic
$\alpha \in [0.1, 0.4)$	$\alpha \in [0.4, 0.7)$	$\alpha \in [0.7, 1]$

Table 5: .Values of α classified according to the subject complexity. Source: The authors.

The algorithm we propose is detailed below:

1. To create the experts' list, experts are asked about their expertise as follows:

1.1 Each expert evaluates its knowledge on the subject in the scale VL, ML, L, M, H, MH, and VH. Their corresponding SVTNN in Table 3 are converted into crisp values using Formula 5, let us call them NK_{Ci} for i = 1, 2,…, N.

1.2 Each expert evaluates questions in the table below in form of VL, ML, L, M, H, MH, and VH with weights measured in form of EU, NVI, NI, M, I, VI, and EI. The weights are assigned by the moderator, converted into crisp values using formula 5, and finally normalized. We called them w_i.

Source of argumentation	Evaluation	Weight
Technical analysis that you have carried out during your professional life	$\widetilde{A}_{1i}$	w_1
Your experience in this subject	$\widetilde{A}_{2i}$	w_2
Your work with national authors	$\widetilde{A}_{3i}$	w_3
Your work with foreign authors	$\widetilde{A}_{4i}$	w_4
Your intuition	$\widetilde{A}_{5i}$	w_5

Table 5. Aspects to assess.

This table containing the aspects to assess was inspired by the one used in [27, 28].

The SVTNNs associated with the evaluations are aggregated through formula 6, like $\widetilde{A}_i = \sum_{j=1}^{5} w_j \widetilde{A}_{ji}$ for i = 1, 2,…, N.

$\widetilde{A}_i$s are converted into crisp values using formula 5, let us call them NK_{ai}.

Finally, for each potential expert i =1,2,…, N calculate $NK_i = \frac{NK_{Ci}+NK_{ai}}{2}$.

2. Corresponding to Stage 2 of Table 4, potential experts express their evaluations on the complexity of the subject using the linguistic scale in VL, ML, L, M, H, MH, and VH of Table 3. Let us denote them by $E_1, E_2, \dots, E_N$ and their evaluations by $v_1, v_2, \dots, v_N$.

Next, $v_1, v_2, \dots, v_N$ are converted into crisp values using Equation 5 denoted by $\bar{v}_1, \bar{v}_2, \dots, \bar{v}_N$ and they are normalized dividing by 10.875, which is the crisp value associated with 'Very High'. Then, $\alpha_i = \max\left(1 - \frac{\bar{v}_i}{10.875}, 0.1\right)$, i = 1, 2,…, N.

Finally, $\alpha = \frac{\sum_{i=1}^{N} \alpha_i}{N}$, and its linguistic interpretation can be seen in Table 5, in form of either "Very complex or not sufficiently-known topic", "Moderately complex or sufficiently known topic" or "Simple or well-known topic". Additionally, n is also fixed.

To finish this stage, the number of experts is established as m = nα.

3 The obtained values NK_i are sorted in descending order. The first m experts corresponding to this order are selected for evaluating in Delphi method. It is recommendable to choose in the previous set experts who satisfy $NK_i \geq 7.2188$, where this threshold corresponds to the crisp value associated with 'High' after applying formula 5.

Example

In this example, the previous algorithm is applied to a real case, corresponding to experts´ selection in certain hotel of the Meliá Group, located in the touristic destination Varadero, in Cuba, to measure the Intellectual Capital.

The moderator establishes the importance of each of the five aspects as it is summarized in Table 6:

Source of argumentation	Linguistic weight	Crisp weight	Relative weights
Technical analysis that you have carried out during your professional life	VI	9.2625	0.22424
Your experience in this subject	EI	10.875	0.26328
Your work with national authors	M	4.6875	0.11348
Your work with foreign authors	I	7.2188	0.17476
Your intuition	VI	9.2625	0.22424

Table 6: Moderator's linguistic evaluation on the importance of each aspect, its crisp corresponding value and the normalized values.

Table 6 contains the crisp value associated with the evaluations, after applying formula 5 and the normalization of these values in the rightmost column.

Thirteen experts for being potentially selected were self-evaluated as it is summarized in Table 7.

Expert	Knowledge	$\tilde{A}_1$	$\tilde{A}_2$	$\tilde{A}_3$	$\tilde{A}_4$	$\tilde{A}_5$
E_1	L	H	H	L	L	MH
E_2	L	H	H	L	L	MH
E_3	L	H	H	L	L	MH
E_4	L	H	H	L	L	MH
E_5	M	M	M	M	M	M
E_6	M	L	L	H	H	L
E_7	M	H	H	L	L	H
E_8	M	H	H	L	L	H
E_9	M	VL	VL	MH	MH	VL
E_{10}	M	L	L	H	H	L
E_{11}	M	M	M	M	M	M
E_{12}	M	M	M	M	M	M
E_{13}	M	M	M	M	M	M

Table 7. Measure of expertise for every potential expert obtained by self-evaluation.

Table 7 contains the linguistic evaluations of the 13 experts according to the linguistic scale in Table 3.

Table 8 summarizes the aggregation of $\tilde{A}_j$s for each expert according to the scalar weights calculated in Table 6, as well as their corresponding SVTNN.

Expert	Knowledge	$\tilde{A}$
E_1	$\langle(1,3,5);0.33,0.75,0.67\rangle$	$\langle(4.30,6.30,\ 8.07);0.33,0.75,0.67\rangle$
E_2	$\langle(1,3,5);0.33,0.75,0.67\rangle$	$\langle(4.30,6.30,\ 8.07);0.33,0.75,0.67\rangle$
E_3	$\langle(1,3,5);0.33,0.75,0.67\rangle$	$\langle(4.30,6.30,\ 8.07);0.33,0.75,0.67\rangle$
E_4	$\langle(1,3,5);0.33,0.75,0.67\rangle$	$\langle(4.30,6.30,\ 8.07);0.33,0.75,0.67\rangle$
E_5	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3,5,7);0.50,0.50,0.50\rangle$
E_6	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(1.44,2.73,4.73);0.33,0.75,0.67\rangle$
E_7	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3.85,5.85,7.85);0.33,0.75,0.67\rangle$
E_8	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3.85,5.85,7.85);0.33,0.75,0.67\rangle$
E_9	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(2.02,2.59,3.59);0.00,1.00,1.00\rangle$
E_{10}	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(1.44,2.73,4.73);0.33,0.75,0.67\rangle$
E_{11}	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3,5,7);0.50,0.50,0.50\rangle$
E_{12}	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3,5,7);0.50,0.50,0.50\rangle$
E_{13}	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3,5,7);0.50,0.50,0.50\rangle$

Table 8. SVTNN values of knowledge and $\tilde{A}$s for each expert.

Finally, Table 9 contains the crisp values associated with knowledge and $\tilde{A}$s for each expert, as well as NKs indexes and their ranking.

Expert	Knowledge	$\tilde{A}_i$	NK_i	Ranking
E_1	2.5312	5.2509	3.8910	7
E_2	2.5312	5.2509	3.8910	7
E_3	2.5312	5.2509	3.8910	7
E_4	2.5312	5.2509	3.8910	7
E_5	4.6875	4.6875	4.6875	3
E_6	4.6875	2.5031	3.5953	11
E_7	4.6875	4.9359	4.8117	1
E_8	4.6875	4.9359	4.8117	1
E_9	4.6875	2.0500	3.3687	13
E_{10}	4.6875	2.5031	3.5953	11
E_{11}	4.6875	4.6875	4.6875	3
E_{12}	4.6875	4.6875	4.6875	3
E_{13}	4.6875	4.6875	4.6875	3

Table 9. Crisp values of knowledge and $\tilde{A}$s for each expert, and their NKs indexes and ranking.

Finally, to select the number of experts, we have to calculate α. We ask every expert how he/she evaluates the complexity of the subject "Intellectual Capital" in hotel business, and their responses are given in Table 10.

Expert	Complexity
E_1	H
E_2	H
E_3	MH
E_4	H
E_5	H
E_6	MH
E_7	H
E_8	H
E_9	MH
E_{10}	M
E_{11}	H
E_{12}	MH
E_{13}	H

Table 10: Evaluation of subject complexity by each expert.

Thus, according to Table 10, we have $\alpha = 0.29628$, which is classified as a "Very complex or not sufficiently-known topic". Twenty-five is the number of elements to measure in the context of Intellectual Capital for this hotel.

Thus, the number of experts to select is $m = 25x0.29628 = 7.4070 \approx 7$. Therefore, the selected experts are E_7, E_8, E_5, E_{11}, E_{12}, E_{13}, and E_1. The selection of E_1 among the set of experts $\{E_1, E_2, E_3, E_4\}$ with equal NK was based on an additional criteria assessed by the moderator.

Conclusion

This paper has the objective of proposing a new experts' selection method for neutrosophic Delphi technique. This method considers experts self-evaluation and the weights assigned to each criteria by the moderator. Single-valued triangular neutrosophic numbers are used for the model. The advantages of the new method are (1) simplicity, (2) it considers indeterminacy, (3) the calculus is made on linguistic terms, and (4) it allows ranking each expert according to their self-evaluations. The indexes are inspired by the well-known K_C and K_a for experts' selection. However, because of those indexes are generalized to the neutrosophic framework, they are more adequate to use due to the aforementioned advantages. Finally, we illustrate the applicability of the method with a real-life example to measure Intellectual Capital in a hotel activity.

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Method for Evaluating the Principle of Interculturality in the Custodial Sentence using the Iadov Technique

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Abstract: The principle of interculturality represents a condition for respecting the rights of others. Assessing the state of interculturality makes it possible to especially ensure the rights of indigenous communities. However, in Ecuador the existing legal norms do not guarantee the intercultural protection of citizens in custodial sentence. This research proposes a solution to the posed problem by developing a method for evaluating the principle of interculturality in the application of a custodial sentence. The method bases its operation on using the Iadov technique. Uncertainty is modeled with the use of neutrosophic numbers. The method was applied to representative people of the indigenous communities of the Pastaza province. As a result, we obtained an assessment of the main indigenous actors in the communities on the intervention of ordinary justice in death cases.

Keywords: Neutrosophy; intercultural principle; Iadov technique; custodial sentence.

1. Introduction

Interculturality raises a peaceful coexistence and the will for effective integration. Intercultural dialogue as a condition of equity that enables harmonious coexistence, mutual solidarity, the reconciliation of differences, integration between individuals and peoples and the awareness that the diversity of ways of life is the source of the cultural wealth of a country and the principle of internal cohesion of a nation [1-3].

Indigenous peoples have their own culture and Customary Law that defends cultural diversity and the principles of equality and non-discrimination [4, 5]. Article 24 of the Organic Code of the Judicial Function, talks about the principle of interculturality, which requires judges to consider elements of cultural diversity related to the customs, practices, norms and procedures of the people, groups or collectivities that are under their knowledge [6].

The Constitution of the Republic of Ecuador of 2008, in its article 171, states that: “The authorities of indigenous communities, peoples and nationalities shall exercise jurisdictional functions, based on their ancestral traditions and their own law, within their territorial scope, with the guarantee of participation and decision of women". The authorities will apply their own rules and procedures for the solution of their internal conflicts that are not contrary to the Constitution and human rights recognized in international instruments. The State will guarantee that the decisions of the indigenous jurisdiction are respected by public institutions and authorities [7].

In the province of Pastaza (Fig 1), we may find seven different nationalities. The Kichwas represent the group with the largest presence in this area. On November 28, 2013, the “Tagaeri-Taromenani” case occurred in which six Waorani indigenous nationals are allegedly guilty of a spear attack, committed against some 20 members of the Tagaeri-Taromenani clans, a tribe that is considered an uncontacted people in the Ecuadorian Amazon. Waorani organizations have called for the alleged criminals to be tried within the community under indigenous laws. However, the Ecuadorian State, through the competent jurisdictional bodies, has resolved that it must be judged through ordinary justice.

Figure 1. Pastaza Province

Based on the situation described above, this research aims to develop a method for evaluating the principle of interculturality in the custodial sentence.

2. Preliminaries

This section introduces the main theoretical references on the object of study and the different concepts that facilitate the understanding of the investigation. It begins with the references of the principle of interculturality. A description of the deprivation of liberty within the framework of interculturality is also covered.

2.1. Principle of interculturality

Interculturality implies a process of communication between people and groups with different identities, dialogue with others on an equal footing, a relationship of respect for diversity and a desire for mutual enrichment with the exchange of knowledge and experiences. Interculturality supports a humanism of reunion and peaceful coexistence; the will for effective integration.

Intercultural dialogue starts from the circumstance that neither group is above the other, condition of equity that enables harmonious coexistence, mutual solidarity, the reconciliation of differences, integration between individuals and peoples and the awareness that the diversity of ways of life is the source of the cultural wealth of a country and the principle of internal cohesion of a nation [8, 9].

Interculturality implies understanding that the dignity of indigenous people and peoples is contained in the set of fundamental rights and freedoms that Positive Law determines, but also, in their own culture and their Customary Law. For the respect and defense of cultural diversity, it is essential to take into account the principles of equality and non-discrimination.

3. Design of the method for the assessment of interculturality in custodial sentences

Obtaining information about a certain phenomenon can be complex. The method for assessing the custodial sentence represents a group decision-making problem [10, 11]. It is based on using methods and techniques to support decision making [12, 13]. The Iadov technique is used as an alternative in the method inference process.

Using the Iadov technique, an indirect route is established for the study of satisfaction. The criteria used are based on the relationships established between the three closed questions, which are inserted within a questionnaire and whose relationship the respondent does not know [14-16]. The technique is based on the application of a survey made up of closed and open questions [17, 18]. The three closed questions establish a relationship in the Iadov Logical Table [19], indicating the scale of individual satisfaction of each respondent, while open questions allow to delve into the positive elements and the recommendations or insufficiencies of the proposal being evaluated [20, 21].

The technique has been used to model uncertainty with the use of neutrosophic numbers [13, 22, 23]. A neutrosophic number is defined as: Let $N = \{(T, I, F) : T, I, F \subseteq [0, 1]1n$ a neutrosophic valuation is a mapping of a group of formulas proportional to N, that is, for each statement p we have:

$$v\ (p) = (T, I, F) \quad (1)$$

In order to facilitate practical application to decision-making and engineering problems, the proposal of the Single Valued Neutrosophic (SVN) sets was made [24] which allows the use of linguistic variables [25, 26] that increase the interpretability in the recommendation models and the use of indeterminacy [27].

Let X be a universe of discourse. An SVN over X is an object of the form.

$$A = \{\langle x, u_A(x), r_A(x), v_A(x)\rangle: x \in X\}d \quad (2)$$

Where $u_A(x): X \rightarrow [0,1]$, $r_A(x),: X \rightarrow [0,1]$ y $v_A(x): X \rightarrow [0,1]$ with $0 \leq u_A(x) + r_A(x) + v_A(x): \leq 3$ for all $x \in X$. The interval $u_A(x), r_A(x)$ and $v_A(x)$ denote the memberships to true, indeterminate, and false of x in A, respectively. For convenience, an SVN number will be expressed as $A = (a, b, c)$, where a, b, $c \in [0,1]$, and $+ b + c \leq 3$ [28].

Neutrosophic Numbers are those satisfying Equation 3 [21, 29]

$a + bI$ (3)

Where a, b are real numbers, and I is indeterminacy part, such that $I^2 = I$ and $0 \cdot I = 0$.

If the coefficients a and b are real, then a + bI is called Neutrosophic Real Number.

Given $N_1 = a_1 + b_1I$ and $N_2 = a_2 + b_2I$ 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),

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

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

For the evaluation, a set of linguistic terms that represent neutrosophic values are used, which corresponds to an absolute value. Table 1 presents the assessment scale used.

Language labels represented	SVN number/ Neutrosophic Number	Value
Clear satisfaction	(1, 0, 0)	1
More satisfied than dissatisfied	(1, 0.25, 0.25)	2
Not defined	I	3
More dissatisfied than satisfied	(0.25, 0.25, 1)	4
Clear dissatisfaction	(0,0,1)	5
Contradictory	(1,0,1)	6

Table 1. Set of terms used as a rating scale.

4. Application of the method for the valuation of custodial sentences

For the implementation of the proposed method, a multi-expert approach was used. The province of Pastaza, which represents the highest concentration of Kichwas in the region, was used as the object of study. A questionnaire was applied to the main Kichwa patriarchs. The purpose of the instrument carried out was to estimate the satisfaction of the patriarchs on the exclusive sentence.

The sample used for the development of the activity was made up of 12 Kichwa patriarchs. The evaluated variables were:

Satisfaction about the application of the principle of interculturality by the Ecuadorian government.

Satisfaction regarding the determination in decision-making of exclusive sentences of members of the Kichwas tribe.

The results of the preferences of the set of Kichwas patriarchs that intervened in the process, are analyzed using the Iadov's Logical Table proposed in Table 2 [30].

	Do you consider correct the principle of interculturality implemented by the Ecuadorian government?								
What is your opinion on the policy implemented by the Ecuadorian government regarding the custodial sentence within the framework of the principle of interculturality?	**Do not**			**I don't know**			**Yes**		
	Do you consider the protection that indigenous communities possess adequate to exercise their right of self-determination?								
	Yes	**I don't know**	**Do not**	**Yes**	**I don't know**	**Do not**	**Yes**	**I don't know**	**Do not**
I like it very much	1	2	6	2	2	6	6	6	6
I do not like it very much	2	2	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
I do not like	6	6	6	6	4	4	6	4	6
I do not know what to say	2	3	6	3	3	3	6	3	4

Table 2. Iadov's Logical Table.

In order to obtain the group satisfaction index (GSI), we worked with the different levels of satisfaction that are expressed on the numerical scale 1 and -1 as reported in Table 3.

Language labels to be represented	**Value**
Maximum satisfaction	1
More satisfied than dissatisfied	0,5
Undefined and contradictory	0
More dissatisfied than satisfied	- 0,5
Maximum dissatisfaction	-1

Table 3. Set of terms used as level of satisfaction.

Once the surveys were applied, we obtained on the individual satisfaction scale results shown in Table 4:

Satisfaction level	**Quantity**	**Percent**
Maximum satisfaction	0	0
More satisfied than dissatisfied	0	0
Undefined or contradictory	1	8,33 %
More dissatisfied than satisfied	3	25,00 %
Maximum dissatisfaction	8	66,66 %

Table 4. Result of satisfaction on the application of the Iadov technique.

The application of the technique allowed us to obtain the Group Satisfaction Index (GSI), which represents a parameter attributed to the agreement of the group of users to whom the instrument was applied. GSI is determined by equation 3.

$$GSI = \frac{A(+1) + B(0.5) + C(0) - D(0.5) + E(-1)}{N} \tag{3}$$

Where:
A, B, C, D, E: represents the number of subjects with an individual index 1,2, (3 o 6), 4,5.
N: represents the total number of users in the group.

The Group Satisfaction Index values range between +1 and -1 as in figure 2. Values between -1 and -0.5 indicate dissatisfaction, values between -0.49 and 0.49 show contradictions due to what is expressed as dissatisfaction and values between 0.5 and 1 indicate that there is satisfaction. Figure 2 shows a scale with the domain of values used to perform the valuation.

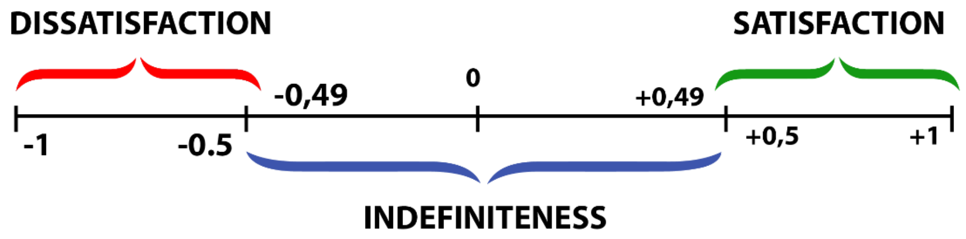

Figure 2: Satisfaction scale.

The processing of the method yielded a GSI = 0.37, considering that there is dissatisfaction. After obtaining an unsatisfactory GSI, the following analysis is performed:

The criteria of the respondents regarding the question whether “Do you consider correct the principle of interculturality implemented by the Ecuadorian government?”, obtained an undefined or contradictory value of 0%, 8.33% considered it more dissatisfied than satisfied and 91.33% thought there was a maximum dissatisfaction.

Regarding question “What is your opinion on the policy implemented by the Ecuadorian government regarding the custodial sentence within the framework of the principle of interculturality?“, results indicate an undefined or contradictory value of 8.33%, 25.00% rate it as more dissatisfied than satisfied and 66.66% considered it as maximum dissatisfaction.

Regarding whether “Do you consider the protection that indigenous communities have adequate to exercise their right of self-determination?” It was considered as maximum dissatisfaction by 100% of respondents.

In addition to the dissatisfaction obtained, the following elements could be identified through open questions:

That in the measures the principle of interculturality is not well implemented to guarantee respect for indigenous determination.

That implementations on criminal law applied in Ecuador that affect the Kichwas communities be extended.

Conclusions

This investigation proposed a method for evaluating the principle of interculturality in the custodial sentence. The proposed method obtained an evaluation process by applying the Iadov technique while modeling the problem through neutrosophic numbers [31].

As a result, the method obtained the criteria issued by the main Kichwa patriarchs for the assessment of the principle of interculturality. This result, quantified by the method, was assessed by a satisfaction index that corresponds to high dissatisfaction.

As a final assessment of the application of the technique, we can conclude that the criteria issued and the results obtained using the Iadov technique corroborated that the application of the exclusive judgment does not correspond to the principle of interculturality.

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Selection of Non-Pharmacological Treatments for mild Cognitive Impairment in older Adults with Neutrosophic-AHP

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Abstract: The aging of population includes a social group that has increased in recent years. Properly attending to the conditions of the elderly represents a problem to be addressed by Public Health institutions. A pathology that occurs very frequently is the cognitive impairment. Selecting the correct treatment for this type of condition is subject to the set of criteria that characterize the patient. Problems of this nature have been addressed by science from the implementation of artificial intelligence. The present research aims to develop a method for the selection of non-pharmacological treatments for mild cognitive impairment in older adults. The method operates using the neutrosophic AHP to model indeterminacy. The result is a case study with the implementation of the proposed method as an example of applicability.

Keywords: Population aging; AHP; Neutrosophic Numbers; mild cognitive impairment.

1. Introduction

Cognitive impairment is a disease that affects older adults and significantly deteriorates their mental health. Currently, people in the elderly category are exposed to stressful situations in which cognitive impairment is unavoidable. This leads people to have all kinds of mental health problems that can eventually turn into chronic mental disorders if they are not properly identified and treated.

Older adults with mental health problems usually have a tendency not to admit their health problems due to fear of the stigma associated with these types of illnesses and the risk of being declared disabled. In the case of adults with mild cognitive impairment, they are usually in a state of denial, a situation that can cause more serious complications and even turn into a chronic mental illness, so it is necessary to treat them right from the appearance of the first symptoms.

If an adult's mental status can be easily assessed and examined, chances are that their mental problems can be detected at a very early stage and can be controlled and cured in a timely manner, as long as they receive appropriate treatments and medications [1]. In order to know the epidemiological clinical behavior of mild cognitive impairment in the elderly, a study was carried out in Ecuador, which determined that there is a prevalence of 38.6%; it was also identified that women have higher rates than men, 18.5% versus 14.3% respectively [2].

In [3], a study associated with this issue was also carried out. It determined that the prevalence in general is 13.6% in those over 50 years of age and the female gender also predominates. Age over 65 years, low level of education and the number of children are the most important socio-demographic variables that play an important role for a person to develop mild cognitive impairment [3].

The scenarios described above become the main motivation to carry out this research; the main objective is to develop a method for the selection of non-pharmacological treatments for mild cognitive impairment in older adults based on neutrosophic AHP[4]. In the preliminaries of this document, we present some findings on mild cognitive impairment in older adults identified from the review of the scientific literature. In the materials section, we propose a method for the selection of non-pharmacological treatments for mild cognitive impairment, based on the mental health status of the people and that supports its functioning on the basis of neutrosophic AHP. In the Results, a case study is used to determine the applicability of the proposed method.

2. Preliminaries

This section carries out a study of the main theories associated with the modeled problem. The current state of the elderly is characterized as the central theme of the research proposal. We also cover the main elements that describe cognitive delay in the elderly. Finally, we introduce the possible non-pharmacological therapies to be selected according to the characteristics of the patient.

2.1. Older adult

According to the Inter-American Convention on the Protection of the Human Rights of Older Persons, someone is considered to be older from the age of 60 onwards, subject to the internal laws of the States, although it may not establish an age over 65 years to be legally considered an older person [5]. Based on this guideline, in Ecuador the Constitution of the Republic of Ecuador of 2008, in its second chapter, article 14 stipulates: The right of the population to live in a healthy and ecologically balanced environment is recognized, which guarantees sustainability and good living [6].

During the Inter-American Convention on the Protection of the Human Rights of Older Persons, with a plenary session in the city of Washington, on March 21, 2019 the activity carried out by Ecuador was praised, as a country that has established norms and laws in favor of the older adults. It also recognizes that it has legislated reforms to dignify the condition of the elderly and whose greatest effect was achieved on April 29, 2019, with the entry into effect of the Organic Law of Older Adults, which seeks to eradicate abandonment or negligence suffered by this human group [7].

Older adults are considered a vulnerable group at the national and international level [8]. The course of the years, physical and mental wear and tear and environmental, demographic, social and economic factors are some of the elements that affect the appearance of mild cognitive impairment in the elderly.

2.2. Cognitive impairment

In order to assess the health status of adults aged 60 and over, the Survey on Health, Well-being and Aging (SHWA) is carried out in coordination with the Ministry of Economic and Social Inclusion and monitored by the National Institute of Statistics and Censuses (NISC) [9]. With this survey, they determined the demographic characteristics, health status and state of mind of the people of 60 years and over of the Ecuadorian population, in order to implement policies, strategies and public programs that improve the social and health conditions of older adults.

An important aspect of aging is cognitive impairment, which reflects a decrease in the performance of one or more of the mental or intellectual abilities: memory, orientation, abstract thinking, language, judgment, reasoning and calculation, constructive, learning and visual spatial ability. Several studies show the weight of age, educational level, socio-economic condition, the presence of affective symptoms play a very important role in the prevalence of cognitive impairment.

While many cognitive functions remain the same as in their youth, older adults experience a decline in some cognitive spheres, such as learning new information and executing fast motor functions. In addition to the decline in cognitive function typical of aging, there are pathologies such as Alzheimer's disease that disproportionately affect older adults. They can also partially or globally alter cognitive functions, both acutely and chronically [10].

The term "cognitive impairment" is a concept that, although it does not specify the intellectual function or functions affected or the underlying cause, should be considered as a situation that reveals the existence of a problem whose diagnosis must be established promptly in order to adopt the appropriate therapeutic measures.

2.3. Non-pharmacological therapies

Non-pharmacological therapies comprise a group of non-chemical interventions that stimulate the performance of cognitive processes, improve affectivity and enhance the independence of daily life. All these actions are reflected in the improvement of the patient's quality of life; some are described below [11]:

Music therapy: Playing a song to a patient with mild cognitive impairment or some form of dementia, especially those suffering from Alzheimer's, helps them awaken emotions and memories of the past, enhancing security and personal identity [12].

Sensory stimulation: The person is exposed to a space with different stimuli either actively or passively in order to cause them a feeling of relaxation and peace. This can be achieved by giving the patient something pleasant to smell or caressing him/her among other stimulations [13].

Activities of daily life: These are the basic tasks that human beings perform in their routine which generate independence; these can be basic: such as bathing, dressing, eating, or walking. The instrumental types that are related to managing money, taking care of another person, preparing food and finally the advanced types that adhere to the social, work and lifestyle of the person.

Cognitive Stimulation: The person is asked to name an object in their own words when visualizing a mimic, a gesture or by simple touch; another example would be assigning them papers as coupons with a monetary value "x" and proceeding to play the buyer and seller business, this activity allows the patient to identify and understand the value of each number [14].

3. Materials and Methods

This section describes the structure and operation of the proposed method. It operates through neutrosophic AHP. The method starts with the identification of the objective to be achieved, see [15, 16]. Then the evaluation criteria are selected on the objective. These criteria can be decomposed into sub-evaluation criteria and so on. Finally, the alternatives to be evaluated are determined. This is represented in a tree as shown in Figure 1, where the first node in the upper level represents the evaluation objective, in a lower level are placed the criteria, even lower are the sub criteria and so on. While the lowest level represents the alternatives.

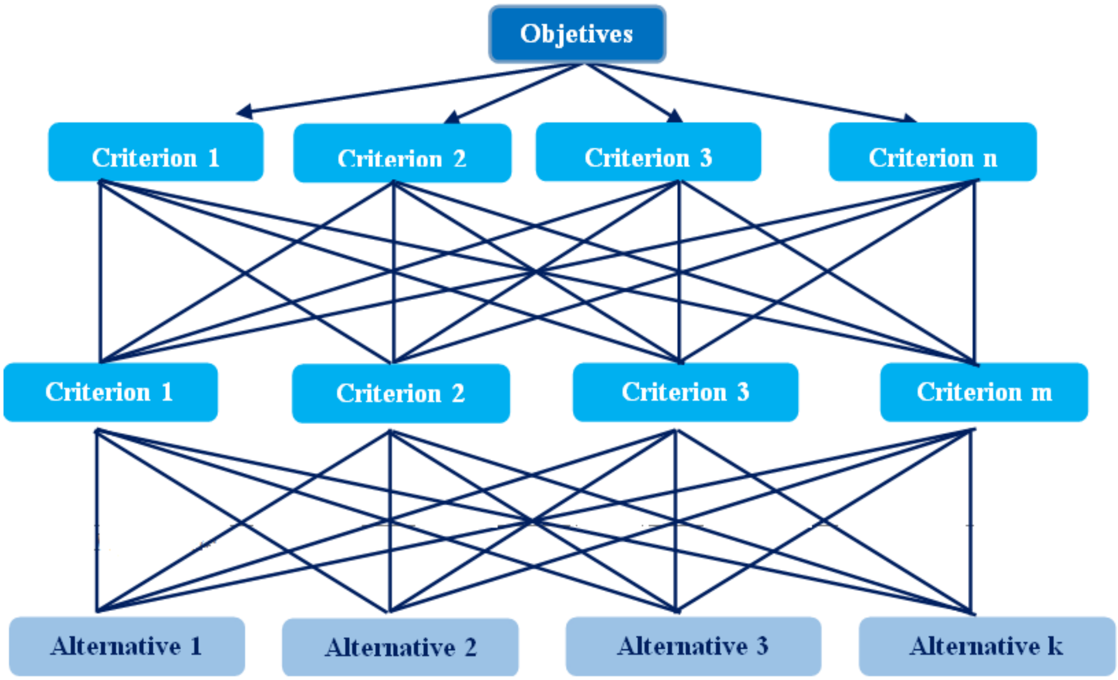

Figure 1. Tree that is the starting point to apply the AHP technique. (Source: [15])

The AHP technique is based on a scale for measuring the relative importance of the elements of the same level within the tree in Figure 1. In this article it is calculated by applying a scale equivalent to a *Triangular Single Value Neutrosophic Number* (TSVNN), as shown in Table 1 [17].

Saaty scale	Definition	Triangular Neutrosophic Scale
1	Equally influential	$\tilde{1} = \langle(1,1,1); 0{,}5; 0{,}5; 050\rangle$
3	Slightly influential	$\tilde{3} = \langle(2,3,4); 0{,}3; 0{,}75; 0{,}70\rangle$
5	Strongly influential	$\tilde{5} = \langle(4,5,6); 0{,}80; 0{,}15; 0{,}20\rangle$
7	Very strongly influential	$\tilde{7} = \langle(6,7,8); 0{,}9; 0{,}10; 0{,}10\rangle$
9	Absolutely influential	$\tilde{9} = \langle(9,9,9); 1{,}0; 0{,}0; 0{,}0\rangle$
2, 4, 6, 8	Sporadic values between two scales close to each other	$\tilde{2} = \langle(1,2,3); 0{,}40; 0{,}65; 0{,}60\rangle$ $\tilde{4} = \langle(3,4,5); 0{,}60; 0{,}35; 0{,}40\rangle$ $\tilde{6} = \langle(5,6,7); 0{,}70; 0{,}25; 0{,}30\rangle$ $\tilde{8} = \langle(7,8,9); 0{,}85; 0{,}10; 0{,}15\rangle$

Table 1. Saaty Scale taken to a TSVNN Scale (Source: [16])

Definition 1. Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow\ ]^-0, 1^+[$, which satisfy the condition -0 ≤ inf $u_A(x)$ +

$\inf\ r_A(x) + \inf\ v_A(x) \leq \sup\ u_A(x) + \sup\ r_A(x) + \sup\ v_A(x) \leq 3^+$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions to true, indeterminate and false of x in A, respectively, and their images are standard or non-standard subsets of $]^-0, 1^+[$ (see [18, 19]).

Definition 2. Let X be a universe of discourse. A *Single Value Neutrosophic Set* (SVNS) A over X is an object of the form: $A = \{\langle x, u_A(x), r_A(x), v_A(x)\rangle : x \in X\}$ (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 membership functions of true, indeterminate and false of x in A, respectively. For convenience, a *Single Value Neutrosophic Number* (SVNN) will be expressed as A = (a, b, c), where a, b, c $\in$ [0,1] and satisfies $0 \leq a + b + c \leq 3$ (see [18],[9]).

Definition 3. A *Triangular Single Value Neutrosophic Number* (TSVNN), which is denoted by: $\tilde{a} = \langle(a_1, a_2. a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}}\rangle$, is a CN over $\mathbb{R}$, whose truth membership functions, indeterminacy, and falsehood are defined below (see [18],[20]):

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}\left(\frac{x-a_1}{a_2-a_1}\right)}, & a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}}, & x = a_2 \\ \alpha_{\tilde{a}\left(\frac{a_3-x}{a_3-a_2}\right)}, & a_2 < x \leq a_3 \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

$$I_{\tilde{a}}(x) = \begin{cases} \dfrac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}\ , & \\ \dfrac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \end{cases} \quad (3)$$

$$F_{\tilde{a}}(x) = \begin{cases} \dfrac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a}}\ , & \\ \dfrac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \end{cases} \quad (4)$$

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

Starting from the reference in Table 1, it is possible to compare the relative importance between two variables. The definition contains the linguistic meaning of how important one variable is over another. The neutrosophic scale gives an equivalent value in the form of TSVNN. This is located in an array.

The following are other concepts needed to apply the Neutrosophic AHP method: A neutrosophic pair-wise comparison matrix is defined in equation 5.

$$\tilde{A} = \begin{matrix} \tilde{1} & \widetilde{a_{12}} & \cdots & \widetilde{a_{1n}} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{a_{n1}} & \widetilde{1_{n2}} & \cdots & \tilde{1} \end{matrix} \quad (5)$$

Such that $\tilde{A}$ satisfies the condition $\widetilde{a_{ji}} = \tilde{a}_{ij}\tilde{a}_{ij}^{-1}$,s according to the inversion operator that appears in Definition 3.

Additionally, two indexes are defined to convert a TSVNN into a real numeric value. These indexes are the Score in Equation 6 and Precision in Equation 7:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (6)$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (7)$$

3.1 Proposal of a method for selecting non-pharmacological treatments for mild cognitive impairment in older adults

The proposed method is designed to support the management flow of selecting non-pharmacological treatments for mild cognitive impairment in older adults. Its inference process is based on the Neutrosophic AHP. Figure 2 shows a diagram illustrating the work flow of the proposed method.

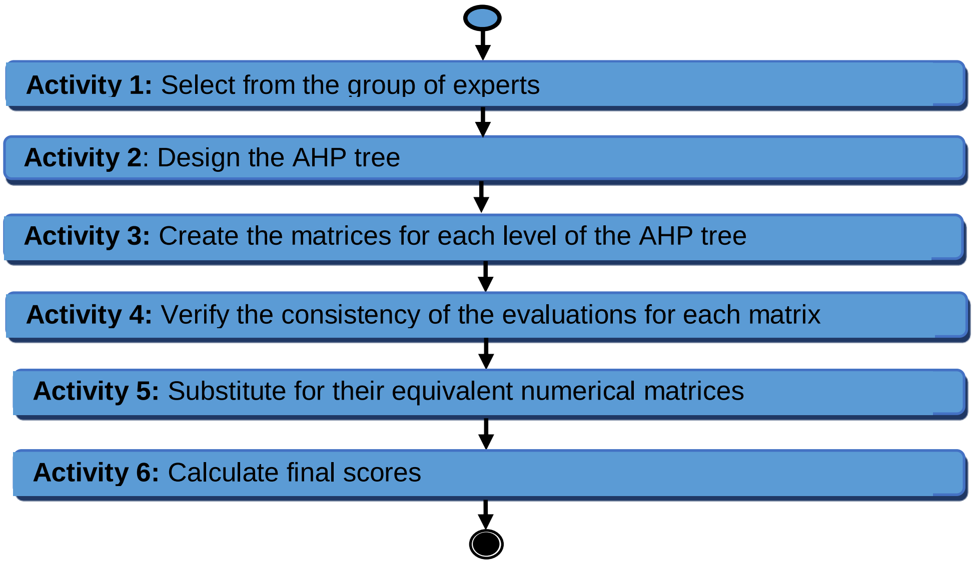

Figure 2: Workflow of the proposed method.

Below is a description of the activities of the Neutrosophic AHP:
Select a group of experts who are capable of conducting the analysis.

The experts must design an AHP tree, like the one shown in Figure 1. This implies that the criteria, sub-criteria and alternatives to carry out the evaluation must be specified.

Create the matrices for each level of the AHP tree for the criteria, sub criteria and alternatives, according to the evaluations of the experts expressed in the form of TSVNN scales, as specified in Equation 5.

These matrices are formed by comparing the importance of each pair of criteria, sub-criteria and alternatives, according to the scales that appear in Table 1.

Verify the consistency of the evaluations for each matrix. For this, it is enough to convert $\tilde{A}$ into a numerical matrix $M = \left(a_{ij}\right)_{nxn}$, such that$a_{ij} = A\left(\tilde{a}_{ij}\right)$ or $a_{ij} = S\left(\tilde{a}_{ij}\right)$, defined in one of Equations 6 and 7, and then apply the methods used in the original AHP. Which consists of:

Calculate the *Consistency Index* (CI) that depends on λ_{max}, the maximum eigenvalue of the matrix M , defined by:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{8}$$

Where n is the order of the matrix.

Calculate the *Consistency Ratio* (CR) with the equation CR = CI/IR, where IR is taken from Table 2.

Order (n)	1	2	3	4	5	6	7	8	9	10
IR	0	0	0,52	0,89	1,11	1,25	1,35	1,40	1,45	1,49

Table 2. IR associated with the order of the matrix

Table 2 shows a set of values that are used as part of the CR calculation, which were obtained experimentally for matrices of order n in the form shown in Equation 5 and are part of the original AHP technique. This guarantees that the consistency between the comparisons given by the expert, if not complete, is at least acceptable, as explained below.

- If $CR \leq 10$ % it is considered that the consistency of the evaluation by the experts is sufficient and the AHP method can be applied. If not, it is recommended that the experts reconsider their evaluations.

2. From here on, the matrices $\widetilde{\text{A}}$ are replaced by their equivalent numerical matrices M, calculated in the previous step. Then proceed as follows:
   - Normalize the entries by column, dividing the elements in the column by the total sum.
3. Calculate the total of the averages by rows, each of these vectors is known as a priority vector.

The final scores are calculated starting from the highest level (Objective), to the lowest level (Alternatives), where the weights obtained for the priority vector corresponding to the immediately higher level are taken into account. This calculation is performed by multiplying each row of the matrix of priority vectors of the lower level by the weight obtained by each of these with respect to those of the upper level, then it is added per row and this is the final weight of the element of this matrix.

In the context of this research, an algorithm for decision making based on Neutrosophic AHP[4, 21, 22] and Fuzzy Cognitive Maps is proposed. Fuzzy Cognitive Maps (FCM) extend Cognitive Maps to the fuzzy domain in the interval [-1, 1] to indicate the strength of causal relationships. A FCM consists of three types of causal relationships between vertices: negative, positive, or unrelated [23, 24]. The adjacency matrix representing a FCM allows causal inferences to be made[25].

The implemented resolution algorithm has the following steps:

a. Selection of relevant indicators.
b. Once the relevant indicators have been selected, the causality between them is modeled with the help of a FCM.
c. Static analysis. The following measures are calculated for the absolute values of the adjacency matrix:

Outdegree, denoted by $od(v_i)$, which is the sum for each row of the absolute values of a variable in the fuzzy adjacency matrix. It is a measure of the accumulated strength of the existing connections in the variable.

Indegree, denoted by $id(v_j)$, which is the sum for each column of the absolute values of a variable in the fuzzy adjacency matrix. Measures the cumulative input force of the variable.

The *centrality*, or *total degree*, of the variable is the sum of $od(v_i)$, with $id(v_j)$, as indicated below:

$$td(v_i) = od(v_i), +id(v_j) \tag{9}$$

Finally the variables are classified according to the following criteria, see [14]:

- Transmitting variables are those with $od(v_i) > 0$ and $id(v_j) > 0$
- The receiving variables are those with $od(v_i) > 0$ and $id(v_j) > 0$
- Ordinary variables satisfy both $od(v_i) \neq 0$ and $id(v_j) \neq 0$

d. The study variables are evaluated on a scale from 1(Bad) to 10 (Excellent), where 5 is Regular. For this stage, the weights of each variable obtained from the Neutrosophic AHP are used and the weighted arithmetic mean of the evaluations is found with the weights obtained.

4. Results

This section describes the result of the implementation of the method of selection of non-pharmacological treatment for mild cognitive delay in older adults. The proposal has been fed by risk factors within the House of “Sagrado Corazón de la Ciudad de Ambato” in Ecuador.

The results of the study are shown below. All calculations are carried out with the help of Octave 4.2.1, which is a free software that emulates MATLAB, therefore it contains packages with numerical mathematical methods and operations with matrices.

The concepts that will be taken into account to issue the diagnosis are based on the research carried out in [26] which are listed below:

1. Music therapy,
2. Sensory stimulation,
3. Activities of daily life,
4. Cognitive Stimulation.

There were five experts, from which the median of their qualifications was taken and the following adjacency matrix was obtained, representing the FCM:

Concept	1	2	3	4
1	0	0,75	0,5	0,25
2	0,75	0	0,6	0,5
3	0,5	0,5	0	0
4	0,25	0	0	0

Table 3. Adjacency matrix representing the FCM. Each concept is denoted by the number in which it appears before (Source: The authors).

Note that Table 3 means the causality of the i-th concept by rows over the j-th concept by column. For example, 0.25 is the element that appears in the fourth row, first column of the table, this is interpreted as that both concepts are directly proportional, because 0.2> 0, however it is closer to 0 than 1. Therefore, the relationship tends to be more independent than dependent on each other.

Table 4 contains the calculations of the indexes $od(v_i)$, $id(v_j)$ and $td(v_i)$, plus the classification of each variable.

Variable	*Outdegree*	*Indegree*	*Total degree*	Classification
v_1	1,5	1,5	3	Ordinary
v_2	1,85	1,25	3,1	Transmitter
v_3	1	1,1	2,1	Ordinary
v_4	0,25	0,75	1	Ordinary

Table 4. *Outdegree*, *indegree*, *total degree* and classification of each variable (Source: The authors).

Table 4 shows the *Outdegree*, *Indegree* and *Total Degree* measures of the values in Table 3, see Equation 9. This allows each variable to be evaluated in terms of its type[27].

Table 5 summarizes the expert evaluations of the weight of each of the variables that influence the selection of non-pharmacological treatments. The neutrosophic measurement scale in Table 1 is used.

Variable	v_1	v_2	v_3	v_4
v_1	$\tilde{1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}$
v_2	$\tilde{7}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$
v_3	$\tilde{5}$	$\tilde{1}$	$\tilde{1}$	$\tilde{2}$
v_4	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$

Table 5: Pair-wise comparison matrix of variables or criteria.

Table 5 describes the relative importance of each variable with respect to the others, according to the values in Table 1.

Subsequently, the elements of Table 5 are converted into numerical values by applying the formula of Equation 7. From the numerical matrix obtained, we have λ_{max}, = 6,0542; CI = 0,008654 and CR = 0,005689; CRX100 = 0,5689% <10%, therefore there is no considerable inconsistency in the evaluations. Once the numerical matrix corresponding to the neutrosophic matrix given in Table 5 was obtained with the help of Equation 7, it is normalized by columns and the arithmetic mean per row is found, giving rise to the weights of each variable, as shown in Table 6.

Table 6 specifies the result of the calculation of the priority vector, these are the weights of each variable in importance.

Variable	Priority vector
v_1	0,375
v_2	0,462
v_3	0,250
v_4	0,062

Table 6. Priority vector for each variable.

Table 7 contains the median of the experts' evaluations for each variable on a scale of 1-10, where 1 means “Bad”, 10 “Excellent” and 5 “Regular”.

Variable	v_1	v_2	v_3	v_4
Value on a scale of 1-10	6	7	5	3

Table 7. Evaluation of the situation regarding the variables.

The total evaluation is carried out as the weighted arithmetic mean of the values in Table 7, with the weights in Table 6, which yields a value of 5.2507 on a scale of 1 to 10. The media values for "Music Therapy" is 3.75, for "Sensory Stimulation" it is 4.625, for "Activities of daily life" it is 2.501 and for "Cognitive Stimulation" it is 0.625, from which "Sensory stimulation" is recommended as the best treatment.

Conclusions

This investigation developed a method for selecting non-pharmacological treatment for mild cognitive impairment in older adults. The Neutrosophic AHP and Fuzzy Cognitive Maps methods were applied to select the treatment. A case study was implemented based on risk factors within the House of "Sagrado Corazón de la Ciudad de Ambato" in Ecuador. Based on the case study, it was possible to recommend non-pharmacological treatment, demonstrating the applicability of the method. It is also expected that this research can help mental health specialists to examine and diagnose in a more efficient way those older adults affected by mild cognitive impairment.

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Neutrosophic Analysis of Complications Generated by Hypothyroidism during Pregnancy

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Abstract: Pregnancy process might be threaten by several complications. Affectations in the thyroid gland provoke that not enough thyroid hormone is produced, altering the heart rate, the body temperature and all the aspects of the metabolism. This research aims to develop a method that allows the estimation of complications generated by hypothyroidism during pregnancy. The method is based on the modeling of uncertainty using neutrosophic numbers under a multi-criteria approach. As the main result, a case study is carried out at the IESS Ambato Hospital in Ecuador, where the applicability of the proposed method is shown.

Keywords: Pregnancy; hypothyroidism; multi-criteria method; neutrosophic numbers.

1. Introduction

Pregnancy has a significant impact on the thyroid gland and thyroid function, often resulting in hypothyroidism in women with limited thyroid reserve or iodine deficiency. Clinical studies are producing critical data demonstrating the harmful effects of hypothyroidism in pregnant women [1-4] .

Hypothyroidism is the most common condition in women of reproductive age [5, 6]. It is characterized by the decrease in the synthesis and secretion of thyroid hormones, giving a state of generalized hypo metabolism, therefore it causes important repercussions in the whole organism [7].

Although various studies have shown that hypothyroidism in pregnancy is quite common; Clinically, it requires specialized and urgent care, since it is associated with adverse pregnancy and perinatal outcomes. Thyroid stimulating hormones (TSH), especially free thyroxine (FT4), are crucial for early brain development in the embryo [8]. Epidemiological studies and case reports have shown that maternal hypothyroidism can have significant negative effects on pregnancy and fetal neurodevelopment [9].

The thyroid gland belongs to the endocrine system and has very important functions, the main one is to produce thyroid hormones as necessary to satisfy the demand of the peripheral tissues [10]. Thyroid hormones play a decisive role in brain development, somatic growth, and the regulation of numerous metabolic processes [5].

The decrease in the availability of maternal thyroid hormones can be a critical factor that damages the neurological development of the fetus in the initial stages of gestation, before the fetal thyroid gland is activated [11]. Several recent studies report increased fetal loss and preterm delivery in mothers with undiagnosed hypothyroidism [7, 8, 10, 12].

Considering the high levels of incidence, in Ecuador there have been several investigations dedicated to the advancement, understanding, prevention, diagnosis and treatment of thyroid disorders and thyroid cancer. However, hypothyroidism during the pregnancy period and its main maternal and infant consequences have not been sufficiently addressed by science; this is the main indicator that drives this research. The main objective of this work is to perform a neutrosophic analysis of the complications generated by hypothyroidism during pregnancy.

As a methodology for the research, we decided to carry out a retrospective design, which allowed the collection of data from 80 medical records of pregnant patients diagnosed with hypothyroidism (defined as thyrotropin [TSH]> 4.0 μIU / mL with normal levels of free thyroxine according to the guidelines of the American Thyroid Association of 2017), which have been admitted at the IESS Ambato Hospital in Ecuador, in the period January - September 2018. The bibliographic review was carried out on Ovid MEDLINE In-Process, in the journal Thyroid: the Official Journal of the American Thyroid Association, and in the academic databases Web of Science and Scopus. This methodological design allowed corroborating the main complications that occurred during pregnancy in the studied patients.

The paper is structured into the following sections: Preliminary, Materials and methods, Results and Conclusions. At the bibliographic references presented at the end. In the Preliminaries, we identify the main characteristics of hypothyroidism during pregnancy and analyze the main consequences that this condition may generate; the methodology to address decision-making problems is also introduced and the neutrosophic linguistic model that supports the main results of the research is formalized. The Materials section develops a method that allows estimating the complications generated by hypothyroidism during pregnancy. As a result, a case study is carried out at the IESS Hospital, where we show the applicability of the proposed method.

2. Preliminaries

This section introduces the main concepts associated with the problem domain. The main elements of Hypothyroidism during pregnancy are described as the core of the research. The section continues with the decision-making models as a form of inference for the proposed method. Finally, we introduce linguistic models for the representation of uncertainty.

2.1. Hypothyroidism during pregnancy

The thyroid gland belongs to the endocrine system, and has the function of producing thyroid hormones as necessary to satisfy the demand of the peripheral tissues. Thyroid hormones play a decisive role in brain development, somatic growth, and the regulation of numerous metabolic processes [13].

The main function of this gland is to synthesize and secrete thyroid hormone which is necessary to regulate basal metabolism. The functioning of this gland is based on processes such as: iodine metabolism; thyroid hormone production, storage, and secretion [12]. Iodine is extracted from the blood, oxidized and coupled intramuscularly with tyrosine radicals to form thyroglobulin, which is a mixture of iodine tyrosine, triiodotyrosine (T3) and thyroxine (T4) stored as a colloid in the lumen of the follicle [14].

The thyroid stimulating hormone works by increasing the cells and vascularization of the gland; In addition, it intervenes in all the processes that control the synthesis and release of thyroid hormone [15]. Thyroid stimulating hormones are regulated by the concentration of free thyroid hormone in peripheral blood by a negative feedback mechanism [16].

Several studies have shown that pregnant women with clinical hypothyroidism are generally at increased risk of complications such as preeclampsia, placental abruption, and postpartum hemorrhage [6, 12-14]. Hence the interest in knowing about the main complications that can occur in pregnant patients who fail to comply with adequate treatment for hypothyroidism [17].

During normal pregnancy, as in all organs, several physiological changes occur that affect thyroid function, which is modulated by three factors [18]:

i. The increase in urinary iodide excretion, secondary to the physiological hyperfiltration of pregnancy, producing a decrease in its plasma concentration and, therefore, the uptake of iodine by the thyroid is increased [19].
ii. Increased Human Chorionic Gonadotropin (HCG) stimulates the thyroid [12].
iii. Increased thyroid hormone transport globulin (TBG): Increased levels of estrogens result from increased production at the liver level, decreased clearance and degradation, and increased glycosylation of this protein [20].

The complications generated by hypothyroidism during pregnancy are multiple and therefore are the reason for prescribing treatment; the main complications are described below:

- Preeclampsia: thyroid hormones have various actions on cardiovascular physiology and in the regulation of blood pressure. Exposure to altered hormonal concentrations can modify these functions. Studies of pregnant women have shown that as serum levels of thyroid stimulating hormones increased, the frequency of hypertensive disorders also increased [20, 21].
- Intrauterine growth restriction (IUGR): research results suggest an interrelation between thyroid hormones and intrauterine growth factors [15]. Other authors claim that treatment for hypothyroidism has led to intrauterine growth restriction, fetal bradycardia, and neonatal hypoglycemia [22].
- Recurrent abortions: the possible causes of abortion are multiple and can be caused by: anatomical, genetic, autoimmune, endocrine, infectious alterations, and due to the exposure to toxic substances [17]. Several literatures determine that hypothyroid women who are in treatment, and maintain normal TSH concentrations, have 4% abortions, while those who remain without treatment have a risk of 31.4% of abortion. The risk of abortion in women with thyroid stimulating hormones is 4.5-10 mIU / L is higher, so they recommend close monitoring and improve the delivery of hormone replacement.
- Preterm delivery: preterm delivery is a situation that can be caused by multiple factors. The literature review identified a possible association between preterm delivery and thyroid disease [18].
- Abruption placentae: it is considered a catastrophic event since the premature separation of the normal inserted placenta can generate high morbidity and mortality in the mother and the neonate. Although hypothyroidism is not the only cause of abrupt placental, several studies report that this pathology may increase the risk of abrupt placental [16].
- Recurrent Urinary Tract Infection (UTI): Thyroid disorders induce alterations at multiple levels. The heart and kidneys are the main targets for thyroid hormones [14]. The deterioration of renal function secondary to hypothyroidism implies heterogeneous mechanisms with dominance of hemodynamic alterations: negative isotropic effect on the heart, reduction in circulating intravascular volume and increase in peripheral resistance with renal vasoconstriction [23].

2.2. Decision making

Decision-making has historically been approached by multiple disciplines, from the classics such as philosophy, statistics, mathematics and economics, to the most recent, such as Artificial Intelligence. The theories and models developed point to rational support for making complex decisions. They include basic activities such as[24-27]:

i. Define the problem of decision making.
ii. Analyze the problem and identify the alternative solutions $X = \{x_1, x_2, , x_n\}, (n \geq 2)$
iii. Establish evaluation criteria.
iv. Select the experts.
v. Evaluate the alternatives.
vi. Sort and select the best alternative.
vii. Implement and follow up.

When the number of criteria satisfies that $C = \{c_1, c_2, , c_m\}, (m \geq 2)$ it is considered a multi-criteria decision-making problem. When the number of experts is such that $K = \{k_1, k_2, , k_n\}, (n \geq 2)$ it is considered a group decision-making problem. Figure 1 shows a diagram with the workflow for solving decision-making problems.

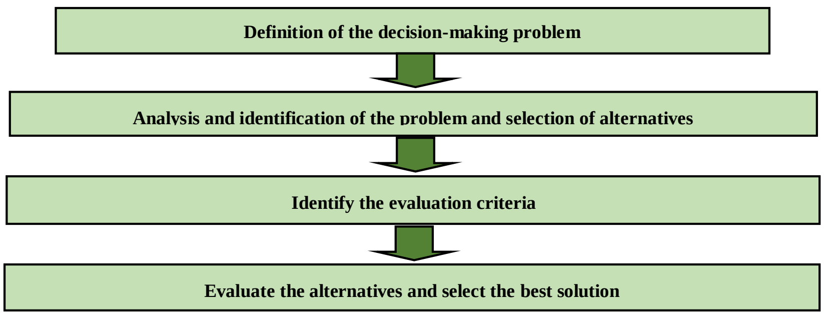

Figure 1: Diagram with the flow for decision-making problems.

According to the decision environment, decision-making problems can be classified into three situations or decision environments:

- Environment of certainty: the elements and/or factors involved in the problem are known precisely. An exact utility value can be assigned to the alternatives involved.
- Risk environment: Some of the elements or factors involved are subject to canges. They are usually solved by assigning probabilities to the alternatives according to the theory of probabilities.
- Uncertainty environment: the available information is vague or imprecise, generally associated with sensory or subjective appraisals from experts.

2.3. Linguistic model

The criteria for the evaluation of complications generated by hypothyroidism may have different characteristics. Therefore, it is appropriate to express each criterion in the appropriate domain (numerical or linguistic). In this context, the extension of the 2-tuple linguistic model proposed in [28] constitutes a way of increasing the interpretation of the data that are introduced in the decision-making problem.

The linguistic representation model based on 2-tuples defines a set of transformation functions for linguistic 2-tuples to carry out the decision-making process without loss of information. Since $\beta \in [0, g]$ is a value that represents the result of a symbolic operation, a linguistic tuple can be assigned to express the information equivalent to that given by β.

Definition 1. Let $S = \{s_0, , s_g\}$ u be a set of linguistic terms. The set of 2 tuples associated with S is defined as $\langle S \rangle = S \times [-0.5,0.5]$. We define the function $\Delta: [0, g] \rightarrow S \times [-0.5,0.5]$ given by:

$$\Delta\beta = (s_i, \propto), with f(x) = \begin{cases} s_i, i = round(\beta) \\ \alpha = \beta - i, \end{cases} \tag{1}$$

where the round assigns to β the integer i∈ {0,1 .., g} closest to a β.

Note that the function Δ is bijective and $\Delta^{-1}: [0, g] \rightarrow sx[-0.5; 0.5]$ is defined by $\Delta^{-1}\{s_i, \propto\} = i + \propto$

Numeric values can be transformed to the S_t language domain in a two-step process. First, transforming numerical values in [0, 1] to $f(S_t)$ using the numerical linguistic transformation function.

Definition 2. Let $V \in [0,1]$ be a numerical value and $S_t = \{s_0, s_1, s_g\}$ a set of linguistic terms. The numerical linguistic transformation function $NS_t: [0,1] \rightarrow f(S_t)$ is defined by:

$$tNS_t(v) = \{(s_0, y_0), (s_1, y_1), , (s_g, y_g)\} \tag{2}$$

With:

$$y_i = \mu_{si} = \begin{cases} 0, if v < \propto or\ v > d, \\ \frac{v-a}{b-a}, if a < v < b, \\ 1, if b \leq v \leq c, \\ \frac{d-v}{d-c}, if c < v < d, \end{cases} \tag{3}$$

Where $y_i \in [0,1]$ and $f(S_t)$ is the set of fuzzy sets in S_t and μ_{si} is the membership function of the linguistic label $S_i \in S_t$.

The unified previous information in fuzzy sets in S_t is subsequently transformed to facilitate the interpretation of the results. This transformation is carried out by the function $\chi: F(S) \rightarrow [0, g]$.

Definition 3. Given the set of linguistic terms $S_t = \{s_0, s_1, s_g\}$ the function $\chi: F(S) \rightarrow [0, g]$ is defined by:

$$X: (f(s_t)) = X(\{(s_j, y_j), j = 0, \dots g\}) = \frac{\sum_{j=0}^{g} j y_j}{\sum_{j=0}^{g} y_j} = \beta \tag{4}$$

where the fuzzy set $F(S_t)$ could be obtained from tNS_t.

Applying the function Δ a β (Definition 1) we can assign a tuple of 2 that expresses the information equivalent to that given by β.

2.4. 2-tuple linguistic neutrosophic number

In [29] the concept of 2-tuple linguistic neutrosophic number sets (2TLNNSs) is proposed to solve this problem based on the SVNS and 2-tuple linguistic sets (2TLSs)[26, 30, 31].

A 2TLNNS is defined as follows [29]: Suppose that $S = \{s_0, , s_g\}$ is a 2TLSs with odd cardinality $t + 1$. It is defined for $(S_t, \propto), (S_i, b), (S_f, c) \in L$ and $a, b, c \in [0, t]$, where $(S_t, \propto), (S_i, b), (S_f, c) \in L$ independently express the degree of truth, indeterminacy and falsehood by 2TLSs, then 2TLNNSs is defined as follows:

$$l_j = \{(S_t, \propto), (S_i, b), (S_f, c)\} \tag{5}$$

Where:

$$0 < \Delta^{-1}(S_{tj}, a) \leq t, 0 < \Delta^{-1}(S_{ij}, b) \leq t, 0 < \Delta^{-1}(S_{Fj}, c) \leq t \text{ and } 0 < \Delta^{-1}(S_{tj}, a) + 0 < \Delta^{-1}(S_{ij}, b) + 0 < \Delta^{-1}(S_{Fj}, c) \leq 3t \tag{6}$$

The Scoring and Accuracy feature allows 2TLNN to be classified as:

Let:

$$l_1 = \{(S_{t1}, \propto), (S_{i1}, b), (S_{f1}, c)\}a$$

2TLNN in L the scoring and precision function is defined as follows:

$$S_{l1} = \Delta\left\{\frac{2t + \Delta^{-1}(S_{t1}, \propto) - \Delta(S_{i1}, b) - \Delta(S_{f1}, c)^{-1}}{3}\right\}, \Delta^{-1}(S(l_1)) \in [0, t] \tag{7}$$

$$H_{l1} = \Delta\left\{\frac{t + \Delta^{-1}(S_{t1}, \propto) - \Delta(S_{f1}, c)^{-1}}{2}\right\}, \Delta^{-1}(H(l_1)) \in [0, t] \tag{8}$$

3. Materials and Methods

This section describes the structure and operation of the method for estimating complications generated by hypothyroidism during pregnancy. The method operates on a neutrosophic environment based on the linguistic decision analysis scheme that can address criteria of different nature and provide linguistic results. Figure 1 illustrates the general structure of the proposed method.

Figure 1. Structure of the method to estimate the complications generated by hypothyroidism during pregnancy.

1. Evaluation framework:

In this phase, the assessment framework is defined for medical complications caused by hypothyroidism during pregnancy. The framework is established as follows:

Let $E = \{e_1, e_2, , e_n\}, (n \geq 2)$ be a set of experts.

Let $C = \{c_1, c_2, , c_k\}, (k \geq 2)$ be a set of criteria.

Let $R = \{r_1, r_2, , r_m\}, (m \geq 2)$ be a set of medical complications.

2. Obtaining information:

Once the framework has been defined, the knowledge of the experts group must be obtained. Each expert provides his preferences through the use of utility vectors. The utility vector is represented as follows:

$$P_l^i = \{P_{j1}^i, P_{j2}^i, , P_{jh}^i\} \tag{9}$$

where P_{jh}^i is the preference given by the c_k criteria of the r_m requirement of the e_n experts.

3. Classification of medical complications.

The objective of this phase is to obtain an easily interpretable collective linguistic global assessment. To do so, the information is unified and aggregated. Finally, a prioritization process is carried out. This phase develops the approach reviewed in Section 2.3 for dealing with heterogeneous information and giving linguistic results.

Unification of information.

The information is unified in a specific linguistic domain (S_t). The numerical information is transformed to the linguistic domain (S_t), following these steps:

a) Select a specific linguistic domain, called a set of basic linguistic terms (S_t).

b) Transformation of numerical values in [0, 1] to $f(S_t)$.

c) Transformation of fuzzy sets S_t into a linguistic 2-tuple.

Information aggregation

The aggregation process is developed in two steps with the aim of calculating a global evaluation of each criterion that affects medical complications.

Assessment of medical complications.

The final step in the prioritization process is to rank the medical complications. This classification makes it possible to select the complication with the highest value. The most critical complication is the one that has the most effective collective evaluation of the $Max\{(r_j, a_j) = 1,2,3,,n\}$ process. Requirements are prioritized based on this value in descending order.

4. Results

In this session an illustrative example is developed to show the applicability of the proposed method. The study was carried out using data from the medical history of a pregnant patient treated at IESS Ambato Hospital in Ecuador, and who was diagnosed with hypothyroidism in Outpatient Consultation and Hospitalization.

1. Evaluation framework

In this case study, the evaluation framework is made up of: 3 experts $E = \{e_1, e_2, e_3\}$ who evaluate the main medical complications recorded in the scientific literature composed of 5 complications $R = \{r_1, r_2, r_3, r_4, r_5\}$ where:

r_1: Hypertensive disorders such as preeclampsia,

r_2: Threat of preterm labor,

r_3: Recurrent urinary tract infection,

r_4: Intrauterine growth restriction,

r_5: Threat of abortion.

From which 3 evaluative criteria are identified $C = \{c_1, c_2, c_3\}$ which are shown below:

c_1: Heart rate,

c_2: Body temperature,

c_3: Disorder in metabolism.

Each expert could give the information numerically or linguistically, taking into account the nature of the criteria. A common linguistic domain S_t is chosen to verbalize the results. Figure 2 shows the linguistic domain used.

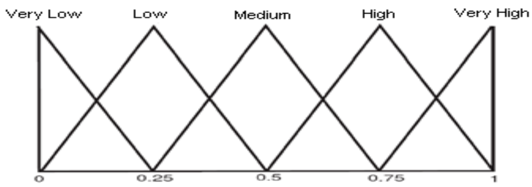

Figure 2: Domain of linguistic values S_t

For numerical values, the following linguistic scale is used with single-value neutrosophic numbers as shown in Table 1

Linguistic terms	SVN number
(EG) Extremely Good	(1,0,0)
(VVG) Very Very Goog	(0.9, 0.1, 0.1)
(VG) Very Good	(0.8,0,15,0.20)
(G) Good	(0.70,0.25,0.30)
(MG) Moderate Good	(0.60,0.35,0.40)
(M) Medium	(0.50,0.50,0.50)
(MB) Moderate Bad	(0.40,0.65,0.60)
(B) Bad	(0.30,0.75,0.70)
(VB) Very Bad	(0.20,0.85,0.80)
(VVB) Very Very Bad	(0.10,0.90,0.90)
(EB) Extremely Bad	(0,1,1)

Table 1. Linguistic Terms Used to Provide Assessments [32].

2. Obtaining information

Once the information on medical complications has been gathered, an evaluation framework is made. Table 2 shows the result obtained. The evaluation criteria are carried out on the S_t scale.

	e_1					e_2					e_3				
	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4	r_5
c_1	(1,0,0)	(0.9, 0.1, 0.1)	(1,0,0)	(0.9, 0.1, 0.1)	(1,0,0)	(1,0,0)	(0.9, 0.1, 0.1)	(0.70, 0.25,0.30)	(0.9, 0.1, 0.1)	(1,0,0)	(0.70, 0.25,0.30)	(0.9, 0.1, 0.1)	(1,0,0)	(0.9, 0.1, 0.1)	(1,0,0)
c_2	(0.70, 0.25,0.30)	(0.8,0,15,0.20)	(0.8,0,15,0.20)	(0.70, 0.25,0.30)	(0.9, 0.1, 0.1)	(0.70, 0.25,0.30)	(0.8,0, 15,0.20)	(0.50, 0.50,0.50)	(0.70, 0.25,0.30)	(0.9, 0.1, 0.1)	(0.70, 0.25,0.30)	(0.8,0, 15,0.20)	(0.50, 0.50,0.50)	(0.70, 0.25,0.30)	(0.9, 0.1, 0.1)
c_3	(0.8,0, 15,0.20)	(0.9, 0.1, 0.1)	(0.8,0,15,0.20)	(0.8,0, 15,0.20)	(0.8,0,15,0.20)	(0.60, 0.35,0.40)	(0.70, 0.25,0.30)	(0.60, 0.35,0.40)	(0.70, 0.25,0.30)	(0.50, 0.50,0.50)	(0.60, 0.35,0.40)	(0.70, 0.25,0.30)	(0.60, 0.35,0.40)	(0.50, 0.50,0.50)	(0.60, 0.35,0.40)

Table 2. Information gathering.

Information is transformed to unify heterogeneous information. Subsequent fuzzy sets S_t are transformed into linguistic 2-tuples.

In this example, a two-step aggregation process is applied to calculate a collective assessment of medical complications. For this investigation, we used the weighting average of the 2-tuples linguistic neutrosophic numbers. 2-TLNNWA is used to add evaluations for each expert. The weighting vectors we used were W=(0.4,0.3,0.3).

	e_1					e_2					e_3				
	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4	r_5	r_1	r_2	r_3	r_4	r_5
c_1	<(s3, 1),(s2,0)(s1,0)>	<(s3 0.9),(s2, 0.1),(s1 0.1) >	<(s3, 1),(s2,0,0),(s1, 0) >	<(s3 0.9),(s20.1) , s10.1) >	<(s3 1),(s2,0)(s3,0) >	<(s3, 1)(s2, 0),(s1,) >	<(s3 0.9),(s2, 0.1),(s1 0.1) >	<(s3 0.70), (s2,0.25),(s1,0.30) >	<(s3 0.9),(s2 0.1), (s1,0.1) >	<(s3 1,0),(s2,0), (s1,0) >	<(s3 0.70),(s2,0.25),(s1, 0.30) >	<(s3 0.9),(s2 0.1),(s1 0.1) >	<(s3 1,0),(s2,0),(s1,0) >	<(s3 0.9),(s2, 0.1),(s1, 0.1) >	<(s3 1,0),(s2,0),(s1,0) >
c_2	<(s3, 0.70), (s2,0.25),(s1,0.30) >	<(s3,0.8),(s2, 0,15), (s10.20) >	<(s3,0.8),(s2,0),(s1,0.20) >	<(s3 0.70), (s2,0.25),(s1,0.30)>	<(s3 0.9),(s2, 0.1),(s1 0.1) >	<(s3 0.70), (s2,0.25),(s1,0.30)>	<(s3,0.8),(s2, 0),(s1,0.20)>>	<(s3, 0.50), (s2,0.50),(s1,0.50) >	<(s3 0.70), (s2,0.25),(s1,0.30)	<(s3 0.9),(s2, 0.1),(s1 0.1) >	<(s3 0.70),(s2,0.25),(s1, 0.30)	<(s3,0.8),(s2,0),(s1,0.20) >	<(s3, 0.50),(s2,0.50),(s1, 0.50)	<(s3 0.70), (s2,0.25),(s1,0.30)	<(s3 0.9),(s2, 0.1),(s1 0.1) >
c_3	<(s3,0.8),(s2, 0),(s1,0.20) >	<(s3 0.9),(s2, 0.1),(s1 0.1) >>	<(s3,0.8),(s2,0),(s1,0.20) >>	<(s3,0.8),(s2,0),(s1,0.20) >	<(s3,0.8),(s2,0),(s1,0.20) >	< (0.60, 0.35,0.40) >	<(s3 0.70), (s2,0.25),(s1,0.30)	< (s3,0.6),(s2 0),(s1,0.35) >	<(s3 0.70), (s2,0.25),(s1,0.30)	<(s3, 0.50), (s2,0.50),(s1,0.50)	< (s3,0.60),(s2, 0.35),(s1,0.40) >	< (s3,0.6),(s20),(s1,0.35) >	< (s3,0.60),(s2, 0.35),(s1,0.40) >	<(s3, 0.50), (s2,0.50),(s1,0.50)	< (s3,0.60),(s2, 0.35),(s1,0.40) >>
-TLNNWA	<(s3,0.8),(s2, 0),(s1,0.20) >	<(s3,0.8),(s2, 0,15), (s10.20) >	<(s3,0.8),(s2,0),(s1,0.20) >>	<(s3 0.70), (s2,0.25),(s1,0.30)>	<(s3 0.9),(s2, 0.1),(s1 0.1) >	<(s3 0.70), (s2,0.25),(s1,0.30)>	<(s3,0.8),(s2, 0),(s1,0.20)>>	<(s3, 0.50), (s2,0.50),(s1,0.50)	<(s3 0.70), (s2,0.25),(s1,0.30)	<(s3 0.9),(s2, 0.1),(s1 0.1) >	<(s3 0.70),(s2,0.25),(s1, 0.30)	<(s3,0.8),(s2,0),(s1,0.20)	<(s3 0.70),(s2,0.25),(s1, 0.30)	<(s3 0.70), (s2,0.25),(s1,0.30	<(s3 0.9),(s2, 0.1),(s1 0.1) >

Table 3. An illustrative example of unified and aggregated information

To calculate the collective evaluation, the 2-TLNNWA operator is used with the weighting vector V=[0.5,0.2,0.3] (see table 2).

c_1	<(s3 0.9),(s2, 0.1),(s1 0.1) >
c_2	<(s3 0.70),(s2,0.25),(s1,0.30)
c_3	< (s3,0.60),(s2,0.35),(s1,0.40) >

Table 5. Collective evaluation for medical complication.

Finally, we sort all the collective evaluations and establish a ranking for the teams to identify the best scoring functions.

c_1	(s3, 0.73)
c_2	(s2, 0.23)
c_3	(s1, 0.26)

Table 6. Results of the scoring function

In the case study, the classification is: e1 e2 e3.

After application of the case study, we determined that the method is practical to use. The aggregation process provides great flexibility so that the model can be adapted to different situations. The way of interpreting the linguistic output is another of the strengths we detected.

Conclusions

The complications generated by hypothyroidism during pregnancy demonstrate the need for thyroid studies to be performed on all pregnant women in order to reduce the morbidity and mortality caused by the complications that may occur if not diagnosed and treated in time. Early diagnosis of thyroid dysfunction during pregnancy and initiation of rational therapy can alleviate adverse pregnancy outcomes.

Our study identified that maternal hypothyroidism was associated with various pregnancy and perinatal complications, including gestational diabetes mellitus, gestational hypertension, severe preeclampsia, caesarean section, preterm birth, major congenital anomalies, and admission to the neonatal intensive care unit.

With the implementation of the proposed method, it was possible to estimate the incidence of complications generated by hypothyroidism during pregnancy. The method operates by modeling the uncertainty using neutrosophic numbers under a multi-criteria approach. The case study was carried out at IESS Ambato Hospital in Ecuador, where the applicability of the proposed method is corroborated.

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Measure of Knowledge in Students at Uniandes, Ecuador, on the Manifestations of Oral Cancer

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Abstract. Oral cancer is a disease that deserves as much attention as possible from specialists. It is vitally important that specialists know the manifestations of this disease and they must be able to early detect it. That is why we carried out a survey on the students and teachers of the Uniandes Dental Care Unit to assess the knowledge they have about this illness. Likert scale was chosen to perform the measurement because of the subjective nature of the opinions. However, more accuracy is necessary to assess the responses. Therefore, we used the indeterminate Likert scale, based on Triple Refined Indeterminate Neutrosophic Sets, for each of the responses, which allowed us taking into account contradictory opinions. It consists of five elements: “Negative membership”, “Indeterminacy leaning towards negative membership”, “Indeterminate membership”, “Indeterminacy leaning towards positive membership”, and “Positive membership”. To measure the result, an indeterminate minimum spanning tree (MST) clustering algorithm is used. The importance of this study lies in the fact that is the first one of this kind carried out in the country, which may be a starting point for other researches on this topic in the national territory.

Keywords: Triple Refined Indeterminate Neutrosophic Set, indeterminate Likert scale, indeterminate minimum spanning tree clustering algorithm, survey, oral cancer.

1 Introduction

Cancer is one of the chronic diseases that, due to globalization processes, increasingly affects a considerable number of people. A disease that has plagued humanity forever is nowadays the second cause of incidence and death in almost all the world.

Oral cancer is a chronic condition; it is not contagious and does not discriminate geographic area, age, sex, race or anatomical location. Its origin is multifactorial and perhaps the only way to cure it is to prevent it, diagnose it and treat it in an adequate way. For this reason, this study aims to assess the degree of knowledge in ninth and tenth semester students of the Uniandes Dental Care Unit about the manifestations of oral cancer; to guide them towards education, prevention and timely detection in professional practice[1]. During the field research, surveys and interviews were carried out in order to collect information on the knowledge of oral cancer; the results justify this investigative work [2].

Cancer begins when cells become abnormal and multiply uncontrollably. These cells form a growth of tissue called tumor. A tumor may have a benign (noncancerous) or malignant (cancerous) nature. Cancer cells may invade nearby tissue and might sometimes spread through the bloodstream and lymphatic system, to other parts of the body [2].

Oral health status is a fundamental aspect that affects perceptions about the quality of life of the general population. The Canadian Dental Association points out that oral health is a state of the tissues of the mouth and related structures that positively contributes to physical, mental and social well-being, to the enjoyment of life's possibilities, allowing the individual talk, eat, and socialize unhindered by pain, discomfort, or embarrassment, [2].

In this sense, oral cancer is a debilitating, disabling, multifactorial disease, which is considered catastrophic and increasingly affects a significant group of people around the world, since due to its destructive nature, it is capable of producing notable anatomical and physiological sequelae in those who suffer from it, [3].

According to the World Health Organization, oropharyngeal cancer is the sixth most frequent worldwide. The incidence, prevalence and severity of this disease vary from country to country. An annual incidence of around

275000 oral cancer and 130000 pharyngeal cancer is estimated. The calculations of the American Society Against Oropharyngeal Cancer, reports that 137000 people will suffer from this disease and 7300 will die due to this cause in the immediate future, [2].

In Quito, Ecuador the Cancer Institute (SOLCA) presents statistical records of tumors, reporting different locations in oropharyngeal structures, where the salivary glands, mouth, nose, sinuses, and tongue are the most frequent, [2].

According to the Pan-American Health Organization (PAHO), Ecuador is among the American countries with the highest prevalence of adolescents who use tobacco, which is one of the main predisposing factors for oral cancer that increases dramatically and affects the youngest population. Until a few years ago, the main causes of this type of cancer were the consumption of cigarettes and alcohol. Currently, it has drawn much attention about the close relationship existing between tumors of the oropharyngeal area and the human papilloma virus (HPV), [4].

At the Uniandes Dental Care Unit, no studies related to this research have been carried out. Either at the city or the province, so this study constitutes a fundamental pillar within the oncology area, whose purpose is to early detect the presence of oral cancer, so that the patient may receive timely treatment and increase his quality of life, through efficient and effective care.

In this research, we considered that the first aspect that must be taken into account to early fight this disease is that dentists or final years dental students be capable of detecting this disease and be duly informed about it. For this purpose, we conducted a survey on ninth and tenth semester students from the Uniandes Dental Care Unit, to assess knowledge about the manifestations of oral cancer. In addition, we interviewed specialists in the area, in order to obtain information that contributes to this investigation.

We considered to evaluate the interview and survey based on a Likert scale, [5, 6], which is a proven way of making subjective evaluations. However, this type of measurement scales has limitations. For example, it does not necessarily accurately capture the person's feeling about what is being valued. That is why we apply an indeterminate Likert scale, which consists of five evaluations that can express more accurately the presence of mixed feelings in each of the respondents. This scale uses the Triple Refined Indeterminate Neutrosophic Sets (TRINS) ([7, 8]) that are part of the neutrosophic theory of the Refined Neutrosophic Sets, [9-14]. TRINS consist of five elements: "Negative membership", "Indeterminacy leaning towards negative membership", "Indeterminate membership", "Indeterminacy leaning towards positive membership", and "Positive membership". In addition, each respondent can evaluate his feelings or knowledge in each of the elements of the scale, which provides greater accuracy to the study. The assessment can be made with the help of five-star or five-face rating graphs. Neutrosophy has been also successfully used to solve health and educational problems, [15-19].

To measure group trends, we used an indeterminate minimum spanning tree (MST) clustering algorithm as defined in [7], based on classical algorithms to find a minimum spanning tree in a connected and weighted graph [20].

This paper is split into the following sections: Section 2, explains the basic concepts of Neutrosophy, Triple Refined Indeterminate Neutrosophic Sets, distance between TRINS[21], indeterminate MST clustering algorithm, among others. Section 3 contains the methods and results of applying the survey and interview to students and teachers of the Uniandes Dental Care Unit[22], evaluated in form of TRINS, and the application of a clustering algorithm. The last section presents the conclusions of the paper.

2 Basic concepts

This section summarizes the main concepts on Neutrosophy[21, 23, 24] and others concepts useful to comprehend this paper.

Definition 1: ([7, 8]) 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 $F_A: U \to [0,1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

Definition 2: ([7, 8]) 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 falsehoods: $F_1, F_2, \dots, F_s$, where all $p, r, s \geq 1$ are integers, and $p + r + s = n$.

Definition 3: ([7, 8]) 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 has a weight $w_m \in [0,1]$ associated with it. For each $x \in X$, there are $P_A(x), I_{P_A}(x), I_A(x), I_{N_A}(x), N_A(x) \in [0,1]$, $w_P^m(P_A(x)), w_{I_P}^m(I_{P_A}(x)), w_I^m(I_A(x)), w_{I_N}^m(I_{N_A}(x)), w_N^m(N_A(x)) \in [0,1]$ 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 defined as follows, [7, 8]:

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

Where $\lambda > 0$.

Definition 4: Let A_j (j = 1,2,...,m) be a collection of m TRINS, then we define the TRINS distance matrix $D = \left(d_{ij}\right)_{m\times m}$, where $d_{ij} = d_\lambda\left(A_i, A_j\right)$ is the generalized TRINS distance between A_i and A_j and satisfies the following conditions:

1. $d_{ij} \in [0, 1], \forall i, j = 1,2,\ldots, m$;
2. $d_{ij} = 0$ if and only if $A_i = A_j$;
3. $d_{ij} = d_{ji}$ for all $i, j = 1,2,\ldots, m$.

The *Indeterminate Likert Scale* consists of 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 nor disagree,
– Agree,
– Strongly agree.

The advantage of the Indeterminate Likert Scale over the classical one is that the surveyed and interviewed person has the possibility to evaluate all the elements of the scale with degrees between 0% and 100%. However, the classical scale only allows him/her to select no more than one element with 100%. Thus, many contradictory feelings of the person are not captured in the classical way. Whereas, using the Indeterminate Likert Scale, the interviewer can assess using e.g., “Negative membership” with 95%, “Indeterminacy leaning towards positive membership” with 4% and “Indeterminate membership” with 1%, and we obtain more accuracy this way.

To obtain the results of the survey, in [7] is proposed an indeterminacy-based minimum spanning tree (MST) clustering algorithm. This algorithm adapts the Kruskal’s algorithm for solving minimum spanning tree, [25]. The minimum spanning tree problem consists in looking for a subset of edges that, forming a tree, include all the vertices and where the total cost of all the edges of the tree is the minimum.

The idea is to define the graph (G, V), where every vertex represents an interviewed denoted by $F_i \in \{F_1, F_2, \cdots, F_m\}$, while every edge F_iF_j is associated with the value d_{ij} of the TRINS distance matrix D. The Kruskal’s algorithm is defined in [25] to solve minimum spanning tree problems and used in [7] with this purpose. To form the cluster, a threshold value $\varepsilon > 0$ is fixed. Next, if $d_{ij} > \varepsilon$ then the edge F_iF_j is disconnected in G. Finally, the resulting graph is formed by clusters; and each of them contains the connected vertexes.

3 Results

This section shows the results of processing the survey of the knowledge on oral cancer applied at Uniandes, Ecuador.

The survey consists of one set of closed questions which are applied to 37 students; and another set of open questions for an interview applied to 10 professionals.

The closed questions and their possible responses of the survey are:

1. Do you spend the necessary time to carry out an interrogation, data collection, lymph node examination and both, extra and intraoral clinical examination?

Yes	
No	

2. What do you consider the highest risk factor for oral cancer?

Genetic predisposition	
Smoking habit	
Physical trauma from irritating elements	
Parallel tobacco and alcohol use	

3. Are people who chew tobacco at higher risk of oral cancer?

Yes	
No	

4. Do you consider that in our environment, men suffer more from oral cancer than women do?

Yes	
No	

5. The virus that is most associated with oral cancer is:

Epstein Barr virus	
Herpes Type I	
Papilloma virus	

6. How does the early lesion of oral cancer appear?

Asymptomatic	
Symptomatic	

7. What could be a warning sign of a cancer injury?

Fordyce granule	
Melanin pigmentation in mucosa	
Chronic ulcers	

8. Can you clinically differentiate a candidiasis from a leukoplakia?

Yes	
No	

9. What is the most frequent type of oral cancer in our environment?

Ameloblastoma	
Mucoepidermoid carcinoma	
Lymphoma	
Lichen planus	
None	

10. What is the type of clinical injury with which oral cancer commonly occurs?

Ulcer	
Dental plaque	
Nodule	
Macula	
None	

11. What is the age with the highest number of cases of oral cancer?

From 18 to 30 years old	
From 31 to 40 years old	
More than 40 years old	

12. If a patient has an ulcer, in how many days we suspect malignancy when despite he/she receiving treatment there is no tendency to heal?

5 days
10 days
15 days
20 days

13. Do you know the oral areas where the cancerous lesions associated with human papilloma virus (HPV) infections are most frequently located?

Yes
No

14. Do you teach your patients to self-test for signs and symptoms of oral cancer and pre-cancer?

Yes
No

15. Do you know about oral washing with toluidine blue in the early diagnosis of malignant lesions?

Yes
No

Through the interviews applied to 10 general dental teaching professionals and specialists in each area, who are tutoring the treatments carried out on patients who come to Uniandes Dental Care Unit during the academic period April-September 2018, the following questions were asked:

1. Do you consider that students make an adequate record in the clinic history, as well as the background and possible predisposing risk factors for oral cancer, before performing dental care on patients?
2. What are the premalignant lesions, related to manifestations of oral cancer that have been most frequently identified by students during dental practices at Uniandes Dental Care Unit?
3. Do students perform clinical and radiological examinations of edentulous and partially edentulous patients, including revision of mucous and tooth-supported prostheses?
4. Given the suspicion of a precancerous oral lesion, do you think that during dental practice at Uniandes Dental Care Unit, toluidine blue washing could be implemented as a test to aid in the early diagnosis of oral cancer; to be able for referring to the specialist?
5. Assessing the level of knowledge that the final year students have; regarding, precancerous and cancerous lesions in the oral cavity. Do you think they are ready to apply their knowledge to benefit patients during clinical practice?

Let us denote by $\mathrm{St} = \{\mathrm{St}_1, \mathrm{St}_2, \cdots, \mathrm{St}_{37}\}$ the set of surveyed students. A team of independent experts was hired for asking the question: Has student St_i the necessary knowledge on oral cancer?

The results are evaluated by consensus of the team members for every one of the students. Experts based their opinions on the answers of the students to the 15 questions. Expert's assessment is subjective, thus, we consider it is more adequate and accurate to use the indeterminate Likert scale supported in a graphical scale of five-symbols rating, as shown in Figure 1.

Has the student the necessary knowledge on oral cancer?

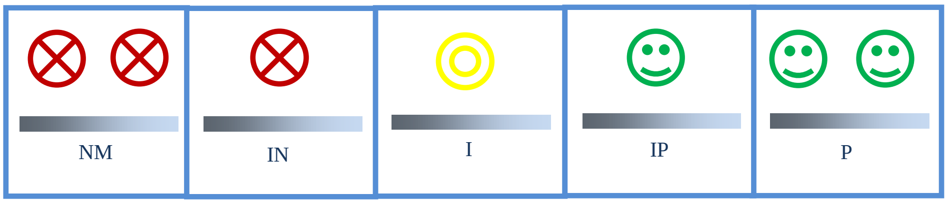

Figure 1: Graphical scale associated with the indeterminate Linkert scale: Negative membership (NM), Indeterminacy leaning towards negative membership (IN), Indeterminate membership (I), Indeterminacy leaning towards positive membership (IP), and Positive membership (PM).

Experts' team was requested about the degree they consider St_i satisfies the question in the following scale:
– Negative membership (NM),
– Indeterminacy leaning towards negative membership (IN),
– Indeterminate membership (I),

– Indeterminacy leaning towards positive membership (IP),
– Positive membership (PM).

Every one of them is associated with a number in the interval [0, 100]%, which are represented in the bar contained into every square. The use of a pictorial scale allows experts to select more easily the most accurate opinion. The opinions are represented by TRINS for the evaluation of each student.

The results of every of the 37 surveyed students was collected and evaluated by experts. Next, TRINS were associated with those evaluations. D, which is the TRINS distance matrix of order 37 was calculated for parameter $\lambda = 2$. Later, we defined the graph (G, V) associated with D, and we applied the Prim's algorithm ([26]) to obtain the indeterminate minimum spanning tree (MST). Finally, those vertices satisfying $d_{ij} > 0.14167$ were disconnected.

Four clusters were obtained, $\{F_1, F_2, F_3, F_4, F_5, F_{11}, F_{12}, F_{31}, F_{33}\}$ which were evaluated as PM, $\{F_7, F_8, F_{10}, F_{13}, F_{14}, F_{15}, F_{16}, F_{17}, F_{18}, F_{19}, F_{29}\}$ were evaluated as IP, $\{F_6, F_{20}, F_{21}, F_{22}, F_{23}, F_{24}, F_{25}, F_{26}, F_{27}, F_{28}, F_{30}, F_{32}, F_{34}, F_{35}, F_{36}, F_{37}\}$ have evaluation of IN, and $\{F_9\}$ have evaluation of NM.

Thus, 24.324% of students have the necessary knowledge on oral cancer, 29.730% have an 'Indeterminacy leaning towards positive membership' evaluation in their necessary knowledge on oral cancer, 43.243% have an "Indeterminacy leaning towards negative membership", and 2.7027% are classified as 'negative membership'.

With respected to the questions asked to the professionals, enumerated with j = 1,2,3,4,5,6,7,8,9,10; the evaluation of the results are summarized in Table 1 for each of the 5 questions.

Profesional\Question	**#1**	**#2**	**#3**	**#4**	**#5**
#1	⟨0.1, 0,0,0.2,0.8⟩	⟨0.7, 0.2,0.1,0,0⟩	⟨0.5, 0,0.1,0,0.4⟩	⟨0.7, 0,0.1,0,0.3⟩	⟨0.1, 0,0,0.1,0.9⟩
#2	⟨0, 0,0,0.2,0.8⟩	⟨0.75, 0.05,0,0,0⟩	⟨0.4, 0.1,0,0,0.5⟩	⟨0.6, 0,0.1,0,0.2⟩	⟨0.6, 0,0.1,0,0.2⟩
#3	⟨0.6, 0.1,0.1,0,0⟩	⟨0.9, 0.1,0,0,0⟩	⟨1, 0,0,0,0⟩	⟨0.9, 0.1,0,0,0⟩	⟨0.9, 0.1,0,0,0⟩
#4	⟨0.2, 0,0.1,0.1,0.6⟩	⟨0.8, 0.1,0,0,0⟩	⟨0.6, 0,0.1,0,0.3⟩	⟨0.7, 0,0.1,0,0.2⟩	⟨0.7, 0.2,0.1,0,0⟩
#5	⟨0, 0,0.1,0.1,0.9⟩	⟨0, 0,0,0,1⟩	⟨0.3, 0.2,0.1,0,0.2⟩	⟨0.65, 0,0.1,0.1,0⟩	⟨0, 0,0,0.1,0.9⟩
#6	⟨0, 0,0.1,0.2,0.8⟩	⟨0.8, 0.1,0.1,0,0⟩	⟨0.6, 0.2,0,0,0.1⟩	⟨0.7, 0,0.1,0.1,0⟩	⟨0.6, 0.1,0.3,0,0⟩
#7	⟨0.2, 0,0,0,0.7⟩	⟨0.85, 0.1,0,0,0⟩	⟨0.7, 0.2,0,0,0.1⟩	⟨0.7, 0,0.2,0.1,0⟩	⟨0.6, 0,0.3,0,0⟩
#8	⟨0.1, 0.1,0,0.1,0.6⟩	⟨0.75, 0.1,0,0,0⟩	⟨0.8, 0.2,0.1,0,0⟩	⟨0.6, 0.1,0.1,0.1,0⟩	⟨0.8, 0.2,0,0,0⟩
#9	⟨0.1, 0,0.2,0,0.9⟩	⟨0, 0,0,0,1⟩	⟨0.4, 0,0,0,0.5⟩	⟨0.5, 0,0.1,0.1,0⟩	⟨0, 0,0,0,1⟩
#10	⟨0, 0,0,0.1,0.9⟩	⟨0, 0,0,0,1⟩	⟨0.4, 0,0,0.1,0.5⟩	⟨0, 0,0,0,1⟩	⟨0, 0,0,0,1⟩

Table 1: Data collected from converting professionals' answers in TRINS on the five-question interview.

Let us remark that the professionals understood the meaning of assessing with five-value scale, thus, they used this scale adequately.

The result of forming D, the TRINS distance matrix that was calculated from Table 1, is summarized in Table 2. Let us note that $\lambda = 2$ and $w_i = \frac{1}{5} = 0.2$, were fixed.

Index	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	0	0.18601	0.34928	0.23324	0.26926	0.24166	0.24920	0.27148	0.27055	0.32435
2	0.18601	0	0.28320	0.11045	0.32481	0.12410	0.14318	0.16643	0.33136	0.38079
3	0.34928	0.28320	0	0.19698	0.46141	0.24739	0.21000	0.18682	0.46989	0.53963
4	0.23324	0.11045	0.19698	0	0.36510	0.10954	0.10630	0.10817	0.37363	0.42755
5	0.26926	0.32481	0.46141	0.36510	0	0.35057	0.36304	0.37390	0.094340	0.25554
6	0.24166	0.12410	0.24739	0.10954	0.35057	0	0.075498	0.11180	0.37256	0.44317
7	0.24920	0.14318	0.21000	0.10630	0.36304	0.075498	0	0.10583	0.38013	0.45222
8	0.27148	0.16643	0.18682	0.10817	0.37390	0.11180	0.10583	0	0.39408	0.45706
9	0.27055	0.33136	0.46989	0.37363	0.094340	0.37256	0.38013	0.39408	0	0.23152
10	0.32435	0.38079	0.53963	0.42755	0.25554	0.44317	0.45222	0.45706	0.23152	0

Table 2: TRINS distance matrix of the results from Table 1.

In Figure 2 we depict the edges of the minimum spanning tree and their associated cost. For simplicity, we omitted the rest of the edges.

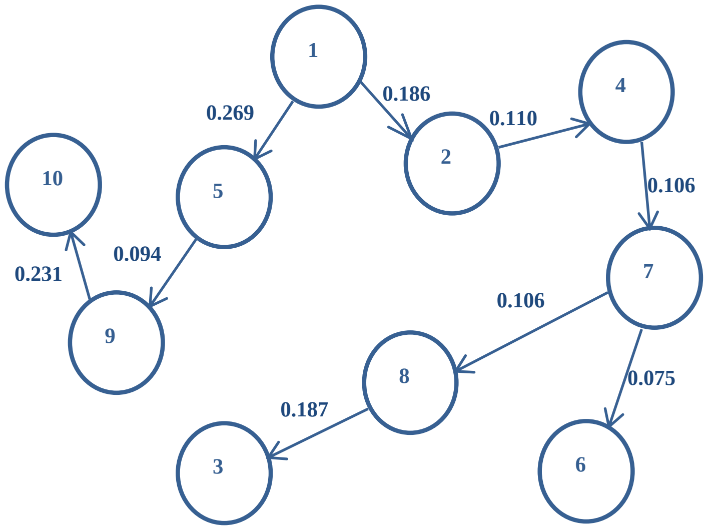

Figure 2: Edges of the minimum spanning tree and their associated cost obtained from the results of Prim's algorithm.

The clusters are obtained fixing $\varepsilon = 0.187$, which is graphically represented in Figure 3.

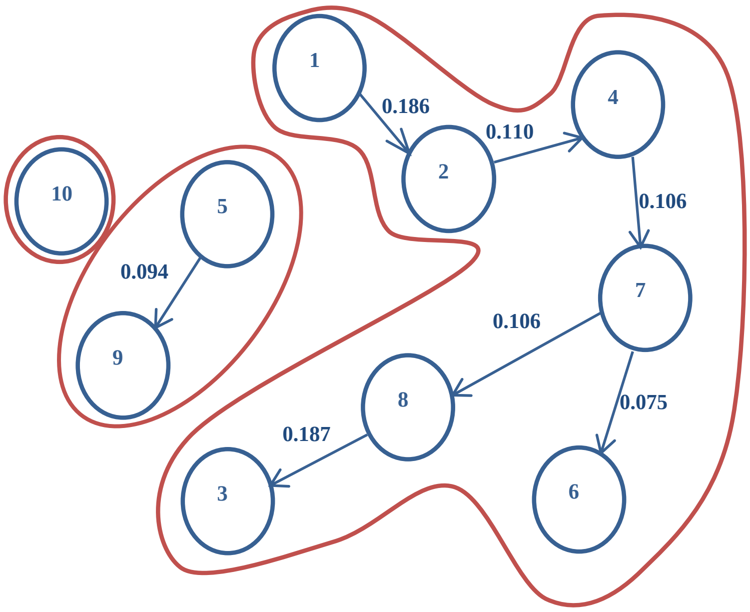

Figure 3: Clusters obtained for $\varepsilon = 0.187$.

Thus, three clusters are obtained, they are: $\{F_1, F_2, F_3, F_4, F_6, F_7, F_8\}$, $\{F_5, F_9\}$, and $\{F_{10}\}$. One cluster prevails, containing 70% of the opinions, where the prevalent judgment is that students have many deficiencies to detect oral cancer and many assertions as well.

Conclusion

In this investigation, we studied the current situation of knowledge on oral cancer by the ninth and tenth semesters' students of the Dental Care Unit at Uniandes, Ecuador. 37 students were surveyed through a 15 closed questions questionnaire, while 10 teachers were interviewed about their opinions regarding the students' knowledge on this topic. From the results, we may conclude that the students do not yet have the necessary knowledge about oral cancer and need training. The use of the indeterminate Likert scale ensured that mixed feelings were captured in the evaluations. The results were based on clusters obtained from applying an indeterminate minimum spanning tree clustering algorithm. Specifically, the Prim's algorithm was used. Only 24.324% of the surveyed students are trained to detect oral cancer, 29.730% of the students are not trained yet, but they show a positive trend, while the rest do not show good results. According to the professionals, there is a predominant cluster, where experts consider that students have some skills to detect oral cancer, but they need more training. For the authors, this is the first time in Ecuador that such a study has been carried out.

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Neutrosophic Statistics to Analyze Prevalence of Dental Fluorosis

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Abstract. Fluorine is a mineral that has been worldwide used for treating teeth, as it is effective in preventing dental cavities. That is why fluorine has been incorporated into toothpastes, as well as in some foods. However, excessive consumption of this mineral constitutes a serious oral health problem. This paper analyzes the occurrence of fluorosis, which is the disease caused by excessive consumption of fluorine, in children belonging to El Oro Educational Unit, located in the Central Ecuadorian Sierra. The study was carried out by means of a survey applied to the children's parents, and the direct study of the infants' teeth. Data is statistically processed, however, during the analysis of the data some of them had indeterminacies, so we decided that the best tool to use is Neutrosophic Statistics, because this theory studies statistics techniques in situations where there is indeterminacy in the data, in the population size, or in the parameters of the hypothesis tests. Moreover, this study has an important impact on the knowledge about the oral health of the children who attend this educational unit. In addition, it is a precedent for improving oral hygiene habits in infants.

Keywords: Neutrosophic Statistics, dental fluorosis, fluorine, survey.

1 Introduction

During the 1940s, the discovery that high amounts of fluorine in water causes abnormal discoloration of the tooth enamel, led to carefully find out how it affects the general health of an individual, thus, it was necessary to investigate how fluorine inserts in hard tissues and in human metabolism, as well as its presence in nature, [1].

In the 1950s, a research on fluorides was conducted in the United States, which have been very useful today to prevent and reduce dental caries. Therefore, the Pan-American Health Organization (PAHO) recommends artificial fluoridation of water supplies as a preventive measure for caries, for the structuring and mineralization of the dental follicle in the first years of life. Since 1962, it has been established in the United States that optimal doses are between 0.7 and 1.2 parts per million (ppm) per day, according to World Health Organization's recommendations (WHO), [2].

Currently, studies of fluorides have led many countries to implement fluorine in water, salt or milk, in addition to the natural sources from which it comes. Today, there are many products enriched with fluorides that can be found in the market, such as mouthwashes, toothpastes, food and materials for dental use, [3].

The excessive intake of fluorine and its indiscriminate use, due to the availability of fluorides that exist in different sources, may cause harmful effects on temporary and permanent dentition such as dental fluorosis. This alteration has been increasing every day. It is mostly due to the summation effect at the systemic level caused by the large amount of fluorine that is daily consumed and that can be found in different sources, [3].

Dental fluorosis, according to the scientific literature, is described as a serious pathology, which is characterized by abnormalities in the dental pieces. This pathology is caused by the existence of an interaction between the fluorine molecules present in the body, at the moment they enter in contact with dental tissues during the mineralization process, thus causing hypo-mineralization, specifically on the enamel surface. Its characteristics are manifested with a considerable increase in the porosity of the enamel, showing an opaque coloration that also affects the dentin. In Ecuador, according to the Ecuadorian Institute for Standardization (INEN 1108-2004), the limit of fluorine molecules present in water for human consumption is 1.5 ppm, which is high if compared to the recommendations of WHO, [4].

Dental fluorosis is an endemic public health problem described by causing alteration in the process of formation of dental organs, causing enamel defects, which can vary from whitish spots to the presence of craters, which are related to the severity degree and the period of formation of the dental organs. This pathology affects a large percentage of the population worldwide and as well as in the Ecuadorian Central Sierra. Taking into account this background, the purpose of this research is to determine the prevalence of dental fluorosis in schoolchildren from 8 to 12 years old from the Educational Unit El Oro. We also analyzed its relationship with triggers, in a population of 138 schoolchildren whose tutors or parents, through a validated survey attached to an informed consent, were evaluated in terms of diet and oral hygiene habits, [5].

This study is carried out because of the presence of dental fluorosis is suspected in the schoolchildren of El Oro Educational Unit, in Totoras parish, due to the fact that the drinking water is not treated or purified. Added to this background, is the ignorance of parents, educators and schoolchildren about the correct use and concentrations of fluoride toothpastes and mouthwashes. Therefore, it is necessary to carry out a study in which the prevalence of dental fluorosis will be determined.

A teeth frontal view of each of the participants is photographed; each photograph was analyzed by two evaluators specialized in the detection of fluorosis using the Thylstrup and Fejerskov Index to determine the degree of fluorosis, [6]. Each participant was asked to dose a portion of commercialized toothpaste, simulating what is performed on a daily basis, the dosages were weighed using a precision balance. Finally, the water sample that was taken from the Educational Unit was chemically analyzed for fluorine concentration.

We decided to carry out this study with the help of Neutrosophic Statistics [7-14]. This theory generalizes classical statistics to the framework of Neutrosophy. This generalization consists in statistically processing data with a certain degree of indeterminacy; this indeterminacy can be present in the sample size, in some data, or in the estimated parameters of the statistical tests.

In this case study, when carrying out the statistical processing of the survey data, we found that there are some imprecise answers, while others do not include precisely a particular answer among the proposals. For this reason, it was determined that Neutrosophic Statistics is more appropriate than classical statistics.

This paper is split into the following sections. Section 2 contains the initial concepts of Neutrosophy and Neutrosophic Statistics. Next, section 3 is presents the results of applying Neutrosophic Statistics in schoolchildren who are being studied. The article ends with the conclusions.

2 Materials and Methods

Neutrosophic Statistics extends classical statistics, such that crisp values are replaced by sets [7, 15, 16]. This section describes the main concepts of Neutrosophy and Neutrosophic Statistics that will be used in this paper to process the data.

In this new statistics, the population size, the parameters used for the calculations, as well as the data may contain indeterminacies, due to the researcher's lack of knowledge, lack of information, contradictory information, or any other reasons.

Neutrosophic Statistics is essentially concerned with indeterminacy as well as randomness, while classical statistics studies only random phenomena.

Neutrosophic Descriptive Statistics comprises all the techniques that describe the characteristics of numerical data.

Neutrosophic Inferential Statistics consists of inference methods from a random sample of neutrosophic elements.

Neutrosophic Data is the data set, such that at least one of them contains some indeterminacy. These are classified into *discrete neutrosophic data* if the data are isolated points, e.g., $5 + i_1$, where $i_1 \in [1, 4]$ or *continuous neutrosophic data*, if the data comprise one or more intervals, e.g., [6, 9], see [17-20].

Quantitative (numerical) neutrosophic data are those represented by numerical ranges. *Qualitative (categorical) neutrosophic data* are those categorical data with indeterminacy, e.g., blue or red (we do not know exactly).

Univariate neutrosophic data consists of the observed data on a neutrosophic single attribute. A *multivariate neutrosophic data* consists of observations of two or more attributes.

A *Neutrosophic Statistical Number* N has the following form [7]:

$$N = d + i \qquad (1)$$

Where d is the *determinate part* and i is the *indeterminate part*.

A *Neutrosophic Population* is a population not well determined at the level of membership.

A *simple random neutrosophic sample* of size n from a classical or neutrosophic population is a sample of n individuals such that at least one of them has some indeterminacy.

Neutrosophic Numbers are those satisfying Equation 2 [17-20]:

$$a + bI \qquad (2)$$

Where a, b are real numbers, and I is indeterminacy, such that $I^2 = I$ and $0 \cdot I = 0$.

If the coefficients a and b are real, then a + bI is called *Neutrosophic Real Number*.

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:

1. $N_1 + N_2 = a_1 + a_2 + (b_1 + b_2)I$ (Addition);
2. $N_1 - N_2 = a_1 - a_2 + (b_1 - b_2)I$ (Difference),
3. $N_1 \times N_2 = a_1 a_2 + (a_1 b_2 + b_1 a_2 + b_1 b_2)I$ (Multiplication),
4. $\frac{N_1}{N_2} = \frac{a_1 + b_1 I}{a_2 + b_2 I} = \frac{a_1}{a_2} + \frac{a_2 b_1 - a_1 b_2}{a_2(a_2 + b_2)} I$ (Division).

Additionally, given $I_1 = [a_1, b_1]$ and $I_2 = [a_2, b_2]$ we have the following operations between them (see [7, 21]):

1. $I_1 \leq I_2$ if and only if $a_1 \leq a_2$ and $b_1 \leq b_2$.
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).

3 Results

The study consists of a survey to the parents of schoolchildren from 8 to 12 years of age from El Oro Educational Unit in Totoras parish, to determine their knowledge about dental fluorosis, the triggers and the appropriate concentrations to maintain optimal oral health. Additionally, the photographic technique was used to determine the degree of fluorosis using the TF technique in schoolchildren.

The call for survey was made to hold a meeting of parents where it was explained as an informative talk about the purpose of the investigation, then, each parent gave its informed consent. Emphasis is placed on three important points: purpose, benefits and risks of the study[22, 23]. It is also explained that with the signature of this document the parent or tutor authorizes the child to participate in the course of the investigation. Along with the consent, a survey is delivered to be completed by the parents or tutors of the examined children. This survey has a total of 17 closed questions to obtain information on the possible risk factors for the presence of dental fluorosis. The document contained questions such as the type of water consumed, packaged beverages, type of salt, type of food diet and oral hygiene conditions. To guarantee patient confidentiality, the surveys were managed with numerical codes.

Photographs were taken with a smartphone's high-resolution camera under natural light conditions. The photographic record was made requesting each participant to remain seated in a chair. The mouth gag was placed according to the age of the patient. The food residues, plate or substance existing on the vestibular surface that interfered with the correct visualization of the teeth were removed with sterile gauze. Each photograph was adequately identified and subsequently analyzed by the researcher and the tutor-teacher, duly prepared and trained to detect fluorosis using the TF index. The values that each researcher will grant to each photograph were saved to tables in Microsoft Excel with the identification data of each participant. In case of discrepancy in the degree of fluorosis according to the analysis of the evaluators, it was decided to choose the most severe degree.

The photographs were accordingly identified by codes to preserve the anonymity of the participant, they were analyzed by two people trained and specialized in the detection and definition of the Fluorosis Index according to the TF index (Thylstrup and Fejerskov), due to their high command of the subject. Using statistically validated unified criteria, we used the aforementioned index, obtaining a value of 95% agreement. In each photograph, the vestibular surfaces of the teeth were analyzed, considering healthy teeth as the tooth with no signs of fluorosis.

From a statistical point of view, the entire population of the educational center was studied, therefore descriptive statistics is applied. When the survey was applied, we detected that there were questions having answers with a certain degree of indeterminacy. For example, in some cases, parents did not remember exactly the brand of toothpaste used by children, or even the brand could be more than one. For this reason, it was determined to use neutrosophic statistics, where these indeterminacies were included. In these cases $I = [0, 1]$ was used as notation to represent indeterminacies.

The population is made up of 79 boys and 59 girls. The recommended toothbrush dimensions by age are specified in Table 1.

	Width of the brushing (Maximum in mm)	**Head length (mm)**	**Height of the filaments (mm)**
Children	9	15-25	9-12
Teenagers	11	17-30	9-13

Table 1: Recommended dimensions of the toothbrush by groups of age.

The highest percentages with respect to the origin of the evaluated people were that 87.0% lives in H. Totoras parish, 82.6% are from Tungurahua province, whereas in relation to the canton, 80.4% are from Ambato. The target of this investigation are children, from whom 20.3% are 8 years old, 24.6% are 9 years old, 26.10% are 10 years old, 18.1% are 11 years old and 10.9% are 12 years old.

In relation to mothers' instruction, educational level is none in 6.5% of them, 62.3% of them has a primary level, 26.8% are in secondary, 1.4% of them are technical and 2.9% of them are professionals. Mothers employed in the informal sector are 23.2%, 32.6% of them are workers and craftswomen, 21.0% are farmers, 6.5% are public employees, 15.2% are private employees, and 1.4% of them are professionals.

In relation to fathers' educational level, 3.6% have none, 58.7% have a primary level, 29.0% have a secondary, 2.9% are technicians, and 5.8% are professionals. Fathers whom are employed in the informal sector constitute 8.0%, workers and craftsmen are 42.8%, 13.8% of them are farmers, 10.1% are public employees, 22.5% are private employees, and 2.9% are professionals.

According to economic income, the majority, 75.4%, receive a salary of 1 and 2 Universal Basic Income (UBI), 23.2% have a salary of 3 and 4 UBI and only 1.4% have a salary of more than 4 UBI.

These data are important because the educational level of the parents directly influences in the health education of the children. In addition, the parents with the highest purchasing power financially guarantee the use of dental products suitable for their children, as well as the best nutrition.

Table 2 summarizes the results of the survey on questions asked to parents about their children's eating habits. Some data contain symbol I, because of the parents were not able to give an answer to the asked questions, or because of there are several possible answers to the same question. Therefore, to maintain the accuracy of the calculations, we decided to include indeterminacy.

Question	Answer	Number of children	Percent
Q1: The water your child consumed in his/her first 4 years of life was:	Drinking water without boiling	78+19I	[56.5, 70.3]
	Boiled drinking water	11+12I	[8.00, 21.7]
	Bottled water	5+2I	[3.6, 5.1]
	Well water	1	0.7
	Filtered water	2	1.4
	River or gap	1	0.7
Q2: The type of milk your child drank during the first 4 years of life, in addition to breast milk was:	Powdered	9+10I	[6.52, 13.8]
	Delivery truck	22+4I	[15.9, 18.8]
	Cover	86+6I	[62.3, 66.7]
	Soy milk	1	0.7
Q3: Your child consumes packaged beverages (juices, soda, soft drinks, iced tea, etc.)	Before the age of three	62	44.9
	After three years old	76	55.1
Q4: The bottled drink your child usually prefers is:	Soda	20+14I	[14.5, 24.6]
	Juices	66+12I	[47.8, 56.5]
	Soft drinks	16+14I	[1.4, 11.6]
	Tea	10	7.2
Q5: The times a week that your child consumes packaged drinks (juices, sodas, tea) is:	Once	45+32I	[32.6, 55.8]
	Three times	23+32I	[16.7, 39.9]
	More than three times	4+2I	[2.9, 4.3]
Q6: The diet your child usually consumes is:	General diet	75+35I	[54.3, 79.7]
	Hypercaloric/Hyperprotein Diet	8+8I	[5.8, 11.6]
	Hypo fat soft diet	6	4.3
	Astringent diet	6	4.3
Q7: The type of salt your child consumes is:	Refined salt	114+9I	[82.6, 89.1]
	Sea salt	10+3I	[7.2, 9.4]
	Grain salt	1	0.7
	None	1	0.7

Table 2: Results of the survey applied to the parents.

Table 3 summarizes the dental hygiene habits of children, according to the survey conducted with their parents.

Question	Answer	Number of children	Percent
Q1: Brand of the toothpaste with which your child regularly brushes	Colgate	121+7I	[87.7, 92.8]
	Oral-B	2	1.4
	Fortident	2	1.4
	Polar	3	2.2
	Blendy	3	2.2
Q2: Your child's tooth brushing starting age was:	He/she has never done it	6	4.3
	Before three years old	83	60.1
	At three years old or later	49	35.5
Q3: The age at which your child started brushing his/her teeth unaccompanied by an adult was:	He/she has never done it	2	1.4
	Before three years old	32	23.2
	At three years old or later	104	75.4
Q4: When you started brushing your child's teeth, did you use the same toothpaste as adults?	Yes	67	48.6
	No	71	51.4
Q5: When your child started brushing his/her teeth, he/she swallowed the toothpaste during brushing	Yes	119	86.2
	No	19	13.8
Q6: The times a day your child brushes his/her teeth is:	Once	27+7I	[19.6, 24.6]
	Twice	63+7I	[45.7, 50.7]
	Three times	27+7I	[19.6, 24.6]
Q7: The amount of toothpaste your child uses to brush his/her teeth is:	One drop	6+8I	[4.3, 10.1]
	Brush half	73+8I	[52.9, 58.7]
	All brush	35+8I	[25.4, 31.2]
Q8: Does your child use mouthwash?	Yes	17+2I	[12.3, 13.8]
	No	117+2I	[84.8, 86.2]
Q9: The age at which your child uses mouthwash is:	He/she has never done that	119	86.2
	Before three years old	6	4.3
	At three years old or later	13	9.4
Q10: The mouthwash brand used by your child is:	Colgate	14	10.1
	Listerine	5	3.6
	Others, parent does not indicate	119	86.2

Table 3: Results of the survey on the use of oral hygiene products

Table 4 summarizes the percentages of the TF index, according to the photographs taken of the children.

Index	Level	Number of children	Percent
TF Index	TF 0	24	17.4
	TF 1	21	15.2
	TF 2	28	20.3
	TF 3	23	16.7
	TF 4	18	13.0
	TF 5	11	8.0
	TF 6	5	3.6
	TF 7	4	2.9
	TF 8	3	2.2
	TF 9	1	0.7
	Total	138	100

Table 4: Level of Fluorosis in number of children and percent

The analysis of data about TF index in Table 4 and their relationship with the data in Tables 2 and 3, have yielded that p-values are bigger than 0.05, thus null-hypothesis is not rejected, which means there is not a significant relationship between these variables and the fluorosis. However, one variable is the exception: “the child uses mouthwash”.

The result of the relationship between TF index and this variable is analyzed with a contingency table, see Table 5. Let us note that between parentheses are the values of de-neutrosophication ([24]) according to formula 3, a de-neutrosophication process gives an interval number $I = [a_1, a_2]$ [25].

$$\lambda([a_1, a_2]) = \frac{a_1+a_2}{2} \qquad (3)$$

	TF 0 (Healthy tooth)	**TF1-TF9 (Ill tooth)**	**Total**
Yes	[6, 7] (6.5)	[11, 12] (11.5)	[17, 19](18)
No	17(17)	[100, 102] (101)	[117, 119] (118)
Total	[23, 24] (23.5)	[111, 114] (112.5)	[134, 138] (136)

Table 5: Contingency table between TF index and the use of mouthwash by the child. Between parentheses, are the de-neutrosophied values.

For processing the data in Table 5, the Chi-square test is applied, [26], then, the obtained p-value is 0.023285<0.05, therefore, the null-hypothesis of independence is not accepted with 95% of significance level.

Figure 1 is the bar graph, which depicts the values in Table 5. Note that there are portions of bars in yellow, representing indeterminacy.

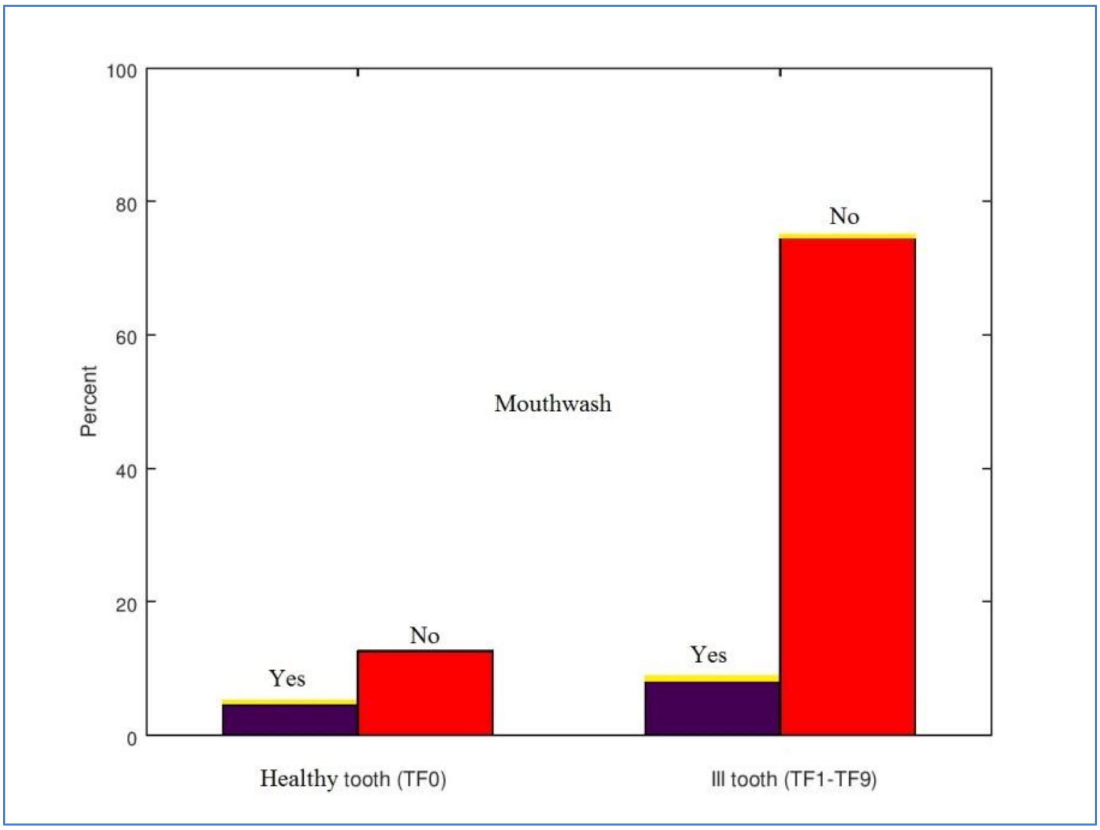

Figure 1: Bar graph representing the values in Table 5.

Let us note that most of the children which do not use mouthwash have some tooth problems.

Conclusion

This paper studies the incidence of fluorosis in El Oro Educational Unit. The population is consists of 138 children of ages from 8 to 12 years old. Fluorosis is a severe disease that deserves the attention of specialists. We statistically processed the survey applied to the children's parents about their nutritional habits and their use of the oral hygiene products. We also studied the TF index for each of them and the correlation between TF level and the others variables. We preferred to use the neutrosophic statistics instead the classical statistics, because of the ambiguity and duplicity of some answers, thus, including indeterminacy guarantees more accuracy in the results. After applying the chi-square test in the contingency table, the obtained result was that there is a relationship between to have a healthy tooth (child with TF 0 level) and to use mouthwash. The more the child uses mouthwash, the less he/she will suffer of fluorosis. The possible reason is that not all mouthwashes contain fluorine, or its content is minimal, containing other substances like alcohol, nonetheless specialists need to analyze the cause of this result. There is independence among TF index and the other variables.

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Multicriteria Evaluation of Labor Stability

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Abstract: The job stability of workers represents an indicator for people's quality of life. Evaluating job stability from a legal point of view would allow quantifying its impact on workers from a legal perspective. The present investigation proposes a method for the legal evaluation of the labor stability of the workers. It bases its operation on the Neutrosophic Multi-criteria Linear Weighting method. A Case study is developed on three Cantons of Los Rios province to demonstrate the applicability of the proposed method. Paper ends with conclusion, recommendation and the projections for future works.

Keywords: Legal evaluation; job stability; Neutrosophic Multi-criteria Linear Weighting method.

1. Introduction

Job stability is an important element in the quality of life indicators of society [1, 2]. Workers are supported by legal norms that guarantee their rights [3, 4]. In Ecuador, great importance is attributed to monitoring the job stability indicator [5].

Integrally in Latin America the labor stability of the workers is stipulated in the Constitution of each Country. International Standards such as the International Labor Organization and the Universal Declaration of Human Rights give great importance to the compliance with this indicator [6, 7].

Job stability may vary according to the job code of each country to investigate. Mini contracts, zero hour contracts, informal jobs, although the names vary there are a coincidence in reality or formality which is also known as suitable employment.

The current Constitution of the Republic of Ecuador guarantees people the right to work is a source of personal fulfillment and the basis of the manifest family economy [8, 9]. However, job stability is an issue that has not been properly addressed. The objective of this research is to develop a method for the legal evaluation of the job stability of workers.

This paper proposes a model to evaluate the job stability from a legal point of view. For this purpose, a Neutrosophic Multi-criteria Linear Weighting operator is used. The advantage to incorporate neutrosophic logic is that indeterminacy can be included independently of truth or false values.

This paper has the following structure: Section 2, dedicated to recall the preliminary concept of Job Stability that will be used in this paper. In section 3, we introduce the method for the legal evaluation of job stability. Section 4 shows the implementation of the method to evaluate the situation in three cantons of “Los Rios” province. The paper ends with the conclusions.

2. Preliminaries

With the aim to introduce the main theoretical references on the object of study, the diverse concepts that facilitate the understanding of the research are presented. A description of job stability and its main legal norms is also made:

The principle of *Job Stability* is the right granted by the law to workers to remain in their jobs until there is justifiable cause to terminate their contract [10]. Job stability should be understood as the shared responsibility held by both the employer and the employee or candidate to ensure their effective participation in the work environment while both parties guarantee the addition of value to the processes, products or services that they generate or offer. That is why when achieving this level of satisfaction, the individual can have a better life condition because he/she would be able to meet many requirements and then he/she would go on to scale others that allow him/her to continue growing until he/she exceeds himself/herself. Stability consists of the right of a worker to keep his/her job indefinitely, without incurring in any fault [11].

3. Structure of the method for the legal evaluation of job stability

The present investigation is modeled through a decision-making process where the objects or decisions are considered as a multicriteria decision-making problem [12, 13]. Multicriteria evaluation constitutes an optimization with several simultaneous objective functions and a decision-making agent. Equation 1 formalizes the posed problem.

$$\text{Max } F(x), x \in X \tag{1}$$

Where:

x: is a vector $[x_1, \cdots, x_n]$ of the decision variables.

X: it is the so-called feasible region. It represents the possible value domain that the variable can take.

F(x): is a vector $[F_1(x), \cdots, F_n(x)]$ of the objective functions that collect the criteria.

Specifically, discrete multicriteria problems basically consist of two types of data that constitute the starting point for different discrete multicriteria decision-making problems (DMCDM). Figure 1 shows a representation of a multi-criteria method.

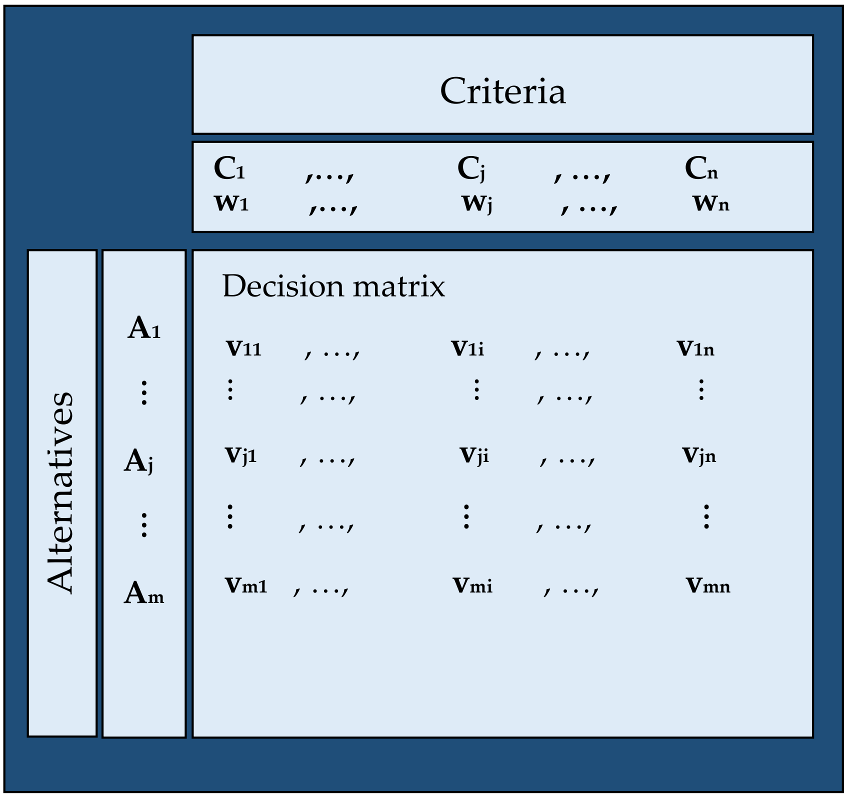

Figure 1. Representation of multi-criteria method.

Figure 1 shows a representation of a multi-criteria decision-making problem where:

r_{ij}: represents the evaluation of the alternative i regarding the criterion j.

w_i: represents the weight of the criterion.

The inference process of the proposed method is based on a multicriteria approach. A weight for the alternative under analysis will be determined. Representing an ordering and aggregation methods [14-16].

The inference can be described mathematically from the linear weighting method. The method consist of calculating an overall score r_i for each alternative A_i as expressed in Equation 2, [17, 18].

$$R_i = \sum_j W_j r_{ij} \tag{2}$$

With the use of the linear weighting, a compensatory process is carried out. The process previously applies the standardization of its criteria. The evaluation problem in question represents a case where [19-21]:

Given a set of *m* alternatives and *n* criteria.

For each j-th criterion the decision maker estimates for each i-th alternative.

Assessment a_{ij} is obtained from the decision matrix that has a cardinal ratio weight. Weight $W_j(j = 1, \cdots, n)$ is assigned also to the cardinal ratio type for each of the criteria C_j.

In the context of multicriteria methods, neutrosophic numbers are introduced in order to represent indeterminacy [22][23]. It constitutes the basis of mathematical theories that generalize classical and fuzzy theories such as neutrosophic sets and neutrosophic logic. [24]. A neutrosophic number (N) is represented as follows [25] [26]:

$N = \{(T, I, F) : T, I, F \subseteq [0,1]\}$, a neutrosophic valuation is a mapping of a group of formulas into N, that is, for each sentence p we have:

$$v\ (p) = (T, I, F) \tag{3}$$

Where: T is the dimension of the space that represents truthfulness, I represents indeterminacy, and F represents falseness, as it is expressed in the Equation 4.

$$R_{i(T,I,F)} = \sum_j W_{j(T,I,F)}\, r_{ij(T,I,F)} \tag{4}$$

A Neutrosophic Linear Weighting method can be mathematically defined as a 3-tuple (R,W, r)

Where:

$R_{i(T,I,F)}$: represents the aggregated function that refers to a dimension of space true, indeterminate, and false (T, I, F).

$W_{j(T,I,F)}$: represents the weight of the criterion associated with the criteria referred to the dimension of the space truth, indeterminacy, and falsehood (T, I, F).

r_{ij}: represents the evaluation of the i-th alternative regarding j-th criterion that refers to a dimension of space truth, indeterminacy, and falsehood (T, I, F).

The proposed method is designed to support the process to evaluate job stability indicators. Figure 2 shows a diagram illustrating this operation.

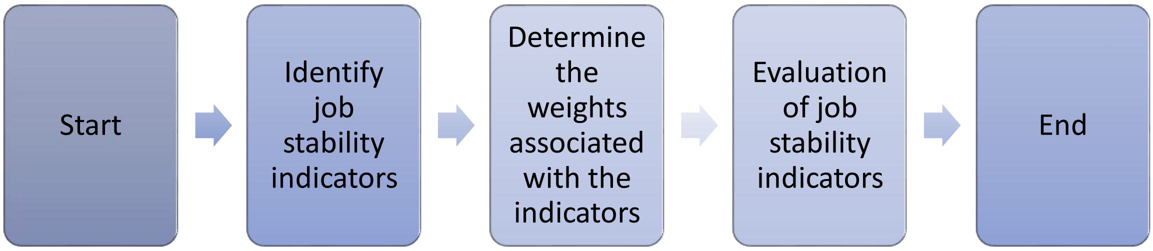

Figure 2. Structure of the proposed method.

The method is designed through a three-stage structure that together determine the legal evaluation of the job stability of the workers.

Stage 1: Identification of job stability criteria.

It represents the set of criteria that are used to quantify the evaluation for the different alternatives. It constitutes a multi-criteria approach formalized as:

$C = \{c_1, \ldots, c_n\}$, $n \geq 2$, the evaluation criteria.

Stage 2: Determination of the weights.

To determine the weights associated with the evaluation criteria. A work group approach is used so that:

$E = \{e_1, \ldots e_m\}$, $m \geq 2$, where E represents the experts involved in the process. It represents a way to evaluate the weight vectors associated with the evaluation indicators.

Stage 3: Evaluation of job stability.

The evaluation stage represents the processing of the method to output the result of the proposed inference. Data are processed using the linear weighting method in Equation 4. As a result, it expresses the attribute value of job stability. The final evaluation is carried out using a score function [27].

4. Implementation of the juridical method for evaluating labor stability

For the implementation of the proposed method, a study was carried out for the evolution of job stability in different regions of the country. Three cantons (Babahoyo, Baba, Quevedo) were taken as reference. The case study was designed to carry out a legal evaluation of the behavior of the job stability indicators of the selected cantons.

Stage 1: Identification of job stability criteria.

For the analysis and operation of the proposed method, 6 evaluation indicators were used as shown in Table 1.

Index	Job stability criteria
1	Individuals have jobs every month of the year.
2	Individuals have jobs every week.
3	Individuals get paid vacations.
4	He/she gets food from his work.
5	He/she obtains a decent residence from his work.

Table 1. Job stability criteria.

Stage 2: Determination of the weights.

For the stage of determining the weights attributed to the job stability criteria, a group consultation was conducted with 5 experts who expressed their assessments of the stability criteria [28-30]. The process obtained the weight vectors corresponding to the job stability criteria. Vectors obtained from the 5 experts were aggregated using the mean of their results. Table 2 shows the result of the evaluation criteria once the aggregation process has been carried out.

Criteria	Vector $\widetilde{W}$
C_1	[0.92,0.10,0.25]
C_2	[0.90,0.05,0.10]
C_3	[0.5,0.05,0.15]
C_4	[0.85,0.15,0.00]
C_5	[0.72,0.18,0.10]

Table 2. Weight attributed to stability criteria.

Stage 3: Evaluation of job stability.

Based on the behavior of the weights attributed to the evaluation criteria, a diagnostic process of the indicators is carried out in the 3 cantons selected as the object of study. The method assumes that the desired utility function is an additive model that is presented in the form [31][32]:

$$v = w_1 * x_1 + w_2 * x_2 + \cdots + w_n * x_n \quad (5)$$

Where:

w_i: is the weight of the i-th criteria and it is the value of the alternative against the i-th criterion.

w_i are obtained from $\widetilde{w}_i$, where every $\widetilde{w}_i$is converted into a crisp value using Equation 6, and later they are normalized, as in Equation 7.

$$\widehat{w}_i = \frac{1}{3}\left(2 + \mathrm{T}_{\widetilde{w}_i} - \mathrm{I}_{\widetilde{w}_i} - \mathrm{F}_{\widetilde{w}_i}\right) \quad (6)$$

$$w_i = \frac{\widehat{w}_i}{\sum_{i=1}^{n} \widehat{w}_i} \quad (7)$$

Then, $W = (w_1, \cdots, w_n)$. Thus, in formula 5 the operators * and + are the usual scalar multiplication of a vector and the vector sum, respectively.

With the weighted average value obtained by the utility function for each alternative, they are sorted [33, 34]. This order solves the decision-making problem and determines the best alternative among the possible ones, which will be the weighted sum [35, 36].

Table 3, 4 and 5 shows the result of the processing carried out for each of the cantons under study.

Criteria	Vector *W*	Preferences in Babahoyo	Result	Crisp value (Score)
C_1	0.20141	[0.74,0.10,0.18]	[0.149,0.020,0.036]	0.69755 (4)
C_2	0.21552	[0.64,0.16,0.20]	[0.138,0.034,0.043]	0.68678 (5)
C_3	0.18025	[0.80,0.15,0.05]	[0.144,0.027,0.009]	0.70272 (3)
C_4	0.21160	[0.90,0.10,0.10]	[0.190,0.0211,0.021]	0.71604 (2)
C_5	0.19122	[0.90,0.05,0.05]	[0.172, 0.100, 0.009]	0.71766 (1)
Index			**[0.794,0.112, 0.119]**	**0.85433**

Table 3. Processing preferences for Babahoyo.

Criteria	Vector *W*	Preferences in Baba	Result	Crisp value (Score)
C_1	0.20141	[0.54,0.30,0.06]	[0.109,0.060,0.012]	0.67875 (5)
C_2	0.21552	[0.64,0.26,0.10]	[0.138,0.056,0.022]	0.68678 (3)
C_3	0.18025	[0.60,0.20,0.10]	[0.108,0.036,0.018]	0.68469 (4)
C_4	0.21160	[0.75,0.20,0.05]	[0.159,0.042,0.011]	0.70193 (1)
C_5	0.19122	[0.70,0.15,0.15]	[0.134,0.029,0.0287]	0.69216 (2)
Index			**[0.647,0.22,0.091]**	**0.77765**

Table 4. Processing preferences for Baba.

Criteria	Vector *W*	Preferences in Quevedo	Result	Crisp value (Score)
C_1	0.20141	[0.80,0.10,0.10]	[0.161,0.020,0.0201]	0.70695 (3)
C_2	0.21552	[0.75,0.15,0.10]	[0.162,0.032,0.022]	0.70259 (5)
C_3	0.18025	[0.80,0.20,0.00]	[0.144,0.0361,0.000]	0.70272 (4)
C_4	0.21160	[0.90,0.10,0.00]	[0.190,0.021, 0.000]	0.72309 (1)
C_5	0.19122	[0.90,0.10,0.00]	[0.172,0.019,0.000]	0.71766 (2)
Index			**[0.830, 0.129, 0.042]**	**0.88634**

Table 5. Processing preferences for Quevedo.

Figure 3 shows a comparative graph showing the behavior between the three cantons under study based on the score function.

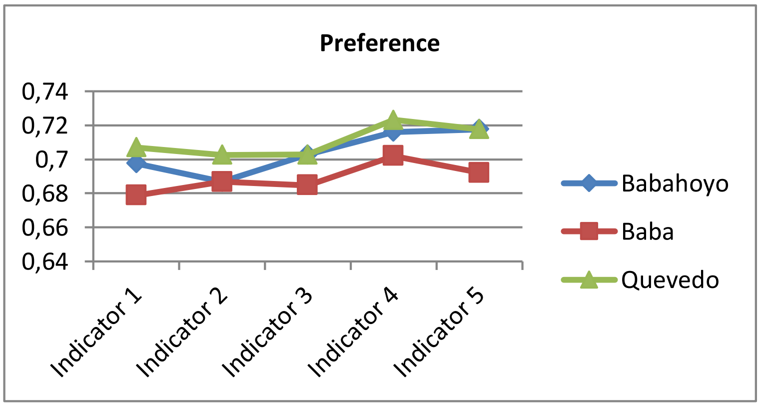

Figure 3. Behavior of preferences between different cantons.

The graph shows the behavior of the three cantons, a similarity in the performance of job stability is evident. However, the canton of Baba has the lowest index of job stability. Quevedo is the one with the best job stability performance and Babahoyo has an intermediate performance compared to the others.

Conclusions

From the development of the proposed research, we obtained a method for the legal evaluation of the job stability of workers. The method bases its operation on neutrosophic linear weighting to model the job stability main indicators.

Through the application of the proposed method, we executed an evaluation of three cantons representing the case studies. The method demonstrated its applicability for legal evaluation of the job stability of workers. The job stability index is determined through its inference process.

Although the proposed case study presents an application of the proposed system, the implementation of other inference engines in the decision-making process is recommended to compare the obtained results.

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Knowledge-based Hiring Recommender Model for Occasional Services in the Public Sector

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Abstract. Public employees often provide their services under contract for occasional services. This form of employment relationship may undergo the consequences of job instability. Classifying occasional job profiles allows us recommending new jobs for those who suffer from job instability. This research proposes a solution to the posed problem by using a Neutrosophic method to determine job profiles of people for the occasional service contract recommendation in the public sector. Ordered Weighted Averaging Distance (OWAD) operator is proposed for aggregation of similarities measures.

Keywords: Single-valued neutrosophic sets, job stability; hiring of public services, OWAD

1. Introduction

In the workplace, workers deal with different forms of hiring. The contract represents the legal support that guarantees the main rights of the people [1, 2]. Among the contractual relationships that can be contracted are services through indeterminate contracts and occasional contracts [3, 4]. The contracts favor labor relations where consequences of labor instability may be experienced [5, 6].

When starting an employment relationship, a set of public order and legal regulations are established. Relationships are caused by self-employment and under the dependence of others in order to guarantee to those who carry out their full development as a human person and to the community the effective integration of the individual in the social body and the regulation of conflicts between the subjects of those relationships [7-9].

Many people live on occasional contracts. Sometimes people spend part of their time looking for new job offers [10]. Knowing the profiles of skills associated with people would guarantee the hiring recommendation for occasional services [11, 12].

Paradoxism is an international movement in science and literature, created by Florentin Smarandache in the 1980s. It is based on disproportionate use of antitheses, oxymoron, contradictions, and paradoxes [13]. During three decades (1980-2020) authors from tens of countries around the globe contributed papers to international anthologies [14].

In 1995, Smarandache extended the Paradoxism to a new branch of philosophy called Neutrosophy that originated many scientific concepts and theories, such as: neutrosophic logic, neutrosophic set, neutrosophic probability and statistics, neutrosophic statistics, neutrosophic sociology and so on, with multiple applications in engineering, computer science, administrative work, medical research etc. [15].

This research aims to develop a neutrosophic method to determine job profiles of people for the recommendation of the occasional services contract in the public sector.

The paper is divided into the following sections: Section 2 is dedicated to the preliminaries concepts of neutrosophic sets, and OWAD operators. In section 3, we propose a method to hire people in occasional services for the public sector. Section 4 contains the results applied to an example. We finish the paper with the conclusions.

2. Preliminaries

This section introduces the main elements that facilitate the analysis and understanding of the proposed solution. We present the main theoretical references used for the development of the proposed method and characterize the elements associated with job stability and occasional services contracts.

2.1 Job stability and occasional service contract.

Contracts for Occasional Services in the Public Sector (COSPS), it is the modality that covers the occasional work granted to public servants temporarily, contained in article 17 of the COSPS, that classifies appointments, in permanent and provisional. Regarding provisional appointments, COSPS makes a sub classification: "Art. 17.- Appointment Classes for the exercise of the public function, the appointments may be: Permanent, provisional, those that are issued to occupy"[16-18].

Likewise, provisional appointment will be granted to those who were promoted, which will be evaluated within a maximum period of six months, through a technical and objective evaluation of their services and if it is determined after this evaluation that who does not qualify for the performance of the position, he/she will be reinstated to the previous position with his/her previous remuneration [19-21].

2.1 OWA operator

First of all we describe the main concepts of neutrosophic set theory.

Definition 1 ([22-24]): 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 $^-0 \leq inf\ T_A(x) + inf\ I_A(x) + inf\ F_A(x) \leq sup\ T_A(x) + sup\ I_A(x) + sup\ F_A(x) \leq 3^+$.

Note 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]. $^-0$ and 1^+ belong to the set of hyper-real numbers.

Definition 2 ([20]): 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 $F_A: U \rightarrow [0, 1]$. $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

The Single Valued Neutrosophic number (SVNN) is represented by

N = (t, i, f), such that $0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Aggregation operations are mathematical functions used in decision-making processes and information fusion process [25, 26] for aggregating values (x, y) in a domain D and to return a single value.

Among the main operators for information aggregation we have the arithmetic mean and weighted arithmetic mean operator [27, 28]:

Definition 3. The WA operator has an associated vector of weights w, with $w_i \in [0,1]$ and $\sum_1^n w_i = 1$, which are expressed as follows:

$$WA(a_1, .., a_n) = \sum_{i=1}^{n} w_i a_i \tag{1}$$

Where w_i represents the importance of the source a_i

An information aggregation operator Ordered Weighted Averaging [29], allows us to unify the classic criteria of uncertainty decision in an expression [30].

Definition 4. An OWA operator is a function $F: \mathbb{R}^n \rightarrow \mathbb{R}$, of dimension n if it has an associated vector *W* of dimension n with $w_j \in [0, 1]$ and $\sum_{j=1}^{n} w_j = 1$, so that:

$$F(a_1, a_2, \dots, a_n) = \sum_{j=1}^{n} w_j b_j \tag{2}$$

Where b_j is the greatest j-th of the a_j.

Each family of operators is used in different contexts. There are several aggregation operator formulations that unify the WA and OWA operators combining the advantages of both [31, 32].

Another extension is the OWA operator based on distance (OWAD)[33].

Definition 5: An OWAD operator of dimension n is a mapping $\mathrm{OWAD}: \mathbb{R}^n \times \mathbb{R}^n \to \mathbb{R}$ that has an associated weighting vector W with $\sum_{j=1}^{n} w_j = 1$ and it is defined as follows:

$$\mathrm{OWAD}(\langle x_1, y_1\rangle, \dots, \langle x_n, y_n\rangle) = \sum_{j=1}^{n} w_j\, d_j \tag{3}$$

where d_j is the jth largest distance between x_i and y_i are the ith argument of the sets X and Y, respectively. In this case the Euclidean distance between single-valued neutrosophic numbers (SVNNs) are used:

$$d(X,Y) = \sqrt{(T_x - T_y)^2 + (I_x - I_y)^2 + (F_x - F_y)^2} \tag{4}$$

The OWAD operator can provide a parameterized family of distance aggregation operators between the minimum and the maximum giving greater flexibility to the process.

3. Design of the method for hiring people in occasional services for the public sector

The proposed method consists of three stages: input, inference, and output. The inference process is guided by management in three components: selection of profiles, evaluation of alternatives and selection of the knowledge base of the similarity profile.

Figure 1 shows a diagram with the general operation of the proposed method.

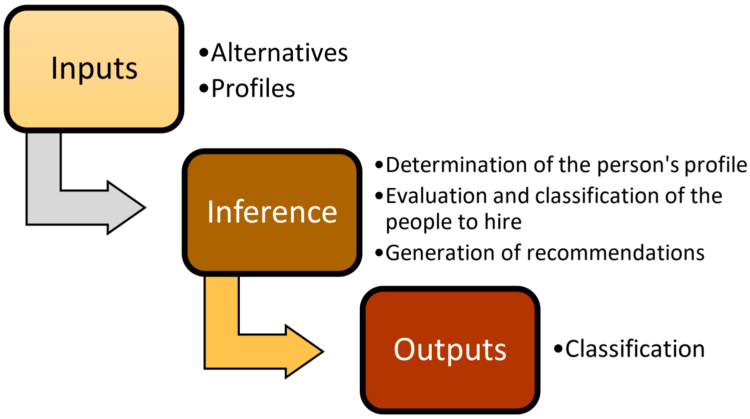

Figure 1. General diagram of the method’s operation.

The proposed method bases its operation on the knowledge management proposal for knowledge-based recommendation systems of Cordón in [34-36]. The proposal allows to represent through linguistic terms and model uncertainty from Single Value Neutrosophic Numbers [37-40].

Figure 2 shows a diagram with the workflow of the inference process.

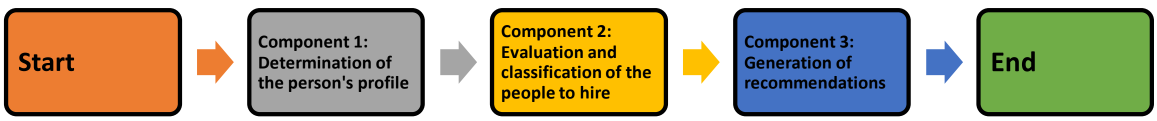

Figure 2. Diagram of the inference process workflow.

Figure 2 summarizes the workflow of the inference process of the proposed method. Below is a detailed description of the components of the method.

Component 1: Creation of the database with the profiles of the people

For the creation of people's profiles, a description of personal characteristics is made. Each person a_i is described through the finite set of details about each person, forming the personal profile.

$C = \{c_1, \dots, c_k, \dots, c_l\}$

Profiles form a characterization of people. They can be obtained through structured interviews with people or in a direct automated way with the use of computational algorithms used to capture people's data: $F_{a_j} = \{v_1^j, anv_k^j, \dots v_l^j\},\ j = 1, \dots, n.$

The evaluations of the characteristics of the people a_j, will be expressed using the linguistic scale S, $v_k^j \in S$ where $S = \{s_1, \dots, s_g\}$ is the set of linguistic terms defined to evaluate the characteristic c_k using the SVN numbers [41-43]. The linguistic terms to be used are defined [44].

The alternatives of the process are associated with the set of characteristics that describe people.

$A = \{A_1, = eA_j, = eA_m\}$

Personal profiles are stored in a database that contains knowledge about the different alternatives of the process. This information is subsequently retrieved.

Component 2: Evaluation and classification of the people to hire

The component starts from the determination of the information of people that is stored in a profile [45, 46], so that:

$P_e = \{p_1^e, \dots, p_k^e, \dots, p_l^e\}$

The profile is made up of a set of attributes that characterize people:

$C^e = \{c_1^e, \dots, c_k^e, \dots, c_l^e\}$

Where $c_k^e \in S$.

This can be obtained through a conversational approach, which can be adapted to increase the precision of the process [37, 47, 48].

Subsequently, people are filtered according to the stored profile to find which are the most appropriate according to their characteristics.

For this purpose, the similarity between the profiles of people is calculated, P_e and each available A_j profile registered in the database. We used OWA operator based on distance (OWAD).

The following expression is used to calculate the total similarity [49-51]:

$$S_j = 1 - OWAD(P_e, A_j) \tag{5}$$

The S function calculates the similarity between the values of the attributes of the people profile and those stored a_j [8, 38, 52].

Component 3: Generation of recommendations

This component is the part of the method that yields the result of the proposed inference. The similarity between the profile of the people and those stored in the database is calculated [40, 45]. Once the similarity determination process has been carried out, the resulting profiles are ordered. The similarity obtained is represented by a similarity vector [53, 54].

$$S = (s_1, \dots, s_n) \tag{6}$$

The recommendation component is designed to generate the best recommendation in response. The best recommendation is considered to be those that best fit the needs of the person's profile, mathematically the greatest similarity.

4. Application of the method for hiring people in occasional services for the public sector

This section describes the implementation of the proposed method to hire people in occasional services for the public sector. As a result of the present investigation, the proposed method was coded using a computational system that allows managers to control and process the method.

The tool allows obtaining reliable data. For the application of the proposal, we start with the set of data stored in several Human Resources departments of public institutions with different alternatives. Below there is a demonstrative example in which a manager starts from the database of his/her own:

$$A = \{A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8, A_9, A_{10}\}$$

Which is described by the attribute set as follows:

$$C = \{c_1, c_2, c_3, c_{4,}, c_5, c_6, c_7\}$$

Attributes will be assessed on the following linguistic scale (Table 1). These ratings will be stored in the database.

Linguistic term	SVN numbers
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0.15,0.20)
Good (G)	(0.70,0.25,0.30)
Medium good (MDG)	(0.60,0.35,0.40)
Medium (M)	(0.50,0.50,0.50)
Medium bad (MDB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very Very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 1. Linguistic terms used [55].

Table 2 shows a view with the data used in this example.

	c_1	c_2	c_3	c_4	c_5	c_6	c_7
A_1	VVG	MDG	VVG	M	VVG	VVG	G
A_2	VG	G	VG	MDG	VG	VVG	VG
A_3	G	VVG	M	M	G	VG	M
A_4	VVG	M	VVG	G	VVG	MDG	VVG
A_5	VG	G	VG	MDG	VG	MDG	VG
A_6	VG	G	VG	MDG	VG	VG	VG
A_7	G	VVG	B	B	G	G	B
A_8	VVG	B	VVG	G	VVG	M	VVG
A_9	VG	G	VG	MDG	VG	VG	VG
A_{10}	VVG	B	VVG	G	VVG	MDG	VVG

Table 2. Database of personal profiles.

If a person u_e, wishes to receive the recommendations of the system, they must provide information about his/her personal profile. In this case:

$P_e = \{VG, VVG, MDG, VG, VG, VVG, MDG\}$.

The next step in our example is to calculate the similarity between the personal profile and the profiles stored in the database. Table 3 shows similarity between the stored profiles and the personal profile using the OWAD operator with weighting vector to avoid extreme values [56],

W=[0.10, 0.10, 0.20, 0.20, 0.20, 0.10, 0.10]

A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
0.82	0.86	0.9	0.76	0.82	0.85	0.79	0.73	0.85	0.74

Table 3. Similarity between stored profiles and personal profile

In the recommendation phase, the profile closest to the personal profile would be recommended. An ordering of the profiles based on this comparison would be as follows.

$$A_3 \succ A_2 \succ A_6 \approx A_9 \succ A_1 \approx A_5 \succ A_7 \succ A_4 \succ A_{10} \succ A_8$$

If the system recommends the two best profiles, these would be the recommendations:

$$A_3, A_2$$

The application of the recommendations provides a neighborhood closest to the comparative profile for the example in question, the solution is A_3.

The demonstrative example allowed to run an example with 10 profiles of workers to process. It is important to note that the larger the knowledge base, the more accurate the recommendation will be. The knowledge base can be feed with more criteria and people that make up a proposal for greater dissemination and another linguistic scales based on SVN number could be defined [57].

Conclusions

The present investigation described the implementation of a method to hire people in occasional services for the public sector. The implemented method allows managers to obtain personal profiles that characterize people for subsequent hiring. The application of the proposal starts from the historical data set that several Human Resources departments of public institutions have for the successive hiring recommendation. The use of OWAD operator gives more flexibility to the process.

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Prioritization of the Social Approach of Employment Modeled by Plitogenic Sets

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Abstract. Employment can only be understood from different approaches, such as the social, economic, and legal approach. To model employment using logic, it is necessary to take into account that these approaches are usually modeled with different logics, e.g., legality is modeled using deontic logic. Furthermore, each of these approaches intrinsically contains indeterminacy. This paper proposes to use plithogenic sets to combine the different logics used to model employment approaches that also include indeterminacy. This idea responds to the definition of Plithogeny as the concept that combines dissimilar entities of different origin to form new entities as a result of their contradictory or non-contradictory interactions. In this article, the social approach is used as the most important attribute within the plithogenic sets. Although plithogenic sets have been used successfully in solving decision-making problems, as far as the authors know, they had never been used to combine different logics on the same concept. Specifically, we link the neutrosophic modal logic in particular neutrosophic deontic modality to describe the social and legal approaches with neutrosophic logic to describe the economic and political approaches.

Keywords: Employment, social sciences, Plithogeny, plithogenic sets, neutrosophic modal logic, neutrosophic deontic modality.

1 Introduction

For Cabanellas [1], in his Elementary Legal Dictionary, *work* is understood as “The human, physical or intellectual effort, applied to the production or acquisition of wealth, it is any activity susceptible of economic valuation by the task, the time or performance ”.

By its intrinsic nature, work reflects a social function, by covering basic needs of individuals, such as: food, housing, health, education. This obliges the States to grant the protectionist character of work, as provided in the Carta Magna where the work is established as a social fact under the protection of The State.

In the same way, work has a human character, since this is the man/woman himself/herself who performs the tasks, as a primitive activity of human beings. From the historical point of view, persons have always needed to work in order to survive, which is what originates the duty of work, guaranteeing the satisfaction of needs that, in turn, gives him/her the character of the right to work. Hence, it is appropriate to point out that both the Ecuadorian Constitution and the current Labor Code stipulate it.

From the international scope, in the preamble to the International Labor Organization (ILO) that was created in 1919, and which is attached to the United Nations (UN), this frames human activity developed through work, noticing: “… That there are working conditions that entail such a degree of injustice, misery and deprivation for large numbers of human beings, that the discontent this causes constitutes a threat to universal peace and harmony; considering that it is urgent to improve these conditions”, [2].

The American Declaration of the Rights and Duties of Man from 1948, also recognizes the duty of people to work, within their capacities and possibilities. The labor legal system has a protective nature of human beings that allows them to fully function and where they need to exercise in a subordinate way an activity that is remunerated. So that they can guarantee their life, health, normal physical development, rest, safeguard their morals, good customs, and enjoy economic and social benefits, essential to be able to live a decent life.

Convention 122 of the ILO (1996), on employment policy, establishes that States must propose active policies that promote full employment, [3]. In Ecuador, in the Constitution of Montecristi, work is considered a right and a social duty and the State must guarantee workers full respect for their dignity, a decent life, fair wages and salaries and the performance of a healthy job, freely chosen and accepted.

Therefore, work is one of the highest values in the legal system of the State, due to its character of preeminence that it has as a human right and that consequently it is protected and promoted.

In this study, work is approached as a social fact; it is understood as a determining factor for the development of nations worldwide and therefore the development of Ecuador as a country. Clad with transcendental importance to achieve a marked influence on the historical-progressive development of this century and an economy that shows a globalized performance.

Hence, it is evident the importance of work in the constitutional rank that is provided in the current National Constitution, where it is stated: "Work is a right and a social duty and an economic right, a source of personal fulfillment and the basis of the economy. The State will guarantee working people full respect for their dignity, a decent life, fair wages and salaries, and the performance of a healthy and freely chosen and accepted job", [4].

According to what has been explained, the aforementioned norm gives labor a series of postulates and principles such as that of irrevocability. In virtue of which it assigns to Ecuadorian State its share of responsibility and guarantee of protection and guardianship, making it responsible of remuneration, optimal working conditions, among other important aspects, such as: the social security, right to work, and social justice. All this protection is contemplated not only in the Constitution but also in the Labor Code and in the International Treaties ratified by the Ecuadorian State. It is worth mentioning the field of Labor Law as a "Social Fact", which justifies giving it the multi-dimensional approach, that is, from the social, political, economic and legal points of view, [5].

In this paper we propose to represent the employment situation of a person, the members of a social group or a community, with the help of the Plithogeny theory, [6,7]. This was introduced by F. Smarandache, who defines Plithogeny as "the genesis or origination, creation, formation, development, and evolution of new entities from dynamics and organic fusions of contradictory and/or neutrals and/or non-contradictory multiple old entities."

Plithogeny pleads for the connections and unification of theories and ideas in any field. As "entities" in his study, Smarandache takes the "knowledge" in various fields, such as soft sciences, hard sciences, arts and letters theories, etc. This theory has proven effectiveness in solving decision-making problems.

Specifically in this paper, we deal with the concept of plithogenic sets. A plithogenic set P is a set whose elements are characterized by one or more attributes, and each attribute may have many values. Two fundamental functions of this concept are the degree of appurtenance of the element x to the set P, and contradiction (dissimilarity) degree which is a function of dissimilarity between each attribute and the dominant attribute, [8-14].

The purpose of this research is to propose a model based on plithogenic sets to evaluate the employment situation of a person or human group from the social point of view. For this, we define the work according to its different approaches, each of them responds to a different logic reflected in the degree of appurtenance. Specifically, we use neutrosophic sets to model the political and economic approaches, while the neutrosophic modal logic ([15]), in particular the neutrosophic deontic modality ([16,17]), serves to model the social and legal approaches, where the social approach is the predominant attribute. Neutrosophic deontic modality generalizes the deontic modality, which is used as the logic of ethics, morality, and law.

The novelty of this article is that plithogenic sets are used as a framework to represent different approaches to the same concept, so that they serve to represent and combine different logics such as deontic logic and neutrosophic logic.

This paper is divided into the following sections: section 2 recalls the basic concepts of plithogenic sets and neutrosophic modal logic; especially the neutrosophic deontic modality is introduced. Section 3 introduces the model of employment from the social attribute point of view based on plithogenic sets. Conclusions are at the end of this paper.

2 Preliminaries

This section summarizes the basic concepts of neutrosophic and plithogenic sets in subsection 2.1. Subsection 2.2 contains the preliminaries of neutrosophic modal logic, and deontic logic.

2.1 Neutrosophic and plithogenic sets

Definition 1: ([18]) Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow \,]^-0, 1^+[$, which satisfy the condition $^-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3^+$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indetermination and falseness of x in A, respectively, and their images are standard or non-standard subsets of $]^-0, 1^+[$.

NS are used only as a philosophical approach, so *Single-Valued Neutrosophic Set* in Definition 2 is defined to guarantee the applicability of Neutrosophy.

Definition 2: ([18]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is an object of the form:

$A = \{\langle x, u_A(x), r_A(x), v_A(x)\rangle : x \in X\}$ (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 membership functions of truthfulness, indetermination and falseness of x in A, respectively. For convenience a *Single-Valued Neutrosophic Number* (SVNN) will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$ and satisfies $0 \leq a + b + c \leq 3$.

Neutrosophic Logic (NL) extends fuzzy logic and a proposition P is characterized by three components:

$NL(P) = (T, I, F)$ (2)

Where component T is the degree of truthfulness, F is the degree of falsehood and I is the degree of indetermination. T, I, and F belong to the interval [0, 1], and they are independent from each other, [19].

Definition 3. ([6]) A *plithogenic set* (P, A, V, d, c) is a set P that includes numerous elements described by a number of attributes $A = \{\alpha_1, \alpha_2, \ldots, \alpha_m\}$, $m \geq 1$, which has values $V = \{v_1, v_2, \ldots, v_n\}$, for $n \geq 1$. For V there are two main features attributes values, they are the *appurtenance degree function* $d(x, v)$ of the element *x*, with respect to some given criteria, and the *contradiction* (*dissimilarity*) *degree function* $c(v, D)$ which is the one between each attribute value and the most important (dominant) one.

Given A a non-empty set of uni-dimensional attributes $A = \{\alpha_1, \alpha_2, \ldots, \alpha_m\}$, $m \geq 1$, and let $\alpha \in A$ be an attribute with its value spectrum is the set S, where S can be defined as a finite discrete set, $S = \{s_1, s_2, \ldots, s_l\}$ $l \in [1, \infty)$, or infinitely countable set $S = \{s_1, s_2, \ldots\}$, or infinitely uncountable (continuum) set $S = (a, b)$, $S = (a, b]$, $S = [a, b)$, or $S = [a, b]$.

Definition 4. ([6]) The *degree of appurtenance* is defined for fuzzy, intuitionistic fuzzy, or neutrosophic degree of appurtenance to the plithogenic set. It is defined as follows:

$\forall x \in P, d: P \times V \rightarrow \mathcal{P}([0,1]^z)$ (3)

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

Definition 5. ([6]) The attribute value *contradiction degree function* is defined as follows:

$c: V \times V \rightarrow [0,1]$ (4)

Such that $c(v_1, v_2)$ represents the dissimilarity between two attribute values v_1 and v_2, and satisfies the following axioms:

- $c(v_1, v_1) = 0$, that means the contradiction degree between the attribute value and itself is zero,
- $c(v_1, v_2) = c(v_2, v_1)$.

Definition 6. Given a plithogenic set (P, A, V, d, c) a *Plithogenic Neutrosophic Aggregation Operator* is defined as in Equation 3:

$$(a_1, a_2, a_3)AND_p(b_1, b_2, b_3) = \left((1 - \bar{c})(a_1 \wedge_F b_1) + \bar{c}(a_1 \vee_F b_1), \frac{1}{2}[a_1 \wedge_F b_1 + a_1 \vee_F b_1], (1 - \bar{c})(a_1 \vee_F b_1) + \bar{c}(a_1 \wedge_F b_1)\right) \quad (5)$$

Where $\bar{c} \in [0, 1]$, $\wedge_F$ is a t-norm and $\vee_F$ is a t-conorm.

It is a *Plithogenic Neutrosophic Intersection* when $\bar{c} = 0$ and it is a *Plithogenic Neutrosophic Union* when $\bar{c} = 1$, [6]. This aggregator is more accurate than both the n-norms and n-conorms between neutrosophic sets.

A plithogenic neutrosophic set can be converted into a crisp value using the following formula, [14]:

$\mathcal{S}(T, I, F) = \frac{1}{3}(2 + T - I - F)$ (6)

2.2 Neutrosophic modal logic

The neutrosophic modal logic is a modal logic where modalities are defined in a neutrosophic framework, [15]. Some types of neutrosophic modalities are the following:

- Neutrosophic Alethic Modalities (related to truth) has three neutrosophic operators:
  i. Neutrosophic Possibility: It is neutrosophically possible that $\mathcal{P}$.
  ii. Neutrosophic Necessity: It is neutrosophically necessary that $\mathcal{P}$.
  iii. Neutrosophic Impossibility: It is neutrosophically impossible that $\mathcal{P}$.
- Neutrosophic Temporal Modalities (related to time):
  i. It was the neutrosophic case that $\mathcal{P}$.
  ii. It will neutrosophically be that $\mathcal{P}$.
  iii. It has always neutrosophically been that $\mathcal{P}$.
  iv. It will always neutrosophically be that $\mathcal{P}$.
- Neutrosophic Epistemic Modalities (related to knowledge):

i. It is neutrosophically known that $\mathcal{P}$.

- Neutrosophic Doxastic Modalities (related to belief):

i. It is neutrosophically believed that $\mathcal{P}$.

- Neutrosophic Deontic Modalities:

i. It is neutrosophically obligatory that $\mathcal{P}$.
ii. It is neutrosophically permissible that $\mathcal{P}$.

Usually, in classical modal logic the alethic modalities are defined as modal logic. It is characterized in the neutrosophic framework as follows:

$\lozenge_N \mathcal{P}$ means "It is (t, i, f)-possible that $\mathcal{P}$", where "(t, i, f)-possible" means it is t% possible (chance that $\mathcal{P}$ occurs), i % indeterminate (indeterminate-chance that $\mathcal{P}$ occurs), and f % impossible (chance that $\mathcal{P}$ does not occur), using neutrosophic statistics, [20-25].

Let $\mathcal{P}(t,i,f)$ be a neutrosophic proposition, with t, i, f subsets of [0, 1], then the neutrosophic truth-value of the neutrosophic possibility operator is: $\lozenge_N \mathcal{P} = (sup(t), inf(i), inf(f))$.

On the other hand, the Neutrosophic Necessity Operator: $\square_N\mathcal{P}$ means "It is (t, i, f)-necessary that $\mathcal{P}$", where "(t, i, f)-necessity" means t % necessary (chance that $\mathcal{P}$ occurs), i % indeterminate (indeterminate-chance that $\mathcal{P}$ occurs), and f % unnecessary (chance that $\mathcal{P}$ will not occur).

Let $\mathcal{P}(t,i,f)$ be a neutrosophic proposition, with t, i, f subsets of [0, 1], then the neutrosophic truth value of the neutrosophic necessity operator is: $\square_N\mathcal{P} = (inf(t), sup(i), sup(f))$.

The neutrosophic truth threshold is $\mathrm{TH} = \langle \mathrm{T_{th}}, \mathrm{I_{th}}, \mathrm{F_{th}} \rangle$, where $\mathrm{T_{th}}, \mathrm{I_{th}}, \mathrm{F_{th}}$ are subsets of $[0, 1]$.

Then we say the proposition $\mathcal{P}(t,i,f)$ is neutrosophically true if:

$inf(t) \geq inf(T_{\mathrm{th}})$ and $sup(t) \geq sup(T_{\mathrm{th}})$;

$inf(i) \leq inf(I_{\mathrm{th}})$ and $sup(i) \leq sup(I_{\mathrm{th}})$;

$inf(f) \leq inf(F_{\mathrm{th}})$ and $sup(f) \leq sup(F_{\mathrm{th}})$.

When $\mathrm{T_{th}}, \mathrm{I_{th}}, \mathrm{F_{th}}$ and t, i, f are single-valued numbers from the interval [0, 1], then we have:

The proposition $\mathcal{P}(t,i,f)$ is neutrosophically true if:

$t \geq T_{\mathrm{th}}$;

$i \leq I_{\mathrm{th}}$;

$f \leq F_{\mathrm{th}}$.

Neutrosophic Semantics of the Neutrosophic Modal Logic are defined as the ordered pair $\langle G_N, \mathcal{R}_N \rangle$, where G_N is a non-empty neutrosophic set, whose elements are called *possible neutrosophic worlds* and $\mathcal{R}_N$ is a neutrosophic binary relation, which is called *neutrosophic accessibility relation* between the possible neutrosophic worlds. Consequently, given $w_N, w'_N \in G_N$, $w_N\mathcal{R}_N\, w'_N$ represents that the neutrosophic world w'_N is *neutrosophically accessible* from the neutrosophic world w_N.

The formulas of the neutrosophic modal logic are the following:

1. Every neutrosophic propositional variable $\mathcal{P}$ is a neutrosophic formula.
2. If A, B are neutrosophic formulas, then $\neg_N A$, $A \wedge_N B$, $A \vee_N B$, $A \rightarrow_N B$, $A \leftrightarrow_N B$, $\lozenge_N A$, and $\square_N A$, are also neutrosophic formulas, where $\neg_N$, $\wedge_N$, $\vee_N$, $\rightarrow_N$, $\leftrightarrow_N$, $\lozenge_N$, and $\square_N$ represent the neutrosophic negation, neutrosophic intersection, neutrosophic union, neutrosophic implication, neutrosophic equivalence, neutrosophic possibility operator, and neutrosophic necessity operator, respectively.

Definition 7. ([15]) The *Neutrosophic (t, i, f)-Assignment* is a neutrosophic mapping:

$v_N: S_N \times G_N \rightarrow [0,1] \times [0,1] \times [0,1]$ (7)

Where, for any neutrosophic proposition $\mathcal{P} \in S_N$ and for any neutrosophic world w_N, it is defined:

$v_N(\mathcal{P}, w_N) = (t_{w_N}, i_{w_N}, f_{w_N}) \in [0,1] \times [0,1] \times [0,1]$ which is the neutrosophic logical truth-value of the neutrosophic proposition $\mathcal{P}$ in the neutrosophic world w_N.

3 The plithogenic model of employment

It is intended in this first part of the section to give an updated vision of the economic, social, political, and legal approaches of labor, as a social fact in the Ecuadorian legal system. The approaches explained below:

Legal approach:

To address this approach, work must be understood as the provision of service, performed in favor of a natural or legal person in exchange for remuneration or salary. In the Ecuadorian Legislation, it is given a protectionist character by the State and certain principles are attributed to this ([4]): Irrevocability, Intangibility, Reality about forms or appearances, More favorable interpretation, Nullity of unconstitutional acts, Progressivity of Rights.

It should be noted that General Principles of Labor Law are understood to be those permanent norms that serve as the basis for the labor legal system. Which in turn serve as the basis for the substantive and adjective law in this matter and that these principles must be respected as they are irrevocable and become part of the assets of the workers.

With regard to the social fact of work, a special protection by the State for workers is evidenced, when the Legislation indicates that the State will guarantee the right to work, not only in those principles mentioned above, but also when it establishes in Article 33 of its Carta Magna: "... The State shall guarantee working people full respect for their dignity, a decent life, fair wages and salaries and the performance of a healthy and freely chosen or accepted job."

All these postulates, previously mentioned, reaffirms social justice and seek the full development of social legislation, based on the fact that just as there are political and legal institutions that protect the right to capital and private property, there are also others that focus on protect the creative activity of work as a social fact.

For all the mentioned above, it is evident that all social activity in the life of human being generates consequences, by the simple fact of relating and living collectively from which legal relationships arise, which in turn bring consequences and also legal effects.

Social approach:

Understanding work, as a lawful exercise of intellectual and physical faculties of a worker, whether for his/her own benefit or that of the others, work as a social function is contemplated in the International American Charter of Social Guarantees as a Declaration of the social rights of the worker, to which Ecuador is engaged as an American State.

It can be highlighted that work as a social fact is essential to boost the economy of the countries. That coupled with the capital factor that most of the time is provided by the employer and that serves as a complement. Sought from this criterion and just as society benefits, the worker and therefore his/her family also benefit as the fundamental nucleus of the society.

Economic approach:

Economically speaking, work involves the exchange of goods and services that suppose the satisfaction of human needs, attributing to work the characteristic of being a productive activity, as Amate et al. pointed out in their work ([26]), whom considers work as a determining factor in the economic and social development of the countries.

From another perspective, for Adam Smith cited by Hurtado ([27]): “labor was considered an exact unit of measurement of quantified value, but not the price factor”. David Ricardo supported him by saying that all production costs are made of labor costs that are paid either directly or accumulated to capital and that from these positions arises the theory that prices would depend on the amount of work that was incorporated into the production of the mentioned goods and services.

Undoubtedly, the State supports the economic approach that is attributed to work, each time that, in the Legislation, it is indicated that it must be the guarantor of providing sources of employment, or better said in constitutional terms, guaranteeing full employment.

Political approach:

Work is the object of the Public Administration of the States, through their respective Ministries, as is the case in the Ecuadorian state of the Ministry of Labor, whose purpose is to protect workers, increasing the productive apparatus and strengthening social peace. Importantly, it should be mentioned that Ecuador has been a member of the International Labor Organization (ILO) since 1934 and that therefore it is obliged to adopt International Standards and adapt them to national legislation.

Remunerated work is the dominant form of employment, which justifies intervention by the State through the National Executive and through the Ministry of Labor, which is one of its attributions to decree wage increases guided by the protective nature of work as a social fact.

Within this perspective, at the discretion of Sabino ([28]), Social Policy can be understood as the “set of actions developed by the State, at any of its levels, aimed at increasing the well-being of the population and solving what at a given moment are defined as social problems ”.

The important point is to understand these policies as having a public nature aimed at satisfying the needs of citizens and the groups that make up the nations, by investing resources that allow improving the quality of life, avoiding unemployment and reducing poverty rates.

In this paper we will represent the concept of work through the plithogenic set (P, A, V, d, c), where P contains the elements of the plithogenic set (workers). A is the set of attributes $A = \{\alpha_1, \alpha_2, \alpha_3, \alpha_4\}$ such that α_1 represents the attribute "social approach", α_2 the "legal approach", α_3 the "economic approach" and α_4 the "political approach".

The values of V are described as follows:

- For the social approach:

a_1 = “The result of the work contributes significantly to the public purse”,

a_2 = “The prosperity and quality of work have a positive influence on the prosperity and quality of life of the community, from the social point of view”,

a_3 = “The company or business from which the job is based invests in social and public works”,

a_4 = “The company or business from which the employment is based exerts a significant positive influence on the social problems of the community, such as the decrease in crime, unemployment, among other negative aspects”,

a_5 = “Employment contributes positively to the level of family life of community members”,

a_6 = “The worker receives a fair wage”,

a_7 = “The worker has not been discriminated for reasons such as gender, race, ethnicity, sexual preference, or so”,

a_8 = “The worker's workplace complies with all the minimum hygienic parameters, such as the existence of necessary means of protection”,

a_9 = “The worker is not underemployed”,

a_{10} = “The worker is not unemployed”,

a_{11} = “The worker receives compensation from the employer in the event of dismissal”.

- For the legal approach:

b_1 = “Employers respect the legal rights of their workers”,

b_2 = “Employers respect all legal regulations that correspond to them”,

b_3 = “The company or business has not been legally prosecuted for acts such as tax evasion, corruption, fraud, abuse of power, illegal hiring of immigrants, among others”,

b_4 = “The worker is legally employed, i.e., works under a legal contract”,

b_5 = “The worker complies with the law of the country, e.g., he/she is not an illegal employed immigrant."

- For the economic approach:

u_1 = “The result of the work is effective”,

u_2 = “The result of the work is efficient”,

u_3 = “The result of the work produces sufficient profits for the company or business”,

u_4 = “The result of the work is profitable for the company”.

- For the political approach:

w_1 = “The worker feels that the Ministry of Labor complies with the established labor policies”,

w_2 = “The worker feels that the country's state policy benefits his/her status”,

w_3 = “The worker receives compensation from the State in case of dismissal”.

V is a 4-dimensional set, with elements (a_i, b_j, u_k, w_l) (i = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11; j = 1, 2, 3, 4, 5; k = 1, 2, 3, 4; l = 1, 2, 3). Thus, V contains 660 elements.

If x is a generic worker, then $d(x, v) \subset [0, 1]$ such that if $v = a_i$ (i = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11) or $v = b_j$ (j = 1, 2, 3, 4, 5) we define $d(x, v) = v_N(\mathcal{P}, w_N)$, where $\mathcal{P}$ is the proposition expressed by a_i or b_j and w_N is the possible world that corresponds to a legal or moral judgment. In particular, we recommend using the operator $\mathcal{OP}$ which means "It is neutrosophically obliged that $\mathcal{P}$".

This logical calculation must comply with certain axioms that are used in classical modal logic with deontic modality, one of them is the following:

$\mathcal{O}_N\mathcal{P} \equiv \neg_N \wp_N \neg_N \mathcal{P}$, which means “It is neutrosophically obligatory that $\mathcal{P}$” is equivalent to say “It is not neutrosophically permissible that neutrosophically no $\mathcal{P}$”, where $\wp_N$ is the operator of neurosophic permission, whereas $\mathcal{O}_N$ is the operator of neutrosophic obligation.

Additionally, the equivalence $\mathcal{F}_N\mathcal{P} \equiv \neg_N \wp_N \mathcal{P}$ means “It is neutrosophically forbidden that $\mathcal{P}$” is equivalent to say “It is not neutrosophically permissible that $\mathcal{P}$”.

Here the neutrosophic negation operator is defined as follows:

$$\neg_N(T, I, F) = (F, 1 - I, T) \quad (8)$$

Exactly, we propose to define $d(x, \mathcal{P}) = \mathcal{O}_N\mathcal{P}$ or $d(x, \mathcal{P}) = \neg_N \wp_N \neg_N \mathcal{P}$.

On the other hand, $d(x, u_k)$ and $d(x, w_l)$ are single-valued neutrosophic sets (k = 1, 2, 3, 4; l = 1, 2, 3), which can be taken from Table 1, where linguistic terms are associated with plithogenic numbers.

Linguistic expressions	**Plithogenic number (T, I, F)**
Very poor (VP)	(0.10, 0.75, 0.85)
Poor (P)	(0.25, 0.60, 0.80)
Medium poor (MP)	(0.40, 0.70, 0.50)
Medium (M)	(0.50, 0.40, 0.60)
Medium Good (MG)	(0.65, 0.30, 0.45)
Good (G)	(0.80, 0.10, 0.30)
Very Good (VG)	(0.95, 0.05, 0.05)

Table 1: Linguistic expressions for rendering classification of substitutions. Source [14].

Finally, c is the contradiction degree such that the values of each uni-dimensional attribute are compared to the dominant value of the attribute with respect to dissimilarity. We recommend to fix D = a_2 as the dominant attribute value of the social approach and the other approaches. For aggregating the results of all workers, Equation 5 is used incorporating the results of contradiction degree.

For illustrating the proposed model, we offer a hypothetical example.

Example 1.

Let us assume that four workers x_1, x_2, x_3, and x_4 of Company M are interviewed about 23 of his/her characteristics of the employment, which are those a_i, b_j, u_k, w_l (i = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11; j = 1, 2, 3, 4, 5; k = 1, 2, 3, 4; l = 1, 2, 3). In relation with the social and legal approaches, it is asked to the worker about there is obligation (or there is not permitted no) a_i, b_j. With respect to the economic and political aspects u_k, w_l, it is used Table 1, nevertheless, for the political approach the neutrosophic modal logic can be utilized.

The contradiction degree is preliminarily defined with the following vector:

$c = (0.1, 0, 0, 0, 0.1, 0.1, 0.1, 0.1, 0.1,0.1,0.1, 0.25,0.25,0.25,0.25,0.25,0.3,0.3,0.3,0.3,0.2,0.2,0.2)$ Let us note that we prioritized the social aspects, which are those having the smallest dissimilarity degrees. Additionally, we compared in dissimilarity every value with respect to the social attributes values.

The answers are summarized in Table 2 in form of plithogenic numbers or single-valued neutrosophic numbers.

Aspect to evaluate/worker	x_1	x_2	x_3	x_4
It is obliged that a_1	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)
It is obliged that a_2	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)
It is obliged that a_3	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)
It is obliged that a_4	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)
It is obliged that a_5	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)
It is obliged that a_6	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
It is obliged that a_7	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)
It is obliged that a_8	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)
It is obliged that a_9	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)
It is obliged that a_{10}	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)
It is obliged that a_{11}	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
It is obliged that b_1	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.40, 0.70, 0.50)
It is obliged that b_2	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
It is obliged that b_3	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
It is obliged that b_4	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)
It is obliged that b_5	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.40, 0.70, 0.50)
u_1	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)
u_2	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)
u_3	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)
u_4	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)
w_1	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)
w_2	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)
w_3	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)

Table 2: Workers' answers to the questions.

Considering a_2 is the dominant characteristic we obtain $(0.14087, 0.59671, 0.84689)$ from aggregating the values of x_1, $(0.048006, 0.636014, 0.943353)$ corresponds to those of worker x_2, $(0.27598, 0.37484, 0.77720)$ to x_3, and $(0.040594, 0.662490, 0.946633)$ to x_4 by using Equation 5. Let us note we selected D = a_2 the dominant attribute value, and we compare it with the other values, even though they correspond to other attributes, this is because of we are prioritizing the social advantages of the employment. $(0.040594, 0.57905, 0.946633)$ is the plithogenic neutrosophic intersection of the values for all the workers, and 0.17164 is the crisp value which is obtained by formula 6. That means Company M has a not good performance with respect to employment from the social viewpoint.

Conclusion

This paper introduces a model of employment based on plithogenic sets. Since Plithogeny is defined as a philosophical theory where new entities are obtained from the interaction, sometimes contradictory, among old entities, it is an adequate theory to represent the four different approaches to the employment: legal, social, economic, and political. Plithogenic sets allow hybridizing the neutrosophic logic with neutrosophic modal logic, particularly the deontic modality. Deontic logic is usually used to model the syntax and semantic related to moral and legal questions, thus, we model legal and social approaches for employment using this logic. On the other hand, neutrosophic logic is applied to model economic and political approaches. This combination of different semantics is possible due to plithogenic sets. To our knowledge, this is the first time that plithogenic sets are used to model employment situations.

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Multicriteria Approach to Calculate the Index of Promotion of Legal Culture

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Abstract. Educational institutions in Ecuador promote the receptive participation style of teachers in the classrooms. However, on many occasions teachers need training in the pedagogical discipline, which makes it impossible to incorporate technical knowledge, vocational training and the creation of legal awareness in students. This research proposes a solution to the problem raised from the development of a method to determine the index of promotion of legal culture. The method operates based on a multi-criteria approach with the use of neutrosophic numbers to model the uncertainty.

Keywords: Legal culture, pedagogical training, neutrosophic numbers.

1. Introduction

Nowadays, the legal pedagogical training of university teachers is very important to ensure the quality of the teaching-learning process in the educational system. It allows to improve the indicators established by the control organisms of Higher Education in Ecuador and to make improvements when necessary [1, 2].

As a way to materialize the legal culture, university teachers share experiences through congresses, scientific meetings, symposia, seminars, colloquia and other educational training activities. However, it is evident that it is not enough to achieve a good real performance, due to the lack of mastery of pedagogical strategies that facilitate their didactic performance [3, 4].

The teacher's task is complex and requires constant training, so the process of learning how to teach is necessary to better understand teaching and enjoy it. The implementation of a legal pedagogy center in higher level institutions with specialized personnel would strengthen proactivity in the learning-teaching process [5-8].

The control bodies, whose function is the institutional and academic evaluation, in relation to the quality of the university, are considered factors that drive higher institutions to provide better service, being highly demanding when selecting teachers to the academic function.

Teachers are not really aware of the role they perform and in various situations they must make emerging decisions in the classroom, since the teaching role of the lawyer who usually performs in free practice, or as a public official does not accredit him being a teacher for not having pedagogical training [9-11].

From the aforementioned analysis, the objective of this research is to develop a method to determine the index of promotion of legal culture through neutrosophic numbers. Seven evaluation criteria are proposed in the method.

The paper has the following structure: Preliminary concepts, which explains in more detail essential aspects of the pedagogy of university law teaching. Section 3 covers some specific concepts related to the neutrosophic method to be used. Section 4 shows the implementation of the method in a real case study. The paper ends with the conclusions.

2 Preliminaries

This section provides a description of the main elements associated with the domain of the modeled problem, in order to understand the main references of the addressed object of study. The bases that contribute to pedagogical training and the legal culture from the formative process are also presented.

2.1 Pedagogical training

Teachers are subject to teacher evaluations with the purpose of improving quality, in which it is evident that they clearly handle legal issues for the most part and that they personally try to teach the best way they can. But there is no constant support for this achievement, and they do not apply the adequate legal pedagogy, not due to lack of interest but due to the shortage of a department that provides accompaniment to the teachers of the law school [12, 13].

It is important that the experts in pedagogy carry out the accompaniment to the teachers of the law school, through constant advice and thus ensure that the trainers have the double training necessary to improve the teaching-learning process [14-16].

In the role of the legal trainer, the problem is that, as in any educational institution, the quality of the teacher impacts, to a greater or lesser extent, on the quality provided by the training center. Educational quality is an issue that has different interpretations, according to the scope in which it is evaluated. It is common in researches covering this topic that certain information is merited in relation to informational backgrounds, such as degrees and postgraduate degrees, among others[17, 18].

In the academic world of law, including judicial schools, this training is linked to disciplinary expertise. That is, the trainer's own terrain [19, 20], the professors of the law school obviously have their experience in the professional field, but they lack pedagogical and didactic knowledge. It is a situation that has caused a high impact, even in the universities of our country. The evaluators of the Higher Education control bodies have observed the lack of pedagogical knowledge. which is why the creation of a Legal Pedagogy center is considered pertinent to improve the level of Higher Education in the country[21] and the accreditation of universities since it is one of the indicators required by CACES [14].

2.2 Legal culture

Law school professors confront their professional activity through a characteristic system of knowledge, product of the personal elaboration of their ideas in a specific institutional and social context. Such knowledge is actually used by the teacher and "subjective, biographical and experiential factors come into play, as well as objective contextual aspects". The teacher is a subject who continually builds, elaborates and tests his personal theory of the world [22-25].

Consistent with the current vision of teaching, considered as an activity of professional thinking in which conceptual change must be recognized as the center of teacher learning [26]. The teacher becomes the builder of knowledge based on the needs of the environment, so it is important to reinforce the solutions to the difficulties that arise on a daily basis in the legal pedagogical process [27-29].

The teacher must always be aware of their actions and how they relate to their students, always trying to be a guide and an advisor, trying to practice a different style of teaching that is closer and more stimulating. One of the processes that are fulfilled in most educational institutions is the tutoring or accompaniment that the teacher carries out to the student. It is the guide of the academic process and not leaving aside personal matters, stimulating the student to meet their goals and if necessary; in several cases they are referred for psychological assistance.

The teachers who attend the training activities are highly motivated by the quality of their teaching. Most of them are teachers who are constantly innovating in their teaching task and want to know how to do better what they are already doing well as assessed by teachers and students themselves. In the proposal section we will see what role this type of teachers can play in the pedagogical and didactic training of their classmates[30].

Each university could use these sensitized teachers with specific preparation for it as facilitators within their immediate context, departments, for the change of culture and values regarding the need and opportunity for pedagogical training. It would be a form of recognition of the teaching excellence of these teachers[31].

3 Design of the method for the determination of the index of promotion of legal culture

This section describes the operation of the method to determine the index of promotion of legal culture. The method is based on the neutrosophic logic to represent the uncertainty through the use of operators for the aggregation of information[32].

Figure 1 shows a general diagram of the proposed method.

Figure 1: General diagram of the proposed method.

The proposed method is designed to ensure the management of the workflow on the determination of the index of promotion of legal culture. It uses a multi-expert multi-criteria approach where the inference is made based on evaluative indicators. It has a processing stage that executes the mathematical analysis of the solution and finally the evaluations of the promotion index are generated as an output parameter of the method [33, 34].

The process of determining the legal culture promotion index consist of four basic activities: definition of the evaluation indicators, determination of the weights associated with the indicators, aggregation of the information and generation of the evaluations, which are described below:

Activity 1. Definition of the evaluation indicators:

The activity of determining the evaluation indicators, which uses a multi-expert multi-criteria approach, consists of obtaining the evaluation indicators for the process of determining the promotion index of the legal culture from the opinion of experts who intervene in the process. The use of between 5 and 7 experts for the evaluation process is recommended.

Activity 2. Determination of the weights associated with the indicators:

From the indicators obtained from the previous activity, an assessment of these is carried out to determine the weights associated with each vector. The use of experts in the process is part of the development of the proposed activity.

Activity 3 Aggregation of information:

Definition 1: OWA operator. A function is an OWA operator of dimension n if it has an associated vector W of dimension n such that its components satisfy $F: \mathbb{R}^n \to \mathbb{R}$, [35, 36]:

1) $w_j \in [0,1]$,
2) $\sum_{j=1}^{n} w_j = 1$,Y
3) $F(a_1, a_2, , , a_n) = \sum_{j=1}^{n} w_j b_j$

Where is the j-th largest of the.$b_j a_j$

The aggregation operator can be expressed using a vector notation as represented in equation 1:

$$F(a_1, a_2 .. a_n) = W^t B \tag{1}$$

Where:

W: is the OWA weight vector associated with the aggregation.

B: is the sorted aggregate vector, where the j-th largest component of B is being the j-th largest of the.$b_j a_i$

Neutrosophic numbers can be expressed in neutrosophic logic as shown in [32, 37-39]:

$N = \{(T, I, F) : T, I, F \subseteq [0, 1]\}$,

A neutrosophic value is a mapping of a group of formulas associated with N, from each proposition p we have [34, 40, 41]:

$$v\,(p) = (T, I, F) \tag{2}$$

Where:

T: represents the truth value,

I: represents the value of indeterminacy,

F: represents the falsehood value.

Mathematically, a Neutrosophic OWA operator can be defined as a 2-tuple (W, B) as represented by equation 3.

$$F(a_1, a_2 .. a_n) = {W_{(T,I,F)}}^t B_{(T,I,F)} \tag{3}$$

Where:

W: is the OWA weight vector associated with the aggregation that has a space of truth, indeterminacy, and falsehood, respectively.(T, I, F)

B: is the sorted aggregate vector, where the j-th largest component of B is b_j being the largest j-th of the a_i, which has a space of truth, indeterminacy, and falsehood (T, I, F)[42, 43].

The proposed method bases the aggregation process using the OWA operator for neutrosophic numbers [44-47].

Additionally, in order to compare two neutrosophic numbers, the following formula is used:

$$s(\tilde{a}) = \frac{1}{3}(2 + T - I - F) \tag{4}$$

For a neutrosophic number.$\tilde{a} = (\mathrm{T}, \mathrm{I}, \mathrm{F})$

Activity 4 Generation of evaluations:

Once the information is aggregated, the evaluations derived from the process are obtained as a result; they represent the output information of the method.

Specifically, the method includes the following 7 evaluation criteria:

Criteria	Description
C1	Domain with experience and suitability in the work specialty
C2	Possession or access to consistent pedagogical training that enables them to understand and facilitate training
C3	Knowledge of teaching strategies
C4	Training in the style of many of the teacher training programs in law schools.
C5	Inclusion of fundamental elements of institutional insertion
C6	Management of realistic strategies adaptable to changing circumstances and events
C7	Teacher evaluations

Table 1. Evaluation indicators.

These criteria are the ones we recommend to measure. Each institution may include new ones or exclude some of those proposed.

The method consists of the following:

1. The experts that we will denote by $\{e_1, e_2, \cdots, e_n\}$ are selected
2. Each expert evaluates the importance of each criterion using the linguistic scale shown below in Table 2.

Linguistic term	Neutrosophic number
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0.15,0.20)
Good (G)	(0.70,0.25,0.30)
Medium good (MG)	(0.60,0.35,0.40)
Medium (M)	(0.50,0.50,0.50)
Medium bad (MB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 2. Linguistic terms used.

Let us call $x_{ij}$the value of the neutrosophic number that appears to the right of Table 2, corresponding to the linguistic term that appears in the left column, which means the opinion of the i-th expert on the j-th criterion. Where i = 1, 2,…, n and j = 1, 2,…, 7

3. To obtain the weights, the linguistic terms that appear in Table 3 are used.

Linguistic term	Value
Not important	(0.10,0.90,0.90)
Less important	(0.20,0.85,0.80)
Slightly important	(0.30,0.75,0.70)
Somewhat important	(0.40,0.65,0.60)
Average importance	(0.50,0.50,0.50)
Important	(0.60,0.35,0.40)
Very important	(0.70,0.25,0.30)
Strongly important	(0.8,0,15,0.20)
Very strongly important	(0.9, 0.1, 0.1)
Extremely important	(1,0,0)

Table 3. Domain of values to assign weight to the criteria.

3.1. Each expert proposes a weight for each criterion, using the scale that appears in Table 3, let's call $\widetilde{w}_{ij}$ the weight assigned by the i-th expert to the j-th criterion.

3.2. We obtained $\widehat{w}_j = \frac{1}{n}\sum_{i=1}^{n}\widetilde{w}_{ij}$ The weight of the j-th criterion is calculated as $w_j = \frac{s(\widehat{w}_j)}{\sum_{j=1}^{7} s(\widehat{w}_j)}$, where $s(\cdot)$ is the operator that appears in formula 4.

4. The results are aggregated using the calculated weights and the evaluations using formula 3, where for each evaluation, $b_j = \frac{\sum_{i=1}^{n} x_{ij}}{n}$ (j = 1,2,…, 7).

4 Method implementation for the determination of the index of promotion of legal culture

This section describes a case study for the exemplification of the results in which it is possible to apply the proposed method. The study is carried out on an institution of higher education at Universidad Autónoma Regional de los Andes, Ecuador. The example presents the fundamental elements synthesized to facilitate the understanding of the readers.

The main elements of the implemented method are described below.

Stage 1: Definition of the evaluation indicators.

During the process of obtaining information for the definition of the evaluation indicators, we concluded that the criteria in Table 1 are adequate to carry out the evaluations.

Activity 2 Determination of the weights associated with the indicators:

Using a multi-expert approach, the weights attributed to each criteria are determined. Five experts were consulted for the process, and they issued their assessments. As a result, the weight vectors associated with each indicator were obtained. Table 4 shows the results after the aggregation of the results issued by the experts.

Criterion	$\widetilde{W}$ (T, I, F)	W
C1	[0.97, 0.25,0.15]	0.15279
C2	[0.75, 0.15,0.10]	0.14863
C3	[0.85, 0.12,0.10]	0.15636
C4	[0.97, 0.25,0.10]	0.15577
C5	[0.65, 0.30,0.25]	0.12485
C6	[0.55, 0.25,0.25]	0.12188
C7	[0.80, 0.25,0.20]	0.13971

Table 4. Weights vectors associated with the indicators.

Stage 2: Implementation of the static analysis.

Activity 3 Aggregation of information:

From the processing of the vectors of associated weights of the indicators and the preferences obtained from the institution used in the case study, the information aggregation process is carried out based on what is expressed in Equation 3. For the process of aggregation, a sorting of the evaluative indicators is carried out.

Table 5 presents the result of the values obtained during the aggregation process.

Criterion	Weights	Preferences
C1	0.15279	[0.95, 0.10,0.15]
C2	0.14863	[0.85, 0.10,0.10]
C3	0.15636	[0.75, 0.12,0.10]
C4	0.15577	[0.75, 0.10,0.10]
C5	0.12485	[0.55, 0.15,0.10]
C6	0.12188	[0.75, 0.20,0.15]
C7	0.13971	[0.25, 0.25,0.10]
Aggregated Value.		[0.70059, 0.14251, 0.11373]

Table 5. Result of the aggregation process.

The crisp value of the aggregated value is 0.81478.

Activity 4 Generation of evaluations:

From the aforementioned analysis of the data in Table 5, an evaluation is generated where an incidence rate of promotion of the legal culture of 0.81478 is identified; representing a high implementation rate from what it is possible to define that this area is a fundamental line of work for the training of teachers.

Conclusions

This paper presented a method for determining the index of promotion of legal culture through a multi-criteria approach. The performance used the representation of neutrosophic numbers to model the uncertainty.

The method also included the use of the OWA operator with neutrosophic numbers to represent the uncertainty about the promotion of legal culture. Through its evaluation, it was possible to make an analysis of the promotion of legal culture. The use of linguistic labels is recommended to improve the interpretability of the analyzed data.

From the identification of the limitations and weaknesses found in the universities under study, due to legal professionals who do not have a good pedagogical training, we must take into account a series of considerations in order to overcome the obstacles that affect the training of the professional future.

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Profiles of Human Trafficking Violence in Regions of Ecuador

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Abstract. People are often vulnerable to become victims of violence, including human trafficking. In Ecuador, considerable crimes of this nature are reported each year. Knowing and generating protection mechanisms against this type of crime constitutes a vitally important task to preserve the integrity of people. This research proposes a solution to the problem described from the development of a method to determine profiles of violence in people from regions of Ecuador. The proposed method bases its operation on the set of neutrosophic numbers to represent the uncertainty.

Keywords: Violence profiles, neutrosophic numbers, multi-criteria decision-making method.

1. Introduction

Human trafficking crimes represent a global phenomenon that constitutes one of the most lucrative illegal activities, after drug and arms trafficking. According to United Nations estimates, more than 2.4 million people are currently being exploited as victims of human trafficking, either for sexual or labor exploitation.[1, 2].

Other forms of human trafficking include servitude, organ trafficking, and the exploitation of children for begging or for war. Up to 80% of victims of human trafficking are women and girls. Human trafficking is a crime against human rights considered as slavery of the 21st century[3, 4].

This crime consists of the forced or deceitful transfer of one or more people from their place of origin (whether internally in the country or transnationally), the total or partial deprivation of their freedom for labor, sexual or similar exploitation. This fact is due to the fact that the means through which a person has been captured to exercise a job have been coercion or deception [5, 6].

Poverty leads some poor rural families to send children to work on banana plantations or small mines or to send them to urban areas where traffickers exploit them. Ecuadorian citizens are trafficked to Western Europe, particularly Spain and Italy, and other Latin American countries [7-9].

The report issued by the United States Department of State for the Ecuador section in 2005 refers to the validity of these terms. In 2003, the International Labor Organization estimated that more than 5,000 minors were exploited in prostitution in Ecuador.

This research describes a neutrosophic method to determine profiles of human trafficking violence in regions of Ecuador. The method is a Decision Support System[10] model for the automatic search for human trafficking profiles, where the real profile of a region is compared with others stored in time. The advantage of the model is that once the profile is identified, it is easier to evaluate and more importantly, to determine how to proceed according to historical precedents. The inclusion of neutrosophic numbers allows modeling with the indeterminacy that is typical of all decision-making processes, as well as the use of a linguistic scale that is more suitable for evaluating people when compared to numerical scales[11-13].

This article is divided into a preliminary section that addresses the issue of human trafficking and the legal framework for dealing with this scourge, in addition to describing concepts such as the neutrosophic number. Section 3 introduces the proposed method; section 4 contains the application of the method to a real case. The paper ends with the conclusions.

2 Preliminaries

In order to understand the main references around the object of study of this research, the main terms associated with the problem that is modeled are described. The concepts of crimes of violence are introduced in the context of the investigation along with the legal norms that support the citizen's right to prevent crimes of violence. Finally, a modeling is carried out on how to represent the uncertainty using neutrosophic numbers.

2.1 Crimes of violence

It constitutes a crime of human trafficking, even with the consent of the victim, to promote, induce, participate, facilitate or favor the recruitment, transfer, reception, reception or delivery of persons through threat, violence, deception or any other fraudulent form, for illicit exploitation, for profit or not for profit [14, 15].

For the purposes of this offense, all forms of forced labor or services, labor slavery, sale and/or use of people for begging, armed conflicts, or recruitment for criminal purposes are considered exploitation.

Remember that trafficking involves capturing, transporting or receiving a person where violence, deception and abuse of vulnerability are applied for the purpose of exploitation, for the purpose of generating illicit income for traffickers [16, 17].

The Executive Decree proposes the fight against different existing forms of exploitation, including sexual exploitation and the “prostitution of women, children, and adolescents”. It is clear that when dealing with persons under 18 years of age, we must refer to paid sexual relations, as one of the manifestations of “child” sexual exploitation, although it also includes adolescents. The use of this concept has been internationally accepted, in order to avoid associating it with myths and stereotypes that consider prostitution as an activity of free choice on the part of those who exercise it. In addition, emphasis has been placed on differentiating from adult prostitution, to the extent that children and adolescents are within criminal networks of sexual exploitation [18].

2.2 Legal norms for the crime of violence

The Ecuadorian Penal Code establishes the legal norm to regulate crimes of violence [19, 20]. Article 188 of the Criminal Code, evidences the purposes for which a person can be violated, which can be listed as follows.

1. To be sold,
2. To be put against his/her will at the service of another,
3. To get any utility,
4. To ask for ransom,
5. To deliver a belonging,
6. To deliver or sign a document that has or may have legal effects,
7. To force her to do or omit something,
8. To force a third party to carry out one of the indicated acts aimed at the release of the plagiarist.

It is in this way that the violence of persons manifests itself as a means to obtain some of the ends determined by the law itself. It is unacceptable that a person is deprived of his freedom, with the sole purpose of obtaining an amount of money in exchange, with the aggravation that if their requirements are not met, the captors do not hesitate to murder the victim[21]. It is even more degrading when children or people who have no possibility of defense are used as targets [22].

2.3 Neutrosophic numbers to model the uncertainty in the commission of crimes

Neutrosophic sets are a generalization of a fuzzy set (spatially fuzzy intuitive set). Let U be a universe of discourse, and M a set included in U. An element x of U is denoted with respect to M as x (T, I, F), which means that x belongs to M in the following way: it is t% true in the set, i% undetermined in the set, and f% false, where t varies in T, i varies in I, f varies in F.

Statistically T, I, F are subsets, but dynamically T, I, F are functions or operations dependent on many unknown or known parameters [23, 24].

In order to facilitate the practical application to the decision-making and engineering problem[25, 26], the proposal of the neutrosophic single-valued sets (SVNN) was made [27] which allows the use of linguistic variables [28, 29] as a way to increase the interpretability in the recommendation models and the use of indeterminacy.

Let X be a universe of discourse. An SVNS A over X is an object of the form.

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

Where $u_A(x): X \to [0,1]$, $r_A(x), : X \to [0,1]$ y $v_A(x): X \to [0,1]$ with $0 \leq u_A(x) + r_A(x) + v_A(x) :\leq 3$ for all $x \in X$. The interval $u_A(x), r_A(x)$ and $v_A(x)$ denote the true, indeterminate, and false memberships of x in A, respectively. For convenience, an SVN number will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$, $0 \leq a + b + c \leq 3$.

3 Method to determine profiles of human trafficking violence in regions of Ecuador

The proposed method’s workflow consist of three stages: Input, Processing and Output.

The core of the method's processing is designed in three main processes: determination of violence profiles, evaluation and classification of alternatives, and generation of recommendations based on the knowledge of the similarity profile. Figure 1 shows a diagram with the general operation of the proposed method.

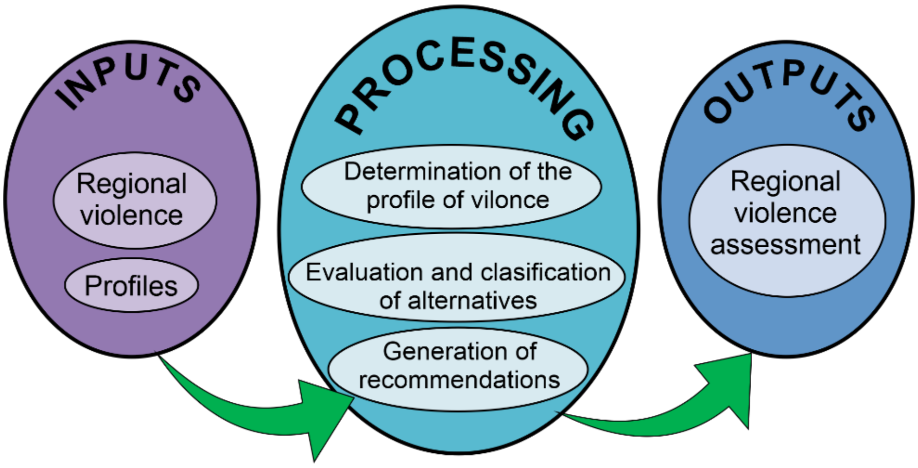

Figure 1: Structure of the operation of the proposed method.

The method operates through a knowledge-based recommendations system [30, 31]. We also implemented the representation of linguistic terms and indeterminacy through neutrosophic numbers[32].

Each of the stages of the method and the mathematical foundations that support the different processes are described below.

Determination of the database with the violence profiles

Each of the areas will be described by a set of characteristics that will make up the profile of the regions. $a_i C = \{c_1, \dots, c_k, \dots, c_l\}$

This profile can be obtained directly from the computational algorithms used to capture data from the regions, using the available statistics. $F_{a_j} = \{v_1^j, \dots, v_k^j, \dots v_l^j\}, j = 1, \dots n$

The assessments of the characteristics of the Areas, a_j, will be expressed from the linguistic scale $Sv_k^j \in S$, where $S = \{s_1, \dots, s_g\}$ is the set of linguistic terms defined to evaluate the characteristic of the SVN numbers. For this, the linguistic terms to be used are defined.

Once the set of areas represented by the alternatives has been described: $A = \{a_1, \dots, a_j, \dots, a_n\}$.

The profiles are saved in a database for later retrieval; this step constitutes the fundamental element on which the operation of the inference process is based. Basically, the database contains the different profiles historically measured in terms of criteria C, which makes it possible to compare some characteristics of the case under analysis with previous ones and thus proceed in a similar way.

This method has the advantage that an automatic, fast, effective and efficient search can be made of these archived cases, in a way that it constitutes a support system for the legislative decision. The basis for this is that the classification of a case on whether or not it is suspected to be a case of human trafficking is a complex problem, usually not that obvious. The database contains both cases involving human trafficking profiles and others trafficking crimes.

Evaluation and classification of alternatives

In this activity the information of the regions about their preferences is determined, being stored in a profile so that: $P_e = \{p_1^e, \dots, p_k^e, \dots, p_l^e\}$.

The profile will be made up of a set of attributes that characterize people: $C^e = \{c_1^e, \dots, c_k^e, \dots, c_l^e\}$ Where $c_k^e \in S$

This can be obtained by example or through the so-called conversational approach which can be adapted [33].

In this activity, the regions are filtered according to the stored profile to find which ones are the most suitable according to the present characteristics.

For this purpose, the similarity between the profile of the areas P_e and each available profile a_j registered in the database is calculated. To calculate the total similarity the following expression is used:

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

The function calculates the similarity between the values of the attributes of the profile of the areas and those stored, Sa_j[34].

Generation of recommendations

Once the similarity between the profile of the regions and those stored in the database has been calculated, each of the profiles are ordered according to the obtained similarity represented by the following similarity vector,$D = (d_1, \ldots, d_n)$

The process of generating recommendations expresses that the best recommendation will be those that best satisfy the needs of the profile of the regions, that is, that present the greatest similarity. Statistically, a lower similarity index is accepted, greater than or equal to α = 0.85.

4 Implementation of the method to determine profiles of violence in people from regions of Ecuador

This section describes the implementation of the proposed method to determine profiles of violence in people from regions of Ecuador. The method allows the classification of the different geographical regions of Ecuador to facilitate decision-making in government analyzes.

For the application of the proposal, we start from the set of data stored in the database on the regions that allow the analysis of the information. Next, a demonstrative example is presented from which we start from the database that has:

$$A = \{a_1, a_2, a_3, a_4, a_5\}$$

Described by the attribute set

$$C = \{c_1, c_2, c_3, c_{4,}, c_5\}$$

The attributes will be assessed on the following linguistic scale (Table 1). These evaluations will be stored to feed the database.

Linguistic term	**SVN numbers**
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0.15,0.20)
Good (G)	(0.70,0.25,0.30)
Moderately good (MDG)	(0.60,0.35,0.40)
Mediun (M)	(0.50,0.50,0.50)
Moderately bad (MDB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 1. Linguistic terms used [35].

Figure 2 shows a graph of the behavior of the complaints made during the period between 2010 and 2014.

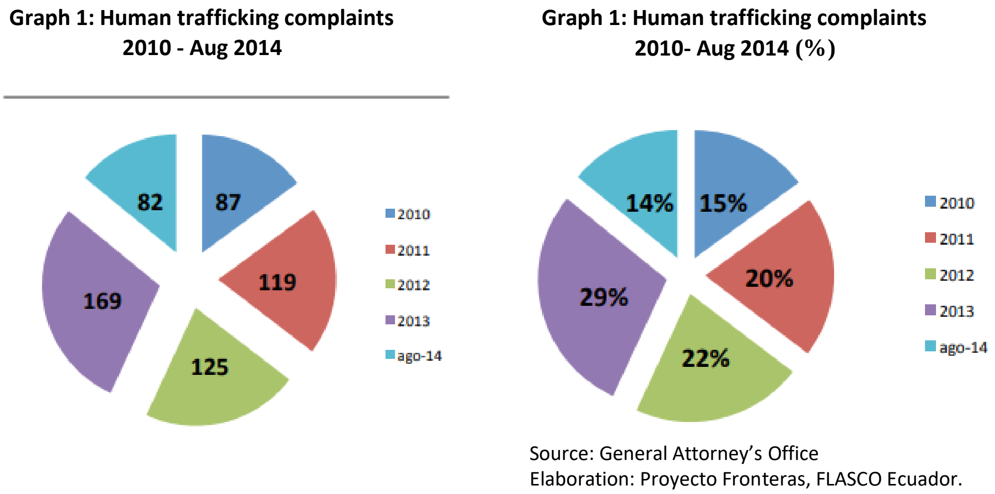

Figure 2: Behavior of complaints between 2010 and 2014

Figure 3 shows a breakdown of the information that illustrates the complaints of persons by province in the corresponding period between 2010 and 2014.

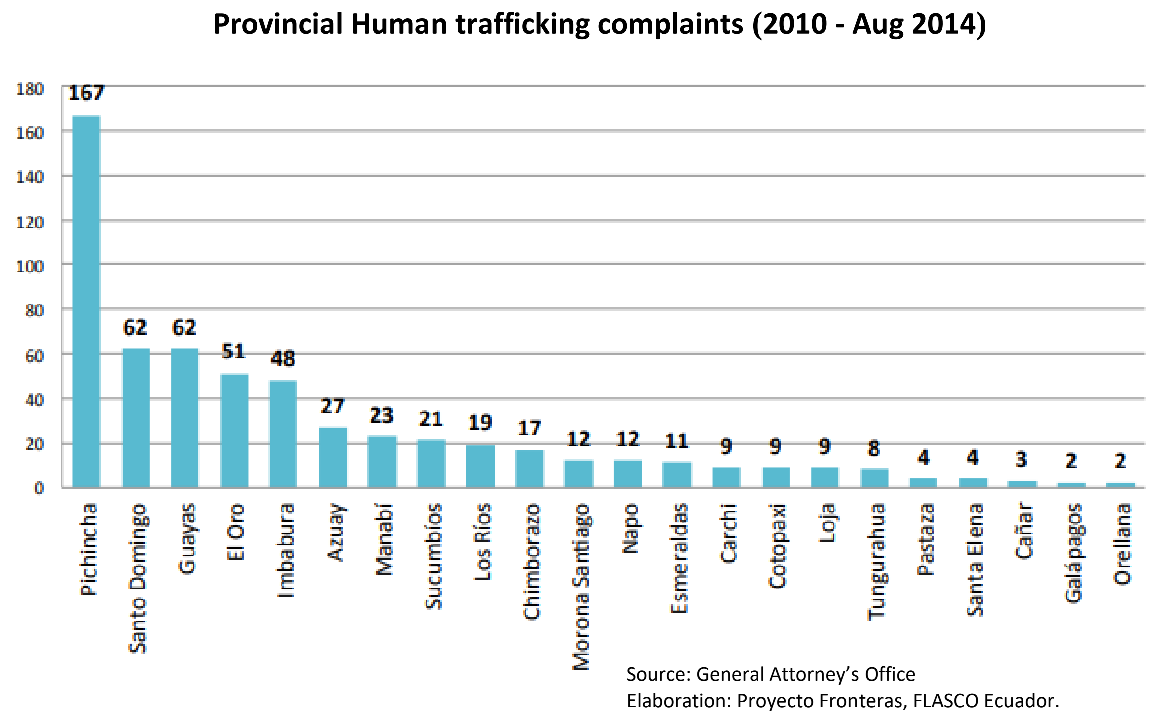

Figure 3: Behavior of complaints by provinces between 2010 and 2014

From the data obtained, the analysis of the proposed case study is carried out. Table 2 shows a view with the data used in this example.

	c_1	c_2	c_3	c_4
a_1	G	G	VG	VG
a_2	G	VG	G	VG
a_3	G	VG	VG	G
a_4	VG	VG	G	G
a_5	G	VG	G	VG
a_6	VG	VG	G	G
a_7	G	VG	G	VG

a_8	VG	G	G	VG
a_9	VG	VG	G	G
a_{10}	G	VG	G	VG
a_{11}	VG	G	G	VG
a_{12}	VG	VG	G	G
a_{13}	G	VG	G	VG
a_{14}	VG	G	G	VG
a_{15}	VG	VG	G	G
a_{16}	G	G	VG	VG
a_{17}	G	G	VG	VG
a_{18}	G	VVG	B	B
a_{19}	G	G	EG	VG
a_{20}	G	G	EG	MDG
a_{21}	G	G	EG	MDG
a_{22}	EG	VVG	EG	MMG

Table 2: Regional profiles database.

The criteria that we propose to evaluate are the following, although in a specific region others could be included.

c1: There are technical, human, logistical, and anti-criminal means to detect in time and effectively eliminate any attempt of human trafficking in the region

c2: The police, political and citizen authorities, among others in the region, reject this type of crime and have no link with human trafficking, as well as being willing to contribute to its confrontation.

c3: The penalties stipulated for citizens who commit this type of crime are reliably applied within the region.

c4: There are multidisciplinary teams of specialists who effectively serve people who have been victims of human trafficking in the region.

If a region u_e wishes to receive the recommendations of the system, it must provide information expressed by the profiles of people. In this case:

$$P_e = \{\mathrm{B}, \mathrm{EB}, \mathrm{EB}, \mathrm{MDB}\}$$

The next step in our example is the calculation of the similarity between the regional profile and the profiles stored in the database.

Stored profile	Similarity
a_1	0.31290
a_2	0.31290
a_3	0.51129
a_4	0.31182
a_5	0.31290
a_6	0.31182
a_7	0.31290
a_8	0.11343
a_9	0.31182
a_{10}	0.31290
a_{11}	0.11343
a_{12}	0.31182
a_{13}	0.31290
a_{14}	0.11343
a_{15}	0.31182
a_{16}	0.31290
a_{17}	0.31290
a_{18}	0.30000
a_{19}	0.31569
a_{20}	0.68682
a_{21}	0.68682
a_{22}	0.31569

Table 3. Similarity between stored profiles and regional profile

In the recommendation phase, the profile that most closely matches the regional profile is evaluated. An ordering of the profiles based on this comparison would be the following.

$\{a_{20}, a_{21}, a_3\}$

In case the system recommends the two closest profiles, these would be the recommendations:

a_{20}, a_{21}.

Conclusions

The present work developed a method to determine profiles of human trafficking violence in regions of Ecuador. The method based its operation on a multi-criteria approach for the evaluation of regional profiles and implemented a knowledge-based recommendations system. It supports its processing by SVN numbers to express uncertainty with the use of linguistic terms.

The application of the proposed method allowed the identification of the regional profiles that most correspond to the group of characteristics of the regions that affect the type of violence that is modeled.

The regional profiles generated constituted the knowledge base that was stored in a database to feed the case base of the proposed method. It is recommended for future research to work on the inclusion of more complex aggregation models for generating recommendations.

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Evaluation of the Impact of Informal Trade using Neutrosophic Cognitive Maps and Weighted Power Mean Operator

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Abstract: The commercial relationships that are generated as part of economic development can be classified as formal or informal according to the nature of their transactions. Informal trade establishes a direct relationship with social forces. However, evaluating the impact of informal trade represents an unsolved task for science. This research proposes a solution to the posed problem by developing a method to evaluate the impact of informal trade. The proposed method consist of modeling causal relationships using Cognitive Maps and the Weighted Power Mean (WPM) operator. It models uncertainty using Neutrosophic Numbers. The proposal has been implemented in the Mariscal de Puyo market, where it was possible to quantify its impact.

Keywords: Cognitive Map; Neutrosophic Numbers; Informal trade; evaluation, WPM operator.

1. Introduction

Trade relations are established as part of economic progress. The relations make up the mercantilist societies from which the social strata are created [1, 2]. Mercantile relations implement a direct relationship with the levels of trade, with which economic transactions are carried out [3, 4]. Transactions can be executed formally or informally [5, 6].

The transactions are in correspondence with the development characteristics of the towns [7]. They are directly related to social forces: poverty, migration and unemployment [8]. Government administrations have generated legal regulations to control, order and organize informal trade [9, 10]. However, the evaluation of the impact of informal trade represents an area of knowledge that has not been sufficiently addressed.

The objective of this research is to develop a method using a Neutrosophic Cognitive Map and the WPM operator [11] to evaluate the impact of informal trade. This paper continues with section 2, which introduces some preliminary concepts. Section 3, develops the framework to evaluate the impact of informal trade. Section 4 presents the Mariscal de Puyo market study case. Paper ends with the conclusions and future works recommendations.

2. Preliminaries

In this section, we present the theoretical referents that characterize the problem under study. The different concepts that facilitate the understanding of the research are also discussed, along with a description of informal trade. In addition, Neutrosophic Cognitive Maps are characterized as a way to model causal relationships and Neutrosophic numbers are presented because they are capable of modeling uncertainty in decision-making problems.

2.1 Informal trade

The retail trade carries out informal commercial activities[12]. Retail trade on public roads is the activity of people who are engaged in the sale of products and the provision of services of various kinds [13, 14]. According to the new developments, it is necessary to evaluate the impact of informal trade on the Mariscal de Puyo market. For which three fundamental aspects were determined to carry out the evaluation: Diversification of the Informal Trade Offer, Use of Public Space and Competitive Advantages for Marketing.

Informality shows its problem from its own definition [15]. In the different studies carried out in the informal sector, it is observed that this term is often used as a synonym for a street market, without formality, without public safety or benefits. However, the most general sense is to consider the informal sector as the group of workers who do not have social security [16, 17]. They are known by various names: street vendors, artisans, unions, micro-entrepreneurs, and others.

2.2 Neutrosophic Cognitive Map

Fuzzy Cognitive Maps (FCM) are a tool that aims to expand the work horizon that involves the implementation of traditional cognitive maps and concept maps [18-20]. These maps, in more advanced versions, can include the combination of techniques belonging to Soft Computing [21], such as Artificial Neural Networks and Fuzzy Logic [22-24]. FCMs belong to a constantly developing area and alternatives are currently being investigated to increase the reliability of the inference process [25-27].

In the 1980s, Romanian polymath F. Smarandache founded the international movement called Paradoxism [28], based on the occurrence of contradictions in science and art, which was then extended to Neutrosophy, based on contradictions and their neutrals. This has formed the basis for a series of mathematical theories that generalize classical and fuzzy theories such as Neutrosophic sets and Neutrosophic logic [29, 30]. Neutrosophic Cognitive Maps (NCM) represent an extension of the FCM to work with neutrosophic numbers. The original definition of truth value in Neutrosophic logic is:

$N\ \{(T,\mathrm{I},\mathrm{F}):T,I,F \subseteq [0,1]\}$

n, in which: T, represents the degree of membership; I, the degree of indeterminacy; and F, the falsehood.

What represents a Neutrosophic evaluation, considered as a mapping of a group of propositional formulas to N, and for each sentence p to obtain the result through equation 1.

$$v(p) = (T,\ I,\ F) \tag{1}$$

The NCM theory expresses that for each connection on the map there is a weight that denotes the degree of causality. This characteristic allows to implement knowledge concerning the strength of each causal relationship [31]. Specifically, the connections in an NCM have associated a numerical value in the range [-1,1] that regulates the direction and intensity of the causal relationship between the concepts that define the system.

3. Framework for evaluating the impact of informal trade

This section describes the operation of the framework to evaluate the impact of informal trade using a Neutrosophic Cognitive Map. The main elements that characterize the proposed method are described below.

The method is built to assess the impact of informal trade. It is divided into three basic activities: input, inference and results. Figure 1 shows a general outline of the proposed method.

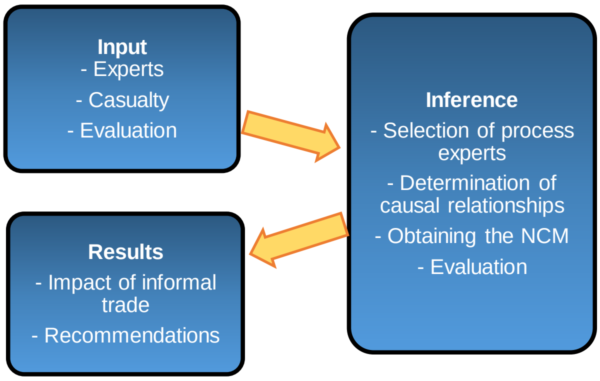

Figure 1. Structure of the proposed method.

The proposed structure for the method supports workflow management for evaluating the impact of informal trade. The method employs a multi-expert multi-criteria approach. The inference process uses data from the set of evaluation indicators proposed for the evaluation of the result.

The inference process is described using soft computing techniques with the implementation of the Neutrosophic Cognitive Map technique [32, 33]. Figure 2 shows a diagram with the activities of the method.

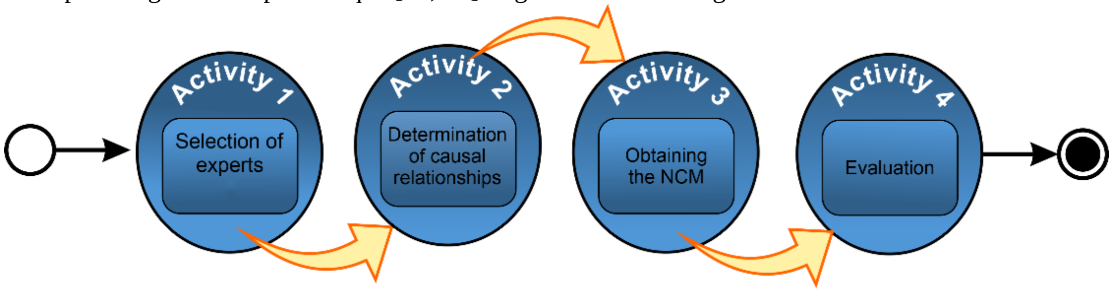

Figure 2. Method workflow activities.

Below there is a description of the proposed activities:

Activity 1. Select the experts and determine the indicators.

The method begins with the selection of experts and the identification of evaluation indicators. For the activity the multi-expert approach is formalized as:

The number of experts involved in the process $E = \{e_1, = e_m\}$, mes,

The number of evaluation indicators of the process $I = \{i_1, = i_n\}$, nes,

Activity 2. Determinations of causal relationships

This activity establishes the relationship of the concepts on the map. Causal relationships are expressed by fuzzy variables from linguistic terms.

During the activity, each expert expresses the relationship between each pair of indicators C_i and C_j on the map. Then, for each causal relationship, K rules are obtained with the following structure: If C_i is A then C_j is B and the weight W_{ij} is C.

Then the Centroid method and the Mamdani inference mechanism are used to add the k rules, and the de-fuzzified value is the weight of the relation.

Activity 3 obtaining the resulting NCM:

Once the causal relationships are identified, this knowledge is organized through the adjacency matrix [34]. The matrix represents the result of the aggregation process of information on the criteria issued by the experts. The resulting Cognitive Map has the causal relationships with the node weights [35, 36].

Static analysis is performed on the resulting knowledge that is stored in the adjacency matrix. As a result, the values of the output degree are obtained using equation (2), where the weights attributed to each manifestation are obtained based on total degree [37]. Values described below are used in the proposed model, based on the absolute values of the adjacency matrix [38]:

$$w_i = \frac{td(v_i)=}{\sum_{i=1}^{n} td_i} \tag{2}$$

Where $td(v_i)$ is the total degree value of the ith node

Activity 4 evaluation

The evaluation activity consists of the inference process carried out in accordance with the proposed method.

The aggregation function used $OAG: [0,1]^n \to [0,1]$ is the Weighted Power Mean (WPM) using the model of Logic Scoring of Preferences (LSP) [11]. The r-th WPM is defined as follows:

$$M_n^{[r]}(\underline{a}, \underline{w}) = \left(\sum_{i=1}^{n} a_i^r w_i\right)^{\frac{1}{r}} \tag{3}$$

where $w_i \in [0,1]$ and $\sum_{i=1}^{n} w_i = 1$ and r could be selected to achieve the expected logic properties. puede ser seleccionadas para lograr propiedades lógicas deseadas.

4. Application of the method to evaluate the impact of informal trade: Mariscal de Puyo market study case

This section describes the implementation of the proposed method. A case study is carried out where it is possible to assess the impact of informal trade. For the proposed method, a multi-criteria evaluation system is implemented. The method allows an evaluation of the impact of trade to be obtained using causally related evaluation indicators. The proposal used the Mariscal de Puyo market as a case study. Below, is a description of the process.

Activity 1. Select the experts and determine the indicators

For the development of the study, 7 experts were consulted who represented the basis for the identification of causal relationships. The knowledge of the indicators that impact on trade was taken into account.

From the work with the experts, 4 evaluation indicators were identified, which are shown in Table 1.

No.	Indicator
1	Crafts
2	Nutrition
3	Services
4	Health

Table 1. Evaluation indicators

The main indicators to be evaluated are conceptually defined:

- Crafts refers to the activity of selling objects and crafts made manually by people.
- Nutrition refers to the sale of food, vegetables, sweets and other products obtained from agriculture.
- The services refer to beauty activities such as hairdressing, manicures and others of this nature.
- Health services refer to chiropedic activity carried out at home and others of this nature.

Activity 2. Determine causal relationships

For the process of identification of the causal relationships, 7 adjacency matrices were obtained corresponding to the 7 experts who participated in the process, which were added to the resulting matrix. Table 2 shows the adjacency matrix resulting from the process.

	C_1	C_2	C_3	C_4
C_1	0	0.25	0.25	0.2
C_2	I	0	I	0
C_3	0	0.5	0	0.2
C_4	0.5	0	0.2	0

Table 2. Adjacency matrix of evaluation indicators

Activity 3. Obtaining the resulting NCM

Figure 4 shows the resulting Neutrosophic Cognitive Map using Mental Modeler Software [39]. The result obtained is a Neutrosophic Cognitive Map of the method for evaluating the impact of informal trade.

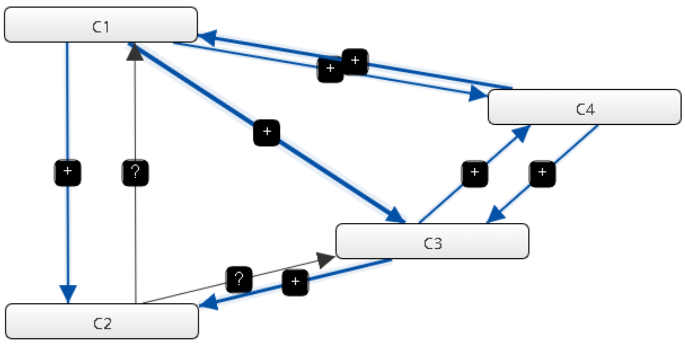

Figure 3. Neutrosophic Cognitive Map.

Activity 4. Evaluation

From the adjacency matrix, the weights attributed to the evaluation indicators were identified by solving equation (2). Table 3 shows the results obtained from the weights.

No.	Evaluation indicators	Weight
C1	Crafts	0.11
C2	Nutrition	0.08
C3	Services	0.10
C4	Health	0.05

Table 3. Weight attributed to evaluation indicators

Once the weights of the indicators have been determined. The preferences of the object of analysis are determined. The preferences are calculated according to the mean of experts' evaluation in the scale 0-1. The evaluation is carried out using WMP operator (3) with r=0.619

Criteria	Weights	Preferences
C1	0.32	0.75
C2	0.23	1
C3	0.31	0.5
C4	0.14	1
Index		0.77

Table 4. Weight and attributed preferences for method development.

Once the evaluation of the impact of informal trade has been obtained, an analysis of the result is carried out. An evaluation index of I= 77 is evident. From the result, we can conclude that the evaluation of the impact of informal trade is at a high level.

Conclusions

From the development of the proposed research, a method for evaluating the impact of informal trade was obtained. The method operates by using a multi-expert multi-criteria approach.

During the implementation of the method, the aggregated Neutrosophic Cognitive Map was obtained with the representation of the causal relationships on the evaluation criteria that determine the impact of informal trade. The resulting Neutrosophic Cognitive Map and the WPM operator forms the basis for the inference of the operation of the proposed method.

With the application of the method in the Mariscal de Puyo market study case, it was possible to demonstrate the applicability of the method that allowed evaluating the impact of informal trade from the set of evaluation criteria. As a result, a high-level evaluation is obtained, which is considered as "Very good".

For the development of future research, the implementation of new information aggregation models that manage knowledge based on different criteria defined in the scientific literature, such as modeling uncertainty in a pessimistic or optimistic way, would be recommended.

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Analysis of the Critical Success Factors of Projects for Engineering Thinking Development

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Abstract. This research constitutes a formative work that enhances the research line of automation and control to implement a program for the development of engineering thinking of students of the Systems and Software Engineering at UNIANDES, Quevedo. The research contributed to form a source of knowledge for Systems students of all levels from a productive approach, following basic principles of didactic engineering and multiple intelligences. It brings the student closer to learning by discovery while applying knowledge of their own competencies specific to their student profile; it also increased their analytical capacity developing automation products from UNIANDES. The procedure fostered interdisciplinary work, and other values in the axiological context that underpin the integral training of future professionals, on the definition of key success factors. We decided to use the neutrosophic TOPSIS technique since the uncertainty and imprecision of the multicriteria decision are incorporated, in the form of three membership functions: truthfulness, indeterminacy and falsehood.

Keywords: Professional training, didactic engineering, Neutrosophic TOPSIS, multi-criteria decision, statistical inference.

1 Introduction

In Quevedo, at Universidad Regional Autónoma de los Andes, UNIANDES, among its academic offers for professional training is the Systems career, which has professionals who have stood out over the years at a local, national and international level. One of the strengths of the career is the current company's demand for automation and control of various areas of production, security, communication among others, and the enhancement of the Systems teaching in the area of automated control, generating research projects whose results are production with an educational-practical-productive approach [1].

Through this project, we managed to get the Systems students to participate in a research work that allows them to apply all the theoretical and practical knowledge acquired in the university while focusing them on a practical technical solution.

One of the fundamental pillars of the UNIANDES pedagogical model is research and through it the students are linked to the scientific field and the technological development of the environment in which they live, thus developing the competencies that support our model. In addition, the present project is related to The Good Living Plan in its Objective 11, Policy 11.3, Guideline 11.3.b[2].

Every project undertaken by UNIANDES has the support of the teachers and the participation of the students; in addition, the respective evaluation will be carried out to verify the achievement of the proposed objectives.

The project has aspects that reflect the professional empowerment of the students and the confidence in their own capacity of the applicability of their knowledge.

It has a course of action or project dimension, with indicators that have to do with the achievement of the proposed purposes to some degree:

1. The interconnection of the university with the educational community measured by the interactions carried out.
2. The generation of knowledge by the educational community measured in the production of new proposals and studies generated.

3. Carrying out a research process and tools for solutions to modern problems through automation, measured in a complex competence acquired by the participants.
4. The creation of opportunities for change derived from the implementation of the project, related to new courses of action and the ability of this project to connect with others.

The training of students [3] and teachers in the effective fulfillment of the teaching-learning process is significant. It is also possible through the development of the project to expand and discover knowledge about computer science and electronics in the trend of the development of engineering thinking of students and teachers, with control systems automated solutions, since it allows them personal control and confidence for their professionalization in future projects related to production.

Automation [4] is a system where production tasks, usually performed by human operators, are transferred to a set of technological elements that try to apply mechanical, electronic and computer-based systems to operate and control production.

In many educational institutions there is no disciplinary learning with automation and control, since the advantages and benefits that it brings in educational institutions have not been investigated as a facilitating element of the teaching-learning process [5].

Currently, every company requires professionals who bring new ideas to solve the problems that technological development requires. Moreover, at a higher educational level, to strengthen the research process in university students, as well as the enhancement of the logical thinking of the professional. The academic board of UNIANDES and the Research and Development Center (RDC), designs research projects on software production and very few projects on automation and control. Thus, out of the final products in Systems Engineering and Informatics Thesis, approximately 99% are developed in software, despite the existence of a line of professorships where Electronics, Artificial Intelligence and Robotics have an impact on the engineering thinking of students. It would allow them to take advantage of the human resources and available infrastructure to generate the management of adaptation of specialized areas for the development of the project[6, 7].

To achieve the objectives of this project, the following research tasks were carried out: bibliographic research, to obtain the scientific and technical foundations of the impact of the creation of software and electronic artifacts as a means for the professional empowerment of UNIANDES Quevedo students. Direct and indirect observation, to obtain data from the available resources for the objective development of this project. The application of interviews and surveys to informants classified by strata that allow identifying the main variables on which technological production should be elaborated.

An applied research was carried out because it is aimed at promoting and encouraging the teaching-learning process at all levels of formal and informal education, it is an investigation that meets the ordinary requirements of feasibility and has the resources and knowledge necessary for its development.

The type of research chosen to formalize this project was experimental and it was used because we are looking for the production of computer and feasible solutions, with an engineering thinking for solving everyday problems from an automation approach.

Through the collection of information, we can describe the structure of the actors, population, who take part in this research. And the universe is considered for the sample because it is a finite population. With the use of research techniques of the students and teachers, the most appropriate one will be selected to determine the existence of an educational process since its beginning in the field of electronics, digital electronics, simulation, artificial intelligence, robotics, special packages in an automation concept for the improvement of the teaching-learning process[8].

Select the panel of experts and get their commitment to collaboration. The people who are chosen must not only be highly knowledgeable about the subject on which the study is carried out, but must also present a plurality in their approaches. This plurality should avoid the appearance of biases in the information available on the panel. Explain to the experts what the method consists of. This is intended to obtain reliable forecasts, since the experts will know at all times what is the objective of each of the processes required by the methodology.

The study of the situation of the most relevant and innovative lines of research and the application of knowledge of different subjects was carried out through a survey of students and professors of the Engineering in Systems and Software program at UNIANDES - Quevedo, from seven questions. Which yielded favorable data.

To select the best strategies to improve the research lines, we used the technique called TOPSIS (Technique for Order Preference by Similarity to Ideal Solution). This method is characterized by its effectiveness and the simplicity of its principle in solving multi-criteria decision problems[9-11].

A multi-criteria decision problem starts from the evaluation given by a group of experts on the subject, around a set of alternatives on certain criteria. The problem is to find the best evaluated alternative. In the case of TOPSIS, the selection is based on finding the alternative that is closest to the ideal solution and further away from the worst solution.

To enrich this technique, de decided to use the neutrosophic TOPSIS. Neutrosophy is the branch of philosophy that studies the origin, nature and scope of neutralities. Logic and neutrosophic sets constitute generalizations of Zadeh's logic and fuzzy sets, of Atanassov's intuitionist logic, among others. The incorporation of neutrosophic sets in TOPSIS guarantees that we into account the uncertainty of decision-making, including indeterminacies. In this case, the Neutrosophic TOPSIS will be used to determine the alternatives that are the strongest and the weakest quantitatively measured, regarding the most relevant and innovative lines of research in the Systems and Software Engineering courses at UNIANDES - Quevedo.

In addition, the key success factors of the lines of research were defined for a correct relationship of the teaching-learning process. All that with the application of the knowledge acquired in the subjects of mathematics, basic electronics, digital electronics, simulation, artificial intelligence, robotics in the projects such as parking lot automation, automated irrigation systems, earthquake alarm systems, tele-manipulated robotic monkeys, inmotic environment control systems, among others.[3-5, 12-19]

2 Materials and Methods

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

Definition 1([20]): Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow]^{-}0, 1^{+}[$, which satisfy the condition $^{-}0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3^{+}$ for all x∈X. $u_A(x), r_A(x)$ and $v_A(x)$ are the membership functions of truthfulness, indeterminacy and falseness of x in A, respectively, and their images are standard or non-standard subsets of $]^{-}0, 1^{+}[$.

Definition 2: ([21]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is a set of the form:

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

Where $u_A, r_A, v_A : X \rightarrow [0,1]$, satisfy the condition $0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ for all x∈X. $u_A(x), r_A(x)$ and $v_A(x)$ denotes the membership functions of truthfulness, indeterminacy and falseness of x in A, respectively. For convenience a *Single-Valued Neutrosophic Number* (SVNN) will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$ and satisfy $0 \leq a + b + c \leq 3$.

SVNNs came up 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 SVNNs, the sum between A1 and A2 is defined as:

A1+A2 = (a1 + a2 - a1a2, b1b2, c1c2) (2)

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

A1xA2 = (a1a2, b1 + b2 - b1b2, c1 + c2 - c1c2) (3)

The multiplication by a positive scalar $\lambda \in \Re$ with SVNS, A = (a, b, c) is defined by:

$$\lambda A = \left(1 - (1-a)^{\lambda}, b^{\lambda}, c^{\lambda}\right) \quad (4)$$

3. Let {A1, A2,…, An} be a set of n SVNN, where Aj = (aj, bj, cj) (j = 1, 2,…, n), then the *Single Value Neutrosophic Weighted Average Operator* (SVNWA) over the set is calculated by the following Equation[22]:

$$P_w(A_1, A_2, \dots, A_n) = \langle 1 - \prod_{j=1}^{n}\left(1 - T_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(I_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(F_{A_j}(x)\right)^{w_j}\rangle \quad (5)$$

(5)

Where $w = (w_1, w_2, \dots, w_n)$ is vector of $A_j (j = 1,2, \dots, n)$ such that $w_n \in [0,1]$ y $\sum w_j = 1$.

Definition 3 ([20, 23, 24]). Let $A^* = (A_1^*, A_2^*, \dots, A_n^*)$ a vector SVNS such that $A_j^* = (a_1^*, b_2^*, c_2^*)$ $(j = 1,2, \dots, n)$ and $B_i = (B_{i1}, B_{i2}, \dots, B_{im})$ $(i = 1,2, \dots, m)$ are m vectors such that $B_{ij} = (a_{ij}, b_{ij}, \dots, c_{ij})$ $(i = 1,2, \dots, m)(j = 1,2, \dots, n)$, then the distance measure between B_i and A^* is as follows:

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

(7)

Definition 4([25, 26]). Let A = (a, b, c) be a 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:

$$S(s) = \frac{1 + a - 2b - c}{2} \quad (8)$$

where S (A) ∈[-1,1].

In this article, linguistic terms will be associated with SVNN, so that experts can carry out their assessments in linguistic terms, because it is more natural. Therefore, we will use the scales shown in Tables 1 and 2.

Linguistic term	SVNN
Extremely Good (EG)	(1,0,0)
Very Very Good (VVG)	(0.9, 0.1, 0.1)
Very Good (VG)	(0.8,0,15,0.20)
Good (G)	(0.70,0.25,0.30)
Moderately good (MDG)	(0.60,0.35,0.40)

Average (A)	(0.50,0.50,0.50)
Moderately Bad (MDB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very Bad (VB)	(0.20,0.85,0.80)
Very Very Bad (VVB)	(0.10,0.90,0.90)
Extremely Bad (EB)	(0,1,1)

Table 1. Linguistic terms used

Linguistic term	SVNN
Very Important (VI)	(0.9, 0.1, 0.1)
Important (I)	(0.75,0.25,0.20)
Average (A)	(0.50,0.50,0.50)
Not Important (NI)	(0.35,0.75,0.80)
Not Very Important (NVI)	(0.10,0.90,0.90)

Table 2. Linguistic terms that represent the weight of the importance of the alternatives.

the following steps will be carried out:

Step 1: Determine the experts' weight.

For this, the specialists evaluate according to the linguistic scale that appears in Table 1, and the calculations are made with its associated SVNN, let's call the SVNN At = (at, bt, ct) corresponding to the t-th decision-maker (t = 1, 2 , ..., k). The weight is calculated by the following formula[27]:

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

where: $\lambda_t \geq 0$ y $\sum_{t=1}^{k} \lambda_t$=1

Step 2: Construction of the neutrosophic decision matrix of aggregated single values.

This matrix is defined by $D = \sum_{t=1}^{k} \lambda_t\, d_{ij}$, where $d_{ij} = \left(u_{ij}, r_{ij}, v_{ij}\right)$ is used to aggregate all individual assessments.

d_{ij} is calculated as the aggregation of the evaluations given by each expert $\left(u_{ij}{}^t, r_{ij}{}^t, v_{ij}{}^t\right)$, using the weights of each decision maker with the help of Equation 8.

In this way a matrix D = $\left(d_{ij}\right)_{ij}$, where each d_{ij} is a SVNS (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 β_j. If $w_j^t = a_j^t, b_j^t, c_j^t$ is the evaluation of the criterion j-th by the t-th expert.

Then Equation 5 is used to aggregate the w_j^t the weights λ_t.

Step 4: Construction of the single valued neutrosophic weighted averaging decision matrix with respect to the criteria.

$$D^* = D \otimes W, where\ d_{ij}^* = W_j \otimes d_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right) \quad (9)$$

Step 5: Calculation of the ideal positive and negative SVNN solutions.

The criteria can be classified as cost or benefit type. Let G1 be the set of benefits type criteria and G2 the cost type criteria. The ideal alternatives will be defined as follows:

$$\rho^+ = \left(a_{\rho^+w}(\beta_j), b_{\rho^+w}(\beta_j), c_{\rho^+w}(\beta_j)\right) \quad (10)$$

Denote the positive ideal solution, corresponding to G1.

$$\rho^- = \left(a_{\rho^-w}(\beta_j), b_{\rho^-w}(\beta_j), c_{\rho^-w}(\beta_j)\right) \quad (11)$$

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

$$a_{\rho^+w}(\beta_j) = \begin{cases} max_i a_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ min_i a_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

$$b_{\rho^+w}(\beta_j) = \begin{cases} min_i b_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ max_i b_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

$$c_{\rho^+w}(\beta_j) = \begin{cases} min_i c_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ max_i c_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

On the other hand,

$$a_{\rho^-w}(\beta_j) = \begin{cases} min_i a_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ max_i a_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

$$b_{\rho^- w}(\beta_j) = \begin{cases} max_i b_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ min_i b_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

$$c_{\rho^- w}(\beta_j) = \begin{cases} max_i c_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ min_i c_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

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

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

$$s_i^- = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^-\right)^2 + \left(b_{ij} - b_j^-\right)^2 + \left(c_{ij} - c_j^-\right)^2\right\}\right)^{\frac{1}{2}} \tag{13}$$

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.

$$\tilde{\rho}_j = \frac{s^-}{s^+ + s^-}$$

Where
$0 \leq \tilde{\rho}_j \leq 1$

Step 8: Determine the ranking of the alternatives.
Additionally, for the statistical processing the following formula was used to calculate the sample size

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

Where:
n: Sample size,
Z: It is the value of the normal distribution with the assigned confidence level,
E: Desired sampling error, N: Population size, p, q: They are taken as 50% or 0.05.

3 Results

In order to collect the information, the survey was used as a way to explore reality. The selection of the sample was random. There is a population of N = 158 students of the Systems and Software Engineering degree at UNIANDES - Quevedo, and the total number of respondents was n = 49, with Z = 1.96 and E = 0.05, after applying the Equation 14.[12]

The surveys carried out examined the main components of the research lines: the teaching-learning environment, the role of the teacher and the student, the use of different subjects of the systems engineering curriculum, the importance for the sustainable development of the race.

The questions to the respondents were the following:

Survey applied on the research lines of the Systems and Software Engineering degree at UNIANDES - Quevedo. Below, there will be eight questions about the research lines of the Systems and Software Engineering degree at UNIANDES - Quevedo. Please answer honestly by ticking only one of the possible answers. We guarantee the anonymity of your responses. 1. Do you know what a line of research is? □ Yes □ Not 2. Do you consider that the lines of research allow a better teaching-learning relationship? □ Yes □ Not 3. Do you consider the lines of research important for the professional practice of the systems and software engineer? □ Yes □ Not 4. How would you rate the contribution made by your career teachers in favor of your engineering training? □ It is a systematic contribution □ It is a sporadic contribution □ It is not a significant contribution 5. Do you consider necessary to develop and offer talks and other training activities that promote the integration of university students to lines of research? □ Yes □ Not 6. How do you evaluate yourself in terms of your level of professional training? □ High level □ Average level □ Low level □ Very low level
7. Do you consider the engineering training received during the years of studies in higher education sufficient? □ Yes □ Not

The results show that the components of the lines of research have a high incidence in the teaching-learning environment and directly affect the role of the teacher on the student in the systems engineering career:

- 85% of the students surveyed express having knowledge about what the lines of research are.
- Out of the total students surveyed, only 12% do not consider the lines of research necessary in their engineering training.
- Only 5% of the surveyed students do not consider the use of lines of research important for the professional practice of systems and software engineers.
- Regarding the contribution that teachers make to their engineering training, only 8% out of the total of surveyed students, do not consider that their teachers work in favor of improving their professional training.
- 93% of those surveyed think it is necessary to develop and offer talks and other training activities that promote research lines.
- The self-evaluation regarding the level of professional training, yields the following data:
    - High level (8.7%);
    - Average level (58%);
    - Low level (32%);
    - Very low level (1.3%)
- For 59% of those surveyed, the lines of research received during their years of studies in higher education are insufficient.

We consulted a group of four specialists who have studied in depth the contribution of the lines of research in the engineering training of the students, including the results of the previous survey. This study included a review of study programs, interviews with teachers, visits to classrooms, interviews with UNIANDES Academic Board, among other activities that allowed them to determine a set of strategies to continue promoting lines of research in the Systems Engineer degree.

They reached to the conclusion that engineering training is a complex process, which requires the integration of both students and teachers. Therefore, they proposed the following criteria to evaluate the lines of research:

$\beta 1$: Little integration and importance in the teaching-learning approach, $\beta 2$: Effective in the teaching-learning approach, $\beta 3$: Insufficient in the teaching-learning approach.

The lines of research to be evaluated are the following:

$\rho 1$: Research that has a direct impact on the country's economy and the number of subjects is high, but they are assigned to the university by the problem bank of the associated companies ("Seismic alarm for the prevention of natural disasters", "Prototype of an automated sprinkler irrigation system", "Functional robotic hand with manipulation capacity");

$\rho 2$: Research that allows the creativity of students and the number of subjects used is high, but they are assigned by the problem bank of the companies associated with the university, and they do not have a direct impact on the economic development of the country ("Web-controlled robotic HAND", "Automation in the control of a multifunction robotic cart").

Results are shown in the following Tables:

Criterion	Expert 1	Expert 2	Expert 3	Expert 4
Little integration and importance in the teaching-learning approach	I	I	I	VI
Effective in the teaching-learning approach	I	I	M	I
Insufficient in the teaching-learning approach	M	VI	NI	I

Table 3. Importance given by each decision maker to each of the criteria

Little integration and importance in the teaching-learning approach				
Lines	**Expert 1**	**Expert 2**	**Expert 3**	**Expert 4**
ρ1	NI	NI	NI	NVI
ρ2	VI	I	I	VI

Table 4. Evaluation of each line regarding the "little integration and importance in the teaching-learning approach".

Effective in the teaching-learning approach				
Lines	**Expert 1**	**Expert 2**	**Expert 3**	**Expert 4**
ρ1	VI	VI	VI	I
ρ2	M	I	M	M

Table 5. Evaluation of the effectiveness of the lines.

Insufficient in the teaching-learning approach				
Lines	**Expert 1**	**Expert 2**	**Expert 3**	**Expert 4**
ρ1	NI	NVI	M	M
ρ2	VI	I	VI	VI

Table 6. Evaluation of each line with respect to “Insufficient in the teaching-learning approach”.

Importance	Expert 1	Expert 2	Expert 3	Expert 4
Linguistics	M	M	M	M
Numerical	0.2	0.2	0.2	0.2

Table 7. Relative importance given to each of the Decision-makers.

Applying the Neutrosophic TOPSIS algorithm, the matrices given in the following tables (Tables 8-12) are calculated:

	β1	β2	β3
ρ1	(0.30629, 0.77785; 0.81907)	(0.87989, 0.12011, 0.11487)	(0.37540, 0.66140, 0.67869)
ρ2	(0.80095; 0.19905; 0.18206)	(0.56472, 0.43528, 0.41628)	(0.85573, 0.14427, 0.13195)

Table 8. Decision table added by experts.

Criterion	Weight
β1	(0.82671, 0.17329, 0.15157)
β2	(0.76091, 0.23909, 0.20913)
β3	(0.71056, 0.29784, 0.27595)

Table 9. Table of the weights assigned by the experts to each criterion.

	β1	β2	β3
ρ1	(0.25321, 0.81635, 0.84649)	(0.66952, 0.33048, 0.29998)	(0.26674, 0.76225, 0.76736)
ρ2	(0.66215, 0.33785, 0.30604)	(0.42970, 0.57030, 0.53835)	(0.60805, 0.39914, 0.37149)

Table 10. Aggregate decision table weighted by experts.

Criterion	Positive ideal value	Negative ideal value
β1	(0.66215, 0.33785, 0.30604)	(0.25321, 0.81635, 0.84649)
β2	(0.66952, 0.33048, 0.29998)	(0.42970, 0.57030, 0.53835)
β3	(0.60805, 0.39914, 0.37149)	(0.26674, 0.76225, 0.76736)

Table 11. Positive and negative ideal values by criterion.

Alternative	d-	d +	CP	Order
ρ1	0.23934	0.60369	0.71610	one
ρ2	0.60369	0.24014	0.28458	two

Table 12. Calculation of the CP for each of the alternatives and their ordering.

According to the results shown in Table 12, we obtained that ρ1 was preferred over ρ2, although both can be carried out. This preference may be because it has a greater impact on the economic development of the country. Once the preferred lines of research have been analyzed, we proceed to extract potential factors (variables) and their impact on the university:

Line of research	Key factors	Impact
Seismic alarm for the prevention of natural disasters	Integration and coordination with the department in charge of forecasting natural	1. Enables an early warning system for natural disasters 2. It incorporates a management way to mitigate the possible consequences of disasters

	disasters	3. Development of our own software for the prevention of natural disasters
Prototype of an automated sprinkler irrigation system	Direct impact on food, and contribution to the economy.	1. Less impact on soils and food. 2. Establishes a working trend for less possessed farmers. 3. Direct influence on the agricultural sustainability of the country.
Functional robotic hand with manipulative ability	Integration with the health of workers, and increased productivity.	1. Establish a safe way of working. 2. It directly influences the productivity of the entity.

Table 13. Key factors of the ρ1 lines of research and their impact on the university. Own elaboration.

Conclusions

- The results obtained through the survey applied to the student community of the Systems Engineering degree in the city of Quevedo, shows that steps are being taken to solve the existing problem, and that there is a need for a change in the way the thinking of new professionals, with their integration into the lines of research.
- The research process developed has allowed scientific production and participation of teachers and students in international scientific events.
- It is very clear that the evaluation of the lines of scientific research, within UNIANDES, is a perfectible task. Therefore, it is not surprising to perceive a wrong operation in criteria and methodologies for the evaluation and follow-up of research. It is also true that the current situation allows the improvement of the process through the initiatives gradually proposed for the development of research projects, knowing the key factors for their success.
- The Neutrosophic TOPSIS technique, where a group of specialists determined that the line of research more important is: Research that has a direct impact on the country's economy and the number of subjects it uses is high, but they are assigned by the Problem bank of the companies associated with the university.

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Business Plan for Entrepreneurs, Actors and Organizations of Social and Solidarity Economy based on Neutrosophic AHP-SWOT

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Abstract. The main purpose of this research is to design a new business plan structure for entrepreneurs, actors and organizations of social and solidarity companies in the province Los Ríos, Ecuador. Thus, this paper aims to create a simple and rigorous guide designed upon the gathering of the necessary information from 24 entrepreneurs of the project "Young Impulse" led by the "Youth Technical Secretariat". We propose to use the neutrosophic AHP-SWOT technique as part of the business plan. We incorporate Neutrosophy because it allows us to explicitly model the indeterminacy that exists in experts' evaluation. On the other hand, the Analytic Hierarchy Process (AHP) and SWOT (Strengths, Weaknesses, Opportunities and Threats) techniques have proven to be effective in decision-making and planning. Social and solidarity economy constitutes a different way of managing economy, it is a sector of the economy that would be halfway between the private sector and business on the one hand, and the public sector and government on the other hand, and that includes cooperatives, associate labor companies, non-profit organizations, and charitable associations. Additionally, we present a study to determine the best strategy to start a business, according to the opinion of the aforementioned 24 entrepreneurs, based on neutrosophic AHP-SWOT.

Keywords: Business plan, entrepreneurship, social and solidarity economy, neutrosophic AHP-SWOT technique.

1 Introduction

Business administration is constantly evolving; companies seek to generate innovative activities not only in search of economic credits, but also in the generation of value added, with the purpose of becoming sustainable over time. This is why companies must determine strategies to differentiate the organization from the competition. This research aims to design the structure of a new business plan for entrepreneurs, actors and organizations of social and solidarity economy in the province Los Ríos, Ecuador[1].

The shortage of economic resources that the world is going through, especially in Ecuador, makes micro, small and medium-sized companies look for different ways to subsist. Therefore, it is essential to strengthen these sectors, because many of them show a productive, administrative, financial, and primitive technology, which affects their competitiveness.

It is necessary that the initiatives of actors of the social and solidarity economy consider indicators such as planning, human resources, environmental management, marketing, administration, accounting and finance to measure internal strengths and weaknesses in order to improve areas that affect their competitiveness.

For this reason, and in order to foster business growth in economic and social aspects, companies need to have an easy, simple, rigorous and accurate guide that allows them to prepare for a favorable change in the business world.

This guide should include effective mathematical models for planning strategies in decision-making, where the accuracy is given by the inclusion of indeterminacy due to ignorance, contradictions and inconsistencies of decision-makers. That is why Neutrosophy is included[2, 3].

A company is an organization that provides or produces goods and/or services demanded by customers, from which it obtains economic benefits. To fulfil its objectives, the company requires material, technical, financial and human resources for its operations.

Entrepreneurial activity is an essential element to understand the economic development of any country. It helps to forecast and adjust public policies where it is necessary to impulse new projects and job creation. Undertaking is to start a new business project assuming the risk that this entails, in exchange for obtaining a business benefit. It is an engine of innovation, competitiveness and growth[4].

Every project to create a company has its starting point in the idea that its promoters consider. Starting from that moment, comes a process of analysis and planning which will lead to determine the viability of the project and the future configuration of the company. Issues such as the target market, its foreseeable evolution, competing companies, the commercial policy to follow, expected sales, the necessary technical and financial resources, should be analyzed [5].

Solidarity economy is a form of production, consumption, and distribution of wealth, focused on the valorization of the human being and not on the prioritization of capital. It promotes associability, cooperation and self-management, and is oriented to the production, consumption, and marketing of goods and services, in a mainly self-managed way, aiming at the expanded development of life, as well as the equality among its members. It advocates for understanding job as a mean of human liberation, within the framework of an economic democratization process, creating a viable alternative to the traditional dimension of capitalist labor[6].

We propose to use neutrosophic AHP-SWOT technique in the modelling [7]. One of its components is the mathematical and psychology-based tool called Analytic Hierarchy Process (AHP) introduced by Saaty [8-13] such that it starts from a hierarchical tree, where the first level consists of a single leaf that represents the objective. The second level contains the criteria that will be used to make the decision; in the even lower levels, the sub-criteria for the criteria of the higher level are represented. The bottom contains the leaves corresponding to alternatives[14-16].

In the original method, experts assign a weight to each criterion and sub-criterion where the weight of the lower level depends on the weights of the higher levels. Finally, a weight is assigned to each alternative in relation to its importance. This tool is very useful, easy to apply and rigorous because it takes into account the relative importance of each element with respect to others at the same level. Moreover, this method ensures that inconsistency is small enough.

On the other hand, it is important for the design of a good business plan to determine what are the strengths (S), weaknesses (W), opportunities (O) and threats (T) that can be foreseen. This is modelled using the SWOT technique, named this way due to the aspects it calculates [17, 18]. This is also a simple and effective method.

Another contribution of this paper is that we propose one strategy for starting a business of social and solidarity economy in Los Ríos. The study was based on neutrosophic AHP-SWOT, according to the 24 entrepreneurs' criteria.

This paper consists of a first section, where we explain the main concepts of Neutrosophy and neutrosophic AHP-SWOT. Next, the following section introduces the business plan guide such that entrepreneurs, actors and organizations of social and solidarity economy should follow as well as the results for determining the best strategy to start a business. The article ends with the conclusions.

2 Preliminaries

This section summarizes some basic definitions of Neutrosophy as well as the algorithm of neutrosophic AHP-SWOT technique introduced by Abdel-Basset et al. [7].

Definition 1: [19, 20] 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: [19-21] 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 $F_A: U \rightarrow [0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

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: [19, 20, 22, 23] 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:

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

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

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

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

Definition 4: [19, 20, 22, 23] 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:

1. Addition: $\tilde{a} + \tilde{b} = \langle(a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle$
2. Subtraction: $\tilde{a} - \tilde{b} = \langle(a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle$
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 $a_1, a_2, a_3, a_4 \neq 0$.
4. Multiplication by a scalar number:

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

5. Division of two trapezoidal neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \left\langle\left(\frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\right\rangle, a_4 > 0 \ and \ b_4 > 0 \\ \left\langle\left(\frac{a_4}{b_4}, \frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\right\rangle, a_4 < 0 \ and \ b_4 > 0 \\ \left\langle\left(\frac{a_4}{b_1}, \frac{a_3}{b_2}, \frac{a_2}{b_3}, \frac{a_1}{b_4}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\right\rangle, a_4 < 0 \ and \ b_4 < 0 \end{cases}$$

6. Multiplication of two trapezoidal neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle(a_1b_1, a_2b_2, a_3b_3, a_4b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_4 > 0 \ and \ b_4 > 0 \\ \langle(a_1b_4, a_2b_3, a_3b_2, a_4b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_4 < 0 \ and \ b_4 > 0 \\ \langle(a_4b_4, a_3b_3, a_2b_2, a_1b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_4 < 0 \ and \ b_4 < 0 \end{cases}$$

Where, $\wedge$ is a t-norm and $\vee$ is a t-conorm.

Definitions 3 and 4 refer to *single-valued triangular neutrosophic number* when the condition $a_2 = a_3$, [24-26].

For simplicity, we use the linguistic scale of triangular neutrosophic numbers, see Table 1 and also compare with the scale defined in [7].

We can find in [7] the theory of AHP technique in a neutrosophic framework. Thus, we can model the indeterminacy of decision-making by applying neutrosophic AHP or NAHP for short.

Equation 4 contains a generic neutrosophic pair-wise comparison matrix for NAHP.

$$\tilde{A}=\begin{bmatrix}\tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n}\\ \vdots & & \ddots & \vdots\\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1}\end{bmatrix} \quad (4)$$

Matrix $\tilde{A}$ 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 [7], they are the so-called score and accuracy indexes, respectively, see Equations 5 and 6:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (5)$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (6)$$

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	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$
		$\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$
		$\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$
		$\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

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

Below, we explain the algorithm introduced by Abdel-Basset et al. [7].

Step 1 Select a group of experts at performing SWOT analysis.

In this step, experts identify the internal and the external factors of the SWOT analysis by employing questionnaires/interviews. Figure 1 shows the SWOT analysis diagram:

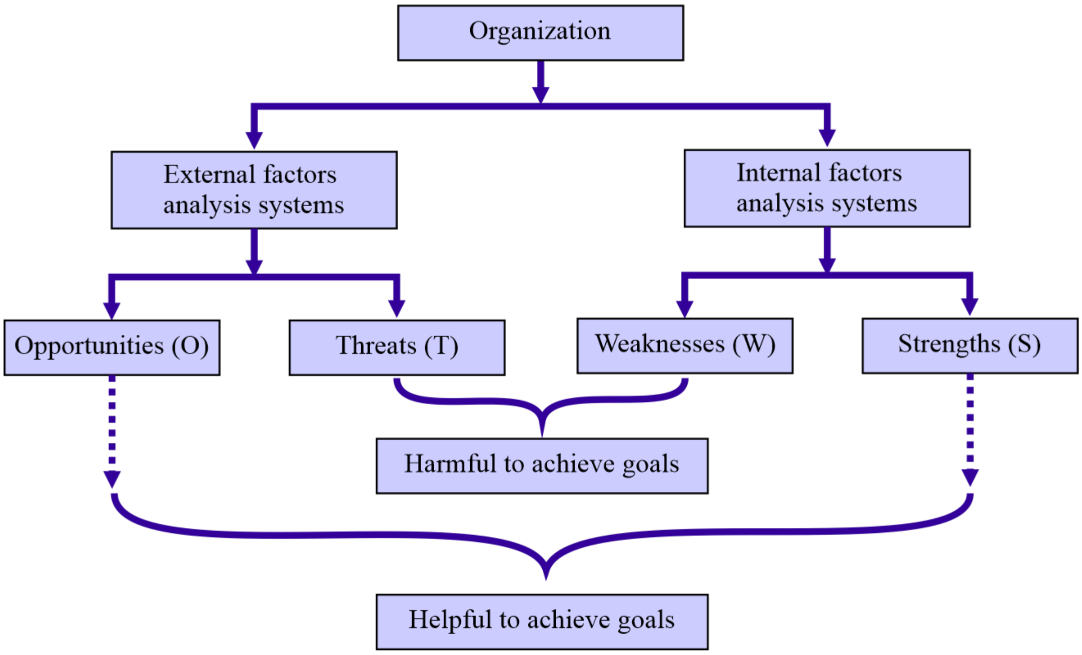

Figure 1: Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis diagram. Source [7].

Step 2 Structure the hierarchy of the problem.

The hierarchy of the problem has four levels:

- The first level is the goal the organization wants to achieve.
- The second level consists of the four strategic criteria that are defined by the SWOT analysis (i.e., criteria).
- The third level contains the factors that are included in each strategic factor of the previous level

(i.e., sub-criteria).

- The final level includes the strategies that should be evaluated and compared. The general hierarchy is presented in Figure 2.

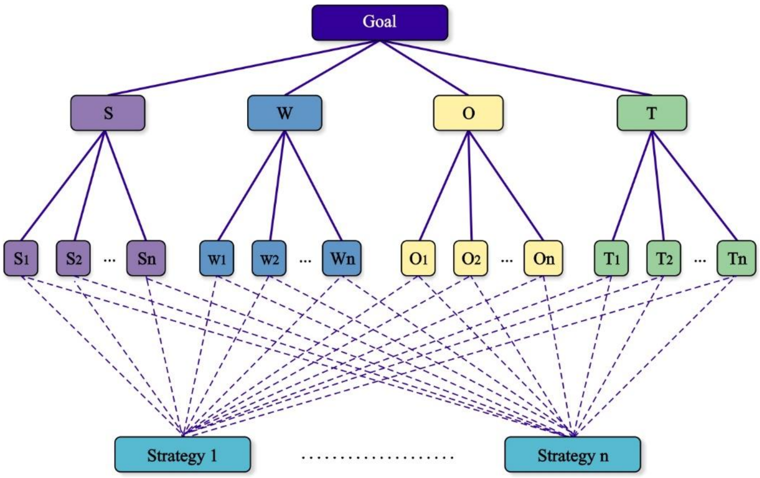

Figure 2: The hierarchy of a problem. Source [7].

Step 3 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[3]. The neutrosophic pair-wise comparison matrix of factors, sub-factors and strategies are as described in Equation 4.

Step 4 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 5 Calculate the weight of 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 ($Alt_1, \ldots, Alt_n$) from the neutrosophic pair-wise comparison matrix, by transforming it to a deterministic matrix using Equations 7 and 8.

To get the score and the accuracy degree of $\tilde{a}_{ji}$ the following equations are used:

$$S(\tilde{a}_{ji}) = {}^{1}\!/_{S(\tilde{a}_{ij})} \quad (7)$$

$$A(\tilde{a}_{ji}) = {}^{1}\!/_{A(\tilde{a}_{ij})} \quad (8)$$

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

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (9)$$

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.

Step 6 Calculate the total priority of each strategy (alternative) for the final ranking of all strategies using Equation 10.

The total weight value of the alternative j (j = 1,..., n) can be n:

$$Tw_{Alt_j} = w_S * \sum_{i=1}^{n} w_{S_i} * w_{Alt_j} + w_W * \sum_{i=1}^{n} w_{W_i} * w_{Alt_j} + w_O * \sum_{i=1}^{n} w_{O_i} * w_{Alt_j} + w_T * \sum_{i=1}^{n} w_{T_i} * w_{Alt_j} \quad (10)$$

where (i = 1,...,n) and (w_S, w_W, w_O, w_T) are the weights of Strengths, Weaknesses, Opportunities and Threats; ($w_{Si}, w_{Wi}, w_{Oi}, w_{Ti}$) are the sub-factor weights; and w_{Altj} is the weight of the alternative j, corresponding to its sub-factor.

Note that Step 4 refers to consider 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 consistency of the evaluations can be determined by equation $CI = \frac{\lambda_{max} - n}{n-1}$ [8], where n is the order of the matrix. In addition, the *Consistency Ratio* (CR) is defined by equation CR = CI/RI, where RI is given in Table 2.

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

Table 2: RI associated to every order.

If CR≤0.1 we can consider that experts' evaluation is sufficiently consistent and hence we can proceed to use NAHP. We apply this procedure to matrix *A* in Equation 9.

3 Design of the business plan

This section contains two subsections, the first one explains the concepts of business plan we based on in this paper. In section 3.2 we describe the plan for the entrepreneurs, actors and organization of social and solidarity economy in Los Ríos province.

3.1 Concepts of business plan

A company is an organized human activity, which uses human and material means with the purpose of obtaining a benefit. If the main activity objective is to achieve economic benefits, and development responsibilities are acquired from them (vis-à-vis the state, citizens, consumers) we are talking about a company in the economic sense, [27].

The company is made up of a set of interrelated parts directly or indirectly achieving a purpose. This purpose is only to obtain outputs through a process of inputs transformations. Likewise, a feedback process is necessary for the company to adapt to the changes that have occurred [28].

Currently, it is not easy to undertake. There are many causes for this difficulty, including the lack of motivation and decision to create a business. Also, inadequate use of administrative tools, techniques for managing businesses, lack of knowledge of the advantages of association and scarce economic resources. All of which have important effects, such as unsuccessful business ideas due to need of trust and knowledge, ignorance of the competition and economic environment of the enterprises, inadequate use of the advantages of association for the enterprises development and the non-execution of a commercial activity [29].

Entrepreneurship can also be defined as the talent that a person has to generate a project or a business idea. It comes with great challenges, such as economic crisis, creation of a competitive advantage, good cash flow management and technological innovation.

For a business plan to be successful, it is necessary that the product or service offered by the company be accepted by the market to which it is directed. By doing so, it would produce an exchange relationship between what's offered and the product or service demanded. Buyers only acquire the products the company offers if they satisfy their needs, that is why the company monitors these activities, [30].

No business idea should be launched as a business project if an economic-financial plan has not been previously carried out to evaluate or validate whether the business, once started, will allow obtaining positive or beneficial results, indicating that it will be profitable for the promoters or shareholders who are going to invest their capital. That allows them to take their management towards positive financial and economic results, [31].

The business plan purpose is to determine the economic, technical, social and environmental viability of a project, taking into account the opportunities, threats, strengths and weaknesses of the company, as well as to analyze the environment in which it will take place, [32].

Zorita in [5] proposes a structure, but it must be taken into account that the models are generally adjusted according to the needs of the company, which would indicate that this structure is not always met.

- Introduction / presentation. Executive Summary,
- Description of the business,
- Market analysis,
- Analysis of the company,
- Analysis of the situation. Diagnosis,
- Strategic approach,
- Marketing and sales operational plan,
- Operations plan. Calendars and deadlines. Information systems,
- Corporate issues. Organization and human resources,
- Economic and financial study,
- Control systems. Dashboard and contingency plans,

• Conclusions.

Structuring a business plan includes all kinds of details that are required when starting a business, such as detailed planning of policies, strategies, prior research, action plans and financing [33].

There are different business plan structures designed by some authors, they all have points in common, but certainly when proposing a new design, we need to make adjustments in order to better access and understand the information.

3.2 Design of the business plan for social and solidarity economy businesses in Los Ríos province

The business plan structure will establish the key elements that will allow entrepreneurs to guide the course of their business in a comprehensive and simple way, allowing them to solve any problem that may occur in the future.

The proposed elements are:

1. Executive Summary

The most important aspects of the business plan are presented in the executive summary. This section should not be very long, it will have a maximum of two pages, and it should arouse the reader's interest. It is recommended to prepare this summary when the entire plan has been completed.

2. Company Description

It should briefly explain what are the functions of the company, what are the products or services it will offer. Here managers should express the purposes of the company and its contribution to the society. In addition, it is convenient to indicate the owner's information. It is important to specify the name of the company and its respective logo and slogan.

3. Strategic Plan

In this section managers must establish the company's goals and what are the strategies to achieve, therefore, it is essential to create the SWOT mission, vision, strategic objectives and analysis.

4. Marketing Plan

In this section, we must develop all the strategies to maximize sales, as well as to indicate how the product will be launched. For this reason, we need to ask ourselves: What is our potential demand? Who are our competitors? By what means advertising will be carried out? A pricing policy must also be set.

5. Administrative and Operations Plan

Operations plan must reflect the organizational structure the company will have. The positions and functions of each member must be included. In addition, managers must describe the production process that will be carried out and the equipment and supplies that the company will have.

6. Financial Plan

The financial plan must show all the financial projections essential to start the business: income budget, investment budget, purchasing budget, marketing and sales budget, administrative budget, financial expenses, income statement, cash flow and the financial evaluation.

To support with more detail social economy companies in Los Ríos province, 24 entrepreneurs from the province closely linked to this type of economy were surveyed. The survey was related to the above-mentioned point 3 about the creation of the SWOT matrix. As a result of the first approach to the subject, the following elements were determined for evaluation:

Strengths

S_1: There is a primacy of the people and the social purpose over the capital, which implies that people feel the company as a mean of personal growth rather than a way of life; therefore, they are motivated with the job.

S_2: It works through the equitable and social distribution of benefits; therefore, the members feel that there is justice in the distribution of profits, which strengthens trust among the members of the organization.

S_3: Solidarity is practiced, the community benefits because company invests in local social works, generating jobs among local workers, achieving social inclusion regardless of gender, race, ethnic origin, or any other discriminatory aspect.

S_4: There is independence of the company from the public powers, which guarantees that many times internal decisions do not depend on external factors.

Weaknesses

W_1: Company is sensitive of the good performance of its members, which is not always possible.

W_2: Usually there is no clarity about the legal status of some solidarity companies, which sometimes prevents making risky but profitable investments beyond the company.

W_3: Due to the size of the company, it may suffer from financial problems.

W_4: Its members may not have the educational level necessary to achieve company's development.

Opportunities

O_1: The members can lean on new information and communication technologies, which from a small budget give ostensible results, such as the use of telework, e-learning, among others.

O_2: They can take advantage of the weakness of traditional capitalist companies that cannot be inserted in markets that include sectors traditionally excluded by society.

O_3: Different companies of this type can organize themselves into bigger associations that allow them to compete with big companies, where in the inside none of them constitutes a threat for the others.

Threats

T_1: This type of economy can be perceived as a threat by traditional companies, therefore it can suffer external aggression.

T_2: It may be sensitive to the economic crises that affect the country.

As a result of this analysis, we propose four strategies that can serve to any social economy company of the province. These can be expanded or decreased depending on the characteristics of the company. Below we detail them:

St_1: To propose and formalize an association of companies with social economy in Los Ríos province with the intention of generalizing it to the entire country.

St_2: To stimulate the implementation of distance work, the exchange of experiences through courses, seminars and scientific events.

St_3: To hire external or internal specialists who determine the legal and financial status of each social company in Los Ríos province, the experiences will be transmitted transparently between the different companies.

St_4: To determine and study alternatives to respond to situations of emerging threats for the company existence. Some of them may consist of finding alternative financial sources like external donations or the commercialization of by-products that allow additional profits for the company.

The evaluation of these strategies contains indeterminacies specific to decision-making and planning, since usually there is no complete certainty about the evaluations given by the experts. That is why the use of Neutrosophy is justified. Moreover, assessments are given in linguistic terms, thus, it is more comprehensible for users and decision makers than to use numeric terms.

24 entrepreneurs of the regional “Young Impulse” project were asked to evaluate the above four strategies applying the AHP-SWOT technique, the question is how they evaluate each strategy for starting a social economy business. This means that with the pass of the time, another strategy may be the more appropriate; therefore, it is convenient to apply this technique at different moments in the company's existence, especially during a crisis.

Table 3 contains the matrix of ratios among the four factors according to the median of entrepreneurs’ criteria.

Factors	Strengths	Weaknesses	Opportunities	Threats
Strengths	$\tilde{1}$	$\tilde{2}$	$\tilde{5}$	$\tilde{5}$
Weaknesses	$1/\tilde{2}$	$\tilde{1}$	$\tilde{5}$	$\tilde{5}$
Opportunities	$1/\tilde{5}$	$1/\tilde{5}$	$\tilde{1}$	$\tilde{1}$
Threats	$1/\tilde{5}$	$1/\tilde{5}$	$\tilde{1}$	$\tilde{1}$

Table 3: Matrix of ratios of Strengths, Weaknesses, Opportunities and Threats according to the median entrepreneurs’ criteria.

In Table 4, we summarize the crisp values obtained by applying Equation 6 to the elements in Table 3.

Factors	Strengths	Weaknesses	Opportunities	Threats
Strengths	1	1.7625	5.3438	5.3438
Weaknesses	0.56738	1	5.3438	5.3438
Opportunities	0.18713	0.18713	1	1
Threats	0.18713	0.18713	1	1

Table 4: Crisp matrix of ratios of Strengths, Weaknesses, Opportunities and Threats.

The weights vector of Strengths, Weaknesses, Opportunities and Threats is

$$W_F = \begin{bmatrix} 0.479820 \\ 0.363346 \\ 0.078417 \\ 0.078417 \end{bmatrix} \text{ and CR = 1.5131\%<10\%.}$$

Tables 5-8 show the crisp matrices of ratios among the Strengths, Weaknesses, Opportunities and Threats, respectively.

Strength	S_1	S_2	S_3	S_4
S_1	1	1	1	0.39506
S_2	1	1	1	0.39506
S_3	1	1	1	0.39506
S_4	2.5312	2.5312	2.5312	1

Table 5: Crisp matrix of ratios of Strengths.

$W_S = \begin{bmatrix} 0.18079 \\ 0.18079 \\ 0.18079 \\ 0.45762 \end{bmatrix}$ and CR = 0%<10%.

Weakness	**W_1**	**W_2**	**W_3**	**W_4**
W_1	1	0.18713	1	0.18713
W_2	5.3438	1	5.3438	1
W_3	1	0.18713	1	0.18713
W_4	5.3438	1	5.3438	1

Table 6: Crisp matrix of ratios of Weaknesses.

$W_W = \begin{bmatrix} 0.078817 \\ 0.421183 \\ 0.078817 \\ 0.421183 \end{bmatrix}$ and CR = 0%<10%.

Opportunities	**O_1**	**O_2**	**O_3**
O_1	1	0.56738	1
O_2	1.7625	1	1.7625
O_3	1	0.56738	1

Table 7: Crisp matrix of ratios of Opportunities.

$W_O = \begin{bmatrix} 0.26578 \\ 0.46844 \\ 0.26578 \end{bmatrix}$ and CR = 0%<10%.

Threats	**T_1**	**T_2**
T_1	1	1
T_2	1	1

Table 8: Crisp matrix of ratios of Threats.

$W_T = \begin{bmatrix} 0.5 \\ 0.5 \end{bmatrix}$ and CR = 0%<10%.

Finally, Table 9 contains the calculation of the weights of the strategies and their ranks.

Factors/Sub-Factors	**Weight**	**Strategies**			
		St_1	**St_2**	**St_3**	**St_4**
Strengths	0.479820				
S_1	0.18079	0.4	0.2	0.2	0.2
S_2	0.18079	0.33333	0.33333	0.16667	0.16667
S_3	0.18079	0.28571	0.28571	0.14286	0.28571
S_4	0.45762	0.083333	0.083333	0.416667	0.416667
Weaknesses	0.363346				
W_1	0.078817	0.33333	0.33333	0.16667	0.16667
W_2	0.421183	0.11111	0.11111	0.55556	0.22222
W_3	0.078817	0.11111	0.11111	0.22222	0.55556
W_4	0.421183	0.12500	0.62500	0.12500	0.12500
Opportunities	0.078417				
O_1	0.26578	0.14286	0.57143	0.14286	0.14286
O_2	0.46844	0.28571	0.14286	0.28571	0.28571
O_3	0.26578	0.37500	0.37500	0.12500	0.12500
Threats	0.078417				
T_1	0.5	0.214286	0.071429	0.357143	0.357143
T_2	0.5	0.1	0.1	0.3	0.5
Total		0.18917	0.24642	0.29282	0.27159
Rank of Strategies		4	3	1	2

Table 9: Ranking and weights calculations for the strategies with respect to SWOT factors and sub-factors.

According to the results in Table 9, the ranking of strategies is:
$\mathrm{St}_3 \succ \mathrm{St}_4 \succ \mathrm{St}_2 \succ \mathrm{St}_1$.

Therefore, the best strategy to apply before to starting a business is “to hire external or internal specialists who determine the legal and financial status of each social company in Los Ríos province, the experiences will be transmitted transparently between the different companies”.

Conclusion

This paper summarizes the investigation on the design of a business plan for entrepreneurs, actors and organizations of social and solidarity economy in Los Ríos province, Ecuador, especially with respect to the project “Young Impulse”. For this purpose, we used the criteria of 24 experimented entrepreneurs, which established the guide that every entrepreneur has to follow to formalize and design his/her business for social and solidarity companies. Among the useful tools for planning and decision-making, we selected the neutrosophic AHP-SWOT technique. This technique is simple to use, rigorous and accurate, since it includes the indeterminacy, which is typical of every decision-making. Finally, we applied this technique to determine the best strategy to follow to start a business. According to the 24 entrepreneurs’ opinions, the selected one is “to hire external or internal specialists who determine the legal and financial status of each social company in Los Ríos province, the experiences will be transmitted transparently between the different companies”

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Procedure for the Acquisition of Goods and Services in Public Procurement

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Abstract. The legislation on public procurement in Ecuador has undergone a profound change with the issuance of the Organic Law of the National Public Procurement System and the use of tools generated by Information and Communication Technologies (ICT). The tender constitutes a contractual award procedure, provided for in this legal body. However, the selection of suppliers for certain non-standardized goods and services represents a conflict that is assumed by decision-makers in the tendering processes. This research proposes a solution to the problem posed from the development of a decision-making method on tenders for non-standard goods and services as part of the public procurement process.

Keywords: Tender, public procurement, neutrosophic numbers, multi-criteria decision making.

1. Introduction

In accordance with the provisions of Article 119 of the Political Constitution of the Republic of Ecuador, public sector entities and public officials are only empowered to do what the Law allows them. For this reason, in matters of public procurement, it is necessary that, prior to starting any process, both the object of the procurement and the legal basis that sustains it be clearly identified. In the same way, it is very important to identify the origin of the economic resources that will be used to finance the hiring; Therefore, depending on who finances the contract, certain procedures will be adopted [1-3].

In Ecuador, before the issuance of the Organic Law of the National Public Procurement System, there was a wide legislative dispersion; Public Procurement was based, fundamentally, on the Public Procurement Law and the Consulting Law. In addition to these normative bodies, the Internal Contracting Regulations were added, where the contracting entities acted without following the same pattern, nor requirements, nor preference margins, which generated that each contracting entity handled the contracting processes differently from the others, hindering the work of control bodies and citizen participation through oversight bodies and other social evaluation mechanisms[4]

Similarly, there was no single registry of suppliers at the national level, each contracting entity handled the qualification processes with which they created a database of some suppliers, which undermined the equal opportunity of participation, especially of the micro, small and medium businesses. This meant that, for each contracting process, each supplier had to gather and present again all the necessary legal documentation [5, 6].

Finally, the participation of the control bodies was prior to hiring, through the corresponding reports from the State Attorney General's Office and the State Comptroller General's Office. It was in 2008 that the Organic Law of the National Public Procurement System was issued.

Contract award procedures are varied, with a close relationship between the amount of the referential budget and the type of award regulated by the Organic Law of the National Public Procurement System. In this legal body the tender operates differently in public works contracts, where it has a leading role, and in the acquisition of goods and services, where its behavior is supplementary.

The process called bidding or tendering is based on the principles of free competition and equality, although the majority of those established in article 4 of the organic law of the national public procurement system affect this contractual award procedure. Free participation guarantees the presence of all people who are in a position to participate under equal conditions. It will allow the Public Administration to really know which is the bidder who presents the best proposal and to choose the most suitable, complying with the implicit principle in the administrative legal system of objective selection [1][7].

Figure 1 shows the annual evolution and percentage of participation in public procurement in Ecuador.

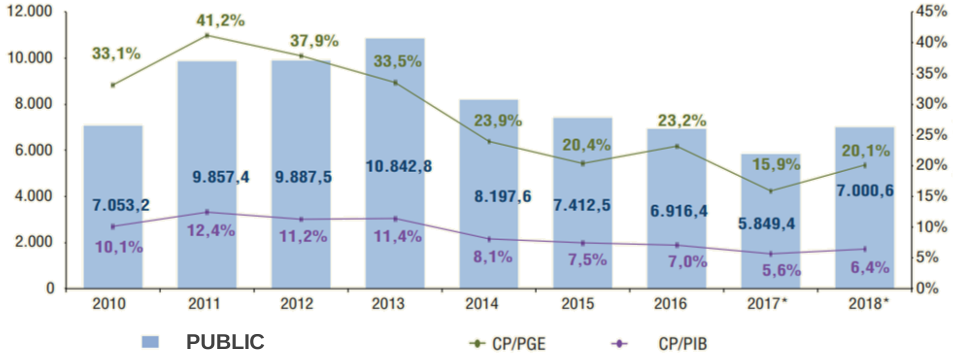

Figure 1: Annual evolution and percentage of participation in public procurement (Millions of dollars and % of representation)
Source: SERCOP - SOCE, Central Bank of Ecuador and Ministry of Finance
Produced by: SERCOP - Directorate of Public Procurement Studies

The graph displays the behavior in millions of dollars that have been invested in public procurement. However, it has had a decline in 2017 with a slight rise for 2018. Public Entities must become aware of what the expression or requirement comprises; more convenient for national and institutional interests that are not always linked or necessarily derived from the lowest price offered; but other factors of equal or perhaps greater importance in the provision, such as technical solvency, opportunity, experience and better prospects.[8]

Based on the aforementioned analysis, the objective of this research is defined as the development of a decision-making method on tendering for non-standardized goods and services as part of the public procurement process.

This article is divided into a section that contains the fundamental concepts of Neutrosophy, section 3 introduces the method that we will apply to solve the problem. Section 4 solves a real problem with the proposed method. The article ends with the conclusions.

2 Preliminaries

This section introduces the main theories used for research development. Specifically, the modeling of uncertainty with the use of neutrosophic numbers is described.

There are various scenarios in which people have to make decisions. A decision-making process can become insufficient when analyzing highly complex problems, especially those problems where the solution can affect many other people. Due to the above, it should be analyzed through discussions and exchange of ideas and opinions among experts, who, due to their experience and knowledge, can help structure the problem and evaluate possible solutions. Figure 2 shows a general diagram of a decision-making process.

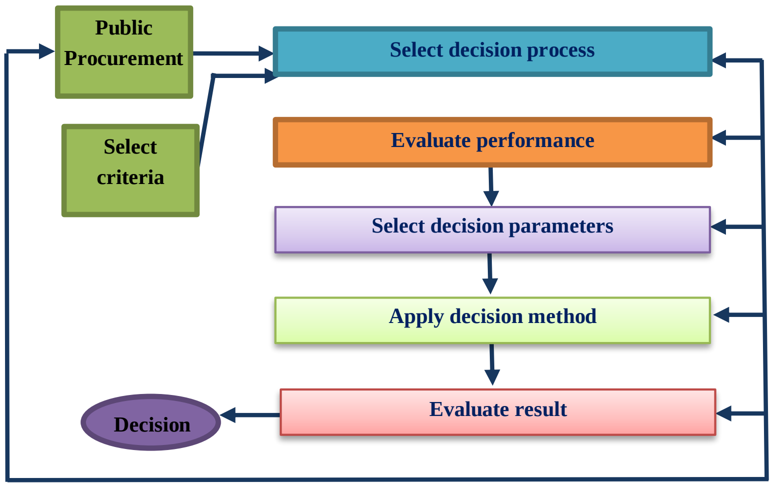

Figure 2: General diagram of a decision-making process.

The decision process requires a comparison between the alternatives that can be chosen in the face of a certain present dilemma. In the first place, it is necessary to separate a decision problem into the elements that compose it for subsequent comparison between them; in this way, decision-making involves taking measurements that allow the application of comparison criteria to establish preferences between them.

Below, we describe the concepts of Neutrosophy that are used in this paper.

Neutrosophy emerged from the movement known as Paradoxism [9] The use of neutrosophic sets allows, in addition, the inclusion of membership functions of truth and falsehood, also membership functions of indeterminacy. This indeterminacy is used because there are contradictions, ignorance, inconsistencies, among other causes with respect to knowledge [10-12]

In the context of multi-criteria methods, neutrosophic numbers are introduced in order to represent the indeterminacy [13, 14]. It constitutes the bases of mathematical theories that generalize classical and fuzzy theories such as neutrosophic sets and neutrosophic logic.[15]. A neutrosophic number (N) is represented as follows [16, 17]:

Let $N = \{(T, I, F) : T, I, F \subseteq [0,1]\}$, a neutrosophic valuation is a mapping of a group of propositional formulas a N, that is, for each p sentence we have

$$v(p) = (T, I, F) \quad (1)$$

Where:

T: represents the truth value,

I: represents the indeterminacy value,

F: represents the falsehood value.

3 Neutrosophic method for decision-making on the tendering of services

The section presents the structure of the method's operation to make decisions about the tendering of services. Operation is guided by a three activity workflow. The method bases its operation on a neutrosophic environment to model the uncertainty.[18, 19]

It is based on a linguistic decision analysis scheme that can address criteria of different nature and provide results in a neutrosophic environment. Figure 2 shows the fundamental activities of the proposed method[20-22].

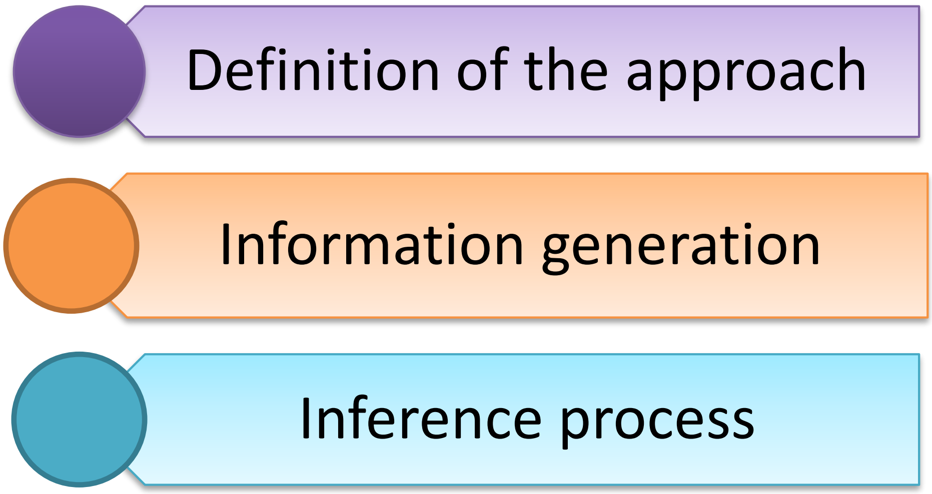

Figure 3: Representation of the method.

The method is designed to support the workflow and to determine and support decision-making on the tender for services. It consists of the following activities: definition of the approach, generation of information and processing and inference. The different stages of the method are described below:

1. Definition of the approach

At this stage, the evaluation framework is defined to specify the decision-making structure for the tender for services. The framework is modeled from the following elements [23-25]:

- $E = \{e_1, \cdots, e_n\}, (n \geq 2)$ is a group of experts.
- $TI = \{ti_1, \cdots, ti_m\}, (m \geq 2)$ it is a set of service providers.
- $C = \{c_1, \cdots, c_l\},\ (l \geq 2)$ It is a set of criteria that characterize the services.

A heterogeneous information framework is used. For each expert, a different numerical or linguistic domain can be used to evaluate each criterion, taking into account its nature in a neutrosophic environment. From the modeling of the elements that define the approach, the information is generated.

In this article, we will use the linguistic scale summarized in Table 1.

Linguistic term	SVN numbers
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0.15,0.20)
Good (G)	(0.70,0.25,0.30)
Fairly good (FG)	(0.60,0.35,0.40)
Average (A)	(0.50,0.50,0.50)
Moderately bad (MB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 1. Linguistic terms used.

2. Generation of information

By defining the framework, the knowledge of the group of experts is obtained. For each expert i, their preferences are provided through the use of utility vectors. The utility vector is expressed by

$P_k^i = \{p_{k1}^i, p_{k2}^i, \cdots, p_{kl}^i\}$

Where: P_k^i represents the preference given to the criteria c_k (k = 1,…, l) over the service providers r_j (j = 1,…, m) expressed by the expert e_i.

In the stage, the information necessary for the processing of the inferences is obtained, from the set of data obtained by consulting the experts, the processing and interpretation of the information is carried out in order to obtain the recommendations on the decision-making in the service tendering process,[26].

3. Processing and evaluation

The processing stage and evaluation is in charge of, based on the framework established with the set of data obtained, carrying out the collective linguistic evaluation that is interpretable for making decisions about the tendering of services. For this the information is unified and aggregated,[27, 28].

The aggregation is done as follows:

Given a vector of weights for each criterion $W = (w_1, w_2, \dots, w_l)$, which satisfies $w_k \in [0,1]$, such that $\sum_{k=1}^{l} w_k = 1$.

The result for each service provider is calculated with the following formula:

$$R_j = \frac{\sum_{k=1}^{l} w_k \left(\sum_{i=1}^{n} p_{kj}^i\right)}{n} \quad (2)$$

A process of sorting alternatives that are prioritized to deal with heterogeneous information and offer linguistic results is carried out [29, 30].

The results are sorted by provider using formula 3.

$s(\tilde{a}) = \frac{1}{3}(2 + \mathrm{T} - \mathrm{I} - \mathrm{F})$ (3)

For a neutrosophic number $\tilde{a} = (\mathrm{T}, \mathrm{I}, \mathrm{F})$

4 Implementation of the neutrosophic method for decision making on the tendering of services

This section describes the operation of the proposed method for which a case study applied to a service organization for the electrical maintenance of facilities was carried out. The objective was to determine the decision-making on service providers that carry out the tender. The example illustrates the applicability of the method.

Activity 1: Assessment framework

For the present case study, a framework composed of:

$\mathrm{E} = \{\mathrm{e}_1, \mathrm{e}_2, \mathrm{e}_3\}$, which represent the 3 experts who participated in the process.

Which carry out the evaluation:

$\mathrm{Ps} = \{\mathrm{Ps}_1, \mathrm{Ps}_2, \mathrm{Ps}_3\}$, from 3 Service Providers

From the valuation of the

$\mathrm{C} = \{c_1, \cdots, c_6\}$ which make up the 6 evaluation criteria.

Table 2 shows the criteria used.

Not	Criterion	Description
1	Certifications	The organization has international certifications to carry out the activity
2	Establishment time	Time that the organization has been established in the national market
3	Attention time	That the provider can solve the problems in a time not exceeding 2 hours
4	Compliance with standards	That the planned actions are carried out according to the regulations provided by the national standardization organization
5	Recognition	Visibility of the organization in the national marking
6	Solvency	Possibility of the organization to guarantee the resolution of problems with the provider's own resources.

Table 2: Criteria used for the selection of suppliers for the electrical maintenance of facilities.

Each expert could provide the information numerically or linguistically, taking into account the nature of the criteria. A common linguistic domain is chosen to verbalize the results that are expressed in Figure 3.

For the numerical values, the following linguistic scale will be used with neutrosophic single-valued numbers proposed in Table 4.

Activity 2: Generation of information

From the information obtained about the service providers, they are stored for further processing. The evaluation framework is presented in Table 3. The evaluation scales used is the one that appears in Table 1.

	e_1			e_2			e_3		
	Ps_1	Ps_2	Ps_3	Ps_1	Ps_2	Ps_3	Ps_1	Ps_2	Ps_3
c_1	(0.60,0.35, 0.40)	(0.70,0.25, 0.30)	(0.9, 0.1, 0.1)	(0.30,0.75, 0.70)	(0.50,0.50, 0.50)	(0.8,0.15, 0.20)	(0.60,0.35, 0.40)	(0.60,0.35,0. 40)	(0.50,0.50,0. 50)
c_2	(0.60,0.35, 0.40)	(0.9, 0.1, 0.1)	(0.60,0.35, 0.40)	(0.9, 0.1, 0.1)	(0.50,0.50, 0.50)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.70,0.25,0. 30)	(0.9, 0.1, 0.1)
c_3	(0.60,0.35, 0.40)	(0.50,0.50, 0.50)	(0.9, 0.1, 0.1)	(0.8,0.15, 0.20)	(0.70,0.25, 0.30)	(0.30,0.75, 0.70)	(0.60,0.35,0. 40)	(0.8, 0.1, 0.3)	(0.50,0.50,0. 50)
c_4	(0.9, 0.1, 0.1)	(0.8, 0.1, 0.3)	(0.60,0.35, 0.40)	(0.50,0.50, 0.50)	(0.60,0.35, 0.40)	(0.50,0.50, 0.50)	(0.9, 0.1, 0.1)	(0.70,0.25,0. 30)	(0.8,0.15,0.2 0)
c_5	(0.60,0.35, 0.40)	(0.70,0.25, 0.30)	(0.9, 0.1, 0.1)	(0.30,0.75, 0.70)	(0.50,0.50, 0.50)	(0.8, 0.1, 0.2)	(0.60,0.35,0. 40)	(0.60,0.35,0. 40)	(0.50,0.50,0. 50)
c_6	(0.9, 0.1, 0.1)	(0.60,0.35, 0.40)	(0.60,0.35, 0.40)	(0.50,0.50, 0.50)	(0.8, 0.1, 0.3)	(0.50,0.50, 0.50)	(0.9, 0.1, 0.1)	(0.50,0.50,0. 50)	(0.30,0.75,0. 70)

Table 3. Presentation of the results for the three providers, the three experts and the six criteria.

The weighting vector is used.$W = (0.38, 0.27, 0.11, 0.05, 0.08, 0.11)$

The results obtained were those shown in Table 4:

Provider	Results	Score
Ps1	$\langle 0.64200, 0.34033, 0.35800\rangle$	0.64789
Ps2	$\langle 0.64300, 0.32283, 0.36600\rangle$	0.65139
Ps3	$\langle 0.69867, 0.28800, 0.30133\rangle$	0.70311

Table 4: Collective evaluation for supplier.

Table 4 summarizes the results of applying Formula 1 in the example, in addition to the score obtained from applying the Equation.

Finally, all the collective evaluations are ordered and a ranking is established among the service providers in order to identify the best calculated scoring alternatives. Therefore, in the case study, the classification of service providers was recommended as follows: $Ps_1 \prec Ps_2 \prec Ps_3$. Consequently, association with the third-party provider is recommended.

Conclusions

Based on the development of the proposed research, a system was obtained to support decision-making in the contract award procedure for the procurement of non-standardized goods and services. The implementation of the proposed system is based on neutrosophic methods to model uncertainty. With the application of the system proposed in the case study, it was possible to demonstrate the applicability of the decision support methodology for the tendering of non-standardized goods and services. Although the proposed case study presents a favorable practical application, the implementation of other multi-criteria decision-making methods is recommended in the decision-making process to compare the results obtained.

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Neutrosophic Evaluation of Depression Severity

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Abstract. Among the mental illnesses, depression is a very common manifestation today. Various methods have been approached in the scientific literature to quantify depression, among which we may find the Hamilton scale. However, depression has a degree of uncertainty in its manifestation conditioned by the severity of the diagnosis. Problems of this nature have been addressed by science from neutrosophic modeling. Based on the scenario described above, the present research proposes a neutrosophic method for evaluating the level of depression. The method bases its operation on the adaptation of the Hamilton scale with neutrosophic numbers to quantify depressive disorder. The method uses the range to indicate the levels of severity of depression recognized by the American Psychiatric Association by means of neutrosophic numbers.

Keywords: neutrosophic numbers; mental diseases; Hamilton scale; depression

1. Introduction

Depressive disorder or depression represents a mental illness that currently affects more than 350 million people in the world, according to the World Health Organization [1]. Depression is characterized by a group of conditions, such as: pathological sadness, decay, apathy, irritability, feeling of discomfort and helplessness towards the vicissitudes of life. Cognitive processes can also generate physical manifestations such as vomiting, loss weight, cardiac ischemia, diabetes, cerebrovascular diseases, cancer, among others [2].

Guaranteeing the identification and diagnosis of patients from the beginning would allow the implementation of antidepressant and opportune psychotherapeutic treatments that avoid aggravating these manifestations [3]. Rating scales for depression and its response to treatment have been proposed in various studies. The proposed scales are intended to evaluate the patient's symptoms in a given time [4].

Hetero-evaluated scales are those in which the evaluator asks about each of the items and evaluates them [5]. Self-assessing scales or questionnaires can be read by the interviewer or by the patient himself, who chooses the items that best reflect his state; the most used are: Beck Depression Inventory (BDI), Hamilton Rating Scale for Depression (HAM-D) and Montgomery Asberg Depression Rating Scale (MADRS) [6].

The symptoms of the patients represent the evaluation criteria to which a weight is matched. The result of the method returns a numerical value that must be previously supplemented with the clinical interview and its respective psychopathological information to determine the diagnosis [7]. The scientific literature describes problems of this nature through multi-criteria modeling for the evaluation of medical diagnosis. Based on the problems raised above, this research proposes a neutrosophic method for the evaluation of depression levels.

2. Preliminaries

This section describes the main theoretical references on the object of study; and the different concepts that facilitate the understanding of the research. A description of the mental illnesses is made and an approximation of the way to measure depression is introduced, specifically the Hamilton scale as a way to measure the severity of depression.

2.1. Mental disorders

Depression is a very common mental illness today. It means knocked down or beaten down; formerly it was called melancholy. Depressive disorder or depression is defined as the grouping of affective, cognitive, volitional and somatic symptoms that entails a great psychological and physical affectation to the person who suffers from it [8].

Depression is often associated with anxiety, with organic brain diseases or with systemic organic diseases [9]. It is also associated with the abuse of alcohol and illegal substances, with alterations in eating behavior and alterations of the personality; also depressive disorder has a direct relationship with chronic physical diseases, which can increase depression and this, in turn, adversely affects the course of the physical disease [10]. People who suffer from depression present signs and symptoms together that affect both the mood, the behavior and the organic part.

2.2. Hamilton scale

The Hamilton rating scale for the evaluation of depression is a hetero-applied scale, designed to be used in patients previously diagnosed with depression. The scale is applied in order to quantitatively assess the severity of the symptoms and assess the changes in the depressed patient [11]. It is valued according to the information obtained in the clinical interview and accepts complementary information from other secondary sources [12]. Different evaluations have made it possible to verify the discriminant validity, reliability and sensitivity to change, both in hospitalized and outpatient populations. [13].

It is a scale to assess the intensity or severity of depressive disorder both in clinical practice and in research. It is used to monitor how symptoms progress in patients. The assessment of the various symptoms corresponds to the moment in which it is applied, with the exception of some items that strictly refer to the previous two days, such as the items about sleep.

2. Materials and Methods

This section describes the structure and operation of the method for evaluating depression. The method models the uncertainty by using neutrosophic numbers to represent it. The inference process is managed from the use of operators for the aggregation of information [14, 15].

The method proposal is structured to ensure the management of the workflow for the evaluation of depression. It uses a multi-expert multi-criteria approach based on defined qualitative indicators to assess this condition. The indicators represent the basis of inference for the evaluation of depression.

It has an aggregation and processing stage that processes the information for the evaluation of depression. The end result of the method is the evaluation of depression.

Figure 1 shows a representation of the structure and operation of the proposed method.

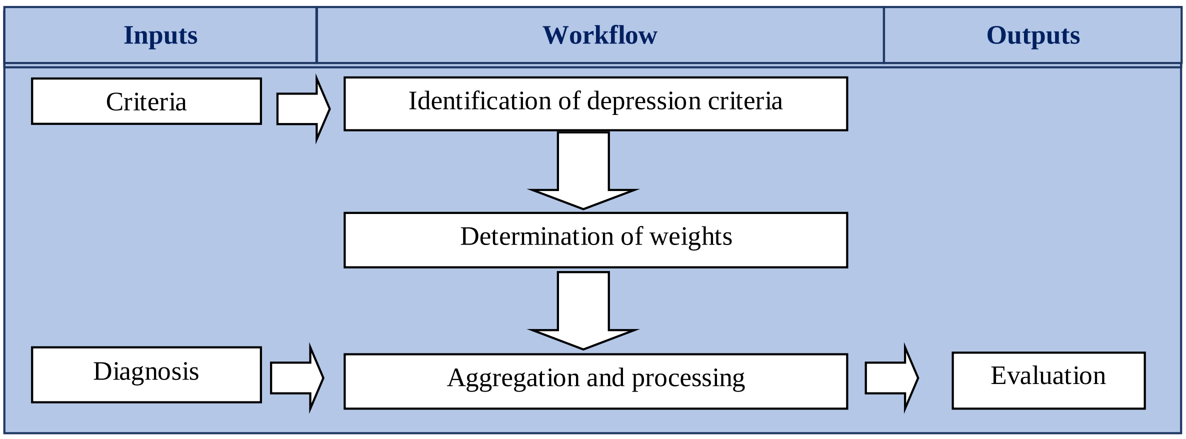

Figure 1: General operation of the proposed method.

The method for the evaluation of depression is made up of three basic activities (determination of the criteria to quantify depression, definition of the weights associated with the depression criteria, aggregation and information processing). The main activities are described below:

Activity 1 identification of depression criteria:

In the activity of identifying the criteria to quantify depression, a multi-criteria approach is used; bases its operation by using the criteria of the Hamilton scale that quantify depression [12].

Activity 2 determination of the weights associated with the depression criteria:

Based on the criteria obtained from the previous activity, they are evaluated to determine the weight vectors associated with each criterion. The activity of determining the weights associated with the depression criteria is carried out through a multi-expert approach, for which the use of 7 to 13 experts who intervene in the process is proposed.

Activity 3 aggregation and processing of information: The activity of aggregation and processing of information represents the fundamental nucleus of the inference of the method. The activity represents the pathway used in the decision support process. The activity starts from the information obtained in the previous activities. It consists of the transformation of a data set into a single element using aggregation operators [16-18].

Definition 1: T-norm operator. An operator $\mathrm{T}: [0,1] * [0,1] \rightarrow [0,1]$ is a T-norm operator if it meets the following properties:

1. Commutative $\mathrm{T}(\mathrm{x},\mathrm{y}) = \mathrm{T}(\mathrm{y},\mathrm{x})$. (1)
2. Associative $\mathrm{T}(\mathrm{x},\mathrm{T}(\mathrm{y},\mathrm{z}) = \mathrm{T}(\mathrm{T}(\mathrm{x},\mathrm{y}),Z)$. (2)
3. Increasing monotone $\mathrm{T}(\mathrm{x},\mathrm{y}) > T(x,y)$ si $x \geq \mathrm{x}' \cap \mathrm{y} \geq \mathrm{y}'$. (3)
4. Neutral element $\mathrm{T}(\mathrm{x},1) = \mathrm{x}$. (4)

The activity is based on the aggregation process using the Ordered Weighted Average (OWA) information aggregation operator. The operator allows the aggregation of information according to predefined parameters, obtaining a representative value. A decision maker can aggregate the information based on the desired degree of optimism or pessimism [15, 19, 20].

Definition 2: OWA operator. A function $F: R^n \rightarrow \mathrm{R}$, is an OWA operator of dimension n if it has an associated vector W of dimension n such that its components satisfy [21]:

1) $\mathrm{W_j} \in [0,1]$, (5)

2) $\sum_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{W_j} = 1$, and (6)

3) $\mathrm{F}(\mathrm{a_1},\mathrm{a_2},,,\mathrm{a_n}) = \sum_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{W_j b_j}$ (7)

Where $\mathrm{b_j}$ is the j-th largest of the $\mathrm{a_j}$.

The aggregation operator can be expressed using a vector notation as represented in equation 8:

$$\mathrm{F}(\mathrm{a_1},\mathrm{a_2}..\mathrm{a_n}) = \mathrm{W^t B} \quad (8)$$

Where:

W: is the OWA weight vector associated with the aggregation.

B: is the ordered aggregate vector, where the j-th largest component of B is b_j this being the j-th largest of the a_i.

Neutrosophic numbers can be expressed in neutrosophic logic as shown in [14, 22, 23]:

Given

$$N = \{(T,I,F) : T,I,F \subseteq [0,1]\}, \quad (9)$$

A neutrosophic value is a mapping of a group of formulas proportional to N, from each p sentence we have [24-26]:

$$v(p) = (T,I,F) \quad (10)$$

Where:

T: represents the dimension of the space that represents the truth,

I: represents falsehood,

F: represents indeterminacy.

Mathematically, a Neutrosophic OWA operator can be defined as a 2-tuple (W,B) as represented by equation 11.

$$F(a_1, a_2 .. a_n) = {W_{(T,I,F)}}^t B_{(T,I,F)} \quad (11)$$

Where:

W: is the OWA weight vector associated with the aggregation that has a space of truth, falsehood and indeterminacy (T, I, F).

B: is the ordered aggregate vector, where the j-th largest component of B is b_j this being the j-th largest of the a_i, which has a space of truth, falsehood and indeterminacy (T, I, F).

The proposed method performs the aggregation process using the OWA operator for neutrosophic numbers.

3. Results

This section describes the implementation of the proposed method through a case study. The study is carried out on a patient who was hospitalized in the Internal Medicine area of the Latacunga General Hospital in Ecuador. The example presents the fundamental elements for the analysis of the proposal.

The main elements of the implemented method are described below:

Activity 1 identification of depression criteria.

During the process of obtaining information for the definition of the depression criteria, the result was 15 criteria that make up the Hamilton scale. Table 1 shows the criteria obtained.

Criteria	**Depression**
C_1	Depressed mood
C_2	Feeling guilty
C_3	Idea of suicide
C_4	Early insomnia
C_5	Medium insomnia
C_6	Problems at work and activities
C_7	Inhibition
C_8	Agitation
C_9	Psychic Anxiety
C_{10}	Somatic anxiety
C_{11}	Somatic Gastrointestinal Symptoms
C_{12}	General somatic symptoms
C_{13}	Genital symptoms
C_{14}	Hypochondria
C_{15}	Weight loss

Table 1: Criteria for depression.

Activity 2 determination of the weights associated with the depression criteria.

To determine the weight associated with the depression criteria, 9 experts were used who participated in the process. Each criterion has a set of indicators that represent the way to assess the criteria. The indicators have been modeled using neutrosophic numbers. As a final result, the weight vectors associated with each criterion were obtained. Table 2 shows the results of the indicators that correspond to each criterion in a neutrosophic domain.

Criteria	**Indicators**	**Neutrosophic scale**
C_1	Absent	[0,1,1]
	These sensations are indicated only when interrogate	[0.10,0.90,0.90]
	These sensations are reported orally and spontaneously	[0.20,0.85,0.80]
	Sensations not communicated verbally, but by facial expression, posture, voice or tendency to cry	[0.30,0.75,0.70]
	The patient manifests these sensations in his verbal and non-verbal communication spontaneously	[0.40,0.65,0.60]
C_2	Absent	[0,1,1]
	Blames himself, thinks he has let people down	[0.10,0.90,0.90]

Criteria	Indicators	Neutrosophic scale
	Ideas of guilt, or meditation on past mistakes or bad actions	[0.20,0.85,0.80]
	The current illness is a punishment. Delusions of guilt	[0.30,0.75,0.70]
	Hears accusing or denouncing voices and / or experiences threatening visual hallucinations	[0.40,0.65,0.60]
C_3	Absent	[0,1,1]
	It seems to her that life is not worth living.	[0.10,0.90,0.90]
	Wish you were dead or have thoughts about dying	[0.20,0.85,0.80]
	Ideas or threats of suicide	[0.30,0.75,0.70]
	Suicide attempts	[0.40,0.65,0.60]
C_4	Absent	[0,1,1]
	occasional difficulty falling asleep, for example more than half an hour	[0.10,0.90,0.90]
	difficulty falling asleep every night	[0.20,0.85,0.80]
C_5	Absent	[0,1,1]
	The patient complains of being restless at night	[0.10,0.90,0.90]
	You are awake at night; any occasion of getting out of bed is scored as 2, unless justified (urinating, taking or giving medication)	[0.20,0.85,0.80]
C_6	Absent	[0,1,1]
	Wakes up in the early hours of the morning but falls asleep again	[0.10,0.90,0.90]
	You can't go back to sleep if you get out of bed	[0.20,0.85,0.80]
C_7	Absent	[0,1,1]
	Ideas and feelings of incapacity. Fatigue or weakness related to your job, activity, or hobbies	[0.10,0.90,0.90]
	Loss of interest in their activity, hobbies or work, manifested directly by the patient or indirectly by inattention, indecision and hesitation	[0.20,0.85,0.80]
	Decrease in time dedicated to activities or decrease in productivity	[0.30,0.75,0.70]
	Stopped working for the present illness	[0.40,0.65,0.60]
C_8	Normal word and thought	[0,1,1]
	Slight delay in dialogue	[0.10,0.90,0.90]
	Obvious delay in dialogue	[0.20,0.85,0.80]
	Difficult dialogue	[0.30,0.75,0.70]
	Absolute clumsiness	[0.40,0.65,0.60]
C_9	None	[0,1,1]
	He "plays" with his, hands, hair, etc.	[0.10,0.90,0.90]
	He wrings his hands, bites his nails, his lips, he pulls his hair.	[0.20,0.85,0.80]
C_{10}	No difficulty	[0,1,1]
	Subjective tension and irritability	[0.10,0.90,0.90]
	Worry about little things	[0.20,0.85,0.80]
	Apparent apprehensive attitude in expression or speech	[0.30,0.75,0.70]
	Terrors expressed without asking	[0.40,0.65,0.60]
C_{11}	Absent	[0,1,1]
	Light	[0.10,0.90,0.90]
	Moderate	[0.20,0.85,0.80]
	Serious	[0.30,0.75,0.70]

Criteria	Indicators	Neutrosophic scale
	Unable	[0.40,0.65,0.60]
C_{12}	None	[0,1,1]
	Loss of appetite, but eats without being stimulated. Feeling of heaviness in the abdomen	[0.10,0.90,0.90]
	Difficulty eating if you don't insist. Request or need laxatives or intestinal medication or for your gastrointestinal symptoms	[0.20,0.85,0.80]
C_{13}	None	[0,1,1]
	Heaviness in the extremities, back or head. Back pain, headache, myalgia. Fatigue and loss of energy	[0.10,0.90,0.90]
	Any of the above symptoms is scored as 2 if it is very well defined	[0.20,0.85,0.80]
C_{14}	Absent	[0,1,1]
	Weak	[0.10,0.90,0.90]
	Serious	[0.20,0.85,0.80]
	Unable	[0.30,0.75,0.70]
C_{15}	None	[0,1,1]
	Self-conscious (bodily)	[0.10,0.90,0.90]
	Concerned about your health	[0.20,0.85,0.80]
	He constantly regrets. Ask for help.	[0.30,0.75,0.70]
	Hypochondriacal delusions	[0.40,0.65,0.60]

Table 2: Neutrosophic scale of the criteria and their measurement indicators.

From the work with the group of experts that intervened in the process, the weight vectors associated with each depression criterion were obtained. Table 3 shows the result of the weight vectors associated with the criteria.

Criteria	W
C_1	[0.1620,0.85,0.80]
C_2	[0.2014,0.85,0.80]
C_3	[0.1520,0.85,0.80]
C_4	[0.1620,0.85,0.80]
C_5	[0.3110,0.83,0.80]
C_6	[0.1716,0.83,0.80]
C_7	[0.1801,0.82,0.80]
C_8	[0.1534,0.85,0.80]
C_9	[0.1718,0.83,0.80]
C_{10}	[0.1820,0.82,0.80]
C_{11}	[0.1012,0.90,0.80]
C_{12}	[0.1110,0.98,0.80]
C_{13}	[0.1522,0.85,0.80]
C_{14}	[0.1910,0.81,0.80]
C_{15}	[0.1830,0.86,0.80]

Table 3: Neutrosophic vectors of weights associated with the evaluative criteria.

Activity 3 aggregation and processing of information.

From the data set obtained in the previous activities, the information is processed. The aggregation process is carried out from the set of neutrosophic vectors of associated weights of the depression criteria and the preferences obtained from the diagnosis that represents an input parameter using equation 11. Table 4 presents the result of the values obtained during the aggregation process.

Criteria	Weights	Diagnosis	Aggregation
C_1	[0.1620,0.85,0.80]	[1,0,0]	[0.0626, 0.85,0.90]
C_2	[0.2014,0.85,0.80]	[0.70,0.25,0.30]	[0,0545,0.85,0.90]
C_3	[0.1520,0.85,0.80]	[0.9, 0.1, 0.1]	[0,0528,0.85,0.90]
C_4	[0.1620,0.85,0.80]	[1,0,0]	[0,0626,0.85,0.90]
C_5	[0.3110,0.83,0.80]	[0.30,0.75,0.70]	[0,0360,0.85,0.90]
C_6	[0.1716,0.83,0.80]	[0,1,1]	[0,1,1]
C_7	[0.1801,0.82,0.80]	[0.9, 0.1, 0.1]	[0,0629,0.85,0.90]
C_8	[0.1534,0.85,0.80]	[0.70,0.25,0.30]	[0,0415,0.85,0.90]
C_9	[0.1718,0.83,0.80]	[1,0,0]	[0,0664,0.85,0.90]
C_{10}	[0.1820,0.82,0.80]	[0.30,0.75,0.70]	[0,0211,0.85,0.90]
C_{11}	[0.1012,0.90,0.80]	[0,1,1]	[0,1,1]
C_{12}	[0.1110,0.98,0.80]	[0.9, 0.1, 0.1]	[0,0386,0.85,0.90]
C_{13}	[0.1522,0.85,0.80]	[1,0,0]	[0,0587,0.85,0.90]
C_{14}	[0.1910,0.81,0.80]	[0.30,0.75,0.70]	[0,0221,0.85,0.90]
C_{15}	[0.1830,0.86,0.80]	[1,0,0]	[0,0707,0.85,0.90]
Evaluation			[0,6510,0.35,0.40]

Table 4: Result of the aggregation process.

From the result of the aggregation process, the evaluation referred to the proposed case study is obtained. An evaluation of the level of depression of a [0, 6510,0.35, 0.80] was obtained. To conclude the evaluation process, the result is interpreted according to the Hamilton scale as: Severe depression.

Conclusions

This investigation proposed a neutrosophic method for the evaluation of depression. It based its operation using the Hamilton scale with neutrosophic numbers to quantify depressive disorder from the modeling of uncertainty. The method used the range to indicate the levels of severity of depression recommended by the American Psychiatric Association through neutrosophic numbers.

The proposed method was implemented for a case study on a patient who was hospitalized in the Internal Medicine area of the Latacunga General Hospital in Ecuador. With the case study the applicability of the method could be verified. The evaluation obtained allows classifying the degree of depression in patients, fulfilling the objective proposed for the present investigation.

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A composite Index of Social Vulnerability to Earthquake Hazard in Canton Atacames

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Abstract. The Atacames Canton in Ecuador is a locality deeply affected by earthquakes and requires an analysis of its social vulnerability to achieve resilience and proactivity to mitigate the damage caused. Since the phenomena involved are under an environment of uncertainty, their analysis depends on a combination of factors whose most appropriate processing is the neutrosophic multicriteria decision-making methods, because they integrate multiple data sets with scoring areas according to criteria. Therefore, the objective of this research is to develop a composite neutrosophic indicator for the analysis of the social vulnerability of earthquakes in the Canton Atacames. For the study, social vulnerability was divided into three components under an environment of uncertainty.

Keywords: earthquakes, social vulnerability, resilience, uncertainty, composite neutrosophic indicator

1 Introduction

Earthquake studies date back to the Chinese Dynasty thirty centuries ago. In this way, each society has been able to prevent itself from the effect of earthquakes. Ecuador is a country with a high seismic index due to its location in a subduction zone between the Pacific Plate and the South American Plate [1]. On average, it has a major earthquake every forty years and it is assumed that an average Ecuadorian, who lives his entire life within those borders, must experience at least two large earthquakes in situ in his life. Therefore, they are working on the relationship between natural disaster and the right to life as part of the human rights of Ecuadorians.[1, 2]. To do this, the identification of vulnerabilities to earthquakes is carried out, which allows preparation and response programs for specific disasters to reduce the social impact of an earthquake.[1-4].

These analyzes are generally based on decision-making methods that integrate multiple data sets. [2, 3, 5, 6]. The choice of evaluation criteria has been different since multicriteria evaluation was adopted as a problem-solving and decision support tool, and most of the studies focused on geophysical factors [7-9]; others have built-in social vulnerability[10, 11]. They provide simple unit comparisons that can be used to illustrate the complexity of dynamic environments in wide-ranging fields. Several authors affirm that multicriteria techniques are highly suitable in multidimensional frameworks by adding unique indicators in a composite one, as it involves making choices by combining criteria of different natures, and requires a series of steps in which decisions must be made.[12-14].

With these studies, it is guaranteed that situations such as what happened on April 16, 2016, in which countless human lives were lost, are not repeated. It is known that the damage caused will not be repaired and that these disasters are unpredictable; but it is important to be proactive as a way to comply with human rights: the right to life[1]. Therefore, the objective of this research is to develop a composite neutrosophic indicator for the analysis of the social vulnerability to earthquakes in the Canton Atacames. In order to comply with the stated above, the following specific objectives are formulated in the sections that comprise this article:

a) Characterize the Atacames Canton seismic zone
b) Determine the indicators that intervene in the social vulnerability of earthquakes

c) Define the composite neutrosophic indicator for the analysis of the social vulnerability of earthquakes in the Atacames Canton (section 3 of this document)

It is intended with the study of the social vulnerability of earthquakes in the Atacames Canton by means of the construction of a compound neutrosophic indicator to enable the early detection of social phenomena that occurred after the occurrence of this natural disaster. What leads to the mitigation of the adverse effects on the lives of residents and therefore their quality of life, after the disaster. In addition, with this indicator, we would achieved proactivity and it will allow us to prevent the loss of human life even when they are in an area of uncertainty due to the unpredictability of the natural phenomenon in question.

1.1 Characterization of the Atacames Canton seismic zone

The Atacames region is located along a tectonic fault with high seismic activity. Due to this, in the earthquake that occurred on April 16, 2016, Atacames was among the cantons with the greatest impact along with Muisne. It is the fourth largest and most populated city in the Esmeraldas Province with approximately sixteen thousand (16 000) inhabitants. Having an excellent economic level due to its tourist development and having one of the largest beaches in Ecuador. Due to this, a large number of attracted people remain in the territory. Which presupposes a greater number of people exposed to the risk of suffering the adverse consequences of an earthquake.

Figure 1. Region under study. Source: Google Maps.

1.2 Indicators of social vulnerability of earthquakes

[2-11] agree in the treatment of the uncertainty imposed by the phenomenon of earthquakes, the social factors that they carry out for their analysis and in addition to the spatial variations in these components result in different levels of vulnerability to an earthquake [4]. Therefore, indicators that reflect these phenomena will intervene, which by their nature are based on empirical and theoretical evidence[15]. Social vulnerability depends on a combination of factors that affect their resilience [2-6]. Due to this, its analysis is divided into three components, which will be translated into indicators. They are listed below:

- physical damage based on geological features and the built environment;
- socio-economic barriers to resilience and recovery;
- and access to trauma and other support services.

It should be noted that the ability of a disadvantaged population to recover from an earthquake is affected by limited economic and political capital. [15]. Numerous studies examining social vulnerability use quantitative indices, often modeled with census data [16-21]. Most of this literature originates from the United States and therefore tends to emphasize the proportion of minority populations as an explanatory variable. The most used indicators of social vulnerability according to the bibliography consulted are [2-5, 15, 20, 22]:

1. Age
2. Time spent in a specific place
3. Percentage of people who moved in the last year
4. Average income for each family
5. Single parent families
6. Seniors living alone
7. Residents who are homeowners
8. Educational level
9. Dependent population
10. Percentage of unemployed

1.3 Construction of a multi-criteria evaluation model

According to the reviewed literature, we can say that certain authors [2, 23-25] present algorithmically sophisticated multi-criteria evaluation models where hierarchical techniques such as AHP Saaty are used in conjunction with other heterogeneous methods related to decision-making. In addition, all the methods used are based on the criteria of experts in a majority way. To carry out this research, we also decided to opt for a strategic, effective and simple technique for solving multi-criteria decision problems: TOPSIS (Technique for Order Preference by Similarity to Ideal Solution). Since this method determines the alternative closest to the ideal solution and, in turn, farthest from the worst solution [26].

Both techniques will be used in their neutrosophic versions because this research will take into account the environment of uncertainty and possible indeterminacies that this social phenomenon brings along. Since Neutrosophy is the branch of philosophy that studies the origin, nature and scope of neutralities. Its incorporation guarantees that the uncertainty of decision-making is taken into account, including indeterminacies where experts will issue their criteria evaluating linguistic and non-numerical terms, which constitutes the most natural form of measurement in human being [27-33].

2 Materials and methods

The following section describes the theoretical and empirical methods used throughout the current research to achieve the specific objectives set. The methods used are listed below:

- Inductive, deductive: to verify the factors raised regarding the research topic in addition to structuring the research profile for its application.
- Analytical-synthetic: to compare all the phenomena involved in the research
- Historical-logical and descriptive-systematic: to analyze the problem situation of the research, it is intended to make a current observation of the phenomena for their interpretation.
- Surveys and interviews: it will be applied to the sample made up of the target population and selected experts (residents, Public Officials and Authorities of the Atacames Canton).

Questionnaires aimed at obtaining information about the real problem and issuing possible solutions were prepared to obtain valid conclusions and support the results.

Sample: part of the population of the Atacames Canton according to the formula that allows obtaining the sample size of a finite population.

Calculation sample (1) $n = \frac{N}{(E)2(N-1)+1}$

Where
n = sample size
N = Population or Universe
E = margin of error 0.1%

- AHP Saaty Neutrosophic: for the description of the method, the following definitions must be presented:

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

Notice that, according to the definition, TA (x), IA (x) and FA (x) are real standard or non-standard subsets of] -0, 1+ [and hence, TA (x), IA (x) and FA (x) can be subintervals of [0, 1].

Definition 2: [34, 35] The Single-Valued Neutrosophic Set (SVNS) N over U is A = {<x; TA (x), IA (x), FA (x)>: x∈U}, where TA: U→[0, 1], IA: U→[0, 1], and FA: U→[0, 1], 0 ≤TA (x) + IA (x) + FA (x)≤ 3.

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

Definition 3: [34-37] 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: $\tilde{a} = \langle (a_1, a_2. a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle \mathbb{R}$

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \le x \le a_2 \\ \alpha_{\tilde{a}}, & a_2 \le x \le a_3 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_3 \le x \le a_4 \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

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

$$F_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\gamma_{\tilde{a}}(x-a_1))}{a_2-a_1}, & a_1 \le x \le a_2 \\ \gamma_{\tilde{a}}, & a_2 \le x \le a_3 \\ \frac{(x-a_2+\gamma_{\tilde{a}}(a_3-x))}{a_3-a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases} \tag{4}$$

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

Definition 4: [34-37] 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:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
2. Subtraction: (5)$\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
3. Inversion: where.$\tilde{a}^{-1} = \langle (a_4^{-1}, a_3^{-1}, a_2^{-1}, a_1^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle a_1, a_2, a_3, a_4 \neq 0$
4. Multiplication by a scalar number:

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

Definitions 3 and 4 refer to single-valued triangular neutrosophic number when the condition a2 = a3, [38-40]. For simplicity, we use the linguistic scale of triangular neutrosophic numbers, see Table 1 and also compare with the scale defined in [41].

The hierarchical analytical process was proposed by Thomas Saaty 1980 [27]. This technique models the problem that leads to the formation of a hierarchy representative of the associated decision-making scheme[28, 29]. 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[30], [31, 32]. 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 [33]. The levels of importance or weighting of the criteria are estimated by means of paired comparisons between them. This comparison is carried out using a scale, as expressed in equation (6)[42].

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

We can find in [41]the theory of AHP technique in 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.

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

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

To convert neutrosophic triangular numbers into crisp numbers, there are two indexes defined in [41], they are the so-called score and accuracy indexes, respectively, see Equations 8 and 9:

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

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

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	$\tilde{2} = \langle (1, 2, 3); 0.40, 0.65, 0.60 \rangle$
		$\tilde{4} = \langle (3, 4, 5); 0.60, 0.35, 0.40 \rangle$
		$\tilde{6} = \langle (5, 6, 7); 0.70, 0.25, 0.30 \rangle$
		$\tilde{8} = \langle (7, 8, 9); 0.85, 0.10, 0.15 \rangle$

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

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[43]. The neutrosophic pair-wise comparison matrix of factors, sub-factors and strategies are as described in Equation 7.

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 to a deterministic matrix using Equations 10 and 11. To get the score and the accuracy degree of the following equations are used:$\tilde{a}_{ji}$

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

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

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

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

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 consider 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 consistency of the evaluations can be determined by equation$CI = \frac{\lambda_{max}-n}{n-1}$[44], where n is the order of the matrix. In addition, the Consistency Ratio (CR) is defined by equation CR = CI / RI, where RI is given in Table 2.

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

Table 2: RI associated to every order.

If CR≤0.1 we can consider that experts' evaluation is sufficiently consistent and hence we can proceed to use NAHP. We apply this procedure to matrix A in Equation 12.

- TOPSIS:

The TOPSIS method was developed by Hwang and Yoon in 1981 and is based on the concept that it is desirable for a given alternative to be located at the shortest distance from an ideal alternative that represents the best (positive ideal or simply ideal), and at the greatest distance from an ideal alternative that represents the worst (negative ideal or anti-ideal) [26, 45]. It is based on the following diagram:

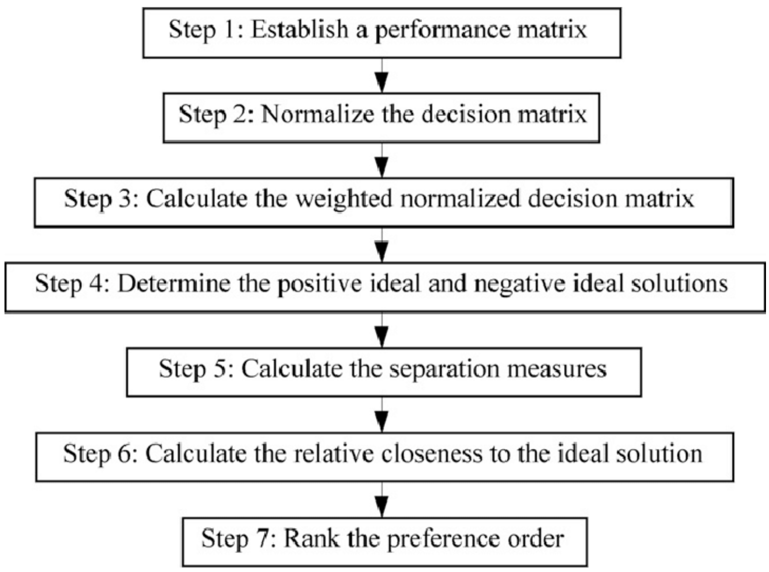

Figure 2. TOPSIS steps.

The construction of the normalized matrix will be as follows:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}} \quad (13)$$

Where: r_{ij} is the normalized value for the qualification of alternative i against criterion j and is the indicator of each alternative i against each indicator j.

For the minimum distance to the positive ideal solution and the maximum distance to the negative ideal solution, it is done according to equations 14 and 15.

$$A^{+} = (x_1^{+}, x_2^{+}, \dots x_{j+l}^{+}) \quad (14)$$

$$A^{-} = (x_1^{-}, x_2^{-}, \dots x_{j+l}^{-} \quad (15)$$

With the normalized values, we proceed to calculate the Euclidean distances of each of the alternatives to the positive ideal solutions and the negative ideal solutions, as shown in 16 and 17:

$$\rho(A^k, A^+) = \| w * (TA^k - TA^+) \| \quad (16)$$

$$\rho(A^k, A^-) = \| w * (TA^k - TA^-) \| \quad (17)$$

Finally, to calculate the Relative Proximity Index (RCi) it is done as follows:

$$RC(A^k, A^i) = \frac{\rho(A^k, A^+)}{\rho(A^k, A^+) + \rho(A^k, A^-)} \quad (18)$$

- Paretto diagram:

The Pareto Chart is a bar graph that illustrates the causes of problems in order of importance and frequency (percentage) of appearance, cost or performance. The Pareto Diagram also allows you to compare the frequency, cost and performance of various categories of a problem. Allows before/after comparison, helping to quantify the impact of actions taken to achieve improvements. It promotes teamwork since the participation of all individuals related to the area is required to analyze the problem, obtain information and carry out actions for its solution. The Pareto Chart is also used to express the costs of each type of defect and the savings achieved through the corrective effect carried out through certain actions. It is a simple and graphic method of analysis that allows to discriminate between the most important causes of a problem (the few and vital) and those that are less so (the many and trivial) so it makes decisions based on the 80-20 proportion [46].

3 Results

As a starting point, questionnaires were prepared in order to determine the primary indicators or bases of the composite indicator. To solve this exercise, we made the following:

1. Determination of the actors (respondents and sample size) as follows:
   - Population: Public Officials: 10%, Authorities: 10%, Atacames Population: 80%
   - Sample: n =$\frac{40000}{(0.1)^2(4000-1)+1} = \frac{40000}{0.01(39\,999)+1} = 99.75 \approx 100\ personas$
2. Verification that an uncertainty problem is present (verified):

Criteria set: $C = \{c_1 \dots c_8\}; m \geq 1; \forall Cm \notin \emptyset, 1 \leq m \leq 6$

Expert set: $E = \{e_1 \dots e_{12}\}; n \geq 1; \forall Em \notin \emptyset, 1 \leq m \leq 100$

Set of alternatives: $A = \{a_1 \dots a_{12}\}; k \geq 1; \forall Ak \notin \emptyset, 1 \leq k \leq 10$

3. Neutrosophic AHP Saaty to determine weights of the criteria on which the experts will be based to evaluate the alternatives of primary indicators:

Criteria	C1	C2	C3	C4	C5	C6
C1	**1**	**⟨6,7,8); 0.90,0.10,0.10⟩**	**⟨6,7,8); 0.90,0.10,0.10⟩**	**⟨6,7,8); 0.90,0.10,0.10⟩**	**⟨7,8,9); 0.85,0.10,0.15⟩**	**⟨5,6,7); 0.70,0.25,0.30⟩**
C2	$\tilde{7}$	**1**	**⟨2,3,4); 0.30,0.75,0.70⟩**	**⟨4,5,6); 0.80,0.15,0.20⟩**	**⟨3,4,5); 0.60,0.35,0.40⟩**	**⟨6,7,8); 0.90,0.10,0.10⟩**
C3	$\tilde{7}$	$\tilde{3}$	**1**	**⟨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⟩**
C4	$\tilde{7}$	$\tilde{5}$	$\tilde{3}$	**1**	**⟨1,1,1); 0.50,0.50,0.50⟩**	**⟨2,3,4); 0.30,0.75,0.70⟩**
C5	$\tilde{8}$	$\tilde{4}$	$\tilde{3}$	$\tilde{1}$	**1**	**⟨1,1,1); 0.50,0.50,0.50⟩**
C6	$\tilde{6}$	$\tilde{7}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	**1**

Criteria	C1	C2	C3	C4	C5	C6	WEIGHT	A x Weight	Eigenvalues approx
C1	0.60	0.79	0.62	0.42	0.48	0.30	0.51381037	3.92	7.632215878
C2	0.08	0.10	0.21	0.30	0.22	0.37	0.214848659	1.46	6.77524613
C3	0.08	0.04	0.08	0.14	0.14	0.12	0.114387057	0.73	6.384170759
C4	0.08	0.02	0.03	0.06	0.05	0.12	0.064888957	0.40	6.151204195
C5	0.07	0.03	0.03	0.06	0.05	0.05	0.04821942	0.31	6.491604374
C6	0.10	0.01	0.03	0.02	0.06	0.05	0.043845539	0.27	6.115818517

eigen value	6.59171
IC	0.12
RC	0.09

Table 3 and 4. Determination of weights of the criteria applying the Neutrosophic AHP method. Source: self made

4. Next, the TOPSIS method is applied to verify the level of participation of the alternatives in the Social Vulnerability composite indicator according to the average evaluations of the evaluation criteria given by the experts consulted.

Alternatives	C1	C2	C3	C4	C5	C6
Percentage of people who moved in the last year	8	8	7	8.5	9	8.9
Average income for each family	8	9	9.5	9.4	8.9	9
Single parent families	10	9.9	10	9	9.5	9.8
Seniors living alone	10	10	10	10	10	10
Residents who are homeowners	10	9.8	9	9.5	9	9.4
Educational level	9.8	9.6	9.7	9.9	9.2	9
Age	5	6	6.1	5.9	5.6	4.9
Percentage of unemployed	7.1	7.9	8.1	8.8	7.4	7
Dependent population	8	7.8	9	8.9	8.6	9.1
Time spent in a specific place	4	5	4.2	4.5	5	4.9
Weights	**0.51381037**	**0.21484866**	**0.11438706**	**0.06488896**	**0.04821942**	**0.04384554**

PIS	NIS
0.197117015	0.078846806
0.197117015	0.098558507
0.197117015	0.082789146
0.197117015	0.088702657
0.197117015	0.098558507
0.197117015	0.096587337

D +	D-	RCi	Priority
0.05575311	0.11150622	0.666666667	6
0.0440767	0.12621647	0.741171637	5
0.00197117	0.16587136	0.988255836	2
0	0.16725933	1	1
0.00394234	0.1644953	0.97659466	3
0.00881534	0.15892082	0.947445196	4
0.12621647	0.0440767	0.258828363	9
0.0705778	0.09820306	0.581837641	8
0.0586071	0.1087543	0.649817095	7
0.15395331	0.0197117	0.113504161	10

Table 5 and 6. TOPSIS data processing. Source: self-made.

For the final discrimination, the experts decided to apply a Paretto, according to the results shown in table 6. From the analysis it was obtained that the most important indicator alternatives for the calculation of the Social Vulnerability composite indicator are:

- Seniors living alone
- Single parent families
- Residents who are homeowners
- Educational level
- Average income for each family
- Percentage of people who moved in the last year
- Dependent population

Conclusion

Once the investigation was completed, the following conclusions were reached:

1. The objective of the investigation is fulfilled since A Neutrosophy composite index of social vulnerability analysis to earthquake hazard in Canton Atacames was determined according to the criteria of experts (officials, specialists and population of the canton).
2. With the inclusion of a composite indicator for the analysis of social vulnerability to disaster preparation and response programs, stakeholder participation initiatives can be taken.
3. The integration of multi-criteria methods under an environment of uncertainty is positive since it provides greater precision to the analysis. In addition, it transforms the values in linguistic terms, which facilitates the obtaining of information by the respondents.
4. The inclusion of expert-determined weights can facilitate the adoption of multicriteria neutrosophic methodologies in disaster planning.

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Neutrosophic Hypothesis to validate a modification for Article 630 of the Integral Organic Criminal Code of Ecuador

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Abstract. In Ecuador, the Conditional Suspension of Sentence is considered a special procedure, whose rules regulate legal acts within society, the investigation of certain crimes and the prosecution of those responsible and, on the other hand, allows for the avoidance of the penalties inherent in the custodial sentence. However, the indiscriminate application of this suspension generates conflict of interests since it can violate the right of the victims to compensation. Based on the foregoing, the present investigation aims to propose a modification for Article 630 of the Integral Criminal Code, which establishes that the conditional suspension of the sentence will not proceed when the crime committed involves death. To this purpose, a neutrosophic hypothesis was applied as a statistical tool to validate the criteria of legal professionals in the city of Babahoyo with regard to the justification and the proposed modification. The results obtained allowed to infer a high qualification about the relevance of the proposal.

Keywords: Conditional Suspension of Sentence, single-value neutrosophic set, neutrosophic hypothesis.

1 Introduction

The punitive and preventive exercise of the State is regulated by criminal law, while the prevailing thinking of society is manifested in the rules that make up the legal system, as a social reflection[1].

The Conditional Suspension of Sentence emerged as a legal figure in some countries, as a procedural mechanism to deal with the social problems related to prison overcrowding.

One element taken into account is the expenditure of state resources on the rehabilitation of those who have transgressed social norms. The States have found it necessary to adapt certain mechanisms so that, based on the proportionality between the crime and the sentence, the need to apply a custodial sentence is verified when in its place, the purpose of the sentence can be achieved, with social rehabilitation and reintegration without the need for imprisonment.

The National Plan for Good Living 2017-2021, called "Rights for All throughout Life," is based on the principle that every human being is a subject of rights, from the beginning of his or her life to the end". However, it is necessary to focus its application on the Ecuadorian legislation, the parameters that govern its adoption, the judicial actors involved in this procedure and the rates of application of the procedure[2, 3].

The analysis of this mechanism should first determine the body of law, mainly the Constitution of the Republic, and the Integral Criminal Code. The importance of the doctrine in criminal matters dealing with the conditional suspension of sentences, in addition to legislation from other countries that also takes into consideration the conditional suspension of sentences [4].

Article 77 of Ecuador's Carta Magna states that "after the person is found guilty, he will serve his sentence in a Social Rehabilitation Center, serving the sentence imposed by the judge or judges, but may also have alternative measures in this type of case[5].

The Conditional Suspension of the Sentence[6] is considered a special procedure, whose rules regulate the legal acts within the society and within an investigation of certain crimes, and prosecutions of those responsible for them. This suspension of sentence may be used to prevent the application of the sanctions inherent to the custodial sentence.

Several authors have defined this legal concept by referring to the history of this legal figure.

The conditional suspension of the sentence is a custodial sentence and this suspension is only given for minor crimes, that is, for less serious crimes that do not cause so much harm to the victim. Many times those who applied for this measure in the past did not enter the prison, replacing the confinement and applied this measure to ensure the rehabilitation of the defendant[7].

In this case, the aforementioned jurist clarifies that it should not be applied to all types of crimes, but only in cases in which, in its effect, the damage received by the victim does not classify the infraction as a serious one. With regard to this specification, other authors made significant contributions to his investigations. Such is the case of Sierra, who expressed "This conditional suspension of the sentence will not apply to those crimes where sexual integrity and legal assets such as life are at stake. Here, the offender or offenders are stigmatized simply because they have committed certain crimes against the legal assets of each human being, which are repugnant to society." [8]

The subjects of the crime are those persons who intervene to commit an illicit act and these will be punished with a penalty equivalent to the degree of responsibility for the act. For this reason, the concept that there are no subjects who participate in the crime to more than one actor, depending on the degree of their participation, is the reason why the proportionality of the punishment is often not taken into account with the crime, because neither participation nor the degree of responsibility is considered[9].

For this reason, when the judges impose the punishment, they must do so in the best possible way so as not to violate any of the rights of the defendants. The motivating sanction establishes the criminal sanctions in which the defendant refrains from adjusting his conduct to the act or deed committed; the causal link that exists between the norms and the criminal types in which it establishes appropriate sanctions for the defendants themselves.

At the same time, however, they must keep in mind that the punitive measure must correspond to the magnitude of the crime committed.

To this end, possible mitigating and aggravating factors must be weighed, which are derived from the circumstances of the crime, and, depending on the nature of the crime, both the existence of the act and the criminal circumstance and the complexity of the crime with which the defendant is charged must be ascertained before a criminal sanction is considered[9-11].

Mitigating circumstances are all those that a prisoner may take advantage of in the case of a less serious crime, and these may reduce the degree of guilt of the person being prosecuted, and thus lead to a reduction of the penalty.

Mitigating factors are the main arguments when applying for the conditional suspension of the sentence. Therefore, the authors propose the following:

LAW REFORMING ARTICLE 630 OF THE INTEGRAL ORGANIC PENAL CODE.

Article 630.- Conditional suspension of the sentence. -

5.- The conditional suspension of the sentence will not proceed in the case of culpable traffic offences resulting in death.

The objective of this work is to validate the proposal and its legal argument by applying a neutrosophic hypothesis test.

2 Materials and methods

The present investigation studied the existing problem in the city of Babahoyo, province of Los Ríos, where hundreds of legal processes have been developed in which defendants have requested the application of the Conditional Suspension of the Sentence. A significant group of specialists on the subject, with vast experience in the type of case mentioned above, was consulted in this city. The composition of the sample, as well as the weights of each type of specialist, are shown in table 1[12-14].

Specialist	Sample	Weight
Lawyers in free practice	52	0.4
Judges of the Babahoyo Criminal Unit	8	0.6

Table 1. Sample composition and weights

A survey composed of 5 statements related to the proposed modification was applied in order to record the value that each specialist assigns to the proposal. The survey used has as a source of fundamental information for statistical inference. Below, we reproduce de 5 statements included in the survey:

1. Sentenced persons have the right to benefit from the Conditional Suspension of Sentence.
2. The indiscriminate application of the Conditional Suspension of Sentences violates the right of the victims to full compensation for the harm suffered.
3. The Conditional Suspension of Sentence should only be applied to certain types of criminal offences established in the regulations.
4. Crimes involving death, regardless of their category, should be excluded from the legal benefit of Conditional Suspension of Sentence.

5. An amendment to Article 630 of the Integral Criminal Code is required, establishing that the Conditional Suspension of Sentence shall not apply when the crime committed involves death.

The fifth affirmation will allow the direct recording of the value that the specialists assign to the proposed reform to Article 630 of the Integral Criminal Organic Code proposed in this investigation. While the first four items allow for the validation of the main elements of the legal argument underlying the proposed reform.

The possible answers were predefined by means of linguistic terms to which Single Value Neutrosophic Sets (SVNS) were assigned, in order to manage the indetermination associated with the process of statistical management of this type of information by applying the necessary elements of neutrality[15-18].

Neutrosophy is a new branch of philosophy, which studies the origin, nature and scope of neutralities, as well as their interactions with different ideational spectra. Neutrosophy have its origin on paradoxism a movement in art and science founded by Florentin Smarandache[19-21].

Smarandache introduced the degree of indeterminacy/neutrality (I) as independent component in 1995 (published in 1998) and he defined the neutrosophic set on three components: (T, I, F)= (Truth, Indeterminacy, Falsehood), where in general T, I, F are subsets of the interval [0, 1]; in particular T, I, F may be intervals, hesitant sets, or single-values[22-24].

It is truly complex to apply the operators of theoretical sets and even more so of the neutrosophic sets. That is why, single value neutrosophic sets (SVNS) were developed to facilitate their use for practical purposes[25, 26].

Below is the definition of a single-value neutrosophic set (SVNS).

Let X be a universe of discourse, a SVNS A over X has the following form[27]:

$$A = \{\langle x, t_a(x), i_a(x), f_a(x)\rangle : x \in X\}d \quad (1)$$

Where

$t_a(x): X \to [0,1], i_a(x): X \to [0,1]\ y\ f_a(x): X \to [0,1]$

with

$0 \leq t_a(x), i_a(x), f_a(x) \leq 3, \forall\ x \in X$

The intervals $t_a(x), i_a(x), f_a(x)$ denote the memberships to true, indeterminate and false from x in A, respectively [4].

To assign a crisp number as a value of a single valued neutrosophic set, a scoring function can be applied. This function will allow operations using a crisp number to contain the degrees of true, indeterminate and false in the SVNS. Although there are several scoring functions in the literature consulted, the one defined below will be used for this research.

Let A = $t_a(x), i_a(x), f_a(x)$ be a single neutrosophic number , a score function s of a single valued neutrosophic number, based on the truth-membership degree, indeterminacy-membership degree and falsehood membership degree is defined by[28]:

$$s(A) = 2 + t_a(x) - i_a(x) - f_a(x) \quad (2)$$

For this investigation will be written:

$$s(V_{ij}) = 2 + t_v(x_{ij}) - i_v(x_{ij}) - f_v(x_{ij}) \quad (3)$$

Where $s(V_{ij})$ is the score of the $SVNS_{ij}$ correspondent to the linguistic term used by the respondent j to value the judicial significance or importance of the i statement.

The linguistic terms, SVNS and the scoring used are shown on Table2.

LINGUISTIC TERM	SVN NUMBERS	SCORING
Extremely High (EH)	(1; 0; 0)	3
Very Very High (VVH)	(0.9, 0.1, 0.1)	2.7
Very High (VH)	(0,8; 0,15; 0,20)	2.45
High (H)	(0.70,0.25,0.30)	2.15
Medium High (MH)	(0,60; 0,35; 0,40)	1.85
Medium (M)	(0,50; 0,50; 0,50)	1.5
Medium Low (ML)	(0,40; 0,65; 0,60)	1.15
Low (L)	(0.30,0.75,0.70)	0.85
Very Low (VL)	(0,20; 0,85; 0,80)	0.55
Very Very Low (VVL)	(0.10,0.90,0.90)	0.3
Extremely Low (EL)	(0; 1; 1)	0

Table 2. Linguistic terms, SVNS and the scoring

Once the sample results are recorded, the weighted average score will be calculated.

Weighted Average Score:

$$was_i = \frac{1}{n}\sum_{j=1}^{n} w_j \cdot s(V_{ij}) \quad (4)$$

Where $w\bar{a}s_i$ is the sample's weighted average score function of the statement i, and w_j is the weight of the respondent's j category.

The was_i is only a sample measure, so it's necessary to demonstrate that the population average parameter is high enough to state that the elements of the judicial argument and the reform to Article 630 of the Integral Organic Criminal Code proposed in this research has a high or greater value for the population of the professionals of the Babahoyo city[4].

Now we must apply a Neutrosophic Hypothesis Test for the population media to estimate the acceptance of the proposal at a population level.

A Neutrosophic Hypothesis is a statement about the neutrosophic values of a single or several population characteristics[29] .

A Neutrosophic Null Hypothesis, denoted by NH_0, is the statement that is initially assumed to be true. While the Neutrosophic Alternative Hypothesis, denoted by NH_a, is the researcher hypothesis, similarly to the classical statistics.

In our particular case, we use the following Neutrosophic Hypothesis form:

$NH_0: \mu \in [a, b]$

$NH_a: \mu > b$

Where μ is the population weighted average score (WAS_i).

The z-critical value, will be calculated by the equation[30] :

$$z = \frac{\bar{x} - [a, b]}{s/\sqrt{n}} \quad (5)$$

A Neutrosophic Level of Significance α, [31]which may be a set, not necessarily a crisp number as in classical statistics. For this research we will assume the set of asymptotic significance level, $[0.95, 0.99]$, which implies the set $\alpha_N = [0.01, 0.05]$.

3 Results

A group of fifteen experts in the field of study was selected for the application of the Neutrosophic TOPSIS technique. They are free practice lawyers and public defenders from the Public Defender's Office in the Criminal Area of the Babahoyo canton, registered with the Los Ríos Bar Association, 40% of which, are women.

The lawyers and judges surveyed from the city of Babahoyo are professionals with vast experience in their profession. They alleged active and repeated participation in trials where the right to the legal benefit of Conditional Suspension of Sentence was invoked. Hence, their criteria are considered as key resources to support the results of this research.

After the application of the survey, preliminary statistical data on the results of the study were obtained, which are shown in the following table of frequencies.

	Frequencies				
Linguistic term	**Statement 1**	**Statement 2**	**Statement 3**	**Statement 4**	**Statement 5**
Extremely High (EH)	14	11	12	14	16
Very Very High (VVH)	12	14	15	14	17
Very High (VH)	14	15	18	17	16
High (H)	10	8	7	10	8
Medium High (MH)	10	12	8	5	3
Medium (M)	-	-	-	-	-
Medium Low (ML)	-	-	-	-	-
Low (L)	-	-	-	-	-
Very Low (VL)	-	-	-	-	-
Very Very Low (VVL)	-	-	-	-	-
Extremely Low (EL)	-	-	-	-	-
Total	**60**	**60**	**60**	**60**	**60**

Table 3. Frequency table

As we can see, all the results are higher than "Medium High" (MH). Therefore, it can be stated that the selected sample grants a high value to the proposal.

In order to avoid the use of aggregation functions in this work, we proceeded to calculate that of each of the responses given by the respondents and this was summarized in figure 1.

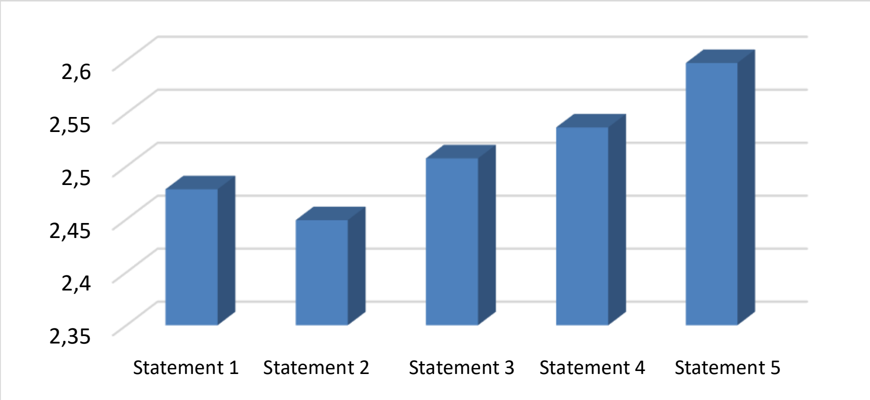

Figure 1. Weighted average score

In all cases a weighted average value of the score obtained, was higher than 2.44, which confirms the conclusion drawn from the frequency table (Table 3). In the case of statement number 5, it has the highest value of all statements, and it is can be qualified, at sample level, as evaluated with a very high importance, according to table 2.

In order to validate the proposal at a population level, the following test of a given neutrosophic hypothesis was proposed setting $\alpha_N = [0.01\,, 0.05]$.

$NH_0 : \mu \in [0\,, 1.85]$

$NH_a : \mu > 1.85$

The following is the result of the test for statement number 5 of the applied survey.

Applying the decision criterion:

Reject $NH_0\ if\ min\{z - critical\} > \max\{Z_{1-\alpha_N}\}$, applying (5), was obtained $Z = 10.6 > \max\{Z_{1-\alpha_N}\} = 2.326$, so the decision to reject NH_0 for the significance level $\alpha_N = [0.01\,, 0.05]$.

Similar results were obtained for the rest of the elements submitted to the specialists' criteria. Therefore, it can be affirmed that, at the population level, both the argumentative elements and the proposed reform to Article 630 will have a positive acceptance among the legal professionals of the city of Babahoyo.

Conclusions

The application of the Neutrosophic Hypothesis Test, allowed positively validating the result of this research with a level of significance of up to 99%.

The proposed reform to article 630 of the Integral Organic Penal Code and the argumentation of it have a high relevance for the lawyers and judges of the city of Babahoyo.

The reform proposed would help those who have been victims because their relatives have died as a result of a crime and the offenders take advantage of the conditional suspension of the sentence. The victims are expressly dissatisfied with the expected retribution for the loss they suffered.

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Opportunities for Software Testing using Neutrosophic Numbers

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Abstract. For software development companies, deciding which development methodology to use when starting a project is in many cases an important task to perform. The selection of development methodology can be modeled as a decision-making problem. Neutrosophy is a philosophical current that starts from Paradoxism. In this article, we describe a methodology selection proposal using neutrosophic numbers, from which the development methodology proposal is decided. The method allows taking into account the indeterminacy in decision-making, in addition to the use of linguistic terms that are more appropriate than numerical ones. The applicability of the proposal is confirmed through a demonstrative example. The paper ends with the conclusions and recommendations for future work.

Keywords: Agile Methodologies, Microsoft Solutions Framework, validation tests, neutrosophic numbers.

1. Introduction

Agile methodologies are an established topic in software engineering that have aroused interest and acceptance in their application in short-term projects with changing requirements, the traditional scheme requires a rigorous definition of roles, activities and artifacts accompanied by modeling and detailed documentation [1]. *The Agile Alliance* is a non-profit organization dedicated to promoting the concepts related to agile software development and helping organizations to adopt these concepts. The starting point was the Agile Manifesto, a document that summarizes the agile philosophy[2],[3].

According to the Manifesto, the individual and the interactions of the development team on the process and tools are valued. People are the main success factor of a software project. It is more important to build a good team than to build the environment. Many times people make the mistake of building the environment first and expecting the team to adapt automatically. It is better to create the team and have it configure its own development environment based on your needs [4, 5].

Developing software that works, rather than getting good documentation. The rule of thumb is not to produce documents unless they are immediately needed to make an important decision. These documents should be short and focus on the fundamentals. Collaboration with the client is more than negotiating a contract. It is proposed that there is a constant interaction between the client and the development team. This collaboration between both the client and the team will be what guides the progress of the project and ensures its success.

It is about reacting to changes, rather than strictly following a plan [6, 7]. The ability to react to changes that may arise throughout the project (changes in requirements, technology, equipment, etc.) also determines the success or failure of the project. Therefore, planning should not be strict but flexible and open.

The above values inspire the twelve principles of the manifesto. These are characteristics that differentiate an agile process from a traditional one. The first two principles are general and summarize much of the agile spirit. The rest have to do with the process to be followed and the development team, in terms of goals to follow and its organization. The principles are:

The priority is to satisfy the customer through early and continuous releases of software that adds value.

- Welcome changes. Changes are captured so that the customer has a competitive advantage.
- Frequently deliver software that runs from two weeks to two months, with the shortest possible time interval between deliveries.
- The business team and the developers must work together throughout the project.
- Build the project around motivated individuals. Give them the environment and support they need and trust them to get the job done.
- Face-to-face dialogue is the most efficient and effective method of communicating information within a development team.
- Software that works is the main measure of progress.
- Agile processes promote sustainable development. Promoters, developers and users should be able to maintain constant peace.
- Permanent attention to technical quality and good design improves agility.
- Simplicity is essential.
- The best architectures, requirements, and designs come from self-organizing teams.
- At regular intervals, the team reflects about how to become more effective, and adjusts its behavior accordingly.

Agile methodology	Traditional methodology
Based on heuristics from code production practices	Based on standards followed by the development environment.
Specially prepared for changes during the project	Some resistance to change
Internally imposed by the team	Externally imposed
Less controlled process, with few principles	Much more controlled process, with numerous policies and regulations
There is no traditional contract or at least quite flexible	There is a predetermined contract
Small groups (-10 members) and working in the same place	Large groups and possibly distributed
Few artifacts	More artifacts
Few roles	More roles
Less emphasis on software architecture	Software architecture is essential and is expressed through models

Table 1. Comparison between agile and "heavy" methodologies

The present research proposes a method based on neutrosophic numbers [8-10]such that the different alternatives based on scenarios are evaluated by a group of experts according to evaluation criteria. The method includes the indeterminacy of decision-making, in addition to allowing calculation with the help of a linguistic scale, which is more suitable for human evaluators.

The article consists of the following sections: Section 2 delves into different aspects of the Microsoft Solutions Framework, recalls the concepts of the neutrosophic number and introduces the method that we will apply. Section 3 contains some additional details and the application of the method in an example. At the end of the paper, we state the conclusions.

2 Preliminaries

The section presents the theoretical bases for understanding the research proposal. Describes the Microsoft Solutions Framework for Agile Application Development. Introduces the associated theory about software testers, validation testing. Finally, we describe the neutrosophic numbers in the context of the present investigation for the selection of the methodology [11-13].

2.1 Microsoft Solutions Framework

Microsoft Solutions Framework (MSF) for the Development of Agile Applications, is Microsoft's proposal for the development of applications using an agile methodology; which incorporates practices to manipulate quality of service (QoS) requirements, such as performance and security[14, 15].

The phases of the MSF are:

Phase 1 - Strategy and scope

Phase 2 - Planning and proof of concept

Phase 3 - Stabilization

Phase 4 - Deployment

The roles in MSF Agile. In the MSF team model there are no hierarchies, they are all equally important. The recommended roles are:

- Business analyst
- Project manager
- Architect
- Developer
- Testing staff
- Deployment personnel
- Experienced users

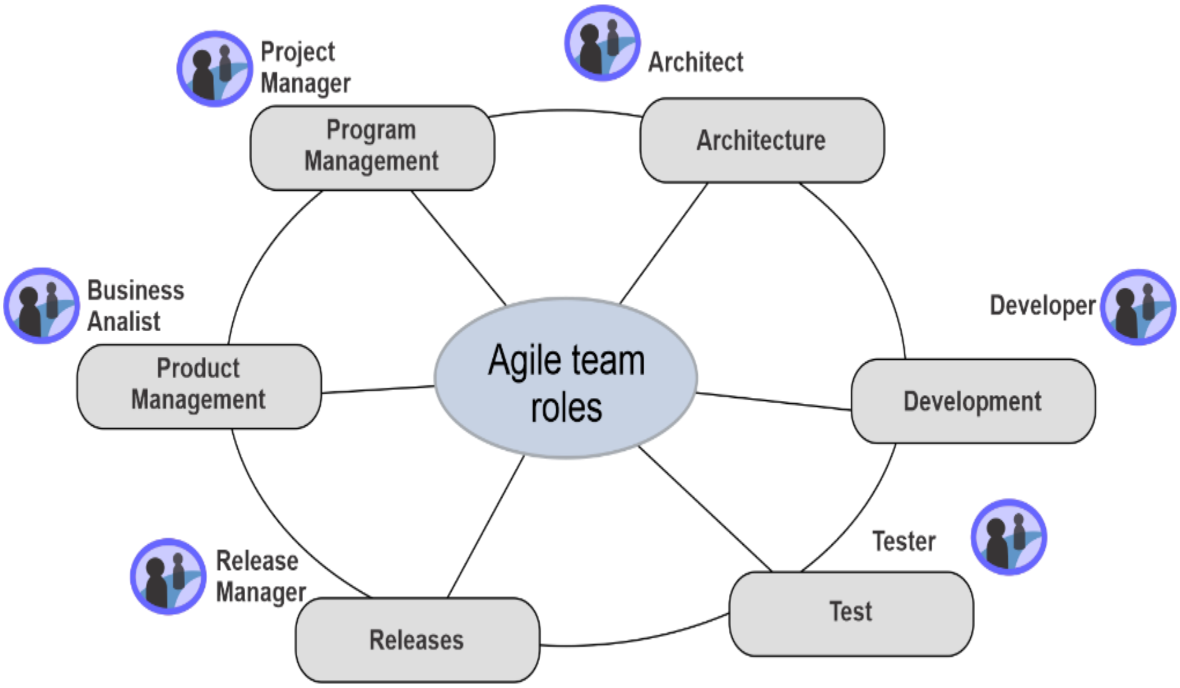

Figure 1. MSF Roles for Agile Application Development

This team of specialists, with different roles, meets on behalf of all the members involved with the production, use and maintenance of the product. Each member of the team, or each role, is responsible for representing the specific needs of all members of their group and none is more important than another. These meetings provide the necessary balances and checks to ensure that a true solution is produced. Figure 1 shows the composition of the team of specialists.

2.2 Software Testers

The test staff manages the test area in MSF Team Model. Their primary goal is to find and report product issues that could adversely affect its value. Test personnel must understand the context of the project and help others base their decisions on that context. A key objective of the test personnel is to locate the significant errors that the product may present during the test phase and to report accordingly. Once a bug is found, it is also up to the testing staff to accurately communicate its consequences and describe workarounds that would reduce its impact. They should write descriptions of the errors and the steps necessary to reproduce them, easy to understand and to follow. They also participate with the rest of the team in defining the quality standards for the product. The purpose of the tests is to see if known functions are working correctly and to discover new problems.

The test staff workflow is as follows:

- Analysis
- Close errors
- Documentation development
- Establishment of test environments
- Establishment of the project process
- Product Launch
- Proof of a customer requirement
- Checking a product requirement

2.3 Scenario testers

A scenario is divided into test tasks and development tasks and testers are in charge of developing and executing the test cases. Assigning a scenario to test indicates that the functionality has been integrated into a framework and is ready to be tested.[16], [17]. Validating that a structure reflects the intended functionality of the scenario requires an understanding of the scenario and its boundary conditions; so the validation tests should be written to cover the full functionality as well as the boundary condition of the scenario and will be executed while bugs are reported

What to do to test scenarios?

MSF proposes a set of activities that must be carried out to test scenarios:

Define test approach

A test approach is a strategy that guides the test plan and its execution, while determining the quality models for packaging the product.[18], [19]. The test approach activities are a starting point for the project's anticipated test plan, but it evolves and changes with it. A test approach should include a mix of techniques, including manual and automated tests, and prior to each iteration, the test approach document should be updated to reflect the goals of the iteration testing and the test data that will be employees.

The sub-activities defined for this activity are:

- Determine the context of the project: The risks of the project and the users that these could affect are identified, as well as the special situations that could affect the level of verification necessary. What is at risk and its impact, should the product fail, must be determined.
- Determine the mission of the test: The goals of the project to be satisfied through the tests are identified, consulting with the architect and business analyst on technical uncertainties and user risks.
- Evaluate possible testing techniques: The tools available for testing, as well as the skills of the test team, should be evaluated to determine possible and appropriate testing techniques for the project.
- Define test metrics: You should use the project context, test mission, and test techniques to determine test metrics. These metrics will include the thresholds for the various types of tests (load, throughput, etc.) or the percentage of automated tests.

2.4 Validation tests

The validation tests ensure the functionality of the system, take a "black box" view of the application and focus on the areas most important to the end user in order to check the functionality corresponds to what is written on the scenario[20, 21]. Writing test cases for validation tests helps testers identify problems using test mechanisms that mimic the real world.

To write a validation test, you must consider the following aspects:

- Identify the test area and environment: Isolate the area where the test will be run. Iteration tests are the set of automated test cases that run after the functionality validation tests. However, a feature does not have to pass this test to be successful. Tests can be run as part of iteration tests if they are automated.
- Identify the details of the test case flow: Identify the test data required for each test case, based on the test approach report, as well as the constraints and boundary conditions for the test cases required in the tasks test. Check if test cases can be automated and identify procedural steps for the scenario flow.
- Write test cases: Write test documentation for test case manuals and automated test cases for iteration tests.
- Other activities to be executed are: the selection of a test case to run it, discovering a possible bug and carrying out exploratory tests refers to the point dedicated to testing the quality of service requirements.

2.5 Neutrosophic numbers for the determination of opportunities in the application of tests

The determination of opportunities in the application of software tests can be modeled as a multi-criteria decision-making problem[22, 23]. From which there is a set of alternatives that represent software development tests $\mathrm{A}=\{\mathrm{A}_1,\ldots \mathrm{A}_\mathrm{n}\},\ \mathrm{n}\geq 2$; which are evaluated based on the set of criteria $\mathrm{C}=\{\mathrm{C}_1,\ldots \mathrm{C}_\mathrm{m}\},\ \mathrm{m}\geq 2$ that characterize the project [10, 24, 25].

The solution is defined with a spectrum that represents the true preference to use a test type with a degree of falsehood and a degree of denial. Problems of this nature have been modeled as a neutrosophic problem.

Neutrosophy is a philosophical current that starts from Paradoxism [26]. In the 1980s, the international movement called Paradoxism developed [27], based on contradictions in science art, was founded by Romanian author Florentin Smarandache currently living in the United States who later extended it to Neutrosophy, based on contradictions and their neutrals with multiple practical applications [26, 28-31].

Neutrosophy allows the representation of neutrality, it was proposed by Smarandache[32]. It represents the basis for a series of mathematical theories that generalize classical and fuzzy theories such as neutrosophic sets and neutrosophic logic. A neutrosophic number (N) is represented as follows [11-13, 33, 34]:

Let $N = \{(T, I, F): T, I, F \subseteq [0,1]\}$, a neutrosophic valuation is a mapping of a group of propositional formulas over N, that is, for each proposition p we have

$$v\,(p) = (T, I, F) \tag{1}$$

Where:
T: represents the degree of truth,
I: represents the degree of indeterminacy,
F: represents the degree of falsehood.
The main evaluation criteria that are taken into account for the selection of the test are made up of the following 5 indicators:
c_1Redundancy,
c_2Complexity,
c_3Dynamism,
c_4Specialization,
c_5Personal.
The linguistic terms that are used to measure the importance of such criteria are summarized in Table 2.

Linguistic term	Value
Not important	(0.10,0.90,0.90)
Less important	(0.20,0.85,0.80)
Slightly important	(0.30,0.75,0.70)
Somewhat important	(0.40,0.65,0.60)
Average importance	(0.50,0.50,0.50)
Important	(0.60,0.35,0.40)
Very important	(0.70,0.25,0.30)
Strongly important	(0.8,0,15,0.20)
Very strongly important	(0.9, 0.1, 0.1)
Extremely important	(1,0,0)

Table 2. Domain of values to assign weight to the criteria.

The linguistic terms [35, 36] we used to evaluate the criteria are summarized in Table 3..

Linguistic term	Neutrosophic number
Extremely good (EG)	(1,0,0)
Very Very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0.15,0.20)
Good (G)	(0.70,0.25,0.30)
Medium good (MDG)	(0.60,0.35,0.40)
Medium (M)	(0.50,0.50,0.50)
Medium bad (MDB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very Very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 3. Linguistic terms used.

1. If it is the group of experts who evaluate the software, then we have the following steps to carry out the evaluation of the alternatives: $E = \{E_1, E_2, \cdots, E_l\}$
2. The experts evaluate the importance of each criterion according to the scale that appears in Table 2. Let $\widetilde{W}_i = (\widetilde{w}_{i1}, \widetilde{w}_{i2}, \cdots, \widetilde{w}_{im})\widetilde{w}_{ij}$ (i = 1,2, .., l) be the vector of the evaluations provided by the i-th expert on the criteria, where $\widetilde{w}_{ij}$ is the element of Table 2 such that the i-th expert selected the degree of importance of the j-th criterion.

The aggregation vector of the weights is calculated by the following formula:

$$\widetilde{W} = \left(\frac{\sum_{i=1}^{l} \widetilde{w}_{i1}}{l}, \frac{\sum_{i=1}^{l} \widetilde{w}_{i2}}{l}, \cdots, \frac{\sum_{i=1}^{l} \widetilde{w}_{im}}{l}\right) \tag{2}$$

3. The experts evaluate the alternatives regarding to the criteria according to the linguistic scale that appears in Table 3. Let us call $\tilde{x}_{ijk}$ the element of Table 3, which corresponds to the evaluation given by the i-th expert according to the j-th criterion on the alternative k-th.
4. For each alternative, we calculate:

$$\tilde{b}_k = \frac{\sum_{i=1}^{l}\sum_{j=1}^{m}\tilde{w}_j \wedge_N \tilde{x}_{ijk}}{lm} \quad (3)$$

Where is the j-th element of the vector, while is the n-norm defined by Equation 4.

$$(T_1, I_1, F_1)\wedge_N(T_2, I_2, F_2) = \left(min(T_1, T_2), max(I_1, I_2), max(F_1, F_2)\right) \quad (4)$$

For each alternative, the score of the neutrosophic number obtained in Equation 3 is calculated, which is a crisp value that is calculated by formula 5.

$$s(\tilde{b}_k) = \frac{1}{3}(2 + T_k - I_k - F_k) \quad (5)$$

Where, $.\tilde{b}_k = (T_k, I_k, F_k)$

The preferred alternatives are those with a higher value of $s(\tilde{b}_k)$

3 Implementation of quality of service (QoS) tests

To validate that a structure reflects the constraints provided in the quality of service requirements, knowledge beyond the constraint is needed and that the performance, safety, stress and load tests are completed and none are blocked. MSF proposes a set of activities that must be carried out to test the quality of service requirements: The test approach was already described when we dealt with the scenario tests, in which it was said that it is the step that precedes the creation of the plan of tests. The test plan allows you to specify what you want to test and how to run and measure the progress of those tests.

To define a performance test, the following sub-activities must be carried out:

Understand the purpose of the test

Specify test settings: Configuration variables include hardware, operating system, software, and other features that are important to use in running tests. Each test configuration can represent one test matrix entry. See figure 2.

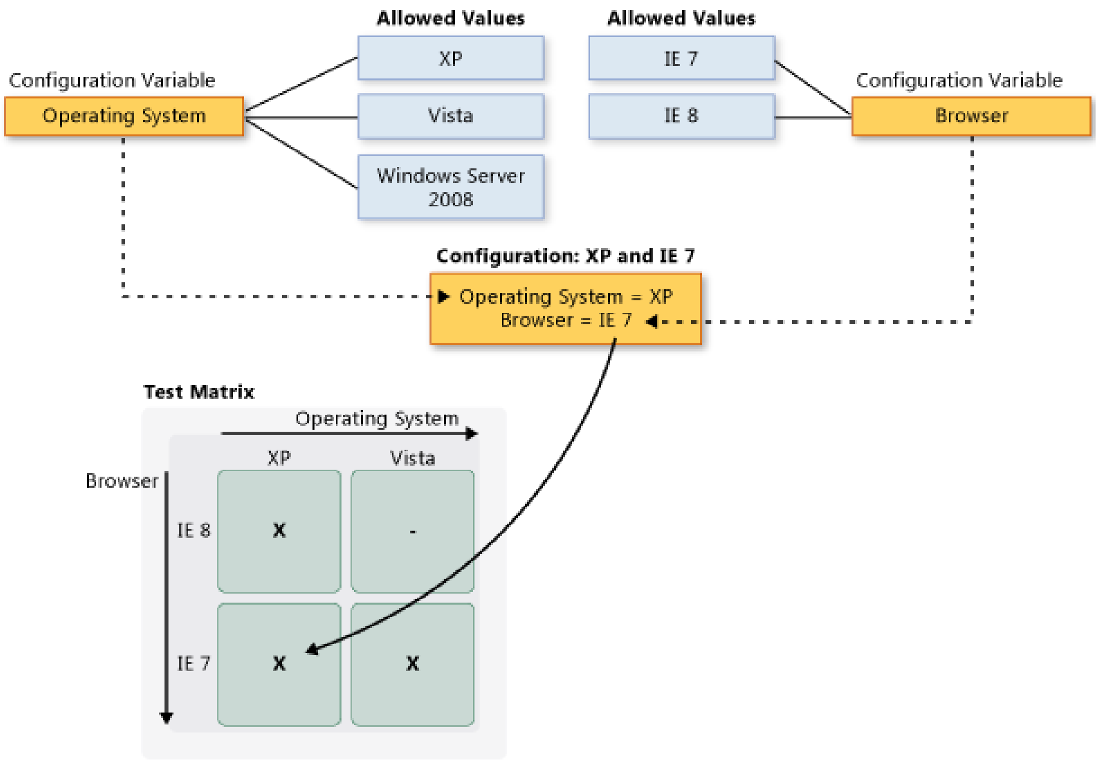

Figure 2. Test configuration variables.

Design the test: The test conditions should be mapped including the prerequisites and the scheduled scenario that needs to be reviewed to determine in which areas performance may be critical.

Security testing or penetration testing uses the threats found in the threat modeling process to simulate an attempt by the adversary to attack the product. This form of testing can be divided into three parts: exploration, identification of the defect and exploitation. Penetration testing may discover new vulnerabilities that become security requirements or errors in the attempt to block entry points and subsequent access to assets.

This form of testing requires special abilities to be able to think and act like the adversary. Stress testing determines an application's breakpoints and pushes the application beyond its upper limit where resources are saturated. They are used to identify the upper limits of application load where the application response has degraded to an unacceptable level or has completely failed.

A stress test is a type of performance test. They can be used to predict application behavior and to validate an application's stability and reliability by running load tests over an extended period of time.

A load test is another type of performance test. Load testing helps to ensure that the application meets your QoS requirements under load conditions. When running load tests, it is common to focus on high traffic areas, 20% of the application being used 80% of the time.

Exploratory testing is a systematic way to test a product, the objective is to discover new scenarios or new service quality requirements. It is important to define a time limit range for the test and to keep a log.

Two other activities to be performed by testers are: Select and run a test case and discover a bug.

Example 1:

This section describes an example to demonstrate the applicability of the proposed method in a test type selection case. The example presents the fundamental elements synthesized to facilitate the understanding of the readers.

After the consultation with 3 experts, the vectors of importance W attributed to each indicator were obtained. Table 4 shows the resulting activity values.

Indicators	**W**
1	(0.63,0.33,0.37)
2	(0.85,0.12,0.15)
3	(0.74,0.20,0.26)
4	(0.88,0.13, 0.12)
5	(0.94,0.02, 0.06)

Table 4. Weights determined for the indicators.

A processing of the evaluations on the fulfillment of the criteria is carried out.

In this example, we will compare three alternatives that are evaluated according to the 5 criteria by the 3 experts. This can be seen in Table 5, 6 and 7, corresponding to the evaluations by each expert, respectively.

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**
A1	MDG	M	B	G	G
A2	VG	MDG	M	B	VB
A3	MDB	M	M	M	MDG

Table 5. Result of the preferences of expert 1.

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**
A1	M	MDG	VB	VG	VG
A2	G	M	MDG	MDB	B
A3	M	MDG	M	M	M

Table 6. Result of the preferences of expert 2.

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**
A1	G	MDG	MDB	VG	G
A2	G	M	MDG	VB	B
A3	M	MDB	M	MDG	MDG

Table7. Result of the preferences of expert 3.

From the result of the preferences, three neutrosophic numbers were obtained, one for each alternative, these are the following:

$\tilde{b}_1 = (0.58867, 0.38867, 0.41133)$,,.$\tilde{b}_2 = (0.45933, 0.54267, 0.54067)$ $\tilde{b}_3 = (0.51333, 0.48000, 0.48667)$

The scores of each of the vectors by alternatives yielded this result:

$s(\tilde{b}_1) = 0.59622$, $s(\tilde{b}_2) = 0.45867$, and $s(\tilde{b}_3) = 0.51556$. Then A1 is preferred, then A2 and lastly A3.

The result expresses that the recommendation is towards the use of dynamic tests.

From the selection of the dynamic test, the test process starts.

For the specific case of testing, it can be said that MSF Agile grants great importance to testing and allows use of the tools integrated into Visual Studio (VS), although other tools can be used as well.

Tests can be run inside and outside VS.Net.

Internally: Test Manager and Test Results

Externally: MSBuild (script)

VS Team Suite allows the creation of WorkItems (tasks and/or bugs) associated with the execution of the tests

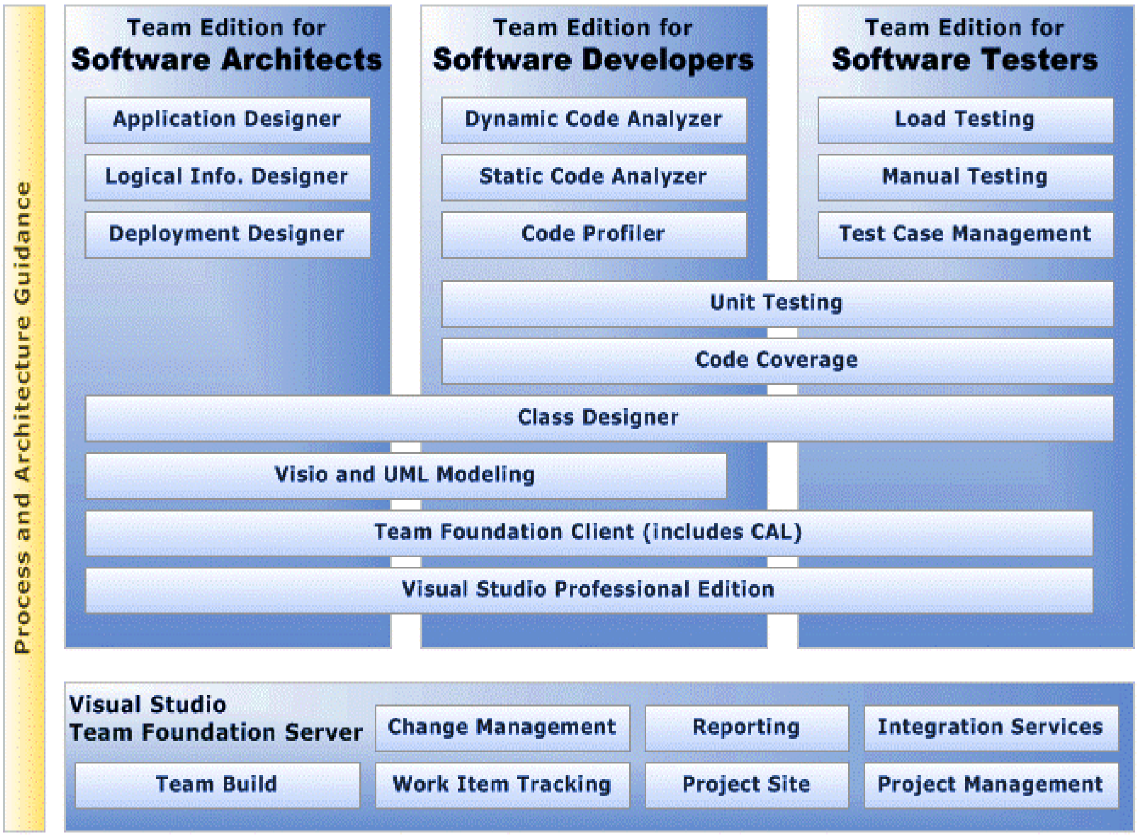

Figure 3. Visual Studio Team Suite as a support tool

VSTS has functionalities for testing Web applications. From Visual Studio you can record a navigation to later add rules to validate the responses. It also has capabilities for generating load tests by defining scenarios.

4. Conclusions

Determining opportunities in the software testing application represents an important task in the early development process. This knowledge constitutes a discrete decision problem that can be modeled using neutrosophic numbers.

Microsoft Solutions Framework represents an agile methodology that provides a closer relationship with customers and seeks that all products are deliverable. A flexible, easy-to-use methodology tends to simplify project management for small and short-term applications. In this article, a multi-criteria decision-making method was proposed for the measurement of alternatives on the Microsoft Solutions Framework methodology. The method allows taking into account indeterminacy in decision-making, in addition to the use of linguistic terms that are more appropriate than numerical terms. As future work, the use of a consensus-based group decision-making model is planned.

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Neutrosophic Multicriteria Method for Evaluating the Impact of Informal Trade on the "Mariscal de Puyo" Market

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Abstract. When people from different backgrounds offer products and services to the general public without complying with the legal parameters that a business requires, they generate a phenomenon known as the Informal Trade. In the "Mariscal de Puyo" market, there has been a flourishing of the informal trade for the commercialization of basic needs, which is gaining space in the internal supply chain of Ecuador. Quantifying its impact on society represents a task little tackled by science. This research proposes a solution to the posed problem by developing a method to evaluate the impact of informal trade. The proposed method bases its operation on a neutrosophic multi-criteria approach. A case study is implemented with the purpose of measuring the impact of informal trade on the "Mariscal de Puyo" market.

Keywords: Multi-criteria decision-making, single-valued neutrosophic set, informal trade.

1. Introduction

The progress of the mercantile society is directly related to the levels of commerce with which economic transactions are carried out [1]. Economic transactions can be managed through a formal or informal market. The informal market has increased and expanded its forms of management in the diverse regions of Ecuador [2, 3].

After the expansion of informal markets, the community changes the perspective on this type of commercial form [4, 5]. Informal trade is characterized by the following aspects [6, 7]:

- Informal management of sales or services.
- A considerable movement of cash and non-commercial bank transactions.
- Evidence of a relationship with poverty, lack of production in the region.
- The development of creativity due to the need to find a profitable way to work.

Informal trade represents the performance of economic or service activities that are kept fundamentally hidden from The State administration, which brings along a set of legal consequences and support for society since people do not have guarantees on the products obtained in such market, although it is obvious that the level of accessibility reaches a greater number of people [8, 9].

Based on the situation described above, this research aims to develop a method for evaluating the impact of informal trade. The proposed method consist of a multi-criteria approach based on evaluative criteria for evaluation.

The international movement known as Paradoxism based on contradictions in science and literature, was founded by Florentin Smarandache, who then extended it to Neutrosophy, which is a science that studies contradictions and their neutrals [10]. To model with single-valued neutrosophic sets makes it possible to make decisions considering indeterminate terms. This is a way to evaluate more reliable than using fuzzy sets, because experts' knowledge is usually full of unclear information, contradiction or inconsistency.

The present paper is divided in the following sections: Section of Materials and Methods contains the basic concepts and the design of the proposed method. Section of Results is dedicated to apply the proposed model to the actual situation of informal trade in the "Mariscal de Puyo" market. We end the paper with the conclusions.

2. Materials and Methods

This section describes the operation of the proposed method to assess the impact of informal trade. We also present the general characteristics of the proposed solution. The main stages and activities that make up the method are described below.

The method for the evaluation of the impact of informal trade is designed under a group of qualities [11]. The qualities that distinguish the method are:

- Integration: the method guarantees the interconnection of the different components as a whole for the evaluation of the impact of informal trade.
- Flexibility: uses 2-tuples to represent uncertainty so as to increase the interoperability of the experts who interact with the method.
- Interdependence: the method uses the input data provided by the experts as a starting point. The analyzed results contribute to a base of experience that forms the core of the inference process.

The method is based on the principles:

- Identification through the team of experts of the indicators to evaluate the impact of informal trade.
- Definition and processing under a multi-criteria approach.
- The use of multi-criteria methods in the evaluation.

The method to assess the impact of informal trade, is structured to manage the workflow of the evaluation process based on a multi-criteria inference method. It has three fundamental stages: input, processing and output of information [12]. Figure 1 shows a diagram illustrating the general operation of the method.

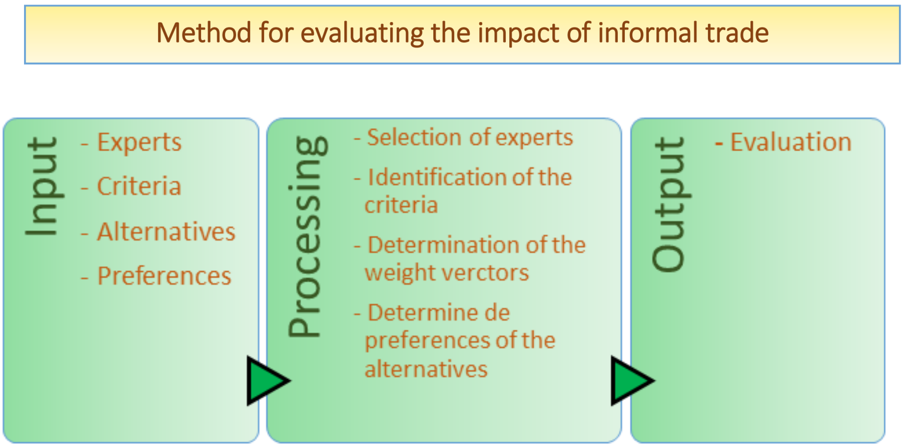

Figure 1. General scheme of the method.

2.1 Description of the stages

The proposed method is designed to ensure workflow management for the informal trade impact assessment process. It uses a multi-expert multi-criteria approach where evaluative indicators are identified to determine the operation of the method.

The processing stage is structured in four activities that control the inference process. Figure 2 shows a diagram with the activities of the processing stage.

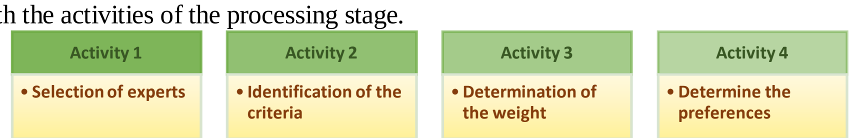

Figure 2. Processing stage activities.

Activity 1 Selection of experts:

The process consists of determining the group of experts involved in the process. For the selection, we used the methodology proposed by Fernández [13]. To start the process, a model is sent to potential experts with a brief explanation of the objectives of the work and the area of knowledge in which the research is focused. Then the following activities are carried out:

Experts are contacted and asked to participate in the panel. The activity results in the recruitment of the group of experts who will participate in the application of the method.

The process should filter out the experts having a low level of expertise, rather choosing those with more knowledge and prestige in the subject of the research. To execute the filtering process, experts carry out a self-evaluation questionnaire. The objective is to determine the knowledge or information coefficient (K_c) they have. Equation 1 expresses the method to determine the level of expertise

$$K_c \in (0,1) \tag{1}$$

Where:

K_c: Knowledge or information coefficient,

Activity 2 Identification of the criteria:

Once the experts involved in the process and the evaluation criteria have been identified, we move on to the next step. The criteria represent the input parameters used in the processing stage. From the experts work group, the following activities are carried out:

A questionnaire is sent to the panel members and they are asked for their opinion of the selection of the evaluation criteria supporting the research. From a previously prepared questionnaire, the set of experts' criteria is obtained.

Responses are analyzed and the areas in which they agree and disagree are identified. This activity let us analyze the behavior of the answers issued by the experts and identify the common elements.

The summary analysis of all the responses is sent to the members of the panel, and they are asked to fill out the questionnaire again and give explanations on the opinions they differ. This allows obtaining a new assessment from the group of experts on the knowledge collected and summarized.

The process is repeated until the responses stabilize. The activity represents the method's stop condition, from which the responses are stabilized. Once the condition is reached, its application is concluded, considering this the general result.

The activity results in the set of evaluative criteria of the method. A multi-criteria approach expressed as $C = \{c_1, c_2, , , c_m\}$ as a set of criteria, where $m > 1$.

Activity 3 Determination of the weight vectors of the criteria:

The experts group involved in the process determine the weights attributed to the evaluation criteria. They are asked to assess the importance level attributed to the evaluation criteria identified in the previous activity.

The weights of the evaluation criteria are expressed by a domain of *single-valued neutrosophic numbers*.

This is defined by the following expressions:

Definition 1: ([14]) Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow \,]^-0, 1^+[$, which satisfy the condition $^-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3^+$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indetermination and falseness of x in A, respectively, and their images are standard or non-standard subsets of $]^-0, 1^+[$.

NS are useful only as a philosophical approach, so *Single-Valued Neutrosophic Set* is defined to guarantee the applicability of Neutrosophy, see Definition 2.

Definition 2: ([14]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is an object of the form:

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

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 membership functions of truthfulness, indetermination and falseness of x in A, respectively. For convenience a *Single-Valued Neutrosophic Number* (SVNN) will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$ and satisfies $0 \leq a + b + c \leq 3$.

Neutrosophic Logic (NL) extends fuzzy logic. As stated by Florentin Smarandache a proposition P is characterized by three components; see[15]:

$$NL(P) = (T,I,F) \tag{2}$$

Where component T is the degree of truthfulness, F is the degree of falsehood and I is the degree of indetermination. T, I, and F belong to the interval [0, 1], and they are independent from each other.

Linguistic terms are used to increase interpretability when determining the weight vectors associated to the criteria [16, 17]. Table 1 shows the set of linguistic terms with their respective values.

Linguistic term	Value
No important	(0.10,0.90,0.90)
Less important	(0.20,0.85,0.80)
Slightly important	(0.30,0.75,0.70)
Somewhat important	(0.40,0.65,0.60)
Average importance	(0.50,0.50,0.50)
Important	(0.60,0.35,0.40)
Very important	(0.70,0.25,0.30)
Strongly important	(0.8,0,15,0.20)
Very strongly important	(0.9, 0.1, 0.1)
Extremely important	(1,0,0)

Table 1. Domain of values to assign weight to the criteria.

Once the weight vectors of each expert involved in the process have been obtained, an information aggregation process is carried out using an average function as shown in Equation 3.

$$w_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \tag{3}$$

Where:
w_j: is the aggregated value, that is to say, the weight of the j-th criteria.
n : is the number of experts involved in the process,
x_{ij}: is the evaluation expressed by expert i on the criteria C_j.
To obtain a crisp value from a single-valued neutrosophic number the following formula can be applied:

$$\boldsymbol{S}(\mathrm{T},\mathrm{I},\mathrm{F}) = \frac{1}{3}(2+\mathrm{T}-\mathrm{I}-\mathrm{F}) \tag{4}$$

Activity 4 Determine the preferences of the alternatives:

The activity to determine preferences consists of identifying the impact that the evaluation criteria have on the studied phenomenon.

For the evaluation of the impact of informal trade, the problem and the evaluation of each alternative from which the evaluation matrix is formed are described [18-20]. The matrix is made up of the alternatives, the criteria and the evaluation of each criterion for each alternative. Figure 3 shows the output of the proposed decision-making problem.

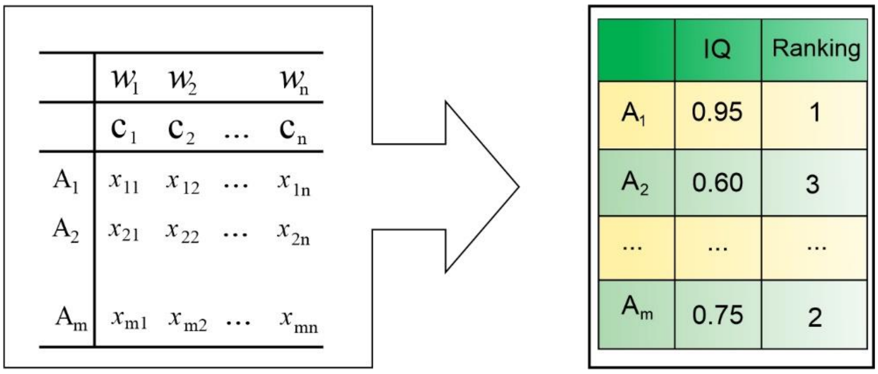

Figure 3. Proposed decision making problem.

After obtaining the preferences of each evaluative criterion about the object of study, we carry out the information inference process. Inference is guided by the use of information aggregation operators.

Le $A = \{A_1, A_2, ..., A_m\}$ be the set of alternatives, and $E = \{E_1, E_2, ..., E_n\}$ be the set of experts. Each expert assesses each alternative by each criterion. Thus x_{ijk} means the evaluation expressed by expert i on the criteria C_j on alternative A_k. The scale of evaluation is given in Table 2.

Linguistic expressions	Single-valued neutrosophic number (T, I, F)
Very bad (VB)	(0.10, 0.75, 0.85)
Bad (B)	(0.25, 0.60, 0.80)
Medium bad (MB)	(0.40, 0.70, 0.50)
Medium (M)	(0.50, 0.40, 0.60)
Medium Good (MG)	(0.65, 0.30, 0.45)
Good (G)	(0.80, 0.10, 0.30)
Very Good (VG)	(0.95, 0.05, 0.05)

Table 2: Linguistic terms and their single-valued neutrosophic numbers for evaluating alternatives according to the criteria.

The aggregation process is carried out with the use of information aggregation operators [21-23]. The fundamental objective is to obtain collective assessments from individual evaluations through the use of aggregation operators. The OWA (Ordered Weighted Averaging) aggregation operator is used to process the proposed method [24-26].

The OWA operators work similar to the weighted average operators, although the values that the variables take are previously sorted in descending order and, opposed to what happens in the weighted averages, the weights are not associated with any specific variable [27-29].

Then, b_j is the value of the evaluation of alternative k-th according to the j-th criteria for all experts.

$$b_{jk} = \frac{\sum_{i=1}^{n} x_{ijk}}{n} \tag{5}$$

The result per alternative is calculated as follows:

$$R_k = \frac{\sum_{j=1}^{n} w_j \wedge b_j}{6} \tag{6}$$

Where, $w_j \wedge b_j := \left(min\left(T_{w_j} \wedge T_{b_j}\right), max\left(I_{w_j} \wedge I_{b_j}\right), max\left(F_{w_j} \wedge F_{b_j}\right)\right)$.

Finally, the alternatives are sorted in descending order according to A_{k_1} is preferred over A_{k_2} if and only if $\boldsymbol{S}(R_{k_1}) > \boldsymbol{S}(R_{k_2})$, using Equation 4.

3. Results

For the implementation of the method, a case study has been developed where we represent an instrument focused on the specific case that is modeled. The object of analysis was the “Mariscal de Puyo” market in Ecuador, which is the only alternative to be considered. The objective was to evaluate the impact of informal trade on this market.

Below are the ratings achieved for each activity:

Activity 1 Selection of experts:

To apply the method, we applied a questionnaire in order to select the group of experts to participate in the process. Eight experts were selected for the panel. The self-assessment questionnaire was applied to the 8 experts. Specifically, four questions were applied to the experts. The following results were obtained to identify the degree of knowledge on the subject:

Question 1. Theoretical analyzes carried out by you on the subject:

Five experts granted themselves the evaluation of “High” and the other 3 experts thought their knowledge is “Average”.

Question 2. Study of works published by Ecuadorian authors:

We obtained a self-evaluation of High for 5 experts, Average for 2 experts and Low for 1 expert.

Question 3. Direct contact with the informal market:

A self-assessment of High was obtained for 5 experts, Medium for 2 experts and Low for 1 expert.

Question 4. Knowledge of the current state of informal trade:

Six experts got themselves a self-assessment of High, Medium for 1 experts and Low for 1 expert.

After aggregating these results we obtain the following conclusions about expertise:

- 5 experts self-evaluate with a level of competence on the subject under study of 10 points.
- 1 expert self-assess with a competence level of 9 points.
- 1 expert self-evaluates with a proficiency level of 8 points.
- 1 experts self-evaluate with a level of competence of 6 points.

The knowledge coefficient K_c represents an important parameter in the application of the proposed method. For the investigation, the K_c per expert are obtained as reported in Table 3, where the values are divided by 10:

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
10	9	1	6	8	1	1	1

Table3. Knowledge coefficient by experts.

Figure 4 shows a graph with the behavior of the experts' knowledge coefficients. From the analysis of the results, we determined to select 7 of the 8 experts originally planned.

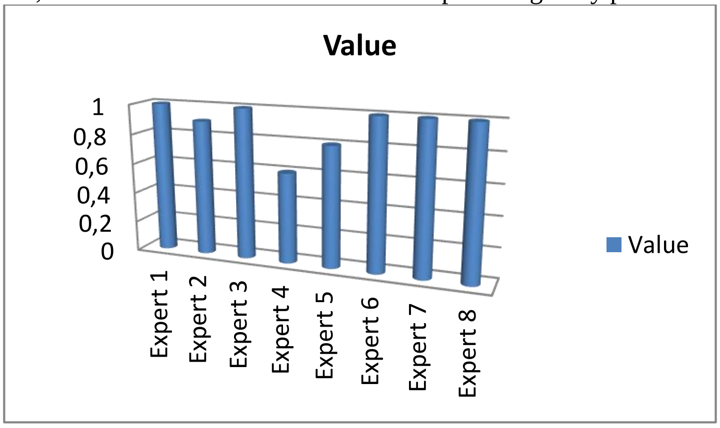

Figure 4. Representation of the knowledge coefficient of the experts.

Activity 2 Identification of the criteria:

For the activity, the experts involved in the process were surveyed. The objective was to identify the assessment criteria to evaluate informal trade. The indicators constitute the fundamental element on which the processing is carried out in subsequent stages.

Table 4 displays the evaluation criteria obtained from the activity.

Number	**Evaluation criteria**
C_1	Product quality certificate
C_2	Competitive prices
C_3	Contribution to the employment of personnel
C_4	Variety of products
C_5	Accessibility
C_6	Hygienic and sanitary conditions

Table 4. Evaluative criteria obtained.

Activity 3 Determination of the weight vectors of the criteria:

To determine the weights on the criteria, we used a multi-expert approach, in which the 7 selected experts intervened. Using single-valued neutrosophic numbers as proposed in Table 1, the group of experts did their job.

From the aggregation carried out using Equation 4, the weights of the 7 experts are combined into a unique value. Table 5 shows the result of the weight vectors as a result from the activity.

Number	Weight vectors W for criteria C
C_1	(0.1630, 0.35,0.40)
C_2	(0.9, 0.1,0.1)
C_3	(0.1521, 0.50,0.50)
C_4	(0.1847, 0.15,0.20)
C_5	(0.1304, 0.75,0.70)
C_6	(0.1739, 0.25,0.30)

Table 5: Weights of the criteria based on experts' opinions.

Activity 4 Determine the preferences of the alternatives:

In order to evaluate the impact of informal trade on the "Mariscal de Puyo" market in Ecuador, an evaluation of compliance with the criteria was carried out. The weight vectors attributed to each evaluation criterion were used as starting information. Compliance with the indicators in the "Mariscal de Puyo" market was evaluated using the set of linguistic labels proposed in Figure 3.

As a result, we obtained a system with fuzzy values that are added as output values. Table 6 shows the result of the process.

Criteria	W	Aggregated Evaluation b_j	$w_j \wedge b_j$
C_1	(0.1630, 0.35,0.40)	(0.67, 0.35,0.40)	(0.1630, 0.35,0.40)
C_2	(0.9, 0.1,0.1)	(0.83, 0.15,0.20)	(0.83, 0.15,0.20)
C_3	(0.1521, 0.50,0.50)	(1, 0,0)	(0.1521, 0.50,0.50)
C_4	(0.1847, 0.15,0.20)	(0.67, 0.35,0.40)	(0.1847, 0.35, 0.40)
C_5	(0.1304, 0.75,0.70)	(0.83, 0,15,0.20)	(0.1304, 0.75,0.70)
C_6	(0.1739, 0.25,0.30)	(0.5, 0.50,0.50)	(0.1739, 0.50,0.50)
Index $\frac{\sum_{j=1}^{6} w_j \wedge b_j}{6}$			(0.27235, 0.43333, 0.45000)

Table 6. Result of evaluations obtained by experts.

The final value of the score degree is 0.46301.

Figure 5 shows the behavior of inferences on the evaluation criteria for the proposed case study.

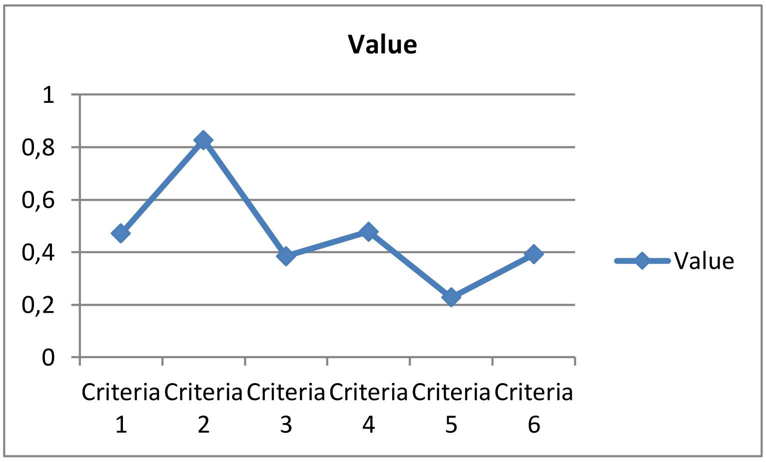

Figure 5. Alternative evaluation per criteria.

From the data presented in Table 6, an impact index of informal trade for the “Mariscal de Puyo” market in Ecuador with a value of 0.46301 is identified. The results are classified as a medium index of impact of informal trade. We made the classification of 0.46301 according to a linguistic value, using the scale shown in Figure 6, such that the maximum truth-value of 0.46301 is obtained when evaluating in the membership function corresponding with the label “medium”.

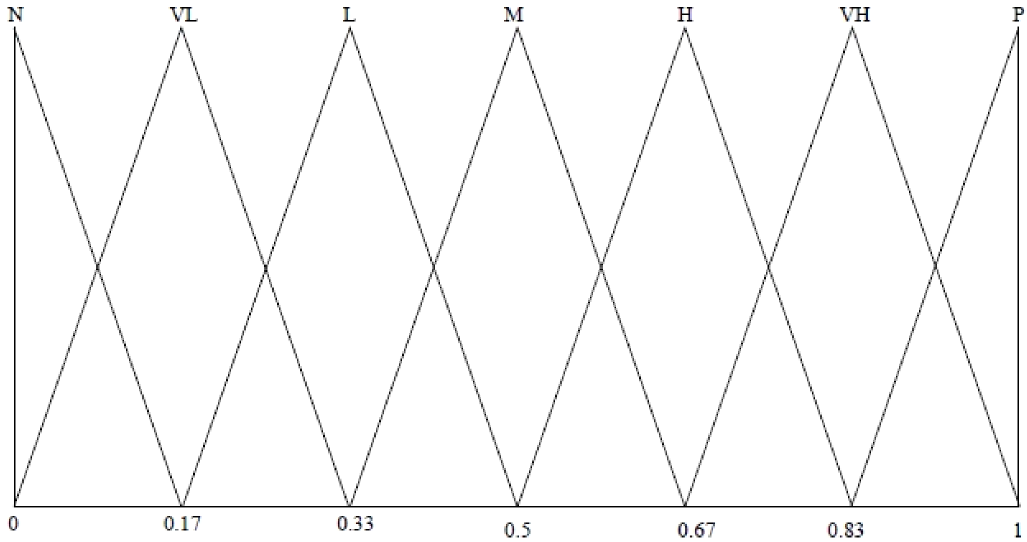

Figure 6. Linguistic labels set.

Where:
N: Null,
VL: Very Low,
L: Low,
M: Medium,
H: High,
VH: Very High,
P: Preferred.

Conclusions

From the implementation of the proposed method, weights of aggregation are obtained for the assessment of the criteria that represented the basis of the evaluation process for the informal market.

Eight potential experts were analyzed, 7 of which were selected based on their competence coefficient for the implementation of the proposed method.

The application of a case study to assess the impact of informal trade made it possible to determine the impact of informal trade on the “Mariscal de Puyo” market using Neutrosophy theory. We reached to the conclusion that informal trade gains space in the Ecuadorian trade network.

By applying the method in a real context, we validated this technique for evaluating the impact of informal trade with the use of information aggregation operators. The proposal can be extended to work with other multi-criteria methods for inference processing where the results obtained by the different methods can be compared.

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Neutrosophic VIKOR for Proposal of Reform to Article 189 of the Integral Criminal Code in Ecuador

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Abstract. Given that in Ecuador, according to the authors' criteria, the crime of aggravated robbery through the use of substances that affect the volitional, cognitive, and motor capacities, as defined in the Integral Criminal Code, does not have a penalty in accordance with the principle of proportionality between the degree of violation of a right and the severity of the penalty, the objective of this research is to apply the VIKOR method with a neutrosophic approach to determine a proposal to reform Article 189 of the Integral Criminal Code, which establishes a penalty, with greater proportionality to the harm committed. From the application of the method, a compromise solution set was obtained, where the best alternative is to establish a penalty of 7 to 10 years.

Keywords: VIKOR extended method; single-value neutrosophic set; principle of proportionality.

1 Introduction

Every criminal system finds itself in a dilemma between fighting impunity and guaranteeing the rights of persons suspected of having committed a criminal offense. If the guarantees are extreme, a system that never sanctions would be created; if the guarantees are relaxed, the innocent person would end up being condemned. The criminal justice system has to strike a balance between preventing injustices from being tolerated in society and ensuring that there is something like social peace in the fight against crime [1-3].

Criminal law is a system for regulating the coexistence of individuals, and for that reason it must have a subtle symbiosis in which the State's right to punish is curbed, while on the other hand it must maintain the guarantees and protection of the rights of the victim and the accused, that is, as an ambivalent right it must be in a fair environment that reconciles the claims of both parties. The Integral Criminal Code of Ecuador is constantly being improved in the perennial quest for justice, and new criminally relevant behaviors adapted to international norms are being criminalized [4].

One of the guarantees of modern criminal law is that penalties must respect the criteria of proportionality, which requires that the prescriptions for criminal conduct and the imposition of criminal sanctions have a sufficiently close relationship in order to ensure a balance between the magnitude of the harm caused by the criminal conduct and the punishment to be imposed on the perpetrator. Article 76 of the Constitution of the Republic of Ecuador requires that penalties be in accordance with the principle of proportionality, that is, there must be a certain consistent relationship between the degree of violation of a right and the severity of the penalty [1, 5].

According to the doctrine, the crime of robbery is a patrimonial crime of enrichment; these crimes are based on the idea of the unjust enrichment of the active subject at the expense of the damage to the passive subject's property. The crime of robbery can be carried out with force on things or violence on people. Within the crime of robbery, there is a plurality of legal assets that range from freedom, physical integrity, and life [6].

The crime of robbery with intimidation or violence is, by its nature, a complex crime, that is, one that is made up of several actions that may in turn constitute several crimes, regardless of whether they are later punished separately, in accordance with the rules of the concurrence of infractions [7].

In Ecuador, it is commonplace for the active subject to use substances that affect the victim's capacities in order to facilitate the commission of the felony, and as a result of these acts, the victim's personal integrity may be affected, whether temporarily or permanently.

This crime is classified in the Integral Criminal Code [4], in its Article 189, when it is expressed:

Article 189.- Robbery-1. The person who, by means of threats or violence, removes or takes possession of another person's property, whether the violence takes place before the act to facilitate it, at the time it is committed, or after it has been committed to procure impunity, shall be punished with five to seven years' imprisonment.

If the act is carried out using substances that affect the volitional, cognitive, and motor capacities, with the aim of subduing the victim, leaving him in a state of drowsiness, unconsciousness, or defenselessness, or to force him to carry out acts that he would not have carried out consciously and willingly, he shall be sentenced to five to seven years' imprisonment.

In accordance with the foregoing, the authors of this investigation consider that the criminal legislation is not equitable in paragraphs 1 and 3 of Article 189 of the Integral Criminal Code, since paragraph 1 provides for robbery by means of threats or violence, while paragraph 3 establishes the robbery in which substances capable of affecting the victim's motor, cognitive, and volitional capacity have been used to break the victim's will and conscience. However, the penalty of imprisonment is the same for both paragraphs, i.e., from five to seven years. Since a robbery carried out only with threats to the victim does not produce the same effect as a robbery carried out with substances capable of seriously affecting the victim's conscience and will. It is noted that there is no proportionality of the penalty in the third paragraph, since the offense is not in accordance with the penalty.

In an analysis of comparative law, it was found that in the Peruvian experience this issue has been treated with particular severity, which is justified by an exemplary punishment that, according to the doctrine, should have a negative preventive effect. Such is the severity of the crime that Article 189 of the Peruvian Criminal Code [8] considers this conduct to be serious and merits a penalty of no less than twenty and no more than thirty if the crime of robbery is committed:

1. When injury is caused to the physical or mental integrity of the victim. 2. with abuse of the physical or mental incapacity of the victim or through the use of drugs, chemical or pharmaceuticals against the victim.3. If the family or the victim is placed in financial distress. The penalty shall be life imprisonment when the agent acts as a member of a criminal organization or if, as a result of the act, the victim dies or suffers serious physical or mental harm.

Article 344 of Uruguayan criminal law[9] provides that “anyone who, through violence or threats, takes possession of a piece of furniture, removing it from its holder, in order to take advantage of it or make someone else take advantage of it, shall be punished with four to sixteen years in prison. In addition, if permanent injury is caused to the passive subject, the penalty is increased by one third [3]”.

In short, it is believed that the antinomy between the principle of minimum intervention and the growing need for protection in an increasingly complex society must be addressed by cautiously accommodating new forms of crime and increasing, in accordance with the principle of proportionality, the types of conduct that cause the greatest harm to the legal assets protected under the Criminal Code [2, 3, 10].

That is why the objective of the present investigation is the application of the VIKOR method with a neutrosophic approach [11] for the determination of a proposal to reform article 189 of the Integral Criminal Code, which establishes a penalty for the crime of aggravated robbery for the use of substances that affect the volitional, cognitive and motor capacity, with greater proportionality to the damage committed.

2 Materials and methods

This section mainly recalls some basic notions related to neutrosophic, crisp VIKOR method and extended VIKOR method, all of which will be used in the subsequent content of this paper. Also, describes how the extended VIKOR method is applied in determining the penalty for the crime of aggravated robbery.

2.1 Some basic concepts of SVNS

Neutrosophy is a mathematical theory developed by Florentin Smarandache to deal with indeterminacy [12]. It originated from Paradoxism[13], an international movement in science and culture, founded in the 1980s, based on excessive use of antitheses, oxymoron, contradictions, and paradoxes. In 1995, Paradoxism was extended to a new branch of philosophy called Neutrosophy[14], creating different scientific branches, such as: neutrosophic logic [15], neutrosophic set [16], neutrosophic probability and statistics [17], neutrosophic decision methods [18, 19], etc.

It has been the base for the development of new methods to handle indeterminate and inconsistent information as the neutrosophic sets and the neutrosophic logic and, especially, in the problems of decision making [20{Bera, 2017 #205, 21, 22]. The truth value in the neutrosophic set is the following [23]:

Let $N = \{(T, I, F): T, I, F \subseteq [0,1]\}n$, be a neutral evaluation of a mapping of a group of formulas propositional to N, and for each sentence p you have:

$$v(p) = (T, I, F) \quad (1)$$

In order to facilitate the practical application to decision-making problems, the use of single-value neutral sets (SVNS)[24] was proposed, through which it is possible to use linguistic terms, in order to obtain a greater interpretability of the results.

Let X be a universe of discourse, a SVNS A over X has the following form:

$$A = \{\langle x, u_a(x), r_a(x), v_a(x)\rangle : x \in X\} \quad (2)$$

Where
$u_a(x): X \to [0,1], r_a(x): X \to [0,1]\ y\ v_a(x): X \to [0,1]$
with

$$0 \le u_a(x), r_a(x), v_a(x) \le 3, \forall\ x \in X$$

The intervals $u_a(x), r_a(x)$ y $v_a(x)$ denote the memberships to true, indeterminate and false from x in A, respectively. For convenience a Single Value Neutrosophic Number (SVNS) will be expressed as A = (a, b, c), where a, b, c ∈ [0.1] and satisfies 0 ≤ a + b + c ≤ 3.

Some operations between SVNS are expressed below:

1. Let $A_1 = (a_1, b_1, c_1)$ and $A_2 = (a_2, b_2, c_2)$ ∈SVNS, the sum between A_1 y A_2 is defined by:

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

2. Let $A_1 = (a_1, b_1, c_1)$ and $A_2 = (a_2, b_2, c_2)$ ∈ SVNS the multiplication between A_1 y A_2 is defined by:

$$A_1 \otimes A_2 = a_1 a_2, b_1 + b_2 - b_1 b_2, c_1 + c_2 - c_1 + c_2) \quad (4)$$

3. The product by a positive scalar $\lambda \in \Re$ positivo with SVNS, A = (a, b, c) is defined by:

$$\lambda A = \left(1 - (1-a)^{\lambda}, b^{\lambda}, c^{\lambda}\right) \quad (5)$$

4. Let $\{A_1, A_2, \dots, A_n\} \in$ SVNS(x), where $A_j = (a_j, b_j, c_j)$ (j = 1, 2, …, n), then, the Single Valued Neutrosophic Weighted Average Operator is defined by [25]:

$$P_w(A_1, A_2, \dots, A_n) = \langle 1 - \prod_{j=1}^{n}\left(1 - T_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(I_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(F_{A_j}(x)\right)^{w_j} \rangle \quad (6)$$

Where:
$w = (w_1, w_2, \dots, w_n)$ is vector of $A_j (j = 1,2, \dots, n)$ such that $w_n \in [0,1]$ y $\sum w_j = 1$.

5. Let A = (a, b, c) be a single neutrosophic number, a score function S of a single valued neutrosophic value, based on the truth-membership degree, indeterminacy-membership degree and falsehood membership degree is defined by:

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

Where
$S(A) \in [-1,1]$

2.2 The VIKOR method

The VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method was presented by [26]. The initial idea of the model is to establish a ranking according to distances in relation to an ideal scenario. The VIKOR method has as its virtue, to ponder the importance of distances in relation to the ideal and best performance scenarios in a potential criterion of the analyzed alternative.

The method is based on the function of the Commitment Programming Method described by Yu and Zeleny [27, 28] .

Assuming as notation the set of alternatives A defined as $a_1, a_2, \dots, a_n$ where for alternative i, the standardized value of its evaluation in criterion j is given by f_{ij}. Thus, we can define the compromise function as [11]:

$$L_{p,i} = \left\{\sum_{j=1}^{m}\left[\frac{w_j\left(f_j^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)}\right]^p\right\}^{\frac{1}{p}} \quad (8)$$

Where: $1 \le p \le \infty$ and $i = 1, 2, \dots, n$ assuming that j denotes a specific criterion and that m is the number of criteria used in the model. Also, f_j^* is the best result obtained for criterion j and that f_j^- is the worst result obtained for criterion j.

Initially the VIKOR method constructs two scores used for the ranking, S and R. The construction of these scores is linked to the compromise function, where to construct S is assumed $p = 1$ and for R is assumed $p = \infty$. This way it is possible to obtain them:

$$S_i = \sum_{j=1}^{m}\frac{w_j\left(f_j^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)} \quad (9)$$

And still:

$$R_i = \max_j\left[\frac{w_j\left(f_j^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)}\right] \quad (10)$$

Where w_i are the weights of the criteria, denoting their relative importance.

Then calculate the Q_j values for $j = 1, 2, \dots, m$ applying equation:

$$Q_i = v\left(\frac{S_j - S^+}{S^- - S^+}\right) + \frac{(1-v)(R_j - R^+)}{(R^- - R^+)}$$

Where:

$S^{+} = \min_{j} S_j$, $S^{-} = \max_{j} S_j$

$R^{+} = \min_{j} R_j$, $R^{-} = \max_{j} R_j$

And v is the weight, which determines the decision-making strategy of the maximum group utility, usually it is fixed as 0.5.

Finally, after ranking the alternatives by sorting each S, R and Q values in the decreasing order, the alternative A_{j1} corresponding to $Q_{[1]}$ (the minimum value among Q_j) as a compromise solution is selected, if the following condition are satisfied:

Condition 1. The alternative A_{j1} has an acceptable advantage in the case, if $Q_{[2]} - Q_{[1]} \geq DQ,$ where $DQ = \frac{1}{(m-1)}$ and m is the number of the alternatives.

Condition 2. The alternative A_{j1} is stable within the decision-making framework, if this alternative has the best ranking in S and/or R.

In the case when one of this conditions is not satisfied, then a set of the compromise solutions is created. This set consist of:

Alternatives A_{j1} and A_{j2}, where $A_{j2} = Q_{[2]}$ when the condition 2 is not satisfied.

Alternatives $A_{j1}, A_{j2}, \dots, A_{jk}$ when the condition 1 is not satisfied and $A_{jk} = Q_{[k]}$ with the maximum value, which still satisfied the equation $Q_{[k]} - Q_{[1]} \geq DQ$.

2.3 VIKOR method under environment of a single valued neutrosophic set (VIKOR-SVNS)

The extended VIKOR method, is achieved with the application of single value neutrosophic sets to model the information for the decision making problem [11, 29]. All initial information for the solution of the decision-making problem is expressed by the interval-valued neutrosophic numbers. This information includes a description of the importance of the decision-makers, individual expert evaluations regarding the ratings of alternatives via attributes and attribute weights[30-32].

The extended VIKOR method of decision support can be described according to 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), first, the importance or share to the final decision of each expert is determined. The experts are evaluated according to the linguistic scale shown in table 1, and the calculations are made with their associated SVNS[24].

Linguistic Term	Evaluation	SVN Numbers
Extremely High	EH	(1; 0; 0)
Very Very High	VVH	(0.9, 0.1, 0.1)
Very High	VH	(0,8; 0,15; 0,20)
High	H	(0.70,0.25,0.30)
Medium High	MH	(0,60; 0,35; 0,40)
Medium	M	(0,50; 0,50; 0,50)
Medium Low	ML	(0,40; 0,65; 0,60)
Low	L	(0.30,0.75,0.70)
Very Low	VL	(0,20; 0,85; 0,80)
Very Very Low	VVL	(0.10,0.90,0.90)
Extremely Low	EL	(0; 1; 1)

Table 1 Linguistic terms used for expert's evaluation.

Call $A_t = (a_t , b_t , c_t)$ the SVNS corresponding to the t-th decision-maker (t = 1, 2,..., k). The weight is calculated by the following formula:

$$\lambda_t = \frac{a_t + b_t\left(\frac{a_t}{a_t + c_t}\right)}{\sum_{t=1}^{k} a_t + b_t\left(\frac{a_t}{a_t + c_t}\right)} \quad (11)$$

Where:

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

Step 2. Each decision-maker performs his evaluations concerning the ratings of the alternatives with respect to the attributes and the attributes' weights. For the assessment of the alternatives by each expert we used the linguistic terms shown in table 2.

Linguistic Term	Evaluation	SVNS
Extremely Important	(EI)	(1.00, 0.00, 0.00)
Very Important	(VI)	(0.9, 0.1, 0.1)
Important	(I)	(0.75,0.25,0.2)
Medium	(M)	(0.5,0.5,0.5)
Low-Important	(LI)	(0.35,0.75,0.8)
Not Very Important	(NVI)	(0.1,0.9,0.9)
Not Important at all	(NI)	(0.00, 1.00, 1.00)

Table 2. Linguistic terms and its SVNS

The neutrosophic decision matrix is defined by $D = \sum_{t=1}^{k} \lambda_t \, d_{ij}$, where $d_{ij} = (u_{ij}, r_{ij}, v_{ij})$ is used to aggregate all individual assessments.

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 of each one with the help of Equation 6.

In this way a matrix D = $(d_{ij})_{ij}$, where each d_{ij} is a SVNS (i = 1,2,.., m; j = 1,2,…, n).

Step 3. Determination of the Weight of the Criteria [7].

Suppose that the weight of each criterion is given by $W = (w_1, w_2, \dots, w_n)$,where w_j it denotes the relative importance of the criterion β_j. If $w_j^t = a_j^t, b_j^t, c_j^t$it is the evaluation of the criterion $\beta_j$by the t-th expert. Then, Equation 6 is used, to add the w_j^t the weights λ_t.

Step 4. Construction of the neutrosophic decision matrix of the weighted mean of single values with respect to the criteria.

$$D^* = D \otimes W, where\ d_{ij}^* = W_j \otimes d_{ij} = (a_{ij}, b_{ij}, c_{ij}) \quad (12)$$

Step 5. Determine the positive and negative ideal solutions for the criteria applying the following equation

The criteria can be classified as either cost-type or benefit-type. Let L_1 be the set of benefit-type criteria and L_2 the cost-type criteria. The ideal alternatives will be defined as follows:

$$\rho^+ = \left(a_{\rho^+w}(\beta_j), b_{\rho^+w}(\beta_j), c_{\rho^+w}(\beta_j)\right) \quad (13)$$

Denotes the positive ideal solution, corresponding to L_1 .

$$\rho^- = \left(a_{\rho^-w}(\beta_j), b_{\rho^-w}(\beta_j), c_{\rho^-w}(\beta_j)\right) \quad (14)$$

Denotes the negative ideal solution, corresponding to L_2.

Where

$$a_{\rho^+w}(\beta_j) = \begin{cases} max_i a_{\rho_i w}(\beta_j), if\ \ j \in L_1 \\ min_i a_{\rho_i w}(\beta_j), if\ \ j \in L_2 \end{cases}$$

$$b_{\rho^+w}(\beta_j) = \begin{cases} min_i b_{\rho_i w}(\beta_j), if\ \ j \in L_1 \\ max_i b_{\rho_i w}(\beta_j), if\ \ j \in L_2 \end{cases}$$

$$c_{\rho^+w}(\beta_j) = \begin{cases} min_i c_{\rho_i w}(\beta_j), if\ \ j \in L_1 \\ max_i c_{\rho_i w}(\beta_j), if\ \ j \in L_2 \end{cases}$$

And

$$a_{\rho^-w}(\beta_j) = \begin{cases} min_i a_{\rho_i w}(\beta_j), if\ \ j \in L_1 \\ max_i a_{\rho_i w}(\beta_j), if\ \ j \in L_2 \end{cases}$$

$$b_{\rho^-w}(\beta_j) = \begin{cases} max_i b_{\rho_i w}(\beta_j), if\ \ j \in L_1 \\ min_i b_{\rho_i w}(\beta_j), if\ \ j \in L_2 \end{cases}$$

$$c_{\rho^-w}(\beta_j) = \begin{cases} max_i c_{\rho_i w}(\beta_j), if\ \ j \in L_1 \\ min_i c_{\rho_i w}(\beta_j), if\ \ j \in L_2 \end{cases}$$

Step 6. Once the ideal values are calculated, S_i , R_i and Q_i, are calculated with the formulas (15), (16) and (17), respectively:

$$S_i = \sum_{j=1}^{m} \frac{w_j(\rho^+ - d_{ij}^*)}{(\rho^+ - \rho^-)} \quad (15)$$

$$R_i = \max_j \left[\frac{w_j(f_j^* - d_{ij}^*)}{(\rho^+ - \rho^-)}\right] \quad (16)$$

$$Q_i = v\left(\frac{S_j - S^+}{S^- - S^+}\right) + \frac{(1-v)(R_j - R^+)}{(R^- - R^+)} \quad (17)$$

Where:

$S^+ = \min_j S_j$, $S^- = \max_j S_j$

$R^+ = \min_j R_j$, $R^- = \max_j R_j$

And v is the weight, which determines decision making strategy of the maximum group utility.

Step 8. According to VIKOR method, the best alternative must has the minimum Q_j and it can be chosen as a compromise solution. For the selection of the minimum Q_j the rules, presented in the section 2.1, are applied.

3 Results

In order to determine the corresponding penalty to be applied for the crime of aggravated robbery for the use of substances that affect a person's volitional, cognitive, and motor capacity, through the extended VIKOR method, 50 law professionals from Los Ríos, Cantón Babahoyo, were consulted, and they are considered specialists in criminal law. Of these, 28 are free-lance lawyers, 13 are public prosecutors and 9 are judges.

All of them were first asked what penalty they considered should be established for the crime of robbery when substances that could affect the victim(s)' volitional, cognitive, and motor capacities have been used, and they mentioned what criteria they followed for their response. Based on the most frequent responses, alternative decisions were determined in this case, which would be given by the possible penalties to be applied:

1. Between 5 and 7 years (maintaining the current penalty).
2. Between 6 and 8 years.
3. Between 7 and 10 years.
4. Between 8 and 11 years.

The consulted experts also considered that the criteria to be taken into account for the decision to choose would be the following:

1. Compliance with the principle of proportionality of the penalty with the crime committed
2. Social impact on persuasion not to commit the crime.

Once completed steps 1 and 2, the neutrosophic decision matrix of unique aggregated values is obtained as shown in table 3.

Strategy	Criterion 1	Criterion 2
1	(0,733 ; 0,261 ; 0,282)	(0,771 ; 0,228 ; 0,263)
2	(0,719 ; 0,271 ; 0,298)	(0,698 ; 0,358 ; 0,361)
3	(0,745 ; 0,264 ; 0,306)	(0,721 ; 0,267 ; 0,288)
4	(0,697 ; 0,342 ; 0,356)	(0,742 ; 0,235 ; 0,259)

Table 3. Neutrosophic decision matrix of unique aggregated values

With the weight that the experts assigned to each criterion (step 3), the weight of the criteria expressed in SVNS was calculated (table 4).

Criterion	Weight (SVNS)
1.- Compliance with the principle of proportionality of the penalty with the crime committed.	(0,853 ; 0,137 ; 0,162)
2.- Impacto social en la persuasión a no cometer el delito	(0,782 ; 0,212 ; 0,218)

Table 4. Weight of the criteria

Then, the neutrosophic decision matrix of the weighted mean of single values with respect to the criteria (step 4) was constructed, as shown in table 5.

Strategy	Criterion 1	Criterion 2
1	(0,626 ; 0,363 ; 0,398)	(0,603 ; 0,391 ; 0,424)
2	(0,614 ; 0,371 ; 0,412)	(0,546 ; 0,494 ; 0,501)
3	(0,635 ; 0,365 ; 0,418)	(0,564 ; 0,422 ; 0,443)
4	(0,594 ; 0,433 ; 0,46)	(0,581 ; 0,397 ; 0,421)

Table 5. Weighted aggregate decision matrix.

The ideal positive and negative SVNS solutions calculated in step 5 are shown in table 6.

Criterion	Positive Ideal Value (ρ^+)	Negative Ideal Value (ρ^-)
1	(0,635 ; 0,363 ; 0,398)	(0,594 ; 0,433 ; 0,46)

2	(0,603 ; 0,391 ; 0,421)	(0,546 ; 0,494 ; 0,501)

Table 6. SVNS positive and negative ideal solutions by criteria.

Finally, values of S_i , R_i and Q_i, calculated by equations (15), (16) and (17) are shown in table 7.

Strategy	S	S Ranking	R	R Ranking	Q	Q Ranking
1	-0,192386404	1	0	1	0,5	3
2	-1,562871007	3	0,191308756	4	0,368089358	2
3	-0,455030698	2	0,132487103	3	0,224276756	1
4	-2,054005833	4	0,075347667	2	0,803073134	4

Table 7. Values of *S*, *R* and *Q* for each strategy

After selection of the minimum Q_j rules were applied, it can be said that the ranking of the alternatives in descending order according to Q, can be expressed as $A_4 \succ A_1 \succ A_2 \succ A_3$ but it is necessary to take into account the fact, that alternatives A_3 , A_2 and A_1 are close to each other and these alternatives must be included into the compromise solution set.

From this it can be concluded that the consulted experts consider with certain preference that, according to the criteria analyzed, a penalty of between 7 and 10 years should be applied to the crime of aggravated robbery through the use of substances that affect a person's volitional, cognitive and motor capacity.

Conclusions

An amendment to the current definition of the crime in Article 189 (3) of the Integral Criminal Code, which refers to the punishment for aggravated robbery through the use of substances that affect a person's volitional, cognitive, and motor capacities, should be considered, since it does not comply with the principle of proportionality of the crime and the penalties established in the code itself and in the Constitution of the Republic of Ecuador.

With the application of the neutrosophic VIKOR technique, four alternatives were evaluated based on the criteria of compliance with the principle of proportionality of the penalty with the crime committed and the social impact on the persuasion not to commit the crime.

As a result, it was found a compromise solution set, where the major alternative is to establish a penalty of 7 to 10 years.

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Neutrosophy Used to Measure the Legal and Socioeconomic Effect of Debtors

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Abstract: As a part of a bad economic planning, people sometimes have to declare themselves debtors. Debts are a legal effect that causes a socio-economic impact. The present work proposes a method to measure the legal and socioeconomic effect in debtors. The method operates based on Neutrosophic logic and user experience. We use the trapezoidal neutrosophic numbers to model the assessment of experts in four rules. The result is obtained using the inference system based on neutrosophic sets. A case study was implemented in the canton of Pastaza with the aim of measuring the socioeconomic legal effect from which we obtained a working tool for decision-making.

Keywords: legal and socioeconomic effect, single-valued trapezoidal neutrosophic number, neutrosophic inference, neutrosophic system.

1. Introduction

As a consequence of a low level in terms of financial culture, many people are declared as debtors. Debts entail facing a set of legal actions that can end with the auction of the assets or in the declaration of insolvency that generates legal and economic repercussions.

Insolvency is not only a judicial, but also social and obviously economic consequence, as a result of the lack of incomes. In Ecuador, an individual is declared insolvent when he/she incurs in the breach of an obligation or contract and is submitted to the jurisdictional decision, in which he/she is sentenced to pay the amount that he/she owed.

Insolvency has constituted one of the most imprecise legal concepts in its meaning, because it includes relatively heterogeneous meanings: equity insufficiency, inability to pay, lack of liquidity, over-indebtedness, assets less than liabilities, among others [1, 2].

Being insolvent represents a recurring feature linked to an economic situation in which a debtor finds himself/herself unable to satisfy his creditor, consequently causing an inability to pay. The moratorium causes an injury to the credit right with the consequent origin of a liability of the debtor.

In accounting or financial terms, it does not seem very difficult to determine who is solvent and who is not, since an arithmetically conclusive answer is obtained not in purely legal terms, since what is decisive is the capacity and the realization value of the assets [3, 4].

The declaration of insolvency is the consequence of the implementation of a judicial process that determines in sentence the payment of what is owed. The procedures established in this regard are contemplated in the General Organic Code of processes; these procedures can be ordinary and executive.

The procedure is considered as the action to proceed before the judicial authority by means of the respective demand to obtain effective judicial protection, being a system of actions or set of acts that include the orderly development of judicial proceedings [5-7].

The procedures used are the methods established by law to regulate the process. It is clear then that a *process* and a *procedure* are not the same thing because the process has several elements that make it up, according to our General Organic Code of Processes.

Insolvency has been approached in the scientific literature from different perspectives, affecting different sectors [8, 9]. The Constitution of Ecuador, in its article 168, states: "The administration of justice, in the fulfillment of its duties and in the exercise of its powers, will apply the following principles: The substantiation of the processes in all matters, instances, stages and procedures will be carried out through the oral system, in accordance with the principles of concentration and contradiction"[10-12].

Based on the aforementioned problems, this research defines a solution in which we propose a method to measure the legal and socioeconomic effect of debtors using neutrosophic logic. We use the trapezoidal neutrosophic numbers to model the assessment of experts in four rules. The result is obtained using the inference system based on neutrosophic sets. The advantage is that Neutrosophy is more accurate, but less determinate, than fuzzy logic. The case study, which consists of one enterprise's evaluation of Pastaza canton, in Ecuador, illustrates the applicability of the method.

The research is divided into the following sections: Materials and methods, where the main theoretical references of the research are presented and the inference process is described. Results and discussions present an example of the implementation of neutrosophic logic based on user experience to measure the legal and socioeconomic effect on debtors.

2. Materials and Methods

This section contains the main concepts of Neutrosophic sets and neutrosophic inference.

Neutrosophy is an evolution form Paradoxism, an international movement in science and art, founded by Florentin Smarandache in 1980s, based on excessive use of antitheses, oxymoron, contradictions, and paradoxes [13]. In 1995, the author extended the Paradoxism (based on opposites) to a new branch of philosophy called Neutrosophy (based on opposites and their neutral) that originated many scientific branches, such as: neutrosophic logic, neutrosophic set, neutrosophic probability and statistics, etc. [14].

Definition 1: [15, 16] The Neutrosophic set N is characterized by three membership functions, which are the truth-membership function TA, indeterminacy-membership function IA, and falsehood-membership function FA, where U is the Universe of Discourse and $\forall x\in U$, TA(x), IA(x),FA(x) $\subseteq]^-0, 1^+[$, and $^-0\leq \inf$ TA(x)+ inf IA (x) + inf FA (x) $\leq$sup TA(x)+ sup IA (x) + sup FA (x)$\leq 3^+$.

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

Definition 2: [15, 16] The Single-Valued Neutrosophic Set (SVNS) N over U is A = {<x; TA(x), IA(x), FA(x)>: $x\in U$}, where $TA:U\rightarrow[0, 1]$, $IA:U\rightarrow[0, 1]$, and $FA:U\rightarrow[0, 1]$, $0 \leq TA(x) + IA(x) + FA(x) \leq 3$.

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: [15-18] 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:

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

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

$$F_{\tilde{a}}(x) = \quad (3)$$

$$\begin{cases} \dfrac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \le x \le a_2 \\ \gamma_{\tilde{a}}, & a_2 \le x \le a_3 \\ \dfrac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases}$$

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: [15-18] 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:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
2. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
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 $a_1, a_2, a_3, a_4 \neq 0$.
4. Multiplication by a scalar number:

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

5. Division of two trapezoidal neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle \left(\frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 > 0 \ \mathit{and}\ b_4 > 0 \\ \langle \left(\frac{a_4}{b_4}, \frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 < 0 \ \mathit{and}\ b_4 > 0 \\ \langle \left(\frac{a_4}{b_1}, \frac{a_3}{b_2}, \frac{a_2}{b_3}, \frac{a_1}{b_4}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 < 0 \ \mathit{and}\ b_4 < 0 \end{cases}$$

6. Multiplication of two trapezoidal neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1 b_1, a_2 b_2, a_3 b_3, a_4 b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 > 0 \ \mathit{and}\ b_4 > 0 \\ \langle (a_1 b_4, a_2 b_3, a_3 b_2, a_4 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 < 0 \ \mathit{and}\ b_4 > 0 \\ \langle (a_4 b_4, a_3 b_3, a_2 b_2, a_1 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 < 0 \ \mathit{and}\ b_4 < 0 \end{cases}$$

Where, $\wedge$ is a t-norm and $\vee$ is a t-conorm.

Definitions 3 and 4 refer to *single-valued triangular neutrosophic number* when the condition $a_2 = a_3$ holds, [19-21].

Neutrosophic numbers are defined as: be $N = \{(T, I, F) : T, I, F \subseteq [0,1]\}$, a neutrosophic valuation is a mapping of a group of formulas proportional to N, this is that for every sentence p have:

$$v\ (p) = (T, I, F) \quad (4)$$

With the purpose of facilitating the practical application to decision-making and engineering problems, the proposal of the Single-Valued Neutrosophic Set was made (SVN) [22],[23],[24], which allow the use of linguistic variables [25-27] increasing the way of interpreting the recommendation models and the use of indeterminacy.

Definition 5. The *Neutrosophic Logic* (NL) is the generalization of the fuzzy logic, where a logical proposition P is characterized by three components:

NL(P) = (T,I,F) (5)

Where the neutrosophic component T is the degree of truthfulness, F is the degree of falsehood, and I is the degree of indeterminacy ([6]).

Definition 6. Let (T_1, I_1, F_1) and (T_2, I_2, F_2) be elements of NL where the sum of the elements of the triplet is 1. The logical connectives of { $\neg$, $\wedge$, $\vee$ } can be defined in the following way:

$\neg(T_1,I_1,F_1) = (F_1,I_1,T_1)$

$(T_1,I_1,F_1) \wedge (T_2,I_2,F_2) = (T = \min\{T_1,T_2\}, I = 1 - (T+F), F= \max\{F_1,F_2\})$

$(T_1,I_1,F_1) \vee (T_2,I_2,F_2) = (T = \max \{T_1,T_2\}, I =1- (T + F), F = \min \{F_1,F_2\})$.

This Neutrosophic Logic is denoted by NL_1.

Definition 7. Suppose that $A = (T_1,I_1,F_1)$ and that $A \rightarrow B = (T_2,I_2,F_2)$ in NL1. Then we can infer B with the values $B = (T_3, I_3, F_3)$ where:

$T_3 = T_2$ if $T_2 > F_1$

$T_3 = 0$ if $F_1 \leq T_2$

$F_3 = F_2$ if $F_2 < T_1$

F3 = 0 if $F_2 \geq T_1$

$I_3 = 1 - T_3 - F_3$.

This inference rule is the *modus ponens rule* for NL1 (MPNL1).

The purpose of *de-neutrosophication* is to convert an ordinary neutrosophic set (a type-1 neutrosophic set) obtained by neutrosophic type reduction to a single real number which represents the real output. The de-neutrosophication process consists of three steps, see [12].

Step 1. Neutrosophic type reduction.

Given an interval neutrosophic set B with $T_B(y)$, $I_B(y)$; $F_B(y)\subseteq[0, 1]$, then, the neutrosophic type reduction transforms each interval into one number, see Equations 6, 7 and 8.

$$T'_B(y) = \frac{(\inf T_B(y)+\sup T_B(y))}{2} \quad (6)$$

$$I'_B(y) = \frac{(\inf I_B(y)+\sup I_B(y))}{2} \quad (7)$$

$$F'_B(y) = \frac{(\inf F_B(y)+\sup F_B(y))}{2} \quad (8)$$

Step 2. *Synthesization*: It is the process to transform an ordinary neutrosophic set (a type-1 neutrosophic set) B into a fuzzy set B . It can be expressed using the following function:

$f(T'_B(y), I'_B(y), F'_B(y))\colon [0,1] \times [0,1] \times [0,1] \rightarrow [0,1]$, f can be defined as follows:

$$T''_B(y) = a * T'_B(y) + b * \left(1 - F'_B(y)\right) + c * \frac{I'_B(y)}{2} + d * \left(1 - \frac{I'_B(y)}{2}\right) \quad (9)$$

Where $0\leq$ a, b, c, d≤ 1 and a + b + c + d = 1.

The purpose of synthesization is to calculate the overall truth degree according to three components: truth-membership function, indeterminacy-membership function and falsehood-membership function. The component truth-membership function gives the direct information about the truth-degree, so it is directly used in the formula. The component falsehood-membership function gives the indirect information about the truth-degree, so (1-F) is used in the formula.

Step 3. Calculation of a typical neutrosophic value: one of the methods of calculation is given, the *center of area*. This method is sometimes called the *center of gravity method* or *centroid method*, the *de-neutrosophicated value*, $dn(T_B(y))$ is calculated by the formula 10:

$$dn(T_B(y)) = \frac{\int_\alpha^\beta T_B(y) y dy}{\int_\alpha^\beta T_B(y) dy} \quad (10)$$

To model using SVNN allows to make calculations based on linguistic terms, see Table 1. This table contains the association of linguistic terms with SVNNs.

Linguistic term	**SVNN**
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0.15,0.20)
Good(G)	(0.70,0.25,0.30)
Medium good (MDG)	(0.60,0.35,0.40)
Medium(M)	(0.50,0.50,0.50)
Medium bad (MDB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 1: Linguistic terms applied in [13-14] associated with a SVNN.

3. Results

This section is devoted to expose the method of Neutrosophic logic used to measure the legal and socioeconomic effect of debtors. Finally, we provide the results of the case study.

To measure the legal and socioeconomic effect of debtors using neutrosophic logic, the scale defined in Table 2 will be taken as linguistic variables. These indicators are:

Ind_1: "Job stability"

Ind_2: "History of previous debts"

Ind_3: "Consistency in payments of previous debts".

The legal and socioeconomic evaluation of debtors is the output variable. It was defined that each of these input or output variables will have associated the labels of Low, Medium, High and Excellent. To assess the impact that linguistic labels have on the output variable, see Table 2.

Label	Impact	SVTNN
Low	Debts can be paid in several months	$\langle(-1, 0, 4, 5); 0.60, 0.35, 0.40\rangle$
Medium	Debts can be paid in one month	$\langle(4, 5, 6, 7); 0.80, 0.15, 0.20\rangle$
High	Debts can be paid in one week	$\langle(6, 7, 8, 9); 0.85, 0.10, 0.15\rangle$
Excellent	Debts can be paid immediately	$\langle(8, 9, 10, 11); 1.00, 1.00, 1.00\rangle$

Table 2. Impact of the input and output variable labels, and their associated SVTNNs.

Using the assessment of experts in the field, we defined the production rules. These rules guarantee that the evaluation of the legal and socioeconomic effect of debtors is always largely determined by the lowest evaluation obtained in the input indicators:

R1: IF Ind_1 is low AND Ind_2 is low AND Ind_3 is low, THEN "the legal and socioeconomic effect of debtors" is low.

R2: IF Ind_1 is medium AND Ind_2 is medium AND Ind_3 is medium, THEN the "legal and socioeconomic effect of debtors" is medium.

R3: IF Ind_1 is high AND Ind_2 is high AND Ind_3 is high, THEN "the legal and socioeconomic effect of debtors" is high.

R4: IF Ind_1 is excellent AND Ind_2 is excellent AND Ind_3 is excellent, THEN "the legal and socio-economic effect of debtors" is excellent.

Figure 1 shows the general scheme of neutrosophic logic to measure the legal and socio-economic effect in debtors.

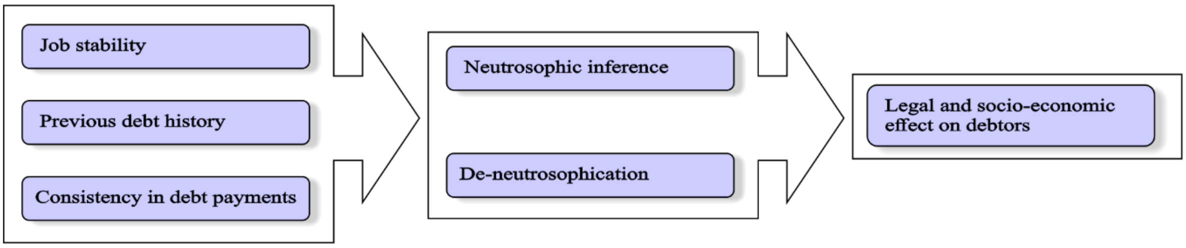

Figure 1. General scheme of the neutrosophic logic of the proposed method.

This is the algorithm for using the method:

1. The input values are the evaluation of x for the three indicators Ind_i (i = 1, 2, 3) using the linguistic scale in Table 1, then, the values of SVTNNs are associated, let us call them $\tilde{s}_1$, $\tilde{s}_2$, and $\tilde{s}_3$.
2. Apply the accuracy index of Equation 10, for each of the values $\tilde{s}_1$, $\tilde{s}_2$, and $\tilde{s}_3$.

$$A(\tilde{a}) = \frac{1}{16}[a_1 + a_2 + a_3 + a_4](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \qquad (11)$$

We call these crisp values as s_1, s_2, and s_3.

3. Evaluate s_1, s_2, and s_3 in the four rules, and apply the de-neutrosophication method, which consists in the following:

3.1. Truncate for each rule R1, R2, R3, and R4, the SVTNNs according to the obtained values s_1, s_2, and s_3, as it is usual in fuzzy systems. Thus, new single-valued neutrosophic sets are obtained for the premises.

3.2. Apply the steps of a fuzzy system method (Mamdani fuzzy model, Sugeno fuzzy model, etc.) for each truthfulness, indeterminacy, and falseness, independently. The de-fuzzification step is not applied. Then, a neutrosophic set B is obtained.
3.3. Apply to B the de-neutrosophication algorithm previously described. The output is the evaluation of the evaluations using the four rules. It is crisp value, let us call it v.
3.4. The linguistic term is obtained evaluating v in SVTNN shown in Table 1, and associating it with the linguistic term where v is a maximum using formula 12.

$$S(\mathrm{T},\mathrm{I},\mathrm{F}) = \frac{1}{3}(2+\mathrm{T}-\mathrm{I}-\mathrm{F}) \quad (12)$$

Where, T is the truth value of v, I is the indeterminate value and F is the false value, when v is evaluated in the SVTNN of Table 1.

To evaluate the results of the present investigation, an experiment will be carried out. The main objective of the experiment will be to demonstrate the applicability of neutrosophic logic based on user experience to measure the legal and socioeconomic effect on debtors. To do this, the process will be tested based on the location of the Pastaza canton. Once this process is completed, the results of the experimentation will be discussed.

One enterprise of the Pastaza canton, let us call it E, is evaluated in the three indicators, the results are shown in Table 3.

Linguistic Variables\Label	Low	Medium	High	Excellent
1- Job stability		X		
2- Previous debt history	X			
3- Consistency in payments of previous debts	X			

Table 3. Degrees of membership of input values to neutrosophic sets.

We obtained $s_1 = s_2 = 0.92500$, $s_3 = 3.3687$. After applying the proposed method we obtained v = 1.29816. Which is associated with the linguistic term Low, thus, the legal and socioeconomic effect of debtors of E is low.

Conclusions

The neutrosophic logic theory applied to perform the analysis and evaluation of the Socioeconomic and Legal Effect generates and delivers accurate data compared to other qualitative methods. This gives the main managers in charge of administrative and economic management the possibility of a better interpretation, free of other subjectivities. Once the research results have been analyzed, a method of evaluating the legal and socioeconomic effect is obtained, contributing to a tool for the analysis of the phenomenon using neutrosophic logic capable of quantifying the variable under study. Neutrosophic logic guarantees an alternative for the development of systems and tools that support business and administrative decision-making for the analysis of different phenomena.

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Validation of a Reform Project for Article 223 of The Ecuadorian Civil Code Through the Use Of Iadov Techniques and Neutrosophic Logic

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Abstract. The objective of this investigation is to validate a reform project for Article 223 of the Ecuadorian Civil Code, which implies the inclusion of a clause establishing that, in the case of controversies regarding the recognition of the common law, whoever demands the declaration of the common law, may request the precautionary measures on the profits that could correspond to him/her. The IADOV technique was adapted to measure the conformity of legal professionals with the proposed reform, as well as elements of neutrosophic logic to complement the analysis of the indetermination associated with the application of this technique.

Keywords: Iadov technique, Satisfaction Index, Indeterminacy, Neutrosophic logic.

1 Introduction

The Ecuadorian constitutional law since 1978, recognizes the legality of the common law union, transforming and protecting the patrimonial order of the family, outside the marriage. The Constitution of the Republic of Ecuador of 1998 established fundamental requirements that guaranteed this legal figure. However, in the Constitution of 2008 (in force), the previous concepts are absolutely disrupted, guaranteeing and recognizing families with a marital bond and families free of a marital bond, generating the personal principles of rights and obligations[1, 2] .

The Ecuadorian Civil Code [3] clearly determines the right of a common-law marriage, perfecting it with fundamental principles of inalienability and legality, and provides that common-law marriages are stable and monogamous, between a man and a woman free of marriage, and that they live together for more than two years, treating each other as husband and wife within society.

The judge to establish the existence of this union will consider the circumstances or conditions in which it has developed. The judge will apply the rules of healthy criticism in the appreciation of the corresponding evidence and will verify that it is not a question of any of the persons listed in the article 95.

On the other hand, not all the common law unions are recognized during their existence, since the persons in voluntary form do not solemnize such union.

This often forces the partners to apply for recognition through the judicial process once the separation has occurred or after the death of one of the partners, in order to ensure the benefits of the assets that correspond to them by virtue of such union.

The assets acquired within the common-law marriage do not correspond to the assets of the partnership, but when the marriage is legally recognized. This implies that the partner under whose name the goods are registered has the exclusive power to dispose of them without the authorization of the other partner.

On many occasions, when the domestic partnership ends, the partner having the ownership of the goods he/she acquired, transfers his domain, leaving the other partner without the possibility of claiming his share. In practice, one of the spouses takes with him all the patrimony acquired jointly, while the other remains helpless, looking for the judicial route to make his/her rights be worth, while the benefited partner alienates and administers freely the goods he/she had during the union.

However, there is no provision in the Ecuadorian legislation that enables to request precautionary measures at the time of filing a lawsuit for a judicial declaration of a common-law relationship to protect the assets that are part of the common-law company[4].

Until such provision is established, there is still a risk that the assets of one of the former partners will be damaged, since the other or his heirs may freely dispose of the assets, which violates the rights and guarantees enshrined in the Constitution of the Republic of Ecuador.

Therefore, the following is proposed before the Civil Code Reform Bill.

Article 1.- A paragraph should be added to Article 229 of the Civil Code, containing the following:

During the dissolution or termination, recognition of the domestic partnership, judicially, at the request of the partner, who does not have the extraordinary administration of their assets, may request precautionary measures such as the seizure, retention and prohibition of disposal as security measures of the assets, while the trial lasts.

Art. 2 .- The partner who will not be able to justify the common law union, according to the requirements, will be punished with the payment of legal costs in favor of the other party, leaving safe the legal actions that assist him.

The aim of this research is to validate the above mentioned reform Project through the application of Iadov technique and neutrosophic logic.

2 Methods

This research was carried out in the Canton of Santo Domingo, that according to the national census (2010), it has a population of 368,013 inhabitants, 27% of which, according to the National Institute of Statistics and Censuses (NIEC), lives in free association.

In the Judicial Unit of Family, Women, Children and Adolescents of the Canton of Santo Domingo, the concern of legal professionals regarding the lack of precautionary measures in this type of litigation was evident.

The formula was applied to calculate the sample size from the size of the universe of professionals [5-7]:

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

Where:
n = sample size
N= Population
E= Margin of error

A simple stratified random sampling was applied, taking as a stratum the position of the professional to be surveyed. The data regarding the sample sizes obtained from the universe of each population and according to each category are shown in table 1.

Law Professionals Population	**Universe**	**Sample**
Judges	9	8
Judicial Servers	64	39
Lawyers in free practice	1331	93
TOTAL	1404	140

Table 1. Data from the selected sample. Source: Authors' elaboration

The Iadov technique is generally used to measure a general satisfaction index from individual satisfaction indexes [8, 9] about a product or service, the implementation of a scientific result or a proposed solution to a problem in a general sense.

In this case it will be used to measure the degree of satisfaction (acceptance) of the law professionals surveyed, with respect to the proposed reform. Although this is not a common use for this technique, it is clearly robust for evaluation through expert consultation prior to its implementation as an amendment to the Civil Code.

A survey was conducted among the selected legal professionals, with the objective of measuring the level of satisfaction they have regarding the validity of the proposed reform to the Civil Code. The survey consisted of 5 questions, three closed questions and two open questions, one of which served as an introduction and the other as a reaffirmation and support of the objectivity of the respondents.

The three closed questions correspond to the "Iadov Logical Framework", which is presented and adapted to this investigation and is shown in table 2.

Question 5: What do you think of this initiative to reform the Civil Code, which recognizes and empowers cohabitants to request precautionary measures, to ensure the estate of the goods, while the judicial declaration of the Union of Fact is resolved?	*Question 1:* Do you think that the current Constitution of the Republic of Ecuador guarantees equal rights and guarantees in the administration of the assets within the common law union?								
	NO			I DONT KNOW			YES		
	Question 3: Do you consider that Article 229 of the Civil Code, currently in force, concerning the assets of this society and its burdens, needs to be amended in order to guarantee legal equality between marriage and common-law marriage?								
	YES	I DONT KNOW	NO	YES	I DONT KNOW	NO	YES	I DONT KNOW	NO
I like it very much	1	2	6	2	2	6	6	6	6
I like it more than I dislike it	2	2	3	2	3	3	6	3	6
I don't 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
I don't like it at all	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

Table 2. The logical picture of the Iadov technique for legal professionals surveyed. *Source: Authors elaboration*

In the 1980s, began the international movement called Paradoxism. It is based on the use contradictions in science and literature. Was Romanian Scholar living in USA Florentin Smarandache, who then extended it to Neutrosophy, based on contradictions and their neutrals[10, 11]. Paradoxism is an international movement in science and culture, founded by Florentin Smarandache in 1980s, based on excessive use of antitheses, oxymoron, contradictions, and paradoxes[12-14]. During three decades (1980-2020) hundreds of authors from tens of countries around the globe contributed papers to 15 international paradoxist anthologies[14, 15]. In 1995, the author extended the Paradoxism (based on opposites) to a new branch of philosophy called Neutrosophy (based on opposites and their neutral), that originated many other scientific areas [16-19].

The resulting number of the interrelation of the three questions indicates the position of each subject in the satisfaction scale, that is, the individual satisfaction. This satisfaction scale is expressed by SVN numbers [10]. The original definition of true value in the neutrosophic logic is shown below:

Let $N = \{(T, I, F): T, I, F \subseteq [0,1]\}$ be a neutrosophic valuation mapping of a group of proportional formulas to N, and for each sentence we have:

$v(p) = (T, I, F)$
(2)

In order to ease the practical application to a decision making and engineering problems, it was carried out the proposal of single valued neutrosophic sets (SVNS) since this allows the use of linguistic variables, and this increases the interpretation of models of recommendation and the usage of the indetermination [20-22].

Let X be a universe of discourse. A SVNS A on X is an object of the form:

$$A = \{\langle x, u_A(x), r_A(x), v_A(x)\rangle : x \in X\} \quad (3)$$

Where:

$u_A(x): X \to [0,1], r_A(x): X \to [0,1]$ and $v_A(x): X \to [0,1]$

With:

$0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ $for\ all\ x \in X.$

The intervals $u_A(x), r_A(x)$ and $v_A(x)$ denote the memberships to true, indeterminate and false of x in A, respectively [20, 23, 24] .

For convenience reasons, an SVN number will be expressed as $A = (a, b, c), where\ a, b, c \in [0,1], and\ a + b + c \leq 3$

In order to analyze the results, a scoring function is established. To order the alternatives we used a score function [10] adapted:

$$s(V) = T - F - I \quad (4)$$

In the event that the assessment corresponds to indeterminacy (not defined) (I) a process of de-neutrosophication developed as proposed by Salmerón and Smarandache [25]. In this case, I $\in [-1,1]$.Finally, we work with the average of the extreme values I $\in [0,1]$ to obtain a single one:

$$\lambda([a_1, a_2]) = \frac{a_1, a_2}{2} \quad (5)$$

Subsequently, the results are aggregated and the weighted average aggregation operator is used to calculate the group satisfaction index (GSI). The weighted average (WA) is one of the most mentioned aggregation operators in the literature. A WA operator has associated a vector of weights V, with $v_i \in [0,1]$ and $\sum_1^n v_i = 1$, having the following form[26]:

$$WA(a_1, \dots, a_n) = \sum_1^n v_i a_i \quad (6)$$

Where v_i represented the importance of the source. This proposal, allows to fill a gap in the literature of the Iadov techniques extending it to deal with indeterminacy and importance of user due to expertise or any other reason [8, 9, 27].

Scale used with individual satisfaction and its corresponding score is shown in Table 3.

Expression	Number SVN	Scoring
Clearly pleased	(1, 0, 0)	1
More pleased than unpleased	(1, 0.25, 0.25)	0.5
Not defined	I	0
More unpleased than pleased	(0.25, 0.25, 1)	-0.5
Clearly unpleased	(0,0,1)	-1
Contradictory	(1,0,1)	0

Table 3. Scale used with individual satisfaction and its corresponding score. Source: [9]

3 Results

By applying the designed survey, it was possible to obtain the personal satisfaction indexes for each of the 140 law professionals surveyed about the proposal provided by this research and its relevance.

The following graph shows the results of the frequencies for each of the categories of personal satisfaction levels.

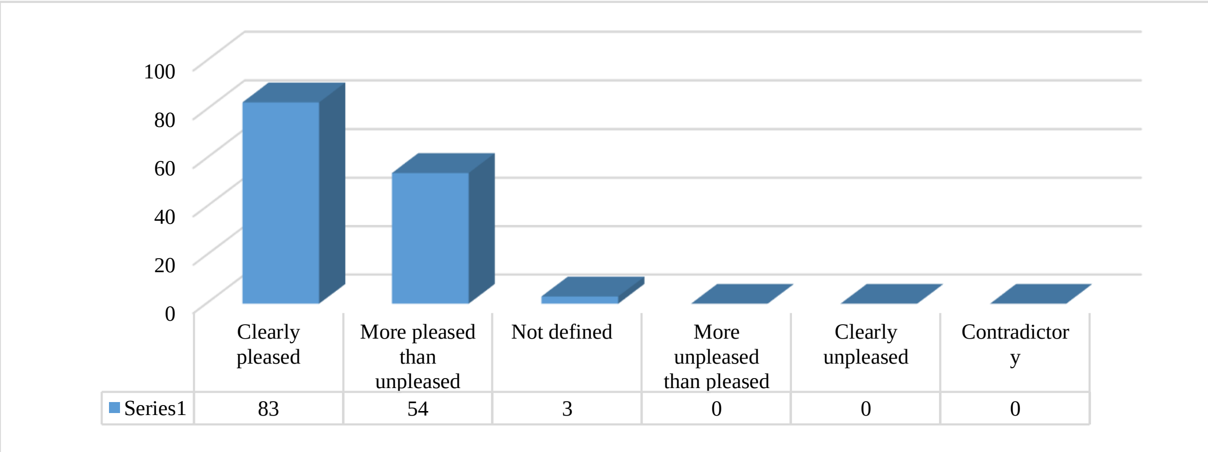

Figure 1. Frequencies observed of personal satisfaction levels. Source: Authors' elaboration

The calculation of the score is carried out and it is determined by I. In this case, it was given different values to each low professional as shown on table 4.

Professional	v_i
Judges	0,4
Judicial Servers	0,3
Lawyers in free practice	0,3
TOTAL	1

Table 4. Weighted index for professional. Source: Authors' elaboration

Applying $WA(a_1, \dots, a_n) = \sum_1^n v_i a_i$

The overall satisfaction index was obtained for the total number of respondents GSI=0.808. The result is positive, which certifies the effectiveness of the proposal as shown in the graph of figure 2.

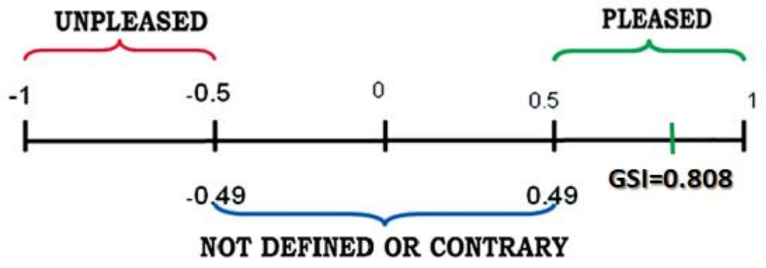

Figure 2. Scale with group satisfaction index (GSI). Source: Authors' elaboration

Conclusions

The dissolution of the corporation is the main reason for declaring a common-law marriage before a judge. However, the deficiencies in the legal system imply that the assets of the corporation are not safeguarded and are left at the disposal of one of the partners.

The use of the Iadov technique, complemented with tools of neutral logic, made it possible to validate the viability of the proposal to modify Article 223 of the Ecuadorian Civil Code through the creation of norms that regulate the precautionary measures in the case of the Declaration of a Union of Fact and other conflicts between cohabitants or their heirs.

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Neutrosophic K-means Based Method for Handling Unlabeled Data

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Abstract. Nowadays, incalculable volumes of data are generated due to the technological development achieved by the current society of information. The exponential growth of information significantly supports people's decision making in their daily activities. In Ecuador, there are many institutions that store the data of their processes. The tourism sector represents an example of this assertion. However, the data generated exceeds the power of analysis and processing of human beings, sometimes relevant information is presented it is not visible for persons. The present investigation proposes a solution to the described problem starting from the development of a method for the treatment of unlabeled data. The proposed method is based on the unsupervised k-means algorithm. We used rough neutrosophic sets to reduce the number of attributes. The proposal has been implemented from the stored dataset of the tourism sector in the City of Riobamba.

Keywords: Machine learning; data mining; rough neutrosophic sets; entropy

1. Introduction

Tourism represents an important source of income in Ecuador's internal economy. Each region of the country has attractions that make it unique as a tourist destination. The city of Riobamba in Ecuador is characterized by representing a very attractive tourist area, it is a city with great cultural heritage that attracts even the most exquisite vacationers [1].

Tourism management itself generates high demands for products and services that include a wide range of different activities such as: transportation, accommodation, supply, shopping, travel agency services, inbound and outbound tourism operators, among others [2, 3]. Without doubt, tourism represents a fundamental source of income and it generates a large amount of data [4].

From the different operations that are carried out in the City of Riobamba, there are stored historical data of the different operations in tourism management. However, the existing data is not properly labeled, which makes it impossible to obtain objective information that contributes to decision-making for the tourism sector [5].

Problems of this nature have been addressed in the scientific literature from data mining techniques for the cleaning, transformation and treatment of unlabeled data [6-8]. This investigation has the objective to develop a method based on k-means for the treatment of unlabeled data.

We use three main tools for solving this problem. One is the combination of rough sets with single-valued neutrosophic sets, to deal with the so-called rough neutrosophic sets, which extends the existing rough fuzzy sets, but including the indeterminacy. The other two techniques are k-means and entropy. The hybridization of these methods creates a more accurate result.

This paper is divided into the following sections: Section 2 contains the preliminary concepts; section 3 exposes the materials and methods that will be used in this paper. Section 4 summarizes the results applied to an actual case study related with a database of touristic industry in the city of Riobamba in Ecuador. The paper ends with the conclusions.

2. Preliminaries

This section introduces an approximation of the main theoretical references that support the research proposal. It begins with a characterization of machine learning. The fundamental elements on the rough sets and some criteria for comparing k-means algorithms are presented. The section continues with the significant elements associated with entropy and information. Finally, the used k-means algorithm is described.

2.1 Machine learning

Machine learning introduces a new paradigm that refers to the study of computational algorithms that automatically incorporate experiences to improve its operation [9, 10]. Machine learning systems simulate the processes that humans perform when they are executing a task.

A machine learning process needs to train a model by applying learning techniques. For the training process, the data that the machine will use to learn this procedure are provided [11-13]. This type of learning has been used in data mining applications with the aim of discovering rules and patterns in large data sets and filtering information [14, 15].

The classification of machine learning techniques can be divided into:

- Supervised or predictive learning: where the objective is to learn to map from X inputs to Y outputs, given a labeled set of N input-output pairs; this set is called Training set.
- Unsupervised or descriptive learning: aims to find interesting patterns in the N entries.
- Reinforcement of learning: it is used to know how it acts or behaves when certain occasional signs of reward or punishment are given.

2.2 Rough sets

Rough sets (RS) are based on the assumption that each object x in the universe of discourse U has associated certain information that represents data and knowledge [16]. It is expressed through attributes that describe the object. Among the advantages of RS for data analysis are [17-19]:

- It is based on the original data and does not require external information, so there is no need to make any assumptions about the data.
- It allows the analysis of qualitative and quantitative traits.

Then a rough set is formalized as follows:

Definition 1. Let U be a finite universe. Let R be an equivalence relation defined in U, which partitions U. (U, R) is a collection of all equivalence classes, called the *approximation space*. Let $w_1, w_2 w_3, \cdots, w_n$ elements of the approximation space (U, R). This connection is known as the *knowledge base* [20]. Then, for any subset B of U, the *upper approximation* $\overline{B}$ and the *lower approximation* $\underline{B}$ are defined as [21, 22]:

The ordered pair $(\overline{B}, \underline{B})$ is called an *approximate set* and its elements are defined as follows:

The *lower approximation* of the set X with respect to R is defined in Equation 1:

$$\underline{B}(X) = \cup_{x \in U}\{R(X): R(X) \subseteq X\} \tag{1}$$

The *upper approximation* of the set X with respect to R is defined in the following form:

$$\overline{B}(X) = \cup_{x \in U}\{R(X): R(X) \cap X \neq \emptyset\} \tag{2}$$

And it also has:

$POS(B) = \underline{B}$: It is certainly a member of X.

$NEG(B) = U \setminus \overline{B}$: It is certainly not a member of X.

$BR(B) = \overline{B} \setminus \underline{B}$: It is possibly a member of X.

Where:

$POS(B)$ refers to the positive region of B,

$NEG(B)$ refers to the negative region of B,

$BR(B)$ refers to the border region of B.

An *approximate set* can be defined by neutrosophic numbers. Neutrosophic logic is a general framework for unifying many existing logics. Generalize fuzzy logic (especially fuzzy intuitionist logic). In 1995, Florentin Smarandache extended Paradoxism (based on opposites) to a new branch of philosophy called Neutrosophy (based on opposites and their neutral), that gave birth to many areas of application [23, 24]. The important idea of NL is to characterize each logical statement in a neutrosophic 3 dimensional $[0, 1]^3$-space, where each dimension of the space represents the truth (T) respectively, the falsehood (F), and indeterminacy (I) of the proposition, where T, I , F are standard or not standard real subset of]-0, 1+[[25].

The classic interval unit [0,1] can be used. T, I, F are independent components leaving room for incomplete information (when they sum up <1), for consequent and contradictory information (when they sum up > 1) or complete information (sum of components = 1)[25-27].

Definition 2. *Neutrosophic sets* are a fuzzy set generalization (spatially fuzzy intuitive set). Let U, be a universe of discourse, and M a set included in U. An element x of U is denoted with respect to the set M as x(T, I, F) and it belongs to M in the following way: It is t% true, it is i% indeterminate, and it is f% false, where t varies in T, i varies in I, and f varies in F[28, 29].

Statistically T, I, F are subsets of [0, 1], but dynamically T, I, F are functions or operations dependent on many unknown or known parameters [26].

In order to facilitate practical application to decision-making and engineering problems, the proposal was made for single-value valued neutrosophic sets [16, 30, 31], which allow us to use linguistic variables [32, 33] increasing the interpretability in the recommendation models and the use of indeterminacy.

Definition 3. Let X be a universe of discourse. A Single-valued neutrosophic set (SVNS) A over X is an object of the form.

$$A = \{\langle x, u_A(x), r_A(x), v_A(x)\rangle : x \in X\} \quad (3)$$

Where $u_A(x): X \rightarrow [0,1]$, $r_A(x), : X \rightarrow [0,1]$ and $v_A(x): X \rightarrow [0,1]$ with$0 \leq u_A(x) + r_A(x) + v_A(x) :\leq 3$ for all $x \in X$. The intervals $u_A(x), r_A(x)$and $v_A(x)$ denote the memberships to true, indeterminate, and false of x in A, respectively. For reasons of convenience, a single-valued neutrosophic number will be expressed as $A = (a, b, c)$, where$a, b, c \in [0,1]$, and $0 \leq a + b + c \leq 3$.

Definition 4. [34] Let U be a non-null set and R be an equivalence relation on U. Let F be neutrosophic set in U with the membership function μ_F, indeterminacy function ν_F and non-membership function ω_F. The *lower* and the *upper approximations* of F in the approximation (U, R) denoted by $\underline{N}(F)$ and $\overline{N}(F)$ are respectively defined as follows: $\underline{N}(F) = \{< x, \mu_{\underline{N}(F)}(x), \nu_{\underline{N}(F)}(x), \omega_{\underline{N}(F)}(x) > | y \in [x]_R, x \in U\}$,

$\overline{N}(F) = \{< x, \mu_{\overline{N}(F)}(x), \nu_{\overline{N}(F)}(x), \omega_{\overline{N}(F)}(x) > | y \in [x]_R, x \in U\}$.

Where:

$\mu_{\underline{N}(F)}(x) = \wedge_{y \in [x]_R} \mu_F(y)$, $\nu_{\underline{N}(F)}(x) = \wedge_{y \in [x]_R} \nu_F(y)$, $\omega_{\underline{N}(F)}(x) = \wedge_{y \in [x]_R} \omega_F(y)$,

$\mu_{\overline{N}(F)}(x) = \vee_{y \in [[x]_R} \mu_F(y)$, $\nu_{\overline{N}(F)}(x) = \vee_{y \in [x]_R} \nu_F(y)$, $\omega_{\overline{N}(F)}(x) = \vee_{y \in [x]_R} \omega_F(y)$.

Then, $0 \leq \mu_{\underline{N}(F)}(x) + \nu_{\underline{N}(F)}(x) + \omega_{\underline{N}(F)}(x) \leq 3$ and $\mu_{\overline{N}(F)}(x) + \nu_{\overline{N}(F)}(x) + \omega_{\overline{N}(F)}(F)(x) \leq 3$, where "$\vee$" and "$\wedge$" mean "max" and "min" operators respectively, $\mu_F(y)$, $\nu_F(y)$, and $\omega_F(y)$ are the membership, indeterminacy and non-membership of y with respect to F.

Especially for decision-making, we define R as the similarity relation, such that there is a similar or equal labels between two elements, see [35].

The membership, indeterminate-membership, and non-membership are defined from the rough set as follows:

$T(x) = \frac{card(\mathrm{S_B(x)} \cap \underline{\mathrm{B}}(\mathrm{x}))}{card(\mathrm{S_B(x)})}$, $I(x) = \frac{card(\mathrm{S_B(x)} \cap (\overline{\mathrm{B}}(\mathrm{x}) \backslash \underline{\mathrm{B}}(\mathrm{x})))}{card(\mathrm{S_B(x)})}$, and $F(x) = \frac{card(\mathrm{S_B(x)} \cap \overline{\mathrm{B}}(\mathrm{x}))}{card(\mathrm{S_B(x)})}$, respectively.

2.3 Entropy and information gain

The entropy in a data source represents the magnitude that measures the information provided about the data source. Entropy provides information about a specific data source or fact [36-38].

Definition 5. Given two classes P and N in a sample space S, where:

$$\mathrm{S} = \mathrm{P} \cup \mathrm{N} \quad (4)$$

Where the cardinality is given by:

$$|\mathrm{P}| = \mathrm{p} \text{ and } |\mathrm{N}| = \mathrm{n} \quad (5)$$

Entropy refers to the amount of information necessary to decide whether a sample of S belongs to P or to N and it is defined as Equation 6, see [39, 40]:

$$\mathrm{E(S)} = \frac{\mathrm{p}}{\mathrm{p+n}} \log_2\left(\frac{\mathrm{p}}{\mathrm{p+n}}\right) - \frac{\mathrm{n}}{\mathrm{p+n}} \log_2\left(\frac{\mathrm{n}}{\mathrm{p+n}}\right) \quad (6)$$

When selecting an attribute b the sample space is divided into child subsets of b, the way to determine how much information an attribute b contributes in a total set of attributes A, is given by [41, 42]:

$$\mathrm{Input(b)} = \mathrm{E(A)} - \sum (\forall \text{ the child sets of B}) \quad (7)$$

Finally, if we have k classes, N instances in the data set, the entropy of the entire set is E, the entropy of each of the subsets is E1 and E2, the number of instances in one class is k1 and in the other k2, then the minimum contribution of information is defined as in Equation 8, see [43, 44]:

$$\frac{\log_2 \mathrm{N} - 1}{\mathrm{N}} + \frac{\log_2 3^{\mathrm{k}} - 2 - \mathrm{K^E} + \mathrm{k} * \mathrm{E1} * \mathrm{E2}}{\mathrm{N}} \quad (8)$$

2.4 K-means algorithm

K-means is one of the most widespread algorithms for grouping. Clustering represents a technique implemented in Data Mining. The idea of k-means is to place all objects in a certain space and given their characteristics to form groups of objects with similar but different features to those that make up other groups. K-means is an unsupervised learning algorithm that has the following characteristics [45, 46]:

- The data set is randomly partitioned into K groups (clusters).
- K center points are selected at random, one from each group (centroids).
- For each data, the distance from the point to each central point of the groups is calculated and the data becomes part of the group whose distance is less than its center.
- If the data is closer to its own group, it stays in its group, otherwise it becomes part of the group of the closest center.
- The previous process is repeated until no point passes the group.

However, the algorithm has some drawbacks:

- The final grouping depends on the initial centroids.
- Convergence in the global optimum is not guaranteed, and for problems with many specimens, it requires a large number of iterations to converge.

3. Materials and methods

This section describes the implementation scenario based on the stored dataset of the tourism sector in the City of Riobamba.

Data set	Type of data	Instances	Attributes
Destination evaluation	Multivariate	1382	4
Historical Tours	Multivariate	720	6
Hotel accommodation	Univariate	1080	5
Transportation	Multivariate	2801	4

Table 1. Data stored from the tourist sector in the City of Riobamba.

A data set with decision attributes was used to execute the algorithms excluding this attribute and then compare the results obtained with those originally indicated by these attributes.

Having data sets for which the decision attribute is known, allows determining the number of groups of the k-means algorithm.

Figure 1 shows a diagram of the flow of the k-means method for the case under study.

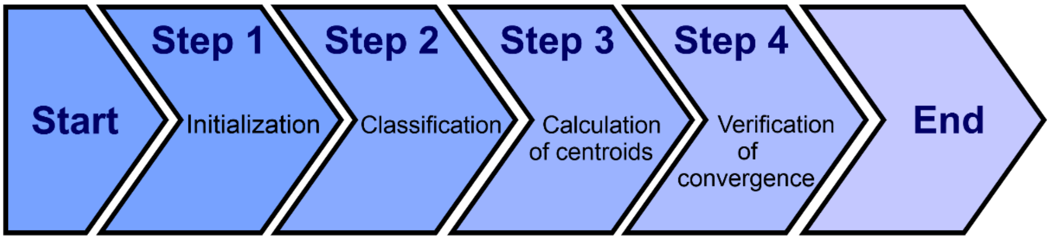

Figure 1. Diagram of the operation of the k-means method.

As in most data mining processes, each repository had to go through the stages of: clean, integrate, select, transform, mine, interpret and present [47]. Figure 1 shows the flow of the k-means method for the case under study. The following is a description of the different steps that describe the method:

Step 1. Initialization: Definition of a set of objects to which the clustering process is applied, which consists of separating the data into groups and a centroid (geometric center of the clusters) for each one. Initial centroids can be determined randomly, while in other cases they process the data and centroids are determined by calculations.

Step 2. Classification: For each data, the square Euclidean distance from the centroids is calculated, the closest centroid to each of the data is determined, and the object is appended to the cluster of the centroid that was selected.

Step 3. Calculation of centroids: The centroids are recalculated for each of the clusters.

Step 4. Verification of convergence: If one of the algorithm's conditions has been met and it must stop, this is called the convergence or stop condition. A set of conditions are defined for processing:

a) The number of iterations.

b) When the centroids obtained in two successive iterations do not change their value.

c) When the difference between the centroids of two successive iterations does not exceed a certain threshold.

d) When there is no transfer of objects between groups in two successive iterations.

If any of the convergence conditions is not met, steps two, three and four of the algorithm are repeated.

For computational processing the algorithms were coded in Python 3.8.12 and it was run on the following platform:

- Intel(r) core(tm) i3-2100 CPU @ 3.10ghzprocessor.

- Operating system: Ubuntu/Linux.

From the k-means algorithm comparison criteria, the one was chosen to maximize the number of success cases, since the last interest is to determine how well the grouping did.

In order to compare the results, three processes were run with the same data sets under the following conditions:

- 90 iterations were made with random processes in order to determine the average effect of the algorithm.
- When ranges were used, there was no point in repeating it more than once as the algorithm is deterministic for a given data set.

3.1 Classic k-means with random centroids

K-means was used as a grouping algorithm so that the resulting groups were then used to label the objects in their decision attribute (D); using the group number in which the object was grouped as the value of the decision attribute (D).

K-means using only the attributes with a contribution of information superior to a border. The entropy of each of the attributes and its information gain were calculated. The method used was as follows:

- Let E (C) be the entropy of the entire set of attributes.
- How much information is provided by the entropy of each of the c condition attributes (C) is calculated.
- Let E(ci) be the entropy of the condition attribute ci.
- Since the selection of the criterion in which value, of the Vc values, to divide the attribute c to calculate the entropy can be very different for each attribute, it is decided to order the Vc values from least to greatest and take the mean as the division criterion.
- The information input of attribute c is equal to: $\mathrm{C} - \sum(\forall \text{ the child sets of } \mathrm{C})$
- The condition attributes that provide the greatest amount of information such as those selected are used to choose the initial centers for the k-means algorithm from them.

Once the attributes to be considered have been chosen, if it is desired that the decision attribute (D) take different values from it, then k-means is run to form groups, using as distances only the attributes selected for their greatest contribution of information. The centers can either be initialized randomly or divide the total range of the values of attribute c into k uniform pieces and take these values as initial centers of the k-means algorithm.

Given that they are the attributes that provide the most information, it was decided to initialize the centers with uniform ranges.

3.2 k-means using only attributes selected by rough neutrosophic sets

We used the theory of rough neutrosophic sets to determine which condition attributes are indispensable and which are dispensable and therefore, proceed to the reduction of attributes, calculating the relation of indispensableness of each one of them.

Being P the set of attributes, $a \in$ P, the attribute *a* is dispensable in P if:

$$\mathrm{IND}(\mathrm{P}) = \mathrm{IND}(\mathrm{p}\{\mathrm{a}\}) \qquad (9)$$

Similarly, once the attributes to be considered have been chosen, if it is desired that the decision attribute (D) take Vd different values, then k-means is run to form Vd groups using only the indispensable attributes for the calculation of distances. The centers can be initialized randomly or the total range can be divided into k uniform pieces. In order to compare the results, the centers with uniform ranges were initialized.

4. Results

From the data recovered from the tourist sector in the City of Riobamba are processed. After applying the previously proposed experiments, we obtained the results that are pr in Table 2.

Characteristic/Data sets	**Valuation of fate**	**Historical Tours**	**Hotel accommodation**	**Transport job**
Total records	1382	720	1080	2001
Total attributes including decision	4	6	5	4
		***k-means* classic**		
Classic *k-means* success rate mean	63.40	35.20	53.20	54.50

Standard deviation of the classic *k-means* success rate	3.80	7.38	3.01	8.45
Variation coefficient of the classic *k-means* success rate	0.08	0.43	0.07	0.15
		***k-means* using information gain**		
Number of attributes removed due to information gain	1	1	1	1
Average success rate using the remaining attributes	56.80	30.40	56.20	48.30
Standard deviation of success rate using only the remaining attributes	0.00	0.00	0.00	0.00
Variation coefficient of success rate using only the remaining attributes	0.00	0.00	0.00	0.00
		Rough neutrosophic sets		
Number of attributes removed by rough sets	2	1	0.00	0.00
Average success rate using the remaining attributes	57.6	32.32	54.20	42.40
Standard deviation of success rate using only the remaining attributes	0.00	0.00	0.00	0.00
Variation coefficient of success rate using only the remaining attributes	0.00	0.00	0.00	0.00

Table 2. Results obtained for the different data sets.

From the analysis of the results presented in Table 2, the following discussions are presented:

1. The classical k-means algorithm is highly dependent on the selection of the initial centers. Random center initialization tends to have high standard deviations, therefore high coefficients of variation.
2. Using entropy and information gain, only the attributes that provide more information are used, uniform ranges are used for centroids instead of random centers. The process becomes deterministic for the same data set; therefore, the standard deviation and coefficient of variation are displayed at zero.
3. Once the data has been labeled, or if already labeled data sets are available, and although the determination of the indispensable and dispensable attributes using rough sets is an expensive process in computational time, once determined, the reduction of attributes benefits likewise the future classification process.
4. The classic k-means with random centers showed that in some cases it obtained a higher success rate than the others. The problem being that its standard deviation is high and, therefore, as the average case will not always occur, it can perfectly yield the worst case, or cases close to it, and in these scenarios its performance is lower than when using information gain or rough sets.

Conclusions

This investigation proposed a machine learning method for dealing with unlabeled data sets which bases its operation on:

To use entropy and information gain to select from which attributes calculate the k-means centers.

Use k-means only with the attributes selected from the previous step to label the data in your decision attribute.

Once the objects have been labeled with the previous steps, approximate sets can be used to determine which attributes are dispensable and which are indispensable and, therefore, proceed to the reduction of attributes.

The calculation of entropy, the information gain and the neutrosophic approximate sets requires a computational effort before calculating the k-means.

By implementing the k-means algorithm on the stored data set of the tourism sector in the City of Riobamba, a classification of the information is obtained from relevant data. The proposal provides a tool for decision-making based on achieving better opportunities for the sector.

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Neutrosophic Hypothesis to validate a Reform Project to Article 87 of the General Organic Code of Processes of Ecuador

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Abstract. Based on the fact that, according to the legislation in force in Ecuador, the appearance at hearings is mandatory for all those who intervene in a case to such an extent that their non-attendance is sanctioned in one case and abandoned in another, without taking into account that this absence may have been due to a fortuitous event or force majeure. The present investigation is focused on validating a project to reform Article 87 of the General Organic Code of Processes focused on making it possible to justify the defendant's absence. For the validation, a Neutrosophic Hypothesis was used, which allowed to demonstrate that the lawyers of Los Ríos Province are at least partially in agreement with the proposed reform.

Keywords: Single-Value Neutrosophic Set**,** score function, Neutrosophic p-value, Neutrosophic hypothesis

1 Introduction

Ecuador's General Organic Code of Processes (GOCP) regulates procedural activity in all matters, except constitutional, electoral and criminal, with strict observance of due process. Among its guiding principles, it states that the principles set out in the Constitution of the Republic, international human rights instruments, international instruments ratified by the State, the Organic Code of the Judicial Function, and those developed in this code shall be applied in all procedural activities [1].

The main premise of GOCP is the adoption of a trial by hearings, which are the central element of the oral process, although this does not mean that an exclusively oral process should be considered, but rather a mixed one, in accordance with the doctrine.

Article 87 states that:

> Effects of failure to appear at hearings, in the event that the parties fail to appear, the following criteria shall be applied:
>
> 1. When the person who filed the complaint or application fails to appear at the corresponding hearing, his failure to attend shall be understood as abandonment.
> 2. When the defendant or requested party does not appear at the corresponding hearing, the hearing shall be continued and the sanctions and effects shall be applied, it being understood that the procedural opportunity to assert his/her rights is lost. However, in case of delay, your participation will be admitted, taking the hearing in the state in which you are. If the judge has the right to hold a hearing, he or she will continue it and must resolve the matter in accordance with the purpose for which it was convened [2].

It should be noted, therefore, that in drafting these rules, no account was taken of the fact that the absence of the defendant may have been caused by some fortuitous event or force majeure.

It is called force majeure or fortuitous case the unforeseen to which it is not possible to resist, such as a shipwreck, an earthquake, acts of authority exercised by public officials, etc. Thus, a fortuitous event or force majeure must be unimputable, that is, it must come from a cause entirely beyond the control of the parties; unforeseeable, that is, it could not have been foreseen within the ordinary and current calculations; and irresistible, that is, it could not have been avoided, even in the event that the appropriate defenses to achieve such objective were opposed[3].

Force majeure or cause majeure, or in Latin vis maior, is a fact that cannot be avoided and neither can it be foreseen. It is of great importance, in law, when establishing liability for damages.

When speaking of a fortuitous case, it is indicated that it is an unforeseen event, something that cannot be avoided. On the other hand, when force majeure is mentioned, it is said that the obligations that were foreseen cannot be fulfilled.

The case of force majeure begins in Roman law. The Romans understood by fortuitous case to mean any event that the human mind could not foresee or that could not be resisted, such as floods, enemy incursions, or fires [4].

The force majeure clause is common in contracts, and serves to cover possibilities beyond the control of the parties such as natural disasters, wars, etc. In international law, force majeure refers to a force that is impossible to avoid or foresee, beyond the control of a State, and which makes it impossible to comply with an international obligation [3].

Its interpretation is very important, because there are many cases that are on the borderline between force majeure and acts of God (such as strikes that prevent the provision of services).

In legal matters, it is very common to use the words force majeure and the responsibility that they produce, the consequences that may lead to legal responsibilities within a process [5, 6].

The sign of abandonment has been evident since Roman times. The Judge, at that time called a Magistrate, decided that the process was concluded when the procedure was finished, which did not affect the actor to present again the same cause for the same action.

Currently, a legal case is declared abandoned as long as there has been no movement within the instance, or no management of it, by either party, accuser or defendant. The abandonment is produced by stopping following the process or also by giving up the process, this produces a definitive separation of the instance. Therefore, procedural abandonment is a way of extinguishing the action within a process by not giving it the procedural momentum when there is inactivity in the procedural acts after a certain period of time has elapsed.

Two elements can be distinguished in abandonment [6]:

Subjective element: the parties are taken into account, which may be natural or legal persons who bring the suit (the actors) against other natural or legal persons (defendants). When the actor does not pursue the case, it is declared abandoned, and the same applies to the defendant. If none of the parties promotes the process as stated by the law, it is logical that the judge will declare the abandonment of it and will not be able to continue with the lawsuit.

Objective element: currently, GOCP states that eighty days must pass for a lawsuit to be declared abandoned, and once the case is declared abandoned, a lawsuit cannot be filed with the same action.

When analyzing the legislation in force in Latin American countries in this regard, we found that in several of them the defendant is able to justify his non-attendance [7].

For example, in Uruguay, Article 310.2 of the General Organic Code of Processes states that if the petitioner does not appear at the hearing, he will be considered to have desisted from it and will be punished with costs, but if he justifies his inability to attend due to unforeseen circumstances or force majeure, he will be suspended for one time only [8].

The Bolivian legislation states in its Procedural Code that if the defendant cannot attend the hearing, he will justify and will only be accepted for one time the non-attendance of the hearing, but he will have to justify with a reason if it is due to a fortuitous case or force majeure. Section II of this chapter of the Procedural Code sets out the steps to be taken to justify the defendant's failure to attend the hearing, presenting documentary evidence that specifically specifies the cause [9].

From this point, it can be concluded that the possibility of justifying non-attendance in order to avoid a penalty may be a guarantee for the person who will be affected by the penalty, which is consistent with the right to due process that must be observed in judicial and administrative proceedings. It is obvious that in procedural matters whoever asserts a claim or an exception or a relevant circumstance in the process from which legal consequences are derived is obliged to provide the corresponding evidence. By virtue of this, such obligation is contracted to summarily prove facts that are true, constituting a fortuitous case or a force majeure that merit the excuse.

However, in Ecuador, according to the current legislation, the appearance to the hearings is mandatory for all those who intervene in a case to such an extent that their non-attendance will be subject to sanctions in one case and in another be declared a case of abandonment.

For this reason, the objective of this research is to validate a draft reform to Article 87 of the General Organic Code of Processes of Ecuador, which would allow the defendant to justify his non-attendance at the hearing, whether due to an act of God or force majeure, in order to guarantee the constitutional principle of legal security set forth in Article 82 of the Constitution of the Republic [10].

This reform draft consists of incorporating a paragraph into Article 87(2) of GOCP, which states the following [2, 11]:

The non-attendance of the defendant at the hearing, duly justified for some reason of fortuitous case or force majeure, shall be justified within a period of 72 hours after the hearing.

2. Neutrosophic Hypothesis

Paradoxism [12] is a movement based on contradictions in science and literature, supported on excessive use of antitheses, oxymoron, contradictions, and paradoxes. From 1980-2020 hundreds of authors from tens of countries around the globe contributed papers to international paradoxist anthologies[13, 14] . It was founded by Romanian polymath Florentin Smarandache, who then extended it in 1995 to a new branch of philosophy called Neutrosophy, based on opposites and their neutral [15-17]. Neutrosophy movement originated many scientific branches, such as: neutrosophic logic, neutrosophic set, neutrosophic probability, neutrosophic statistics, and so on, with multiple applications in engineering, computer science, medical research etc. [18-22].

In this study, we make use of a neutrosophic hypothesis, where the distinction between the classical (statistical) hypothesis and the neutrosophic one is that in neutrosophic statistics the variables that describe the characteristics of the population are neutrosophic ones (they have indeterminate values or some unknown values, or an inexact amount of terms if the variable is discrete), or for the values we compare at least one of the characteristics of the population is neutrosophic (it is indeterminate, unknown or vague) [23].

A null hypothesis, denoted by NH0, is the affirmation that is initially assumed as true, while the alternative neutrosophic hypothesis, denoted by NHa, is the other hypothesis. When testing NH0 against NHa, there are two possible conclusions: reject NH0 (if the evidence of the sample clearly suggests that NH0 is false), or accept NH0 hypothesis (if the sample does not support the evidence against NH0) [24].

3 Materials and methods

In order to accomplish the proposed objective, a survey was applied to legal professionals in the Babahoyo Canton, Los Ríos Province. We considered a population of 2818 lawyers of the above mentioned province, registered in the computer system of the Lawyers' Forum, of the Judiciary Council of Ecuador.

The sample size was calculated using the formula for finite population sample calculation:

$$n = \frac{Z^2 \cdot p \cdot q \cdot N}{Ne^2 + Z^2 \cdot p \cdot q} \quad (1)$$

The technique of simple random sampling combined with intentional sampling was applied, given the limitations of access to these professionals.

The survey was designed to measure the agreement of the lawyers surveyed with the main elements that support the judicial argument presented in this research, and to validate the proposed reform to Article 87, paragraph 2 of the General Organic Code of Processes.

The instrument applied was designed with the format of statements according to the Likert type surveys, as shown below:

1. The Carta Magna explicitly recognizes access to justice as a right.
2. A declaration of abandonment plays a defining role in non-criminal hearings because it makes it impossible to bring another lawsuit for the same cause.
3. The defendant's right to legal security is being violated by not allowing him to justify his non-attendance at a non-criminal hearing.
4. Article 87(2) of the General Organic Code of Processes should be amended to provide for the possibility of justifying the defendant's non-attendance at the hearing, when this is due to an act of God or force majeure.

The respondent was asked to state their position for each statement between “Totally Agree” and “Totally Disagree”. To statistically process the survey results, the linguistic terms associated with a set of single-value neutral numbers were used as shown in table 1.

Linguistic term	SVN
Strongly agree (SA)	(1 , 0 , 0)
Agree (A)	(0.8 , 0.15, 0.20)
Partially agree (PA)	(0.60 , 0.35, 0.40)
Neither agree or disagree (NAD)	(0.50 , 0.50 , 0.50)
Partially Disagree (PD)	(0.40 , 0.65 , 0.60)
Disagree (D)	(0.20 , 0.85 , 0.80)
Strongly disagree (SD)	(0 , 1 , 1)

Table 1. Linguistic terms and its SVN associated

Single-value neutrosophic sets (SVNS) [25-27] for the management of undefined and inconsistent information is a relatively new approach based on Neutrosophy.

Neutrosophy is a mathematical theory developed by Florentin Smarandache to deal with indetermination. It has been the basis for the development of new methods to handle indeterminate and inconsistent information such as neutrosophic sets and neutrosophic logic and, especially, in decision-making problems.

The truth value in the neutrosophic set is defines as follows [27]:

Let N be a set defined as: $N = \{(T, I, F): T, F, I \subseteq [0,1]\}$, a neutrosophic valuation n is a mapping of the set of propositional formulas, that is, for each p statement we have $v(p) = (T, I, F)$.

The single-value neutrosophic set (SVNS) [5] is a special case of a neutrosophic set, it was developed with the aim of facilitating real-world applications of neutrosophic sets and theoretical set operators.

A single-valued neutrosophic set (SVNS)[27] A in X is characterized by truth $T_A(x)$, indeterminacy $I_A(x)$, and falsehood $F_A(x)$, membership functions. For each point x in X, there are $T_A(x), I_A(x), F_A(x) \in [0,1]$ and $0 \leq T_A(x), I_A(x), F_A(x) \leq 3$.

A is denoted by $\{A = [\, x, T_A(x), I_A(x), F_A(x)] \mid x \in X\,\}$.

A single-value neutrosophic number (SVN number) allows the use of linguistic variables [28].

To convert the SVNs into crisp numbers, a scoring function was applied [29]. For each statement in the survey:

$$p(x) = 2 + T(x) + I(x) + F(x) \qquad (2)$$

In the case of this research, the scoring function can be expressed as

$$p(x)_s = 2 + T(x)_s + I(x)_s + F(x)_s \qquad (3)$$

Where:

x is the number of the respondents,

s is the number of the statements

and $p(x)_s$ is the score function value of the respondent x for the stamen s.

The average value of the score function was then calculated using the formula:

$$\bar{p}(s) = \frac{\sum_{x=1}^{47} p(x)_s}{47} \qquad (4)$$

Where:

$\bar{p}(s)$ is the score function average of the statement s

Degrees of agreement were assigned for each of the 7 intervals into which the range (between 0 and 3) of the average score function was divided, see Table 2.

Agreement degree	Interval
Strongly agree	$2.57 < \bar{p}(s) \leq 3$
Agree	$2.14 < \bar{p}(s) \leq 2,57$
Partially agree	$1.71 < \bar{p}(s) \leq 2.14$
Neither agree or disagree	$1.29 < \bar{p}(s) \leq 1.71$
Partially Disagree	$0.86 < \bar{p}(s) \leq 1.29$
Disagree	$0.43 < \bar{p}(s) \leq 0.86$
Strongly disagree	$0 < \bar{p}(s) \leq 0.43$

Table 2. Intervals of the average score by agreement degree

This allowed the application of a neutral hypothesis test for the mean of the scoring function of the last survey statement, which specifically refers to the proposed modification.

A neutrosophic hypothesis is a statement about the neutrosophic values of a single or several population characteristics. The distinction between the classical (statistics) hypothesis and neutrosophic hypothesis is that in the neutrosophic statistics the variables that describe the population characteristics are neutrosophic (i.e. they have some indeterminate values, or several unknown values, or an inexact number of terms if the variable is discrete), or for the values that we compare at least one of the population characteristics is neutrosophic (i.e. indeterminate or unclear or vague value)[30] .

As in classical statistics, we use the classical standard normal distribution of a random variable z, which is a normal distribution with the mean value $\mu = 0$, and standard deviation $\sigma = 1$.

If the neutrosophic null hypothesis about variable x is:

$$NH_0: \mu \in [a, b]$$

Where $[a, b]$ is the hypothesized interval with $a \leq b$, then the neutrosophic test statistic is:

$$z = \frac{\bar{x} - [a,b]}{s/\sqrt{n}} \qquad (5)$$

A Neutrosophic P-Value is defined in the same way as in classical statistics: the smallest level of significance at which a null hypothesis can be rejected, only that the neutrosophic P-value is not a crisp number as in classical statistics, but a set (in many applications it is an interval)

With the application of this contrast, we intended to verify that the lawyers of Los Ríos province, are at least partially in agreement with the proposal presented in this work given the judicial argument exposed, for a level of significance between 0.90% and 0.95%, which shows the neutral character of the hypothesis test carried out.

3 Results

By applying the survey we obtained the sample results summarized in figure 1.

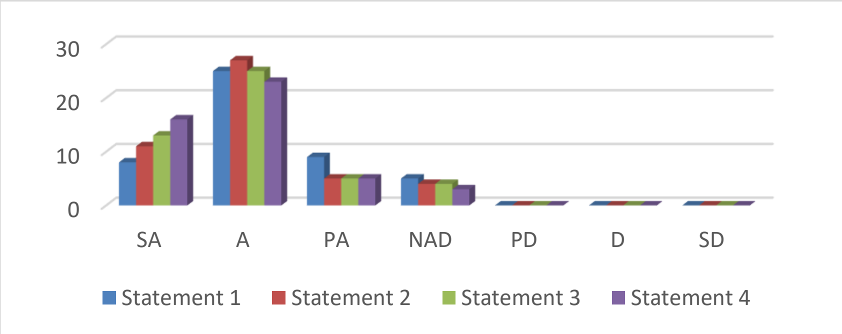

Figure 1. Sample results

In the bar graph it can be seen at first sight that for none of the elements that support the argument, degrees of agreement lower than "Neither agree or disagree" were obtained. For each of the proposed statements, "Agree" categories were obtained from more than 20 of the respondents. Finally, it should be noted that for the statement referring to the proposal for modification presented (4), the greatest number of opinions with a "Strongly agree" degree of agreement was obtained.

This sample analysis was complemented by the calculation of the central tendency statistic applied (4), through which it was possible to assign a global category for each question of the survey as proposed in table 2.

The average values of the scoring function were higher than 2.32 in all cases, so we can assure that 100% of the consulted lawyers agree with the proposals of this research. It is worth noting that the maximum average value for a question (2.513) was reached for question number 4, which is a good indicator of the level of acceptance of the proposal at the sample level. The results mentioned above are shown in table 3

	Statement 1	Statement 2	Statement 3	Statement 4
$\overline{p}(s)$	2,328	2,434	2,457	2,513
Agreement Degree	A	A	A	A

Table 3. Agreement degree for each statement

In order to demonstrate the assertion made: that the lawyers of Los Ríos province are, at least, partially in agreement with the Project of Reform to Article 87 of the General Organic Code of Processes of Ecuador regarding the fact that the defendant can justify his non-attendance at the hearing, whether by chance or force majeure, the following neutral hypothesis was put forward.

$$NH_0: \overline{P} \in [0\,, 1.71\,]$$
$$NH_1: \overline{P} > 1.71$$

As in this case, the interval was used as a level of significance. The contrast statistic used is:

$$z = \frac{2.513\ - [0\,, 1.71]}{0.84/\sqrt{47}}$$
$$z = [6.55\,, 20.51]$$

Therefore:

$$Neutrosophic\ p - value = [0\,, 0]$$

Then, we reject NH_0 because $max\{[0,0]\} < min\{[0.05, 0.1]\}$.

In fact, these values of neutrosophic p-value, allow us to assure, for a level of significance even of 100%, that the population mean of the scoring function for the studied universe is higher than 1.71, and therefore, the hypothesis raised about a positive acceptance level of the proposal is confirmed.

Conclusions

The consulted lawyers in this study showed a high degree of acceptance of both the basis of the legal argument presented, and the proposed amendment. The use of a Neutrosophic Hypothesis, allowed to demonstrate that the average population value of the acceptance of the presented reform is higher than 1.71, that is, it can be affirmed that the lawyers of Los Ríos province are at least partially in agreement with making an amendment to Article 87 of the General Organic Code of Processes, on the possibility of the justification of the non-attendance of the defendant to the hearing, when this is due to fortuitous case or force majeure.

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Neutrosophic Estimation to validate a Legal Argument about the Use of Congruous Alimony as a Family Burden on Child Support Determination Trials.

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Abstract. The Constitution of the Republic of Ecuador clearly establishes the prevalence of the rights of children and adolescents, based on the principle of the Best Interests of the Child. However, this research is intended to validate a legal argument, which shows that this principle is violated in maintenance trials if the Mediation Act on Congruous Maintenance agreements is accepted by considering it as a new right holder. With this purpose, we applied a survey to a significant sample of lawyers and law students to measure their agreement with the main points of the argument. The population ratio was estimated using the Large-Sample Neutrosophic Confidence Interval for the Population Proportion. The estimated population results confirmed the relevance of the legal argument conducted.

Keywords: Legal argument; Estimation; Neutrosophic Confidence Interval; child support; congruous alimony.

1 Introduction

The rights of children and adolescents are determined by national and international legislation, which has been applying policies that benefit this priority group, thus guaranteeing respect for and compliance with their rights, in order to achieve effective coexistence between the members of the family unit, society and The State. Thus avoiding the violation of rights by their parents at the time of receiving the necessary care, with regard to alimony and its application to the right to equality [1, 2].

Children and adolescents are a special group. It is very important that they be given more rights than other human beings have. If we want to guarantee their integral development, we must impose their right on everything. This will allow them to grow up in an environment of harmony and, therefore, in the future they will have better perspectives to form themselves as people of benefit to society[3].

In Section Five of Chapter Three (Rights of Persons and Groups of Attention), Title II of the Constitution of the Republic, Article 44 establishes that "the State, society and the family shall promote, as a priority, the integral development of children and adolescents, and shall ensure the full exercise of their rights; the principle of the best interests of the child and his or her rights shall prevail over those of other persons." Children and adolescents will have the right to their integral development, understood as a process of growth, maturation and deployment of their intellect and their capacities, potentialities and aspirations, in a family, school, social and community environment of affectivity and security. This environment will allow the satisfaction of their social, affective-emotional and cultural needs, with the support of national and local inter-sectorial policies[4].

On the other hand, the father and mother are obliged to look after the wellbeing of their children from conception until they reach the age of majority and the law has provided that, in the absence of the main obligors, there are also subsidiary obligors who in this case are the ones who must assume responsibility. These are the grandparents, the uncles and others determined by the law.

In article 69 of the Constitution of the Republic of Ecuador [5, 6], the above mentioned is stated.

Article 69 - Protection of the Family - To protect the rights of the family members: Responsible maternity and paternity shall be promoted; the mother and father shall be obliged to care for, raise, educate, feed, develop integrally and protect the rights of their children, particularly when they are separated from them for any reason.

Food is one of the fundamental rights of children, as it is above any other right. This is in order to cover the basic needs of minors. The right to food has its origin in the very existence of man, unlike other living beings, a human being cannot survive by himself, it is always necessary to protect him; since food is one of the vital needs of people, someone has to provide it. In this case, it is the moral and legal duty of the children to ensure that their parents look after them and The State guarantees, through its policies, the protection of children and adolescents.

Apart from the divisions that may already be established based on the source, food may also be congruous or necessary, accrued or future; provisional or definitive. Congruous food is defined in Article 351 of the Civil Code as: that which enables the person fed to subsist modestly, in a manner corresponding to his/her social position[7].

Congruous alimony is owed to the spouse, to the children, to the descendants, to the parents, and to the one who made a substantial donation. However, all these people lose the right to congruous food if they seriously injure the food provider. They also lose the right to congruous alimony and, as in the previous case, they are reduced to those simply necessary "when the law expressly limits what is necessary" and this happens in the case of the child of a family absent from the home and who is not well behaved. Currently there is a legal void in which abandonment is not a requirement for demanding congruent alimony for spousal support, however, it is seen at courts that they are presented as a family burden in the alimony trials for the reduction of pensions for this concept[8].

That is why, with this research work, we propose a legal argument that establishes that there is a violation of the principle of the Superior Interest of the Child when taking into account the Mediation Act about the agreement of congruous alimony as a family burden[9, 10].

The objective of this research is to estimate the level of conformity that exists on the part of the lawyers participating in this type of family litigation, with respect to the current judicial procedure, as well as the degree of acceptance of the aforementioned proposal, through the application of the Large-Sample Neutrosophic Confidence Interval [11] for the Population Proportion.

2 Materials and methods

In order to fulfil the objective of the investigation, a study was made of the population composed of law professionals who work in cases related to the subject analyzed in the Canton of Tulcán, Province of Carchi, Ecuador, obtaining an approximate universe of 345 people, who are lawyers in free practice or students of higher levels. For this purpose, a survey was applied to 108 of them, randomly chosen, which represents approximately 31% of the population, so it is considered a significant sample.

However, in both groups, bias was identified in the information collected about their direct participation in at least one case, in which a congruous alimony mediation act was presented as a justification for the reduction or limitation of alimony. Therefore, it was necessary to identify the neutrosophic frequencies.

In the 1980s, the international movement known as Paradoxism [12-14] (based on contradictions in science and art) was founded by Florentin Smarandache, who then extended it to Neutrosophy (based on contradictions and their neutrals) originating new fields of research’s like neutrosophic statistics [15-18]. Neutrosophic Statistics refers to a set of data, such that the data or a part of it are indeterminate in some degree, and to methods used to analyze these data [16, 17, 19, 20].

A Neutrosophic Frequency Distribution [18, 20] is a table displaying the categories, frequencies, and relative frequencies with some indeterminacies[17, 18, 21]. Most often, indeterminacies occur due to imprecise, incomplete or unknown data related to frequency. Therefore, relative frequency becomes imprecise, incomplete, or unknown too.

In this case, we represent the frequencies as a neutrosophic statistic number, which have the form [22-25]:

$$N = d + i \quad (1)$$

with $i \in [i_a, i_b]$

Where

d: is the determinate (sure) part of N,

i: is the indeterminate (unsure) part of N.

i_a: is the inferior limit of i range

i_b: is the superior limit of i range

So (1) is equivalent to:

$$[N + i_a, N + i_b]$$

Setting $min_{nf} = N + i_a$ and $max_{nf} = N + i_b$, the expression we will use to represent the estimated neutrosophic frequencies is:

$$\left[min_{nf}, max_{nf}\right]$$

To compute the total for the neutrosophic frequencies[21, 26], we compute the total min and max of m categories estimated frequencies by the following equations:

$$tmin_{nf} = \sum_{j=1}^{m} min_{nfj} \quad (2)$$

$$tmax_{nf} = \sum_{j=1}^{m} max_{nfj} \quad (3)$$

Where:
$tmin_{nf}$ is the total minimum of the estimated frequencies for *m* possibilities.
$tmax_{nf}$ is the total maximum of the estimated frequencies for *m* possibilities.
min_{nfj} is the inferior limit of the neutrosophic estimated frequency range for the possibility *j*.
max_{nfj} is the superior limit of the neutrosophic estimated frequency range for the possibility *j*.
To calculate the neutrosophic relative frequency of each possibility:

$$min_{nrfj} = \frac{min_{nfj}}{tmax_{nf}} \quad (4)$$

$$max_{nrfj} = \frac{max_{nfj}}{tmin_{nf}} \quad (5)$$

Where:
min_{nrfj} is the inferior limit of the neutrosophic relative frequency for the possibility *j*.
max_{nrfj} is the superior limit of the neutrosophic relative frequency for the possibility *j*.

The survey applied is composed of the following questions:

Question 1: Do you think it is right for the Mediation Centers to set up a spousal support agreement knowing that they live together?

Question 2: Do you agree that children should have their child support reduced because the defendant is filing the spousal support agreement as the family's burden?

Question 3: Do you believe that the judge by accepting such a mediation agreement is violating the Best Interest Principle for Children?

Question 4: Do you agree with the statement made in the critical judicial analysis document presented in this research?

Although we worked with a statistically significant sample, it was convenient to apply a population estimate of the proportion of responses, to reinforce the validation of the proposal based on the results of the survey. The Large-Sample Neutrosophic Confidence Interval for the Population Proportion was used for this purpose.

Using the classical statistics we can define Large-Sample Confidence Interval for the Population Proportion (π) as follow:

$$I\pi = \left[p - (z\ critical\ value) \cdot \sqrt{\frac{p(1-p)}{n}}, p + (z\ critical\ value) \cdot \sqrt{\frac{p(1-p)}{n}}\right] \quad (6)$$

For the case when $min\{np \geq 5\}$ and $min\{n \cdot (1-p) \geq 5\}$, where:

p =sample proportion= number of sample individuals that possess the property of interest divided by sample's size and n = sample's size.

With the distinction from the classical statistics that in neutrosophic statistics the parameters p and n may be sets instead of crisp numbers, and the z critical value may be a set as well. [27]

The neutrosophic sample statistics p, for $min\{n\}$ large enough, has a neutrosophic sampling distribution (normal curve) that approximates the population mean π and its standard deviation:

$$\sigma = \sqrt{\frac{\pi(1-\pi)}{n}}$$

3 Results

From the results of the applied survey and taking into account the bias in the information collected, the following graph of neutrosophic frequencies was obtained about the composition of the sample.

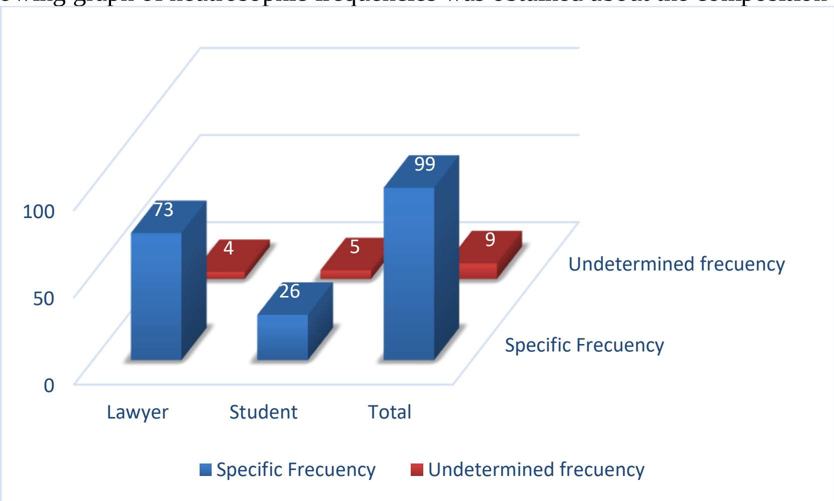

Figure 1. Sample Neutrosophic frequencies

As we can notice, we surveyed between 73 and 77 lawyers who participated in at least one maintenance trial where congruent maintenance was used as justification for a reduction of the alimony. Meanwhile, between 24 and 31.3% of those surveyed were students with at least one similar experience.

The sample results of the application of the survey are shown below (table 1). The neutrosophic proportions were obtained by applying formulas (4) and (5).

Answer	**Question 1**		**Question 2**		**Question 3**		**Question 4**	
	Frequency	**Proportion (p)**	**Frequency**	**Proportion (p)**	**Frequency**	**Proportion (p)**	**Frequency**	**Proportion (p)**
Yes	101	[0.93 , 1.02]	97	[0.89 , 0.98]	95	[0.88 , 0.96]	101	[0.93 , 1.02]
No	7	[0.06 , 0.07]	11	[0.10 , 0.11]	13	[0.12 , 0.13]	7	[0.06 , 0.07]
Total	$[\mathbf{99}, \mathbf{108}]$	$[\mathbf{0.99}, \mathbf{1.09}]$	$[\mathbf{99}, \mathbf{108}]$	$[\mathbf{0.99}, \mathbf{1.09}]$	$[\mathbf{99}, \mathbf{108}]$	$[\mathbf{1.00}, \mathbf{1.09}$	$[\mathbf{99}, \mathbf{108}]$	$[\mathbf{0.99}, \mathbf{1.09}]$

Table 1. Neutrosophic proportions per question

At the sample level, a proportion of positive responses above 89% can be observed for all questions with 98.1% for question 4, which refers to the acceptance of the proposed analysis.

To estimate the neutrosophic confidence interval of the population ratio, we used the neutrosophic confidence level $[0.95 , 0.99]$ for a neutrosophic critical value of $[1.645 ,\ 2.326]$.

First, it must be verified that $min\{np\} \geq 5$ and $min\{n \cdot (1-p)\} \geq 5$ is fulfilled for each one of the questions of the survey. For example:

Question 1

$min\{np\} \geq 5$

$min\{[99 , 108] \cdot [0.93 , 1.02]\} \geq 5$

$99 \cdot 0.93 \geq 5$

$92.07 \geq 5$

$min\{n \cdot (1-p)\} \geq 5$

$min\{[99 , 108] \cdot (1 - [0.93 , 1.02])\} \geq 5$

$99 \cdot 0.06 \geq 5$

$6.42 \geq 5$

When the verification was done for the rest of the questions, the results shown in table 2 were obtained.

Verification	**Question 1**	**Question 2**	**Question 3**	**Question 4**
$min\{np\} \geq 5$	$92.07 \geq 5$	$88.92 \geq 5$	$87.08 \geq 5$	$92.07 \geq 5$
$min\{n \cdot (1-p)\} \geq 5$	$6.42 \geq 5$	$10.08 \geq 5$	$11.92 \geq 5$	$6.42 \geq 5$

Table 2: Verification of the minimum requirement

Given the results in Table 2, the neutrosophic confidence interval of the population ratio can be estimated. By applying (6) to each of the questions we obtained:

$$I\pi_j = \left[p_j - (z\ critical\ value) \cdot \sqrt{\frac{p_j(1-p_j)}{n}},\ p_j + (z\ critical\ value) \cdot \sqrt{\frac{p_j(1-p_j)}{n}}\right]$$

Where $j =\ question\ number$ with $j = 1, 2, 3, 4$

In table 3, we can follow the steps to calculate the neutrosophic interval of confidence of the population proportion as a neutrosophic set.

	Question 1		**Question 2**		**Question 3**		**Question 4**	
Neutrosophic Interval	**min**	**max**	**min**	**max**	**min**	**max**	**min**	**max**
Neutrosophic Z	1,645	2,326	1,645	2,326	1,645	2,326	1,645	2,326
p_j	0,935	1,020	0,898	0,980	0,880	0,960	0,935	1,020
$1 - p_j$	0,065	0,071	0,102	0,111	0,120	0,131	0,065	0,071
$\sqrt{p_j(1-p_j)}/n$	0,024	0,027	0,029	0,033	0,031	0,036	0,024	0,027
$Z \cdot \sqrt{p_j(1-p_j)}/n$	0,039	0,063	0,048	0,077	0,052	0,083	0,039	0,063
$p_j - Z \cdot \sqrt{p_j(1-p_j)}/n$	0,896	0,957	0,850	0,903	0,828	0,877	0,896	0,957

$p_j + Z \cdot \sqrt{p_j(1-p_j)/n}$	0,959	1,047	0,927	1,013	0,911	0,995	0,959	1,047
$I\pi_j$	0,896	1,047	0,850	1,013	0,828	0,995	0,896	1,047

Table 3: Neutrosophic interval of confidence of the population proportion calculation.

As can be seen, for each of the questions asked, a positive response was estimated in favor of the main points of the proposed critical judicial analysis. It can be assured, with a significance level of between 95 and 99%, that more than 89.6% of the population studied would answer Yes to question number 1, more than 85% to question number 2, between 82.8 and 99.5% to question number 3, and more than 89.6% would answer Yes to question number 4.

This allows us to infer that the proposal of the present investigation would have a high level of acceptance within the community of law professionals of the Canton of Tulcán, with experience in food trials.

Conclusions

The application of the neutrosophic statistics, allowed to estimate the population proportion in spite of the bias present in the collected information, as well as to contribute with certain flexibility to its level of significance. The results obtained from the use of the Large-Sample Neutrosophic Confidence Interval for the Population Proportion, constitute the statistical foundation of the validity of the proposed critical analysis given the favorable population estimate for each of its elements.

Therefore, it can be assured that the majority of the lawyers of the studied population consider that the Principle of the Superior Interest of Children is being violated, with the current procedures identified in this research.

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Indeterminate Likert Scale for the Analysis of the Incidence of the Organic Administrative Code in the current Ecuadorian Legislation

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Abstract. In this investigation, we make use of the indeterminate Likert scale to analyze the results of a survey applied to legal professionals in the province of Tulcán, Ecuador, on the incidence of the Administrative Organic Code in the current legal system. With the use of this scale, we sought the possibility that the surveyed professionals would express their degree of acceptance, indetermination, and non-acceptance of this code. The results we obtained showed positive levels of acceptance, especially among public employees of the Decentralized Autonomous Governments, but also significant values of indetermination or neutrality.

Keywords: Triple Refined Indeterminate Neutrosophic Sets, Likert scale, satisfaction index.

1 Introduction

The entry into force of the Organic Administrative Code (OAC), a regulatory body from which The State has the power to organize itself. Therefore, its analysis involves making observations and clarifications with the highest standards of application of investigative methods and techniques [1].

This Code regulates the exercise of the administrative function of the agencies that make up the public sector. Individuals are entitled to the right to good public administration, which is specified in the application of the Constitution, the International Instruments, the Law and this Code. Individuals shall comply, without the need for any additional requirement, with the provisions of the Constitution, the Laws and the Legal Order in general and the decisions adopted by the competent authority. The Legislative Function approved this body of regulations in June 20, 2017 in the official Registry Number R.O. 31, Second Supplement [2, 3].

The problem of legal analysis of the OAC and its impact on the current Ecuadorian legal system is described fundamentally in terms of the changes that this new legal body makes within the legal framework. In a block of constitutionality, as well as the formal adaptation that has been made upon the basic guarantees of due process. A neo-constitutional trend, the limitation of state power that historically had not been addressed, since administrative law as such presents facultative attributions of the state that historically had not been admitted as such within the processes and procedures [4, 5].

In order to process the results, we proposed to use an indeterminate Likert scale based on Neutrosophy instead of a classic Likert scale[6].

A typical Likert scale survey does not allow its respondents to simply select from “yes/no”; it provides specific choices that are degrees of “agreeing” or “disagreeing”. The most basic Likert scaling format is a 5-column answer, with choices like: strongly disagree, disagree, neither agree nor disagree (do not know), agree and strongly agree. The neutral option is generally opted by the person who is unsure. That is why typical Likert scale has a limitation, since it is numerical and only offers a single option with 100% of certainty.

Indeterminate Likert scale is based on Neutrosophy, [4, 5]. Neutrosophy is the branch of philosophy that studies all related to neutralities, due to the lack of information, contradictory information, paradoxical and imprecise information, among others[7-9]. Indeterminate Likert scale will eradicate the need to go with the dominant choice or a forced option which cannot always be true if it is varying from the other option only be a small or a shade of difference[10-12].

The experts exact feelings/thinking/options cannot be captured very realistically by Likert scale, but certainly indeterminate Likert scale based on Triple Refined Indeterminate Neutrosophic Sets (TRINS) can do this very accurately [4, 5].

Here, the indeterminacy concept is divided into three: indeterminacy leaning towards truth membership, indeterminacy membership and indeterminacy leaning towards false membership. This division helps increasing the accuracy and precision of the indeterminacy and to fit in the Likert's scale.

2 Materials and methods

This section contains the main concepts related to Neutrosophy [13-15] that we use in this paper, especially Triple Refined Indeterminate Neutrosophic Sets.

Let X be a space of points (objects) with basic elements in X represented by x. A single-valued neutrosophic set (SVNS) A in X is characterized by truth $T_A(x)$, indeterminacy $I_A(x)$, and falsehood $F_A(x)$ membership functions. For each point x in X, there are $T_A(x), I_A(x), F_A(x) \in [0,1]$

and $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$. A is denoted by $A = \{\langle x, TA(x), IA(x), FA(x)\rangle \mid x \in X\}$.

The refined neutrosophic logic is defined by [16, 17]:

Definition 1 The truth T is divided into several types of truths: $T_1, T_2, \ldots, T_p$, and I into various indeterminacies: $I_1, I_2, \ldots, I_r$, and F into various falsities: $F_1, F_2, \ldots, F_s$, where all $p, r, s \geq 1$ are integers, and $p + r + s = n$.

Definition 2 [16, 17]**:** A triple refined indeterminate neutrosophic set (TRINS) A in X as given above is characterized by positive $P_A(x)$, indeterminacy $I_A(x)$, negative $N_A(x)$, positive indeterminacy $I_{PA}(x)$ and negative indeterminacy $I_{NA}(x)$ membership functions. Each has a weight $w_m \in [0,5]$ associated with it. For each $x \in X$, there are:

$P_A(x), I_{PA}(x), I_A(x), I_{NA}(x), N_A(x) \in [0,1]$

$w_P^m(P_A(x)), w_{I_P}^m(I_{PA}(x)), w_I^m(I_A(x)), w_{I_N}^m(I_{NA}(x)), w_N^m(N_A(x)) \in [0,5]$

And

$0 \leq P_A(x) + I_{PA}(x) + I_A(x) + I_{NA}(x) + N_A(x) \leq 5$

Therefore, a TRINS A can be represented by:

$A = \{\langle x, P_A(x), I_{PA}(x), I_A(x), I_{NA}(x), N_A(x)\rangle \mid x \in X\}$

In a TRINS-based Likert scale, there can be a separate option for indecision, since equal amount of agreement and disagreement can be represented in degree of weak agreement and degree of weak disagreement, individually.

Definition 3 [16, 17]**:** The intersection of two TRINSs A and B is a TRINS C, denoted as $C = A \cap B$, whose truth membership, indeterminacy leaning toward truth membership, indeterminacy membership, indeterminacy leaning toward falsehood membership and falsehood membership functions are associated to A and B:

1. $T_C(x) = \min(T_A(x), T_B(x))$,
2. $I_{T_C}(x) = \min(I_{T_A}(x), I_{T_B}(x))$,
3. $I_C(x) = \min(I_A(x), I_B(x))$,
4. $I_{F_C}(x) = \min(I_{F_A}(x), I_{F_B}(x))$,
5. $F_C(x) = \max(F_A(x), F_B(x))$.

Definition 4 [16, 17]**:** The generalized Triple Refined Indeterminate Neutrosophic weight is defined as:

$$w(A) = \sum_{i=1}^{n}\left\{w_T(T_A(x_i)) + w_{I_T}\left(I_{T_A}(x_i)\right) + w_I(I_A(x_i)) + w_{I_F}\left(I_{F_A}(x_i)\right) + w_F(F_A(x_i))\right\}$$

Where, $w_T, w_{I_T}, w_I, w_{I_F}, w_F$ denote the weights of every membership.

3 Survey design and processing of information

The survey for the analysis of the incidence of the Administrative Organic Code [18, 19] in the Ecuadorian legislation in force was applied to 75 professionals, who are public employees of the Decentralized Autonomous Governments of Tulcan or free practice lawyers of the same city, who were asked about their degree of acceptance of the Administrative Organic Code [20].

The questionnaire we applied was designed so that, in each statement, the respondent would reflect the degree to which Strongly disagree (1), Disagree (2), Neither agree or disagree (3), Agree (4) and Strongly agree (5) with the proposal, rating each state on a scale of 1 to 10. The applied questionnaire is shown in Table 1.

Statement	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
1. The structure of the current Organic Administrative Code is correct.					
2. The current Administrative Organic Code presents an efficient formulation of criteria.					
3. The current Administrative Organic Code has obtained a strong advance for the dynamism of the administrative regulations.					
4. The current Administrative Organic Code efficiently protects the rights of the citizens of Ecuador					

Table 1. Applied questionnaire.

Once the results were obtained, the TRINS [21]matrix was constructed for each respondent by taking each rating per statement as an indeterminate Likert scale with (1) negative membership, (2) indeterminacy leaning toward negative membership, (3) indeterminate membership, (4) indeterminacy leaning toward positive membership, and (5) positive membership. Thus, for each respondent, we obtained his or her degree of acceptance of the statements, and the answers to Statement 1, Statement 2, Statement 3, and Statement 4 in the form of TRINS, denoted as G_1, G_2, G_3 and G_4, respectively.

The total approval rate GT of the respondent was then calculated through this expression:

$$\mathrm{GT} = G_1 \cap G_2 \cap G_3 \cap G_4$$

To obtain a unique crisp value, the generalized Triple Refined Indeterminate Neutrosophic weight was calculated with:

$$w(GT) = w_T\left(\mathrm{T_A}(GT)\right) + w_{\mathrm{I_T}}\left(\mathrm{I_{T_A}}(\mathrm{GT})\right) + w_{\mathrm{I}}\left(\mathrm{I_A}(\mathrm{GT})\right) + w_{\mathrm{I_F}}\left(\mathrm{I_{F_A}}(\mathrm{GT})\right) + w_F\left(\mathrm{F_A}(\mathrm{GT})\right)$$

Where, $w_T, w_{\mathrm{I_T}}, w_{\mathrm{I}}, w_{\mathrm{I_F}}, w_F$ denote the weights of every membership.

In order to sort the total approval ratings in terms of highest and lowest acceptance, the weights assumed for each membership were:

$$w_T = 5, w_{\mathrm{I_T}} = 4, w_{\mathrm{I}} = 3, w_{\mathrm{I_F}} = 2, w_F = 1$$

Thus, those with the highest values will be the ones with the highest acceptance index over the Organic Administrative Code. For a better understanding, the acceptance index was calculated by: $AI = \frac{w_T}{5}$ and the following scale was used:

– If $AI > 1$ the respondent is Strongly agree with the OAC.
– If $0{,}75 < AI \leq 1$ the respondent is Agree with the OAC.
– If $0{,}5 < AI \leq 0{,}75$ the respondent is Neither agree or disagree with the OAC.
– If $0{,}25 < AI \leq 0{,}5$ the respondent is Disagree with the OAC.
– If $AI \leq 0{,}25$ the respondent is Strongly disagree with the OAC.

Finally, we made a statistical analysis of the results.

4 Results

With the application of the survey and the processing of the information described above for each respondent, the results shown in Table 2 were obtained.

N	GT TRINS	W(GT)	AI	N	GT TRINS	W(GT)	AI
1	(0.3, 0.2, 0, 0.1, 0.8)	3,3	0,66	38	(0.6, 0, 0, 0, 0.3)	3,3	0,66
2	(0.7, 0.3, 0, 0, 0.2)	4,9	0,98	39	(0.7, 0, 0, 0, 0)	3,5	0,7
3	(0, 0.1, 0.1, 0.1, 0.6)	1,5	0,3	40	(0.8, 0, 0, 0, 0)	4	0,8
4	(0.8, 0, 0, 0, 0.4)	4,4	0,88	41	(0.7, 0, 0, 0, 0.5)	4	0,8
5	(0.8, 0, 0, 0, 0.2)	4,2	0,84	42	(0.8, 0, 0, 0, 0.3)	4,3	0,86
6	(0.7, 0.1, 0, 0.1, 0.3)	4,4	0,88	43	(0.6, 0.2, 0, 0, 0.5)	4,3	0,86

7	(0.1, 0.3, 0.3, 0.3, 0.8)	4	0,8	44	(0.7, 0.1, 0, 0, 0.3)	4,2	0,84
8	(0.6, 0, 0, 0, 0.2)	3,2	0,64	45	(0.7, 0.3, 0, 0, 0.2)	4,9	0,98
9	(0.7, 0, 0, 0, 0.3)	3,8	0,76	46	(0.8, 0.1, 0, 0, 0.5)	4,9	0,98
10	(0.9, 0, 0, 0, 0)	4,5	0,9	47	(0.7, 0, 0, 0, 0.5)	4	0,8
11	(0.7, 0.2, 0, 0.1, 0.2)	4,7	0,94	48	(0.2, 0.3, 0.4, 0.3, 0.8)	4,8	0,96
12	(0.8, 0.1, 0, 0, 0.2)	4,6	0,92	49	(0.8, 0.1, 0, 0, 0.3)	4,7	0,94
13	(0.5, 0.4, 0.1, 0.1, 0.7)	5,3	1,06	50	(0.8, 0.1, 0, 0, 0.2)	4,6	0,92
14	(0.6, 0, 0, 0, 0.3)	3,3	0,66	51	(0.7, 0.1, 0, 0, 0.2)	4,1	0,82
15	(0.7, 0.1, 0, 0, 0.3)	4,2	0,84	52	(0.6, 0, 0, 0, 0.3)	3,3	0,66
16	(0.7, 0, 0, 0, 0)	3,5	0,7	53	(0.4, 0.1, 0.2, 0, 0.8)	3,8	0,76
17	(0.7, 0, 0, 0, 0.3)	3,8	0,76	54	(0.7, 0.1, 0, 0, 0.3)	4,2	0,84
18	(0.7, 0, 0, 0, 0.5)	4	0,8	55	(0.7, 0, 0, 0, 0.2)	3,7	0,74
19	(0.3, 0.1, 0, 0.1, 0.8)	2,9	0,58	56	(0.7, 0.2, 0, 0, 0.2)	4,5	0,9
20	(0.6, 0, 0, 0, 0.3)	3,3	0,66	57	(0.6, 0, 0, 0, 0.3)	3,3	0,66
21	(0.8, 0, 0, 0, 0.2)	4,2	0,84	58	(0.7, 0, 0, 0, 0.4)	3,9	0,78
22	(0.7, 0.2, 0.1, 0, 0.5)	5,1	1,02	59	(0.2, 0.3, 0, 0.2, 0.7)	3,3	0,66
23	(0.7, 0, 0, 0, 0.5)	4	0,8	60	(0.7, 0.1, 0.1, 0, 0.2)	4,4	0,88
24	(0.1, 0.3, 0.5, 0.5, 0.7)	4,9	0,98	61	(0.8, 0.3, 0, 0, 0.5)	5,7	1,14
25	(0.7, 0.2, 0, 0, 0.4)	4,7	0,94	62	(0.7, 0, 0, 0, 0.4)	3,9	0,78
26	(0, 0.1, 0.1, 0.1, 0.8)	1,7	0,34	63	(0.6, 0, 0, 0, 0.2)	3,2	0,64
27	(0.8, 0.1, 0.1, 0.2, 0.4)	5,5	1,1	64	(0.7, 0, 0, 0, 0.2)	3,7	0,74
28	(0.1, 0.2, 0.1, 0.1, 0.6)	2,4	0,48	65	(0.4, 0.6, 0.3, 0.4, 0.8)	6,9	1,38
29	(0.6, 0.2, 0, 0, 0.4)	4,2	0,84	66	(0.1, 0.2, 0.1, 0.2, 0.8)	2,8	0,56
30	(0.7, 0.2, 0, 0, 0.3)	4,6	0,92	67	(0.2, 0.4, 0.1, 0, 0.7)	3,6	0,72
31	(0.7, 0.1, 0, 0, 0.2)	4,1	0,82	68	(0.6, 0.1, 0, 0, 0.5)	3,9	0,78
32	(0.7, 0.1, 0, 0, 0.4)	4,3	0,86	69	(0.7, 0.2, 0, 0, 0.2)	4,5	0,9
33	(0.8, 0, 0, 0, 0.5)	4,5	0,9	70	(0.4, 0.3, 0, 0.2, 0.7)	4,3	0,86
34	(0.6, 0.2, 0, 0, 0.2)	4	0,8	71	(0.8, 0, 0, 0, 0.2)	4,2	0,84
35	(0.7, 0, 0, 0, 0)	3,5	0,7	72	(0.2, 0.3, 0, 0.3, 0.7)	3,5	0,7
36	(0.7, 0, 0, 0, 0.4)	3,9	0,78	73	(0.7, 0, 0, 0, 0.2)	3,7	0,74
37	(0.8, 0, 0, 0, 0.4)	4,4	0,88	74	(0.1, 0.3, 0.2, 0.3, 0.7)	3,6	0,72
38	(0.8, 0, 0, 0, 0.4)	4,4	0,88	75	(0.6, 0, 0, 0, 0.3)	3,3	0,66

Table 2: Total approval rate in TRINS form, generalized TRIN weight and the acceptance index obtained by respondent

Regarding the interpretation of these values, we may see in Figure 1 that the highest values correspond to the acceptance of the current OAC, although the number of respondents who do not have a certain position on this is significant.

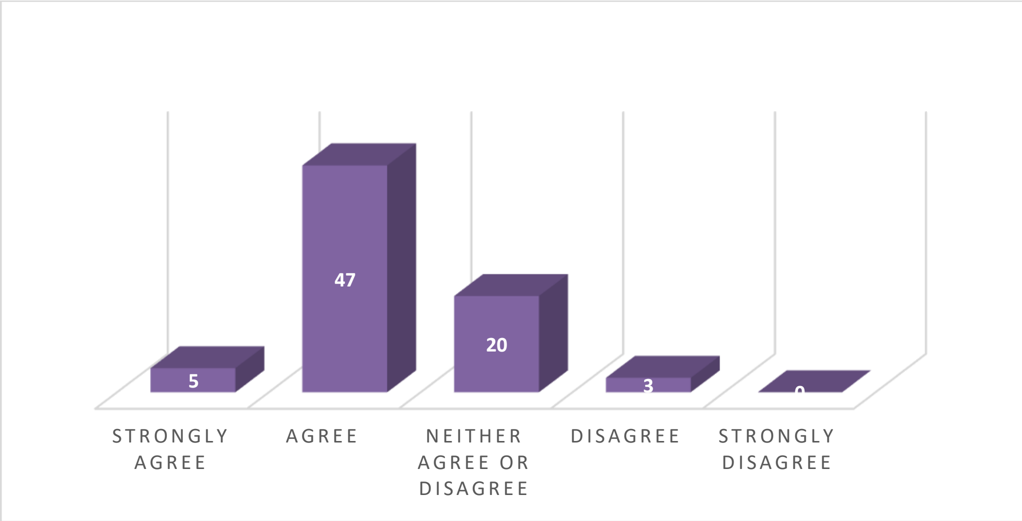

Figure 1. Figure 1. Level of satisfaction of respondents with the current OAC according to the AI.

When analyzing the information obtained through the hierarchical clustering algorithm, with Ward link and Euclidean distance, and the help of the program Orange3.26, two groups can be clearly identified, as shown in figure 2.

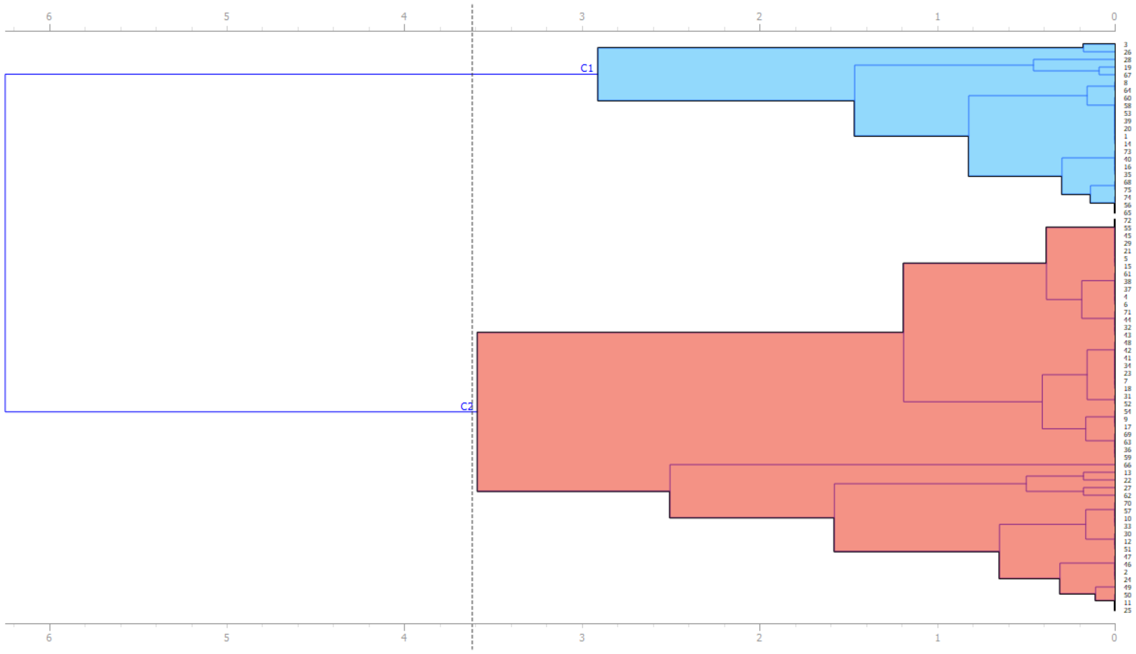

Figure 2. Clusters formed by a hierarchical clustering algorithm

The first group, with a majority of 52 respondents, is satisfied with the current OAC. Fifty percent are public employees of the Decentralized Autonomous Governments of Tulcán and 50% are self-employed lawyers. 47 of them agree and 5 strongly agree.

The second group consists of only 23 respondents. 20 of them do not agree or disagree and 3 disagree. Sixty-five percent are free exercise lawyers and 35% are public employees of the Decentralized Autonomous Governments of Tulcán.

In terms of the position of those surveyed according to their profession, there is greater rejection of the OAC by lawyers, since 100% of those who were dissatisfied are lawyers and in addition, 29.27% of the total number of lawyers show indetermination when it comes to qualifying them. Only 2.44% of the lawyers strongly agree with the OAC.

On the other hand, public employees show a higher rate of satisfaction in general, with 64.7% and 11.76% agreeing and strongly agreeing, respectively. 23.5% neither agree nor disagree with the OAC.

This last appreciation can be reinforced by observing in figure 3 the range of the satisfaction index and the medians of each group of professionals surveyed.

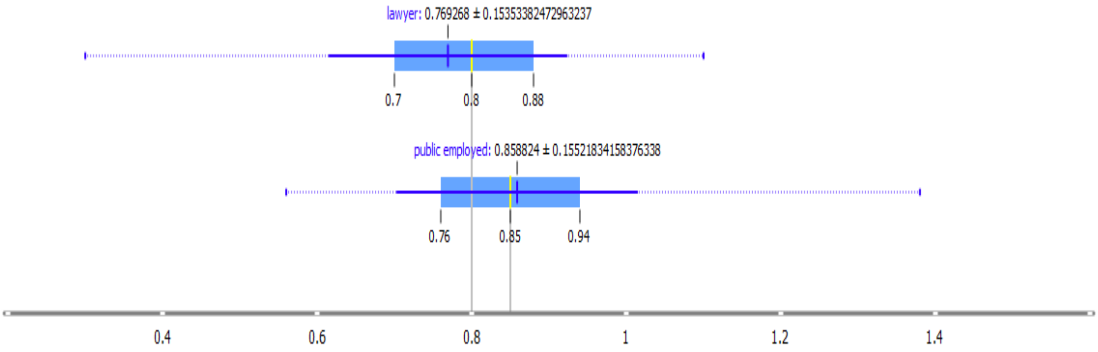

Figure 3. Box plot of AI by profession

In summary, according to the satisfaction index found in the study sample, a positive evaluation can be inferred with respect to the OAC by specialists in the subject in Ecuador.

Conclusions

With the use of the Indeterminate or Neutrosophic Likert Scale, the level of acceptance that the current Organic Administrative Code has among professionals in Ecuador, who are specialists in the subject, could be appreciated with greater rigor. The use of TRINS ensured that mixed feelings were captured in the evaluations. According to the results, the professionals surveyed are most satisfied with the current OAC. Although there is a significant percentage whose position is undetermined or neutral. No significant values of dissatisfaction were obtained. The professionals with the greatest dissatisfaction with this standard were the self-employed lawyers. It can be said that the current OAC has a positive, although not absolute, level of acceptance, from which it can be inferred that it still needs to be improved.

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Multicriteria Analysis of the Violation of the Right to Education in Young People

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Abstract. The right to education has been violated by the extinction of alimony for young people who have reached 21 years of age and are in higher education. So this research is aimed at the problem in order to raise a proposal that makes a solution viable. The research line applied in the realization of this paper is "Challenges, Perspectives and Improvement of Legal Sciences in Ecuador". The results that are pursued with this investigation is promote good compliance with the constitutional norms of Ecuador and avoid the violation of human rights. For this, the technique known as neutrosophic AHP was applied. This is a variant of the numerical AHP designed by Saaty, which by incorporating the neutrosophic sets, the uncertainty of decision-making is taken into account, in addition to the calculation with linguistic terms and the inclusion of indeterminacy. This technique will be applied to choose between two alternatives: the convenience or not of maintaining alimony in active students over the age of 21. This analysis is complicated due to the variables to be analyzed, which is why the versatility of the chosen mathematical technique is validated.

Keywords: right to education, alimony, higher education, Neutrosophic AHP**.**

1 Introduction

This research is a current and important issue since it deals with the right to education, a topic established in the Constitution of the Republic of Ecuador and the Organic Code of Children and Adolescents[1]. This right has been violated by the extinction of alimony to young people over the age of 21 who are studying in higher education. A detailed investigation of this social phenomenon by the authors of this paper made it possible to determinate that there are not degree works or scientific articles or projects dealing with this topic in the law career at the Department of the CDIC, of the Autonomous Regional University of the Andes UNIANDES, Tulcan, as in the other extensions and the other local libraries.

According to the Constitution of the Republic of Ecuador, in its article 26, it declares that, "Education is a right of people throughout their lives and an inescapable and inexcusable duty of the State". In the same way, article 27, second paragraph of the same norm establishes that "education is essential for the knowledge, exercise of rights and the construction of a sovereign country, and constitutes a strategic axis for national development" [2].

Based on the above-mentioned, education must be guaranteed throughout a person's life and even more for young people who is still studying. Once their alimony has been extinguished, the constitutional guarantee is not fulfilled due to the lack of financial support from their parents. This is when the problem arises, because their parents can't be supportive and the student needs to look for a work, they put aside their higher studies and choose not to complete them due to the lack of financial support from their parents [3-5].

As a groundwork it is necessary to state that, in Ecuador in 2003, the Organic Code of Children and Adolescents was promulgated, which was published in Official Register 737 of Jan. 3, 2003. This norm protects children and adolescents, and consider the family as a fundamental group of society as a natural environment for the growth and well-being of all its members. That is why, they must receive protection and assistance necessary to be able to fully assume their responsibilities within the community. Likewise, in accordance with the Constitution of the Republic of Ecuador, mainly in the area of human rights, exercising a power as a State of rights and justice, recognizing children and adolescents as a group of priority attention [6].

Taking into account the aforementioned, it can be said that the responsibility of the care of children and young people is shared between the State and the Family, so, it is necessary that, the average age for the completion of third-level studies is up to 24 years. As long as they can demonstrate that they are still studying. Failure to do so would result in the violation of their constitutional rights such as education, which would be evidenced by not complying with State policies, to which education refers, not only in a primary or secondary setting, but rather in a higher education setting[7-9].

With the stated in the previous paragraph, young people will have the possibility of completing their higher studies, forging themselves as a professional according to the requirements of education in Ecuador. That is why this research is aimed precisely at studying this problem, and the possible solution to reform certain articles of the Childhood and Adolescence Code. Which allow the right to education not to be violated with the extinction of alimony for young people who have reached the age of 21 and are studying at higher education. This avoid the violation of their constitutional rights from which all Ecuadorians benefit, it is for this reason that the viability of giving continuity to this research project is presented, in order to prevent the continued violation of constitutional rights and due process [10].

In terms of education, the purpose of alimony has been gaining much importance, not only in the problem of fixing the food tables. It also has been important to investigate an antecedent of the target students that have completed their studies, both primary and secondary and higher, how many of these target students have become professionals; how many of them have achieved it with the mutual sacrifice of parents; how many have done it on their own behalf who has been left with custody of them whatever the case of the father or mother. It is necessary to highlight the role of State to guarantee education for students who live without any of their parents[11].

In this social environment there are cases that, at the time of having reached the age of 21 established by law, the father or mother who is obliged to give the alimony to the young person, requests that the alimony be extinguished. Situation that occurs frequently and leaves the students unprotected, without compliance with their guarantees in various aspects, but even more so in their educational studies without being able to complete them, so it is clearly observed that there is a violation of constitutional rights. That is the aim of this investigation: the right to education, same which is legally recognized in our Carta Magna [12].

In this case, Neutrosophy will be used as a decision-making tool. Neutrosophy is the branch of philosophy that studies the origin, nature and scope of neutralities. Logic and neutrosophic sets constitute generalizations of other theories, such as fuzzy sets, intuitionist fuzzy sets, fuzzy sets in the form of intervals, among others.[13]. The use of neutrosophic sets allows, in addition to the inclusion of membership functions of truth and falsehood, also membership functions of indeterminacy[14]. This indeterminacy is present because there are contradictions, ignorance, inconsistencies, among other causes with respect to knowledge. On the other hand, the technique known as AHP (Analytic Hierarchy Process), is an easy to apply and efficient method, which allows sorting alternatives, according to an order calculated from the evaluation of a group of experts. This evaluation is carried out using a scale where the relative relationships between criteria, sub-criteria and finally the alternatives are evaluated [15-19].

Neutrosophic AHP has several advantages over classical AHP, for example, it has a structure framework richer than classical AHP, fuzzy AHP and intuitionistic fuzzy AHP. It describes the expert's judgment values efficiently managing vagueness and uncertainty over fuzzy AHP and intuitionist fuzzy AHP because it considers three different degrees: degree of membership, degree of indeterminacy and degree of non-membership. Another advantage is that it is calculated from linguistic terms, which allows a more natural communication with experts [20-27].

Likewise, it can be said that this analysis is carried out in order to allow young people to benefit from the alimony, at least until their professional training, or that they can subsist on their own, without depending neither on the father nor the mother. That is considered the best alternative solution to comply with the Good Living of which all Ecuadorians are worthy, that is why the subject to be discussed presents the sustenance and importance, being therefore viable the present investigation to formulate a proposal of solution. The objective of this paper is to highlight the importance of alimony for students over 21 years who are still studying in higher education.

Due to the complexity and sensitivity of the subject to be discussed, we decided to use a mathematical tool to compare criteria from experts, specifically the neutrosophic AHP. This technique was selected, in addition to its simplicity and effectiveness, because usually the authors of the topic evaluate the aspects qualitatively in the form of linguistic terms. In this case, only two alternatives will be evaluated, Criterion 1 and Criterion 2, which is the symbolic way it will be used to determine the importance of the issue in question.

2 Neutrosophic Analytic Hierarchy Process

This section summarizes the definitions, theories and methods that will be used to achieve the objective proposed in this article.

First, to apply the technique known as AHP[28, 29], it is necessary to start from the evaluation of a group of experts to solve a specific problem, which has a main objective. This technique is usually represented graphically with a tree, see Figure 1, where the highest level node is unique and represents the Objective of the task, the children of this node in the immediately lower level represent the criteria that will be used to measure the fulfillment of the objective. At the lower level, the sub-criteria used to detail the previous criteria can be represented, further down, other sub-criteria can be represented and so on. The last level contains the nodes that represent the alternatives to be evaluated with respect to each of the criteria and sub-criteria of the higher levels.

See that the tree shown in Figure 1 represents an AHP with four levels, although the number of levels could be increased by adding more sub-criteria or one level could be reduced by eliminating the third one that represents sub-criteria [22-26].

As in this article the Neutrosophic AHP method will be developed [30, 31], below are the main definitions of neutrosophic logic[32-34] and its application in the neutrosophic AHP.

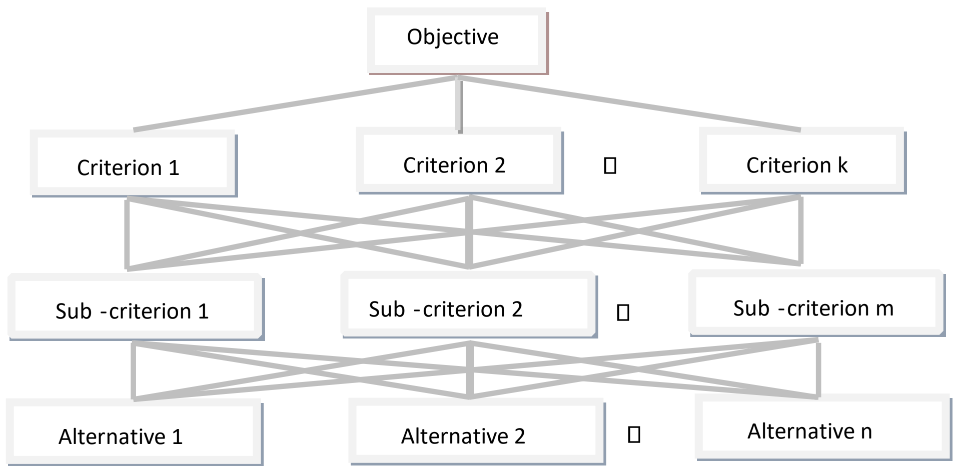

Figure 1. Tree-shaped diagram of the elements necessary to apply the AHP technique.

Definition 1: [35-44] 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 $\forall x\in U$, $T_A(x), I_A(x)$, and $F_A(x) \subseteq]^-0, 1^+[$, 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: [35-44] 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 $T_A: U\to[0, 1], I_A: U\to[0, 1]$, 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: [35-44] 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:

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

$I_{\tilde{a}}(x) =$

$$\begin{cases} \frac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \le x \le a_2 \\ \beta_{\tilde{a}}, & a_2 \le x \le a_3 \\ \frac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases} \quad (2)$$

$F_{\tilde{a}}(x) =$

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

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

Definition 4: ([35-44]) 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:

1. Addition: $\tilde{a} + \tilde{b} = \langle(a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle$
2. Subtraction: $\tilde{a} - \tilde{b} = \langle(a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle$
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 $a_1, a_2, a_3, a_4 \neq 0$.
4. Multiplication by a scalar number:

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

5. Division of two trapezoidal neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \left\langle\left(\frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\right\rangle, a_4 > 0 \text{ and } b_4 > 0 \\ \left\langle\left(\frac{a_4}{b_4}, \frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\right\rangle, a_4 < 0 \text{ and } b_4 > 0 \\ \left\langle\left(\frac{a_4}{b_1}, \frac{a_3}{b_2}, \frac{a_2}{b_3}, \frac{a_1}{b_4}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\right\rangle, a_4 < 0 \text{ and } b_4 < 0 \end{cases}$$

6. Multiplication of two trapezoidal neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle(a_1 b_1, a_2 b_2, a_3 b_3, a_4 b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_4 > 0 \text{ and } b_4 > 0 \\ \langle(a_1 b_4, a_2 b_3, a_3 b_2, a_4 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_4 < 0 \text{ and } b_4 > 0 \\ \langle(a_4 b_4, a_3 b_3, a_2 b_2, a_1 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_4 < 0 \text{ and } b_4 < 0 \end{cases}$$

Where, $\wedge$ is a t-norm and $\vee$ is a t-conorm.

Definitions 3 and 4 refer to *single-valued triangular neutrosophic number* when the condition $a_2 = a_3$ holds [40].

We can find in [45] the theory of AHP technique in a neutrosophic framework. Thus, we can model the indeterminacy of decision-making from applying neutrosophic AHP or NAHP for short.

Equation 4 contains a generic neutrosophic pair-wise comparison matrix for NAHP.

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \quad (4)$$

Matrix $\tilde{A}$ must satisfy condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, based on the inversion operator of Definition 4, according to the scale summarized in Table 1 of triangular neutrosophic numbers.

For converting neutrosophic triangular numbers into crisp numbers, there are two indexes defined in [46], they are the so-called score and accuracy indexes, respectively, see Equations 5 and 6:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{5}$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \tag{6}$$

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	$\tilde{9} = \langle(9,9,9); 1.00, 0.00, 0.00\rangle$
2, 4, 6, 8	Sporadic values between two close scales	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$ $\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$ $\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$ $\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

Table 1. Saaty's scale translated to a neutrosophic triangular scale.

Other definitions that are needed to apply the neutrosophic AHP are expressed below: To get the score and the accuracy degree of $\tilde{a}_{ji}$ the following equations are used:

$$\mathbf{S}(\tilde{a}_{ji}) = 1/\mathbf{S}(\tilde{a}_{ij}) \tag{7}$$

$$\mathbf{A}(\tilde{a}_{ji}) = 1/\mathbf{A}(\tilde{a}_{ij}) \tag{8}$$

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

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \tag{9}$$

Next, we determine the ranking of priorities from the previous matrix as follows:
1. Normalize the column entries by dividing each entry by the sum of the column.
2. Take the total of the row averages.

The *Consistency Index* (CI) is calculated for matrices in formula 9, which is a function depending on λ_{max}, the maximum eigenvalue of the matrix. Saaty establishes that consistency of the evaluations can be determined by equation $CI = \frac{\lambda_{max} - n}{n-1}$, [47],where n is the order of the matrix. Also, the *Consistency Ratio* (CR) is defined by equation CR = CI/RI, where RI is given in Table 2.

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

Table 2. RI associated to every order.

If CR≤0.1 we can consider that experts' evaluation is sufficiently consistent and hence we can proceed to use NAHP. We apply this procedure to matrices A in Equation 9. Consult [45] for more details on NAHP.

The Neutrosophic AHP consists of applying the following steps:

1. Select a group of experts who are capable of conducting the analysis.
2. The experts must design an AHP tree, like the one shown in Figure 1. This implies that the criteria, sub-criteria and alternatives must be specified to carry out the evaluation.
3. Create the matrices for each level of the AHP tree for the criteria, sub-criteria and alternatives, according to the evaluations of the experts expressed in the form of SVTNN scales, as specified in Equation 5.

These matrices are formed by comparing the importance of each pair of criteria, sub-criteria and alternatives, following the scales that appear in Table 1.

4. Verify the consistency of the evaluations for each matrix. For this it is enough to convert $\widetilde{A}$ in a numerical matrix M = (a_{ij}): nxm, such that $a_{ij} = A(\tilde{a}_{ij})$ or $a_{ij} = S(\tilde{a}_{ij})$, defined in one of the

Equations 6 and 7, to then apply the methods used in the original AHP. Which consists of the following:

- Calculate the Consistency Index (CI): it depends on λ_{max}, the maximum eigenvalue of the matrix M and which is defined by:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (8)$$

Where n is the order of the matrix.

- Calculate the Consistency Ratio (PC): with equation PC = IC / IR, where IR is taken from Table 2 [7, 48, 49].

Order (n):	1	2	3	4	5	6	7	8	9	10
IR	0	0	0,52	0,89	1,11	1,25	1,35	1,40	1,45	1,49

Table 2. IR associated with the order of the matrix

- If PC≤10% consistency of evaluation by experts is considered sufficient and the AHP method can be applied. If not, it is recommended that the experts reconsider their evaluations.

5. From here on the matrices they are replaced by their equivalent numerical matrices M, calculated in the previous step. Then proceed as follows:
   - Normalize the entries by column, dividing the elements in the column by the total sum.
   - Calculate the total of the averages per row, each of these vectors is known as a priority vector.
6. The final scores are calculated starting from the highest level (Objective): to the lowest level (Alternatives): where the weights obtained for the priority vector corresponding to the immediately higher level are taken into account. This calculation is performed by multiplying each row of the matrix of priority vectors of the lower level by the weight obtained by each of these with respect to those of the upper level, then it is added per row and this is the final weight of the element of this matrix.

3 Results

In this section, the Neutrosophic AHP technique will be applied to determine the importance of the subject under study. First, a group of seven specialists or experts was appointed, who have studied in depth the contribution and importance of maintaining alimony to young people once they have reached the age of 21 and are in higher education. This study included a review of study programs, interviews with teachers, visits to classes, interviews with UNIANDES executives, among other activities. It was decided to evaluate the following alternatives:

1. Alternative 1, it is important to grant alimony to young people who have reached the age of 21 and are studying in higher education.

2. Alternative 2, maintain the extinction of alimony to young people who have reached age of 21 and are studying in higher education.

Table 3 shows the experts' evaluation of the criteria to measure the alternatives. We make reference to the number assigned to the criterion and not to the description in words.

Criterion	1	2	3	4	5	6	7
1	$\tilde{1}$	$\tilde{5}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
2	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{3}^{-1}$
3	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
4	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$
5	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$
6	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{1}$
7	$\tilde{3}^{-1}$	$\tilde{3}$	$\tilde{5}$	$\tilde{5}$	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{1}$

Table 3. Matrix of the evaluation of the criteria according to the experts, using linguistic values.

Then the values given in the form of linguistic terms are converted into numerical values, as expressed in Table 4, using the function a (□): given in Equation 7. In addition, the value of IC and PC is added see Equation 5 and λ_{max}, calculated with the eigenvalue function of the Octave 4.2.1 software. For the rest of the calculations this software was used, [6]. Finally we can see the calculation of the priority vector.

Criterion	1	2	3	4	5	6	7	Priority Vector
1	0.9375	5.1562	5.1562	5.1562	2.6437	2.6437	2.6437	0.334410
2	0.2120	0.9375	5.1562	2.6437	0.3182	0.9375	0.3182	0.096940
3	0.2120	0.2120	0.9375	2.6437	0.3182	0.2120	0.2120	0.050220
4	0.2120	0.3182	0.3182	0.9375	0.2120	0.2120	0.2120	0.035719
5	0.3182	2.6437	2.6437	5.1562	0.9375	2.6437	2.6437	0.208733
6	0.3182	0.9375	5.1562	5.1562	0.3182	0.9375	0.9375	0.127504
7	0.3182	2.6437	5.1562	5.1562	0.3182	0.9375	0.9375	0.146474
λ_{max}= 7.46869, CI = 0.078115; PC = 5.7863%≤10%								

Table 4. Matrix of the evaluation of the criteria according to the experts, using numerical values. Are added IC, PC, λ_{max} and the priority vector.

Then the comparison between both alternatives is summarized for each of the criteria from 1 to 7, see Table 5-11. For each cell, the values are given in the form of the linguistic terms in the scale of Table 1 and their corresponding numerical value calculated by Equation 7. It should be noted that it is not necessary to calculate the PC, by the order of the matrix that only is 2.

Criterion 1			
	Alternative 1	**Alternative 2**	**Priority Vector**
Alternative 1	$\tilde{1}$ (0.9375):	$\tilde{1}$ (0.9375):	0.5
Alternative 2	$\tilde{1}$ (0.9375):	$\tilde{1}$ (0.9375):	0.5

Table 5. Comparison of the alternatives with respect to Criterion 1 and its priority vector.

Criterion 2			
	Alternative 1	**Alternative 2**	**Priority Vector**
Alternative 1	$\tilde{1}$ (0.9375):	$\tilde{2}$ (1.8375):	0.64380
Alternative 2	$\tilde{2}^{-1}$ (0.56146):	$\tilde{1}$ (0.9375):	0.35620

Table 6. Comparison of the alternatives with respect to Criterion 2 and its priority vector.

Criterion 3			
	Alternative 1	**Alternative 2**	**Priority Vector**
Alternative 1	$\tilde{1}$ (0.9375):	$\tilde{3}$ (2.6437):	0.74240
Alternative 2	$\tilde{3}^{-1}$(0.3182):	$\tilde{1}$ (0.9375):	0.25760

Table 7. Comparison of the alternatives with respect to Criterion 3 and its priority vector.

Criterion 4			
	Alternative 1	**Alternative 2**	**Priority Vector**
Alternative 1	$\tilde{1}$ (0.9375):	$\tilde{3}^{-1}$(0.3182):	0.25760
Alternative 2	$\tilde{3}$(2.6437):	$\tilde{1}$ (0.9375):	0.74240

Table 8. Comparison of the alternatives with respect to Criterion 4 and its priority vector.

Criterion 5			
	Alternative 1	**Alternative 2**	**Priority Vector**
Alternative 1	$\tilde{1}$ (0.9375):	$\tilde{3}^{-1}$(0.3182):	0.25760
Alternative 2	$\tilde{3}$(2.6437):	$\tilde{1}$ (0.9375):	0.74240

Table 9. Comparison of the alternatives with respect to Criterion 5 and its priority vector.

Criterion 6			
	Alternative 1	**Alternative 2**	**Priority Vector**
Alternative 1	$\tilde{1}$ (0.9375):	$\tilde{5}$(5.1562):	0.83087
Alternative 2	$\tilde{5}^{-1}$(0.21198):	$\tilde{1}$ (0.9375):	0.16913

Table 10. Comparison of the alternatives with respect to Criterion 6 and its priority vector.

Criterion 7			
	Alternative 1	**Alternative 2**	**Priority Vector**
Alternative 1	$\tilde{1}$ (0.9375):	$\tilde{3}$(2.6437):	0.74240
Alternative 2	$\tilde{3}^{-1}$(0.3182):	$\tilde{1}$ (0.9375):	0.25760

Table 11. Comparison of the alternatives with respect to Criterion 7 and its priority vector.

The result of the evaluation of the alternatives with respect to the criteria is shown below, where the values of the priority vector of the criteria are specified in parentheses.

Criterion	**1**(0.334)**:**	**2**(0.097):	**3 (**0.050)**:**	**4 (**0.036)**:**	**5 (**0.209)**:**	**6 (**0.128)**:**	**7 (**0.146)**:**	
Alternative 1	0.5	0.6438	0.7424	0.2576	0.2576	0.8309	0.7424	0.74455
Alternative 2	0.5	0.3562	0.2576	0.7424	0.7424	0.1691	0.2576	0.25545

Table 12. Matrix of the evaluation of the alternatives regarding the 7 criteria. The weights calculated for these can be seen in parentheses.

From the results obtained in Table 12, it can be concluded that the results obtained in Alternative 1 are preferred over those of Alternative 2. This means that the experts confer a very high importance on them. Alimony pensions to young people who have reached the age of 21 and are in higher education, 74% higher than 25% of maintaining their extinction.

Conclusions

- The methodology used during the development of this research, allowed to carry out an analysis of the different positions, and to determine the need to propose the reform of the article that deals with the extinction of the alimony within the Ecuadorian legislation.
- With the study, it was possible to determine that the present research work is framed within the legal field, it is a current problem and there was a need to demonstrate the great importance for the beneficiaries of the problem raised through a mathematical tool.
- The technique known as Neutrosophic AHP, yielded as a result that it is very important to grant alimony to young people who have reached the age of 21 and are studying in higher education.

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TOPSIS with a Neutrosophic Approach for a Study of Strategies to Confront the Crime of Feminicide in Ecuador

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Abstract. In this investigation, we make use of the neutrosophic TOPSIS technique for the evaluation of four strategies in order to achieve the decrease of feminicide crimes in Ecuador, which constitute a problem that continues to increase, mainly in the canton of Babahoyo. Four alternatives were evaluated, based on the criteria of fifteen specialists on the subject. This technique, based on Neutrosophy, made it possible to capture the specialists' evaluation criteria in a way that was more in line with the truth. As a result, we found that the decision alternative, or the most important strategy, is to establish a more preventive criminal legislation for the protection of victims of domestic and gender violence.

Keywords: Feminicide, Neutrosophy, TOPSIS, single valued neutrosophic set.

1 Introduction

According to author Diana Russell [1], feminicide is the act in which a female is killed by someone of the opposite sex driven by pleasure, contempt, hate or a sense of possession towards women. A shorter interpretation of this definition is the murder of a woman by a man, because the simple fact of being a woman.

Feminicide occurs because humanity has produced behaviors that admit attacks against the integrity, health, and the main right to life of women. Feminicide is made up of discrimination and machismo, of violence against women, of legal voids coming from the government, from which an unsafe coexistence for women is produced, because it benefits the set of crimes that we ask to clarify and eradicate[2].

As for its legal treatment, the author expresses[3]:

"The Law is a non-neutral legal body. In this regard, too much has been written to prove that, as a social element, it is impregnated by gender relations. For this reason, feminist legal theory has projected that it is a product of patriarchal societies and has been built mainly from the experience of men. It is a "naturalized" model of the human being, which therefore reflects and protects values, needs and interests that correspond mostly only to that half of humanity".

With the acceptance of laws that condemn feminicide in the country, it is proposed to develop a criminal policy with a gender perspective that strengthens, on one hand, the tactics of persecution and punishment of those who practice violence against women and, on the other hand, that certifies the settlement and compensation of the victims. The objective is to diminish impunity so that the criminal justice system can carry out its task of special and general prevention of crime[4, 5].

Gender violence has always been a problem in Ecuador. Among the results derived by the Ministry of the Interior with the support of Ecuador's National Institute of Statistics and Censuses, the following elements are highlighted from a survey applied to a total of 1,800 women in 2014 (Figure 1)[6].

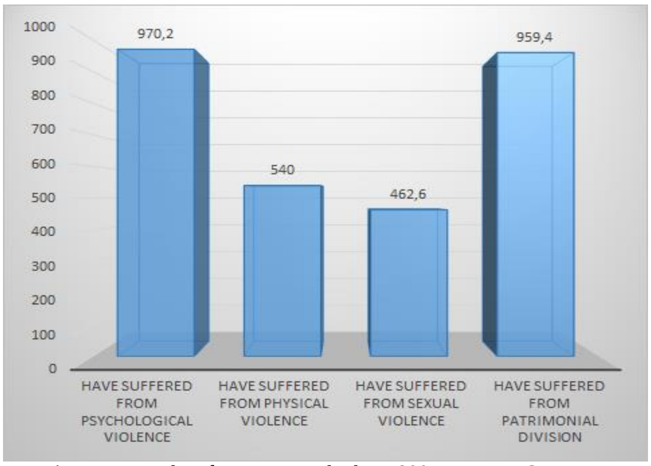

Figure 1. Results of a survey applied to 1800 women in Quito

This study also shows that 6 out of 10 women have experienced some type of gender-based violence, with a higher percentage among indigenous people (67%) and Afro-descendants (66.7%). It was also observed that 1 out of 4 women have experienced sexual violence at some point in their lives. 64% of feminicides are perpetrated by the lover or ex-boyfriend at the house of the victim or the aggressor.

The investigations recognize that the individuals who have committed these crimes are often people close to the home. The higher percentages of feminicide have been caused by ex-boyfriends, husbands, ex-spouses and boyfriends. Parents, friends, stepparents, lovers and sons-in-law are also among those involved.

According to the national media, in 2011 Ecuador begin to debate the possibility of incorporating into Ecuadorian legislation a criminal law that is adapted to gender situations. Thus, on August 14, 2014, the Integral Organic Penal Code introduced two articles referred to the criminal type of feminicide and its aggravating factors, which describes the crime and the situations that aggravate it, and also establishes the respective penalties[7].

In the canton of Babahoyo, there are few trials, if any, for the crime of feminicide, despite the fact that all of the requirements that could be included in this type of crime are usually met. The death of women is usually typified as murder and not as feminicide; and the elements of conviction are not enough to show that they are carried out according to the conditions and with elements established by the law.

For this reason, this research makes a study of possible strategies to follow so that this problem does not continue to advance in the country and that it is given the legal treatment that corresponds to such crime.

2 Materials and methods

In order to study the best strategies to reduce the occurrence of feminicide crimes and to achieve an adequate legal treatment of these cases, the TOPSIS technique (Technique for Order Preference by Similarity to Ideal Solution) was used. This method is characterized by its effectiveness and the simplicity of its principle in the solution of multi-criteria decision problems. To enrich this technique, the neutrosophic TOPSIS is applied, see [8-10].

Neutrosophy is a mathematical theory developed by Florentin Smarandache to deal with indetermination [9, 11, 12]. It has been the base for the development of new methods to handle indeterminate and inconsistent information, such as the neutrosophic sets and the neutrosophic logic and, especially, in the decision-making problems [9, 13, 14].The truth value in the neutrosophic set is defined as follows [15-17]:

Let X be a universe of discourse, a SVNS A over X has the following form [18, 19]:

$$A = \{\langle x, u_a(x), r_a(x), v_a(x)\rangle : x \in X\}d \qquad (1)$$

Where

$u_a(x): X \to [0,1], r_a(x): X \to [0,1]\ y\ v_a(x): X \to [0,1]$

Con

$0 \le u_a(x), r_a(x), v_a(x) \le 3, \qquad \forall\, x \in X$

The intervals $u_a(x), r_a(x)$ and $v_a(x)$ denote the memberships to true, indeterminate and false of x in A, respectively.

For convenience a Single Valued Neutrosophic Number (SVNS) 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 the neutrosophic sets for practical purposes. Some operations between SVNS are expressed below:

1. Let $A_1 = (a_1, b_1, c_1)$ and $A_2 = (a_2, b_2, c_2)$ ∈SVNS, the sum between A_1 and A_2 is defined by:

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

2. Let $A_1 = (a_1, b_1, c_1)$ and $A_2 = (a_2, b_2, c_2)$ ∈ SVNS the multiplication between A_1 and A_2 is defined

by:

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

3. The multiplication by a positive scalar $\lambda \in \Re$ with SVNS, A = (a, b, c) is defined by:

$\lambda A = \left(1 - (1-a)^{\lambda}, b^{\lambda}, c^{\lambda}\right)$ (4)

4. Let $\{A_1, A_2, \ldots, A_n\} \in$ SVNS(x), where $A_j = (a_j, b_j, c_j)$ (j = 1, 2, …, n), then, the Single Valued Neutrosophic Weighted Average Operator is defined by[20]:

$$P_w(A_1, A_2, \ldots, A_n) = \langle 1 - \prod_{j=1}^{n} \left(1 - T_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n} \left(I_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n} \left(F_{A_j}(x)\right)^{w_j} \rangle$$

(5)

Where:

$w = (w_1, w_2, \ldots, w_n)$ is vector of $A_j (j = 1,2, \ldots, n)$ such that $w_n \in [0,1]$ y $\sum w_j = 1$.

5. Let A = (a, b, c) be a single neutrosophic number, a score function S of a single valued neutrosophic value, based on the truth-membership degree, indeterminacy-membership degree and falsehood membership degree is defined by[21, 22]:

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

(6)

Where

$S(A) \in [-1,1]$

6. Let $A^* = (A_1^*, A_2^*, \ldots, A_n^*)$ a vector SVNS such that $A_j^* = (a_1^*, b_2^*, c_2^*)$ $(j = 1,2, \ldots, n)$ and $B_i = (B_{i1}, B_{i2}, \ldots, B_{im})$ $(i = 1,2, \ldots, m)$ are m vectors such that $B_{ij} = (a_{ij}, b_{ij}, \ldots, c_{ij})$ $(i = 1,2, \ldots, m)(j = 1,2, \ldots, n)$, then the distance measure between B_i and A^* is as follows:

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

(7)

This article will associate linguistic terms with SVNS, so that experts can carry out their evaluations in linguistic terms, which is more natural. Therefore, the scales shown in table 1 will be taken into account.

LINGUISTIC TERM	EVALUATION	SVNS
Very Important	(VI)	(0.9, 0.1, 0.1)
Important	(I)	(0.75,0.25,0.2)
Medium	(M)	(0.5,0.5,0.5)
Low-Important	(LI)	(0.35,0.75,0.8)
Not Very Important	(NVI)	(0.1,0.9,0.9)

Table 1. Linguistic terms and its SVNS

The TOPSIS method for SVNS assumes that, having a set of alternatives and a set of criteria, the following steps will be carried out [23, 24]:

Step 1: Determine the weight of the experts

The experts are evaluated according to the linguistic scale shown in table 2, and the calculations are made with their associated SVNS.

LINGUISTIC TERM	EVALUATION	SVN NUMBERS
Extremely High	EH	(1; 0; 0)
Very Very High	VVH	(0.9, 0.1, 0.1)
Very High	VH	(0,8; 0,15; 0,20)
High	H	(0.70,0.25,0.30)
Medium High	MH	(0,60; 0,35; 0,40)
Medium	M	(0,50; 0,50; 0,50)
Medium Low	ML	(0,40; 0,65; 0,60)
Low	L	(0.30,0.75,0.70)
Very Low	VL	(0,20; 0,85; 0,80)
Very Very Low	VVL	(0.10,0.90,0.90)
Extremely Low	EL	(0; 1; 1)

Table 2. Linguistic terms used for expert's evaluation

Let us call $A_t = (a_t, b_t, c_t)$ the SVNS corresponding to the t-th decision maker (t = 1, 2,..., k). The weight is calculated by the following formula:

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

Where:
$\lambda_t \geq 0$ y $\sum_{t=1}^{k} \lambda_t = 1$

Step 2: Construction of the single valued neutrosophic aggregated decision matrix

This matrix is defined by $D = \sum_{t=1}^{k} \lambda_t d_{ij}$, where $d_{ij} = \left(u_{ij}, r_{ij}, v_{ij}\right)$ is used to aggregate all individual assessments.

d_{ij} is calculated as the aggregation of the evaluations given by each expert $\left(u_{ij}{}^t, r_{ij}{}^t, v_{ij}{}^t\right)$, using the weights of each one with the help of Equation 5.

In this way a matrix D = $\left(d_{ij}\right)_{ij}$, where each d_{ij} is a SVNS (i = 1,2,.., m; j = 1,2,…, n).

Step 3: Determination of the Weight of the Criteria ([7]).

Suppose that the weight of each criterion is given by $W = (w_1, w_2, \ldots, w_n)$,where w_j it denotes the relative importance of the criterion β_j. If $w_j^t = a_j^t, b_j^t, c_j^t$it is the evaluation of the criterion $\beta_j$by the t-th expert. Then, Equation 5 is used, to add the with w_j^t the weights λ_t.

Step 4: Construction of the single valued neutrosophic decision matrix of the weighted mean with respect to the criteria.

$$D^* = D \otimes W, where\ d_{ij}^* = W_j \otimes d_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right) \tag{9}$$

Step 5: Calculation of the positive and negative SVNS ideal solutions

The criteria can be classified as either cost-type or benefit-type. Be G_1 the set of benefit-type criteria and G_2 the cost-type criteria. The ideal alternatives will be defined as follows[25]:

$$\rho^+ = \left(a_{\rho^+w}(\beta_j), b_{\rho^+w}(\beta_j), c_{\rho^+w}(\beta_j)\right) \tag{10}$$

Denotes the positive ideal solution, corresponding to G_1.

$$\rho^- = \left(a_{\rho^-w}(\beta_j), b_{\rho^-w}(\beta_j), c_{\rho^-w}(\beta_j)\right) \tag{11}$$

Denotes the negative ideal solution, corresponding to G_2.

Where

$$a_{\rho^+w}(\beta_j) = \begin{cases} max_i a_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ min_i a_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

$$b_{\rho^+w}(\beta_j) = \begin{cases} min_i b_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ max_i b_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

$$c_{\rho^+w}(\beta_j) = \begin{cases} min_i c_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ max_i c_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

And

$$a_{\rho^-w}(\beta_j) = \begin{cases} min_i a_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ max_i a_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

$$b_{\rho^-w}(\beta_j) = \begin{cases} max_i b_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ min_i b_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

$$c_{\rho^-w}(\beta_j) = \begin{cases} max_i c_{\rho_i w}(\beta_j), & if \quad j \in G_1 \\ min_i c_{\rho_i w}(\beta_j), & if \quad j \in G_2 \end{cases}$$

Step 6: Calculation of the distances to the ideal positive and negative SVNS solutions

With the help of Equation 7, the following equations are calculated[21]:

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

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

Step 7: Calculation of the Proximity Coefficient (PC).

The PC of each alternative is calculated with respect to the positive and negative ideal solutions.

$$\tilde{\rho}_j = \frac{s^-}{s^+ + s^-}$$

Where

$0 \le \tilde{\rho}_j \le 1$

Step 8: Sorting the alternatives.

3 Results

A group of fifteen experts in the field of study were selected for the application of the Neutrosophic TOPSIS technique. They are free practice lawyers and public defenders from the Public Defender's Office in the Criminal Area of the Babahoyo canton, registered with the Los Ríos Bar Association. 40% of these are women. All of them have had vast experience and theoretical preparation in dealing with the crimes of feminicide and gender violence inside and outside the country. Their evaluations and corresponding weights (step 1) are shown in table 3.

EXPERT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
EVALUATION	MH	MH	H	H	H	H	VH	VH	VH	VH	VVH	VVH	VVH	VVH	VVH
λ_t	0,049	0,049	0,053	0,053	0,053	0,053	0,055	0,055	0,055	0,055	0,059	0,059	0,059	0,059	0,059

Table 3. Results of the experts' weight determination

The experts agreed that the strategies to be considered would be the following:

1. Classification of feminicide in the Integral Organic Criminal Code.
2. Training of public agents acting in the legal norms on violence against women.
3. More preventive criminal legislation for the protection of victims of domestic and gender violence.
4. Establishment of rules to ensure that the principle of the need for proof is considered in crimes of feminicide.

After a debate on the criteria to be analyzed, they decided that it would be appropriate to analyze the strategies to be followed according to two criteria:

1. Social impact on the reduction of feminicide crimes
2. Adequate legal treatment as a feminicide crime

The single valued neutrosophic aggregated decision matrix (step 2) was obtained from the results of the expert assessment of the strategies according to the two criteria, as shown in tables 4 and 5.

ESTRATEGY	**EXPERT**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	VI	VI	I	VI	I	M	VI	I	M	VI	I	I	M	I	M
2	M	M	I	M	VI	M	M	VI	I	VI	M	I	M	VI	VI
3	M	I	I	M	VI	I	I	I	M	VI	I	I	VI	I	VI
4	VI	VI	I	VI	I	M	VI	I	M	VI	I	I	M	I	M

Table 4. Experts' assessment of strategies in terms of the criterion Social impact on the reduction of feminicide crimes

ESTRATEGY	**EXPERT**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	VI	VI	M	M	VI	M	I	M	I	M	M	I	VI	I	VI
2	I	VI	VI	M	M	I	M	I	VI	I	VI	M	M	VI	VI
3	M	I	VI	VI	VI	M	I	M	I	I	I	VI	VI	VI	M
4	VI	VI	M	M	VI	M	I	M	I	M	M	I	VI	I	VI

Table 5. Expert assessment of strategies in terms of the criterion "Adequate legal treatment as a feminicide crime"

Taking into account the SVNS associated to the linguistic variables used, the aggregations of the experts' assessments for each strategy were made according to each criterion. Results are shown in table 6.

ESTRATEGY	CRITERION 1	CRITERION 2
1	(0,707 ; 0,293 ; 0,272)	(0,687 ; 0,313 ; 0,297)
2	(0,68 ; 0,32 ; 0,308)	(0,715 ; 0,285 ; 0,272)
3	(0,711 ; 0,289 ; 0,262)	(0,728 ; 0,272 ; 0,256)
4	(0,707 ; 0,293 ; 0,272)	(0,687 ; 0,313 ; 0,297)

Table 6. Single valued neutrosophic aggregated decision matrix

The weights that each experts assigned to each criterion (step 3) are shown in table 7.

CRITERION	EXPERT														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1.-Social impact on the reduction of feminicide crimes	MI	M	I	M	MI	MI	MI	I	M	I	I	I	MI	MI	MI
2.-Adequate legal treatment as a feminicide crime	I	M	M	M	M	MI	MI	MI	MI	MI	M	M	MI	I	M

Table 7. Evaluation of the weight of each criterion according to the experts

With these ratings, the weight of the criteria expressed in SVNS was calculated (table 8).

CRITERION	WEIGHT (SVNS)
1.-Social impact for the reduction of feminicide crimes	(0,739 ; 0,261 ; 0,242)
2.-Adequate legal treatment as a feminicide crime	(0,693 ; 0,307 ; 0,3)

Table 8. Weights of criteria

Then, the single valued neutrosophic decision matrix of the weighted mean with respect to the criteria (step 4) is shown in table 9.

ESTRATEGY	CRITERION 1	CRITERION 2
1	(0,522 ; 0,478 ; 0,448)	(0,476 ; 0,524 ; 0,508)
2	(0,503 ; 0,497 ; 0,476)	(0,496 ; 0,504 ; 0,49)
3	(0,526 ; 0,474 ; 0,44)	(0,505 ; 0,495 ; 0,479)
4	(0,522 ; 0,478 ; 0,448)	(0,476 ; 0,524 ; 0,508)

Table 9. Weighted aggregate decision matrix.

The ideal positive and negative SVNS solutions calculated in step 5 are shown in table 10.

CRITERION	POSITIVE IDEAL VALUE	NEGATIVE IDEAL VALUE
1	(0,526 ; 0,474 ; 0,44)	(0,503 ; 0,497 ; 0,476)
2	(0,505 ; 0,495 ; 0,479)	(0,476 ; 0,524 ; 0,508)

Table 10. SVNS positive and negative ideal solutions by criteria.

The distances to the positive and negative SVNS ideal solutions (step 6), as well as the Proximity Coefficient (PC) and the resulting order of the alternatives (steps 7 and 8), are shown in table 11.

ALTERNATIVES	d+	d-	PC	ORDER
1	0,028848946	0,01934405	0,59861284	3
2	0,029253255	0,018873979	0,60783163	4
3	0	0,039605326	0	1
4	0,028848946	0,022455394	0,56231005	2

Table 11. Distances to ideal solutions, proximity coefficient and order of alternatives

This result shows that the most important strategy in order to decrease the number of feminicides in the country and that these cases have the appropriate legal treatment, is to establish a more preventive criminal legislation for the protection of victims of domestic and gender violence. Secondly, a rule must be established to ensure that the principle of the need for proof is observed in crimes of feminicide.

Conclusions

The criminal legislation in Ecuador, and in several countries, has been insufficient to reduce violence against women, and it is even perceived that the levels of violence continue to increase. Given this reality, the majority of Ecuadorian women live in concern, particularly in the city of Babahoyo.

National and international studies by different authors, which have addressed the issue of violence against women, are largely oriented only towards the crime of feminicide, without proposing legal reforms to reduce it.

With the application of the neutrosophic TOPSIS technique, four alternatives were evaluated to achieve the reduction of feminicide in Ecuador, as well as a more adequate legal treatment in these cases, based on the criteria of fifteen experts on the subject. This technique, based on Neutrosophy, made it possible to capture the specialists' evaluation criteria in a more accurate way.

As a result, we found that the best alternative, or the most important strategy, is to establish a more preventive criminal legislation for the protection of victims of domestic and gender violence and to punish those who, knowing the state of vulnerability of a woman, of the violence under which she lives, do not inform the competent authorities.

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Neutrosophic Analysis of the Facultative Vote in the Electoral Process of Ecuador

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Abstract. Youth participation in the country's electoral processes has a great impact on Ecuadorian political life. Analyzing the incidence of the facultative vote and the responsibility that the use of the right implies in electoral democracy, constitutes an important task to guarantee citizen rights. These elements can be analyzed in the scientific literature through statistical studies. The present research aims to carry out an analysis of the incidence of the facultative vote of young people between 16 and 18 years old in the electoral process of Ecuador. To model the uncertainty in the proposed analysis, the neutrosophic statistics are used to include in the study the uncertainty about the fluctuation of the youth population and the invalid votes.

Keywords: Statistical analysis; facultative vote; Ecuadorian elections; neutrosophic numbers

1. Introduction

The participation of young Ecuadorians in electoral processes has had a significant evolution in active participation in elections after the constitution of 2008, known as Montecristi. The new legal framework placed in the hands of young people a great tool for political participation, which at first would be considered as a fact of little importance for young people [1, 2]. The increase in political rights influences the participation of 16-year-old. They obtain the necessary information through mechanisms used by the National Electoral Council (NEC) from the educational institutions where are concentrated the majority of young people empowered by the Ecuadorian Constitution to vote. This is a facultative right, that is, they decide their participation in this process [3, 4].

Knowing the importance of this exercise, based on the analysis of the incidence that the voluntary vote of young people has and the responsibility that the use of their right implies in electoral democracy, constitutes an important task to guarantee the needs of this sector in the society. This research took as a reference the one carried out by the National Electoral Council in 2014, on young voters under the age of eighteen, who reckoned 577,130, between men and women nationwide. In this and other investigations, the prevalence of ignorance of respondents regarding the age to access the right to vote was noted [5, 6].

The facultative vote in Ecuador is the result of various proposals from different sectors of society, which were present in the drafting of the Constitution in Montecristi [7, 8]. The proposals for the facultative vote were developed and debated at table No. 1, in charge of "Fundamental Rights and Constitutional Guarantees", where the right to vote evolved towards universalization, with a marked expansion of voters and their integration into the decisions of general interest as an important factor to improve the substantial life of the State democracy [9, 10].

The right to vote is optional for adolescents, from sixteen years old and even before turning eighteen [11, 12]. On this point, the inclusion of adolescents in active suffrage is the full recognition of citizenship, guarantees and rights that the State accepted since the Constitution of 1998. In 2003, the Code of Childhood and Adolescence was elaborated through which developed the participation rights of children and adolescents. In 2008 adolescents became part of the right to active suffrage and enjoy the political rights contemplated in the Constitution and laws [13, 14].

In this article, neutrosophic statistics is used to study voting among Ecuadorian youth with an age range between 16 and 18 years, during 3 consecutive voting periods. Neutrosophic statistics extend the classical statistics, where some of the elements such as population, sample size, and distribution parameters are calculated as an interval instead of crisp values. This is because we consider indeterminacies of the study population, as well as the samples, due to the existence of young people who could have voted and did not do so for justified reasons, as well as invalid votes, such as blank votes. This paper expose a preliminary section where the main concepts of Neutrosophy are described, including neutrosophic statistics. Section 3 includes the results of the study. Last section states to the conclusions.

2 Preliminaries

This section describes the basic concepts that will be used in the study, specifically the concept of the neutrosophic number [15-17]. In the 1980s, the international movement called Paradoxism [18], based on contradictions in science and literature, was founded by Smarandache, who later extended it to Neutrosophy, based on contradictions and their neutrals [19, 20]. Neutrosophic sets are a generalization of a fuzzy set (spatially of a fuzzy intuitive set) [15, 21, 22]. Let U be a universe of discourse, and M a set included in U. An element x of U with respect to the set M that is denoted as x (T, I, F) belongs to M in the following way: Is t% true in the set T, i% indeterminate (unknown) in the set I, and f% false in the set F, where t varies in T, i varies in I, f varies in F [6, 9, 23].

In order to facilitate the practical application to decision-making and engineering problems, the proposal of single value neutrosophic sets (SVNS) was made [9, 24-26] which allow the use of linguistic variables, which increases the interpretability in the recommendation models and the use of indeterminacy [27-29].

Statically T, I, F are subsets of [0, 1], but dynamically T, I, F are functions or operations dependent on many unknown or known parameters[25, 30].

Definition 1. Be a universe of discourse. An SVNS on is an object of the following form X AX [31-33]:

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

Where, $u_A(x): X \rightarrow [0,1]$, $r_A(x), : X \rightarrow [0,1]$ y $v_A(x): X \rightarrow [0,1]$ con $0 \leq u_A(x) + r_A(x) + v_A(x) :\leq 3$ for all $x \in X$. The intervals $u_A(x), r_A(x)$ and $v_A(x)$ denote the true, indeterminate, and false memberships of x in A, respectively. For convenience, an SVN number will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$, and $0 \leq a + b + c \leq 3$.

In order to work with neutrosophic numbers, neutrosophic statistics also have been defined. The confidence interval represents an application domain of the applied neutrosophic statistics [34-36]. The population sample neutrosophic confidence interval can be defined in the same way as the classic large sample confidence interval for the population proportion π[37-39]:

$$p \pm (Critical\ value\ Z)\sqrt{\frac{p(1-p)}{n}} \tag{2}$$

for the case when min and min,$\{np\} \geq 5\{n(1-p)\} \geq 5$

Where:

p: is the sample proportion, the number of individuals in the sample who possess the property of interest divided by the size of the sample;

n: sample size,

π: population proportion$= \frac{\text{Number of individuals in the population who own the property of interest}}{\text{Total individual of interest}}$

With the classic statistics distinction that in neutrosophic statistics the parameters p and n can be sets instead of crisp numbers z, and the critical value can also be a set (for example, it can be the confidence level) [40-42].

The neutrosophic sample statistic p, for n sufficiently large, has a neutrosophic sampling distribution, a normal curve that approximates the population mean π and its standard deviation according to formula 3.

$$std = \sqrt{\frac{\pi(1-n)}{n}} \tag{3}$$

It is necessary to include some algebraic operations between intervals:

Additionally, given and we have the following operations between them$\mathrm{I}_1 = [\mathrm{a}_1, \mathrm{b}_1]\mathrm{I}_2 = [\mathrm{a}_2, \mathrm{b}_2]$[43]:

$\mathrm{I}_1 \leq \mathrm{I}_2$ If and only if $\mathrm{a}_1 \leq \mathrm{a}_2 \mathrm{b}_1 \leq \mathrm{b}_2$

1. $\mathrm{I}_1 + \mathrm{I}_2 = [\mathrm{a}_1 + \mathrm{a}_2, \mathrm{b}_1 + \mathrm{b}_2]$ (Addition);
2. $\mathrm{I}_1 - \mathrm{I}_2 = [\mathrm{a}_1 - \mathrm{b}_2, \mathrm{b}_1 - \mathrm{a}_2]$ (Subtraction),
3. $\mathrm{I}_1 \cdot \mathrm{I}_2 = [\min\{\mathrm{a}_1 \cdot \mathrm{b}_1, \mathrm{a}_1 \cdot \mathrm{b}_2, \mathrm{a}_2 \cdot \mathrm{b}_1, \mathrm{a}_2 \cdot \mathrm{b}_2\}, \max\{\mathrm{a}_1 \cdot \mathrm{b}_1, \mathrm{a}_1 \cdot \mathrm{b}_2, \mathrm{a}_2 \cdot \mathrm{b}_1, \mathrm{a}_2 \cdot \mathrm{b}_2\}]$ (Multiplication),
4. $\mathrm{I}_1/\mathrm{I}_2 = \mathrm{I}_1 \cdot (1/\mathrm{I}_2) = \{\mathrm{a}/\mathrm{b}: \mathrm{a} \in \mathrm{I}_1, \mathrm{b} \in \mathrm{I}_2\}$, always that $0 \notin$ I2 (Division).

3 Results and discussions

For the statistical analysis, the data from the National Electoral Commission for the corresponding period between 2009 and 2017 were used. The SPSS statistician was used to facilitate the calculation and analysis of the data. The electoral participation of young people between 16 and 18 years old in the presidential elections of the years 2009-2013 and 2017 shows an increase. Happening in the same way in the presidential elections to elect the president of the Republic of Ecuador in 2019. Many may be the factors that had an impact on young people, the place where they live, educational level, the non-mandatory nature, among other.

The training carried out by one of the highest organism of state functions, such as the electoral function, which through the National Electoral Council organizes according to the planning jointly with attached institutions such as the Institute of Democracy. The aforementioned institutions brought the necessary information to the educational establishments for the knowledge of the young people and the motivation to exercise their optional right. As well as the importance of choosing who would represent and govern the Ecuadorian state.

The recruitment of young people by Political Organizations who consider this electoral population interesting develops different activities and even political training schools. The non-compulsory vote of those under 18 years of age has not been any impediment to democratic expression, as it is shown in the participation of the facultative vote in 2017 was 71.70% of an optional electoral population of 676,401 voters in relation to 2009 where 64.80% corresponds to an optional electoral population of 453,882. Figure 1 shows a graph with the behavior of the corresponding period between 2009 and 2017.

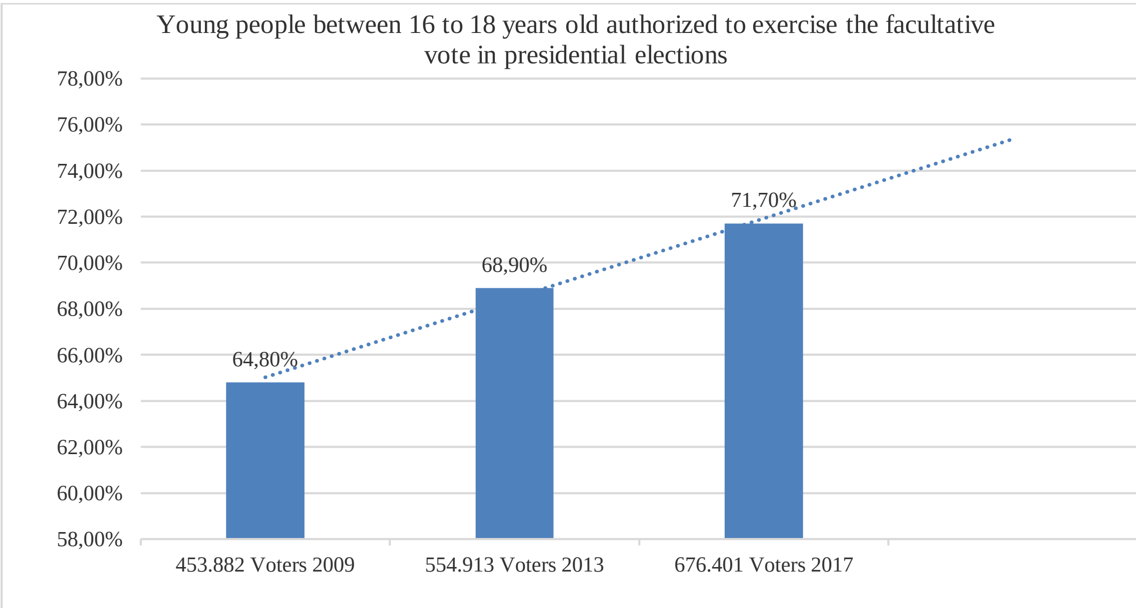

Figure 1: Scheme of the behavior of the facultative vote between 2009 and 2017.

The Ibero-American Youth Organization (IYO) states that all people between 15 and 29 years old are young [44]. Legally in Ecuador, young people are considered people whose ages are between 18 and 29 years old, it is proposed to reform the participation of young people in politics through the National Assembly to the Ecuadorian Code of Democracy.

A quota of young people not less than twenty-five percent (25%) will be incorporated into each list to be registered in the candidacies for multi-person elections. This is an indicator of improvement of the participation of young people under 18 years of age. This proves an interest of those who will administer the country and the planning of good public policies is that young people live aware of the national reality and stop being naive.

Organizational participation must be through youth collaborations where the full involvement of young people promoted in the civic, social, economic, cultural, artistic and political fields where trust and value to democracy have been created.

One characteristic of exercising the electoral vote is that it is secret and there are variants where it is exerted in a not necessarily effective way, such as a blank vote and a null vote. For greater accuracy of the results, an estimate of invalid votes in the country was considered in this study, which is why population intervals were included in the research instead of exact sizes, the main idea is to infer with greater accuracy the voting behavior and effectiveness. To consider this, we include the neutrosophic confidence intervals as the population size.

Another reason to include intervals is in the intention of considering the real youth population, which for reasons of population dynamics does not vote, that they are traveling or another similar reason, although they could be interested in voting. This prompted us to consider the size of the youth voting population per year at the officially given size with an error of $\pm 0.1\%$. This value is the approximation given by the experts consulted that there may be young people who do not vote, but who intend to do so.

Taking into account the above-mentioned, the official youth population of voting age is estimated at$P_{2009} = [4.4934 \times 10^5,\ 4.5842 \times 10^5]$, $P_{2013} = [4.4934 \times 10^5,\ 4.5842 \times 10^5]$ y $P_{2017} = [4.4934 \times 10^5, 4.5842 \times 10^5]$.

The proportions obtained are:

$p_{2009} = [0.63975, 0.65639]$,,.$p_{2013} = [0.68218, 0.69596]$$p_{2017} = [0.70990, 0.72424]$

Taking z = 2.58, which means 99% confidence, we have the following neutrosophic confidence intervals:

For 2009 we have,$[0.63975, 0.65639] \times 100\%$

For 2013 we have,$[\ 0.68043, 0.69773] \times 100\%$

For 2017 it is.$[0.70818, 0.72599] \times 100\%$

An increase in the electoral vote is perceived.

Conclusions

The participation of young Ecuadorians in democratic life is fundamental since there is a positive effect on human relations with the strengthening of social integration. This participation of young people, which is optional to exercise the right to choose, produces positive effects on society.

In recent years, the participation of young people in Ecuador has developed in a quantitative way, which represents a different vision where political culture is created so that in the future they can have an active representation.

The statistical analysis of the behavior of variables related to the facultative vote constitutes an important element to guarantee the demands of all the sectors and in this sense the present investigation is framed. From the development of the research, an analysis was obtained on the behavior of the facultative vote in young people between 16 and 18 years of Ecuador.

The statistical analysis reflected that in the process of 2013, there was an increase compared to 2009 and that in turn 2017 increased compared to 2013, which shows the increase in the participation of young people. Modeling with the support of neutrosophic statistics made it possible to determine the behavior of the facultative vote with indeterminacy from the statistical tests of the confidence interval, including the indeterminate population size. These uncertainties included are due to estimates of young people who did not vote due to force majeure and who should have voted, in addition to including an estimate of invalid votes.

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A Model for Recommending Custody of Minors based on Neutrosophic Cognitive Map

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Abstract. Minors can be left without legal custody due to many different reasons. When a minor is in distress he/she is at the mercy of the decision of the competent entity for the granting of his/her guardian. However, based on the affective relationships established by the different family members, determining parental responsibility constitutes a highly important decision. This research proposes a solution to the problem described by means of a recommendation system to assign parental responsibility and its incidence in the best interests of minors. The proposed method bases its operation on the use of Neutrosophic Cognitive Maps (NCM) to model the uncertainty in causal relationships. A case study is presented to demonstrate the applicability of the proposal.

Keywords: Parental responsibility; recommendation; Neutrosophic Cognitive Map; custody of minors

1. Introduction

The well-being of boys and girls in all their aspects such as health, physical and mental state, home, family, social condition and education is an international priority. In 1953, the United Nations General Assembly established that United Nations Children's Fund (UNICEF) is a permanent body, to later expand its scope to minor issues, being the starting point to create the second Declaration of the Rights of the child [1, 2]. The Declaration of the Rights of the Child indicates that children need special care, establishing adequate legal protection, before and after birth [3]. This statement mentions:

- The right to equality, without distinction of race, religion or nationality.
- The right to have special protection for the child's physical, mental and social development.
- The right to adequate food, shelter and medical care.
- The right to education and special treatment for those children who suffer from a mental or physical disability.
- The right to protection against any form of abandonment, cruelty and exploitation.

In Ecuador, from the moment it was constituted as a Republic, two legal bodies have been drafted. These are: the Juvenile Code with its respective reforms and the Childhood and Adolescence Code [4].

The latter has had to go through several changes, since what is sought is to confer a norm that is appropriate to the comprehensive protection of children and adolescents. Under the provisions of this norm, they will enjoy equality according to the law and there will be no discrimination because of the sex, religion, social origin, political ideology, affiliation, health, sexual orientation, disability or any other condition, whether of the minor, his/her parents, representatives or family members. Childhood and Adolescence Code, which the National Congress described as an "organic law" based on the article 142 of the Constitution, in its first part establishes the protection that The State, society and the family must provide to the minor, to the full enjoyment of their rights, establishing that this code protects all people from their prenatal state until they turn eighteen [5, 6].

Article 44 of our Carta Magna refers to the principle of the best interest of the child, in which various precepts are enshrined that require the state and society to respect in all areas the rights of minors, promoting their comprehensive development. Article 45 indicates a list of rights, such as: the right to health, education and family life, in which through this research project it we may corroborate that sometimes children are deprived of this right.

The constitution of the Republic of Ecuador must ensure equality in opportunities and rights to all those who make up the family nucleus, since it consecrates the family as the fundamental nucleus of society, therefore, the rights of each person must be protected. One of them promoting a responsible parental relationship giving children care, upbringing and education, protecting their rights and well-being in the event of being left without legal custody [7, 8].

The constitution itself mentions the best interests of the child, and it exalts all the measures that public and private entities must take, always protecting the best interests of the child. Based on this, administrators of justice, especially those in charge of childhood issues, must make their decisions independently of social pressures. When solving a controversy where the minor is involved, the well-being of the boy or girl will always come first.

When a minor is in distress, he/she is at the mercy of the decision for the granting of his/her custody. However, based on the affective relationships established by the different family members, determining parental responsibility constitutes a highly important decision. In our society, we often have to deal with the problems that arise at the moment in which the competent entity of justice has to choose the family that will assume the care and protection of the minor. In these cases the law does not have a tacit interpretation, but it is necessary to analyze various aspects that generally finish in decision-making under uncertainty.

Judges, or justice administrators in general, are in an environment of uncertainty regarding the granting of legal custody. A minor requires care and attention both affective and emotional, satisfying his/her needs and taking good care of his/her interests. A hasty decision will affect both its emotional and psychological state in short and long terms.

This research proposes a solution to the problem described, through a method for recommending the custody of minors based on parental responsibility and its incidence in the best interests of minors.

In 1980s, the international movement called Paradoxism based on contradictions in science and literature, was founded by Romanian polymath Florentin Smarandache, who then extended it to Neutrosophy, based on contradictions and their neutrals [9]. A Neutrosophic Cognitive Map (NCM) is used to represent and model the causal relationships among the factors which determine the performance of the custody of minors. This technique generalizes the Cognitive Maps and Fuzzy Cognitive Maps (FCM) in a neutrosophic framework, such that these causal relationships include the symbol I, which represents the indeterminacy usually contained in the knowledge and information of decision-makers. Thus, NCM is more trustworthy than fuzzy or crisp cognitive maps, because it contains indeterminacy. The importance of this work is that the proposed method is useful as a decision-support system for recommending custody of minors

The research is divided into several sections: Materials and Methods, Results and Conclusions. In the introduction, a state of the art is made on the different situations in which a child can be left without legal custody and the existing legal codes and procedures have to assign him/her a legal custody. In the Materials and Methods session, a method for recommending custody of minors based on parental responsibility is presented, which consists of four basic activities and is based on a Neutrosophic Cognitive Map to model uncertainty in causal relationships. The Results show a case study to demonstrate the applicability of the proposal.

2. Materials and Methods

This section describes the details of the method for recommending child custody based on parental responsibility. The method models the causal relationships between the different concepts [10] using a neutrosophic cognitive map.

The method supports the following principles:

- Integration of causal knowledge using the Neutrosophic Cognitive Map (NCM) for recommending custody of minors.
- Identification of causal relationships through the team of experts.
- Orientation of information towards the well-being of the minor.

The design of the method is structured for the recommendation of custody of minors. It has three basic stages: input, processing and output. Figure 1 shows the general outline of the proposed method.

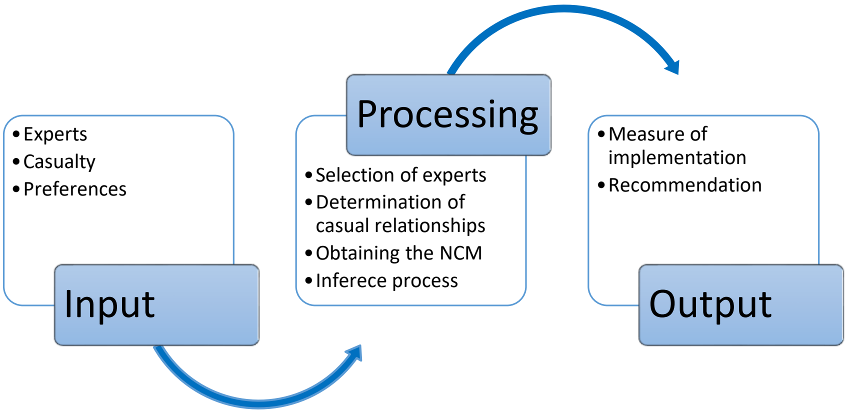

Figure 1. Structure of the proposed method.

The proposed method is structured to support the management of the inference process for recommending custody of minors. We use a multi-criteria approach as the basis for inference, which helps experts to feed the base of knowledge, [11-13].

The set of evaluative indicators represent one of the inputs of the method that is required for the inference activity. The inference activity represents the core for the reasoning of the method. It bases its processing on the modeling of causal relationships with the use of a Neutrosophic Cognitive Map [14-16].

2.1 Description of the method

This section provides a description of the proposed method. The activities that guarantee the inference of the processing stage are detailed. These activities are: identifying the evaluation criteria, determining the causal relationships, obtaining the NCM resulting from the causal relationships and the inference process.
Figure 2 shows the flow of the processing stage.

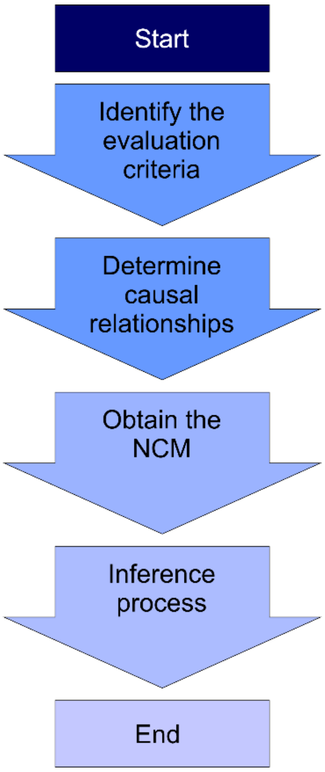

Figure 2. Processing stage workflow.

Activity 1: Identification of the evaluation criteria

The activity begins with the identification of the experts involved in the process. The experts group determines the criteria that will be taken into account for the inference process.

The activity uses a work group system using a multi-criteria approach. Formally, the problem of recommending the custody of minors can be defined based on parental responsibility through:

The impact criteria for the custody process are denoted by $C = \{C_1, \ldots, C_n\}$.

The number of experts involved in multi-criteria assessment is denoted by $E = \{E_1, \ldots E_n\}$:

Activity 2: Determinations of the causal relationships of the criteria

Once the impact criteria for the custody process are obtained, the causal relationships are determined [17]. Causal relationships are the expression of causality between the impact criteria for the custody process [18].

The determination of the causal relationships consists of establishing from the work group the implication among concepts. The resulting information represents the primary knowledge to feed the inference process. Causal relationships are represented by fuzzy variables expressed as linguistic terms [19, 20].

In linguistic models, sets of linguistic labels with granularity not greater than 13 are generally used. It is common to use sets of odd granularity, where there is a central label and the rest of the labels are symmetrically distributed around it [21, 22]. Figure 3 shows the set of linguistic terms used for this investigation.

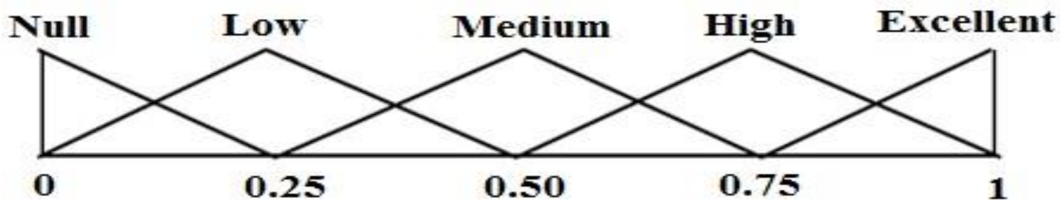

Figure 3. Linguistic labels set.

Activity 3: Obtaining the NCM

During the knowledge engineering stage each expert expresses the relationship between each pair of concepts C_i and C_j of the map. So, for each causal relationship, K-rules are obtained with the following structure: If C_i is A then C_j is B and the weight W_{ij} is C.

The theory of NCM is the following:

Definition 1: ([9]) Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow \,]^-0, 1^+[$, which satisfy the condition $^-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3^+$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indetermination and falseness of x in A, respectively, and their images are standard or non-standard subsets of $]^-0, 1^+[$.

NS are useful only as a philosophical approach, so *Single-Valued Neutrosophic Set* is defined to guarantee the applicability of Neutrosophy, see Definition 2.

Definition 2:([9]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (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 $u_A, r_A, v_A : X \rightarrow [0,1]$, 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 membership functions of truthfulness, indetermination and falseness of x in A, respectively. For convenience, a *Single-Valued Neutrosophic Number* (SVNN) will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$ and satisfies $0 \leq a + b + c \leq 3$.

Neutrosophic Logic (NL) extends fuzzy logic. As stated by Florentin Smarandache, a proposition P is characterized by three components; see [23]:

$$NL(P) = (T, I, F) \quad (2)$$

Where component T is the degree of truthfulness, F is the degree of falsehood and I is the degree of indetermination. T, I, and F belong to the interval [0, 1], and they are independent from each other.

A *neutrosophic number* is formed by the algebraic structure a+bI, where I = indetermination. Below, we formally describe some important concepts.

Definition 3: ([24]) Let R be a ring. The *neutrosophic ring* $\langle R \cup I\rangle$ 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 $\langle R \cup I\rangle$ and in addition $0 \cdot I = 0$. Also, I^{-1}, the inverse of I is not defined.

E.g., a neutrosophic ring is $\langle \mathbb{Z} \cup \mathrm{I} \rangle$ generated by $\mathbb{Z}$, which is the set of integers.

Some operation using I is $\mathrm{I}+\mathrm{I}+\ldots+\mathrm{I} = \mathrm{nI}$.

Definition 4: ([25]) A *neutrosophic number* N is also defined as a number as follows:

$$N=d+I \tag{3}$$

Where d is the *determined part* and I is the *indeterminate part* of N.

Let $\mathrm{N}_1 = \mathrm{a}_1 + \mathrm{b}_1\mathrm{I}$ and $\mathrm{N}_2 = \mathrm{a}_2 + \mathrm{b}_2\mathrm{I}$ be two neutrosophic numbers, then some operations between them are :

1. $\mathrm{N}_1 + \mathrm{N}_2 = \mathrm{a}_1 + \mathrm{a}_1 + (\mathrm{b}_1 + \mathrm{b}_2)\mathrm{I}$ (Addition),
2. $\mathrm{N}_1 - \mathrm{N}_2 = \mathrm{a}_1 - \mathrm{a}_1 + (\mathrm{b}_1 - \mathrm{b}_2)\mathrm{I}$ (Difference),
3. $\mathrm{N}_1 \times \mathrm{N}_2 = \mathrm{a}_1\mathrm{a}_2 + (\mathrm{a}_1\mathrm{b}_2 + \mathrm{b}_1\mathrm{a}_2 + \mathrm{b}_1\mathrm{b}_2)\mathrm{I}$ (Multiplication),
4. $\frac{\mathrm{N}_1}{\mathrm{N}_2} = \frac{\mathrm{a}_1+\mathrm{b}_1\mathrm{I}}{\mathrm{a}_2+\mathrm{b}_2\mathrm{I}} = \frac{\mathrm{a}_1}{\mathrm{a}_2} + \frac{\mathrm{a}_2\mathrm{b}_1-\mathrm{a}_1\mathrm{b}_2}{\mathrm{a}_2(\mathrm{a}_2+\mathrm{b}_2)}\mathrm{I}$ (Division).

A *neutrosophic matrix* is a matrix whose components are elements of $\langle \mathrm{R} \cup \mathrm{I} \rangle$.

Thus, it is possible to generalize the operations between vectors and matrices on R to the ring $\langle \mathrm{R} \cup \mathrm{I} \rangle$.

A *neutrosophic graph* is a graph with at least one neutrosophic edge linking two nodes, that is to say, there is an edge with an indetermination on its two nodes connection, [9], see Figure 4.

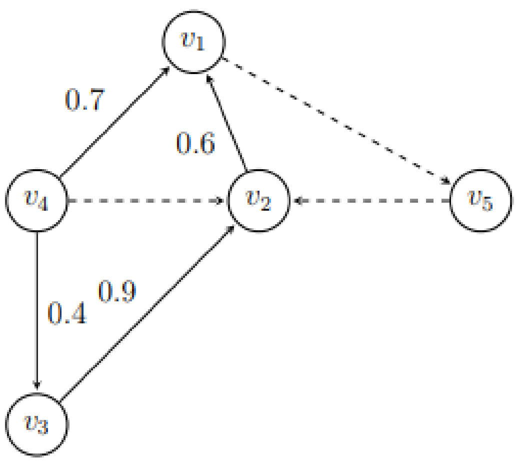

Figure 4: Example of neutrosophic graph. Source[9].

The de-neutrosophication process was introduced by Salmeron and Smarandache in [25], which converts a neutrosophic number into a numeric value. This process provides a range of numbers for centrality using as a base the maximum and minimum values of $\mathrm{I} = [\mathrm{a}_1, \mathrm{a}_2] \subseteq [0,1]$, based on Equation 4:

$$\lambda([\mathrm{a}_1, \mathrm{a}_2]) = \frac{\mathrm{a}_1 + \mathrm{a}_2}{2} \tag{4}$$

Each node constitutes a causal concept; this characteristic makes the representation flexible to visualize human knowledge. The adjacency matrix is obtained from the values assigned to the arcs. Figure 4 shows a representation of the NCM and the adjacency matrix [26-28].

The values obtained by the group of experts are aggregated, conforming to the general knowledge of the relationships between the criteria. Activity results in a NCM [29-31]. Then we carry out the static analysis of the assessment of the causal relationships. The knowledge stored in the adjacency matrix is taken as a reference. For the development of the proposed method, we work with the degree of output as shown by Equation 5, [32-34].

$$id_i = \sum_{i=1}^{n} \left\| I_{ji} \right\| \tag{5}$$

Activity 4: Inference process

A system modeled by an NCM will evolve over time, where the activation of each neuron will depend on the degree of activation of its antecedents in the previous iteration. This process is normally repeated until the system stabilizes or a maximum number of iterations is reached.

Inference process consists of calculating the state vector over time, for an initial condition A^0, [35].

Analogously to other neural systems, the activation of C_i will depend on the activation of neurons that directly affect the C_i concept and the causal weights associated with that concept. Equation 6 shows the expression used for processing.

$$A_i^{(K+1)} = f\left(A_i^{(K)} \sum_{i=1;\, j\neq i}^{n} A_i^{(K)} * W_{ji}\right) \tag{6}$$

Where:

$A_i^{(K+1)}$: is the value of the concept C_i in the step k+1 of the simulation,

$A_i^{(K)}$: is the value of the concept C_j in the step k of the simulation,

W_{ji}: is the weight of the connection that goes from the concept C_j to the concept C_i and f (x) is the activation function.

Unstable systems can be totally chaotic or cyclical and are frequent in continuous models. In summary, the inference process in an NCM may show one of the following characteristics [17, 36]:

Stability states: if $\exists t_k \in \mathbb{N}: A_i^{(t+x)} = A_i^{(t)} \forall t > t_k$, therefore, after iteration t_k the NCM will produce the same state vector. This configuration is ideal, as it represents the encoding of a hidden pattern in causality [37, 38].

Cyclical states: if $\exists t_k, P \in \mathbb{N}: A_i^{(t+p)} = A_i^{(t)} \forall t > t_k$. The map has a cyclical behavior with period p. In this case the system will produce the same state vector every P-cycle of the inference process [39, 40].

Chaotic state: The map produces a different state vector in each cycle. Concepts always vary their trigger value [41, 42].

3. Results

This section illustrates the implementation of the proposed method. A case study is described for recommending the custody of minors based on parental responsibility. The proposal used as a scenario of implementation a reference case of canton of Patate in Ecuador. The results of the study are described below:

Activity 1: Identification of the evaluation criteria

For the development of the study, 5 experts who are licensed Law workers were consulted. The group represents the basis to define the impact criteria in the custody process and causal relationships.

The experts group identified the set of criteria. Table 1 shows those criteria:

Index	Criterion
1	Acceptance degree by the boy or girl
2	Affectivity with the boy or girl
3	Income level
4	Social suitability

Table 1. Impact criteria in the custody process

Activity 2: Determination of the causal relationships of the criteria

For the identification of causal relationships, we obtained information from the group of experts participating in the process. As a result, 5 adjacency matrices were identified with the knowledge expressed by each expert. The matrices were aggregated and a resulting adjacency matrix is generated as the median of the

5-experts opinions. Where there is a symbol I for some expert, we evaluated as I = [0, 1] the aggregated result. Table 2 shows the adjacency matrix yielded by the process.

	C_1	C_2	C_3	C_4
C_1	0	1	I	1
C_2	1	0	0.75	I
C_3	0.25	0	0	1
C_4	0	0.25	1	0

Table 2. Adjacency matrix of the impact criteria in the custody process

Then, $Id_1 = 2+I = [2, 3]$; $Id_2 = 1.75+I = [1.75, 2.75]$, $Id_3 = 1.25$, and $Id_4 = 1.25$.

Using formula 4, we have $\lambda(Id_1) = 2.5$; $\lambda(Id_2) = 2.25$, $\lambda(Id_3) = 1.25$, and $\lambda(Id_4) = 1.25$.

The normalized weights of the criteria are:

$w_1 = 0.32$, $w_2 = 0.29$, $w_3 = 0.195$, and $w_4 = 0.195$. Therefore, when sorting the de criteria we have $C_1 \succ C_2 \succ C_3 \sim C_4$.

Activity 3: Obtaining the NCM

Once the impact criteria for the custody process and their corresponding causal relationships in Activity 2 have been obtained, the knowledge is represented in the resulting NCM. See Figure 5.

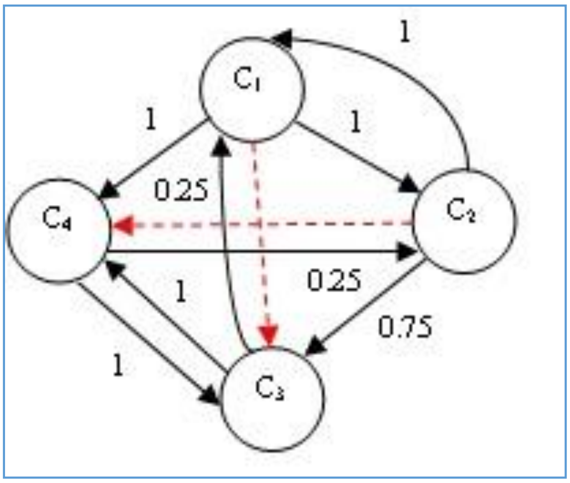

Figure 5. Resulting neutrosophic cognitive map.

Activity 4: Inference process

The adjacency matrix has the necessary information to determine the weights attributed to each indicator. Equation 5 is used to calculate the weights. Table 3 shows the results of the calculation.

Criteria	Evaluation indicators	Weights
C_1	Acceptance level by the boy or girl	0.32
C_2	Affectivity with the boy or girl	0.29
C_3	Income level	0.195
C_4	Social suitability	0.195

Table 3. Weight attributed to the indicators.

Once the weights of the indicators have been determined. The preferences of the object of analysis of the proposal are determined. For this case, 3 degrees of relationship were analyzed (Aunt, Grandmother and Sister). Tables 4, 5 and 6 show the results of the calculation made for each degree of relationship. The preferences are calculated according to the mean of experts' evaluation in the scale 0-10.

Criteria	Weights	Aggregated preferences according to experts' experience
C_1	0.32	8.5
C_2	0.29	6.5
C_3	0.195	10
C_4	0.195	6.5

Table 4. Calculation of preferences attributed to the degree of "aunt" relationship.

Table 4, presented the processing carried out for the degree of "aunt" relationship , based on the criteria referred to in Table 1, the degree of relationship preferences is determined, subsequently the process of information aggregation is carried out as part of the inference process.

Criteria	Weights	Aggregated preferences according to experts' experience
C_1	0.32	7.5
C_2	0.29	7.5
C_3	0.195	8.8
C_4	0.195	10

Table 5. Calculation of preferences attributed to the degree of "grandmother" relationship.

Table 5, presented the processing carried out for the degree of "grandmother" relationship , based on the criteria referred to in Table 1, the degree of relationship preferences is determined, subsequently the process of information aggregation is carried out as part of the inference process.

Criteria	Weights	Aggregated preferences according to experts' experience
C_1	0.32	6.0
C_2	0.29	5.0
C_3	0.195	8.8
C_4	0.195	7.2

Table 6. Calculation of preferences attributed to the degree of "sister" relationship.

Table 6, presented the processing carried out for the degree of "sister" relationship, based on the criteria referred to in Table 1, the degree of relationship preferences is determined, subsequently the process of information aggregation is carried out as part of the inference process.

The weighted mean of the results in Tables 4-6 are calculated and we obtained an index of 7.8225 for the "aunt" relationship, 8.2410 for the "grandmother" relationship, and 6.4900 for the "sister" relationship. Thus, it is likely that grandmothers are preferred over aunts and sisters in case of the custody of minors.

Conclusions

Through the development of the proposed research, we obtained a method for recommending the custody to minors based on parental responsibility. The method requires a group of experts to identify criteria with a multi-criteria approach. With the implementation of the method, the resulting aggregated Neutrosophic Cognitive Map is obtained, which expresses the knowledge of the group of experts with the representation of the causal relationships on the evaluation criteria. The knowledge stored in the Neutrosophic Cognitive Map represents the basis for the inference of the operation of the proposed method that guarantees the recommendations on child custody based on parental responsibility. The application of the method in the case under study demonstrates the applicability to recommend the custody of minors from parental responsibility taking into account the set of criteria previously defined.

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Neutrosophic Method to Evaluate Competencies of Mayoral Candidates

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Abstract. Democracy in Ecuador is based on the election of the highest authorities through popular election and the territorial division over which the elected has functions and powers to fulfill in case of being elected. The candidates make commitments on which they would work, as well as the concrete actions that they would take in office if elected. However, there are inconsistencies between the government plans proposed by the candidates and the obligations that are required by law to comply with the low level of competencies. This research proposes a solution to the posed problem with the development of a method to evaluate the competencies of mayoral candidates in the execution of government plans. The proposed method bases its operation on a multi-expert multi-criteria approach with the use of neutrosophic numbers.

Keywords: Multi-criteria decision-making method, neutrosophic numbers, government plans, mayoralty

1. Introduction

The democratic system in Ecuador is expressed through its electoral process where every four years citizens have the duty to choose who will lead the different levels of sectional governments [1, 2]. The elections are carried out under the principle of autonomy in force for prefectures, mayors and rural parish councils recognized as Decentralized Autonomous Governments [3, 4].

As stated in the Democracy Code, within the necessary requirements to be able to run for an elected position, it is required according to article 97 the presentation of a work plan. This document must contain, among other elements; a multi-year work plan with proposals and strategies that allow defining the actions that will be carried out if they are elected [5, 6].

In addition, the Constitution states in article 264 which are the powers that the Decentralized Autonomous Governments must assume exclusively. This leads to inquire as to whether or not there is concordance between government plans and the functions and powers that the law imposes on Decentralized Autonomous Governments [7, 8].

The Strategic Planning for Political Parties represents the transformation that occurs within political movements about the capacity that these organizations have to link members in a constant, participatory way and according to the guidelines that the organization preaches, in many cases they correspond to personal demands of the managers beyond the political vision of the group.

The plans made to the candidates for prefect and mayor in the city of Quito for the 2009-2013 elections revealed that not all of them had the minimum content established by this body, being the point of greatest recurrence of non-application in relation to the citizen participation mechanisms [9].

There is a paradigm regarding the public perception of the fulfillment of the campaign promises. Those must be supported by the work plans presented. However, its fulfillment is conditioned by two relevant factors. The first is related to the costs involved in the fulfillment of these proposals that many times have not been analyzed in depth. This situation has resulted that, after being chosen those present a financial reality inconsistent with the magnitude of the proposals made. On the other hand, external factors that are related to unplanned priorities imposed by the own community or by higher powers such as macroeconomic factors, local and national regulations, among others[10].

In this context, the "Carta Magna" sets out the minimum obligations that the Decentralized Autonomous Government must assume and that must be present in the government plans of all candidates. On the other hand, the norm that regulates the electoral process, the Code of Democracy, provides in article 97, that all candidates for popular election must present a work plan that must contain at least four elements. Those elements are: A diagnosis that present the current situation, the presentation of a general objective and several specific ones, a work plan applicable during the four years of mandate with the actions to be carried out if elected and finally the presentation of the way in which the accountability of the management throughout the period would be[11].

On the other hand, the Organic Code of Territorial Ordering, Autonomy and Decentralization (OCTO), describes the functions of the Decentralized Autonomous Governments in article 54, and additionally the powers are recognized in article 55. The Royal Spanish Academy defines competition as the ability and willingness to do something [12]. Therefore, the competence is the aptitude assumed by an individual where he demonstrates the ability, talent or skill to execute an activity with success known as cognitive competence. Cognitive competence refers to the different intellectual competences demonstrated when developing a task; this allows the subject to appropriate knowledge to solve problems and transform their environment [13].

The generic skills are acquired in the formative or educational period and in the practice of work. They are used for any professional activity. They are supported by human factors, such as creativity, intellectual conditions and the ability to transfer knowledge to new situations[14, 15]. Examples of generic skills are: decision-making, initiative, empathy and sympathy, numerical and computational skills, verbal and conversational skills, problem solving, communication, personal attitudes, the use of technological information[16].

Quantifying the performance of the rulers in their functions represents an important task to avoid inconsistencies between the government plans proposed by the candidates and their obligations under the law. The aforementioned represents a problem of evaluation of the powers of the rulers that can be dealt with, from science by means of multi-criteria methods. Based on the above, the objective of this research is defined: to develop a method to evaluate the competencies of mayoral candidates based on multi-criteria methods. The use of the method is illustrated with the support of an example.

This article is divided into the following sections: Section 2 contains the fundamental concepts used in this investigation, such as the neutrosophic numbers and the Neutrosophic Linear Weighting method [17-20]. In section 3, we explain the method to use. In section 4, we apply the method to a real problem. Lastly, we expose the conclusions.

2 Preliminaries

In order to introduce the main theoretical references on the object of study, the different concepts that facilitate the understanding of the research are presented. A summary of the neutrosophic multicriteria methods for modeling uncertainty about the assessment of competencies is made [21-23]. In the 1980s, the international movement called Paradoxism[24], based on contradictions in science and literature, was founded by Romanian scientist Florentin Smarandache, who later extended it to Neutrosophy, based on contradictions and their neutrals[25, 26].The use of neutrosophic sets allows, in addition to the inclusion of membership functions of truth and falsehood, and additionally membership functions of indeterminacy. This indeterminacy is due to the existence of contradictions, ignorance, inconsistencies, among other elements [18, 27, 28].

Decision making is a selection process between alternative courses, based on a set of criteria, to achieve one or more objectives [29]. With regard to the concept of "decision making", Schein, declares[30]: it is the process of identifying a problem or opportunity and selecting an alternative for action among several existing ones, it is a key diligent activity in all types of organizations [31]. A decision-making process where objects or decisions vary is considered a multi-criteria decision-making problem. Multi-criteria evaluation constitutes an optimization with several simultaneous objective functions and a decision agent[32, 33]. Equation 1 formalizes the problem posed.

$$Max = F(x), x \in X \quad (1)$$

Where:

x: is a vector of the decision variables $[x_1, \cdots, x_n]$

X: is the so-called feasible region. Represents the domain of possible values that the variable can take.

F (x): is a vector of the objective functions that collect the criteria.$[F_1(x), \cdots, F_n(x)]$

Max: represents the function to be maximized, this is not restrictive.

Specifically, discrete multicriteria problems consist of two types of data that constitute the starting point for different discrete multicriteria decision-making (DMD) problems. Figure 1 shows a representation of a multi-criteria method.

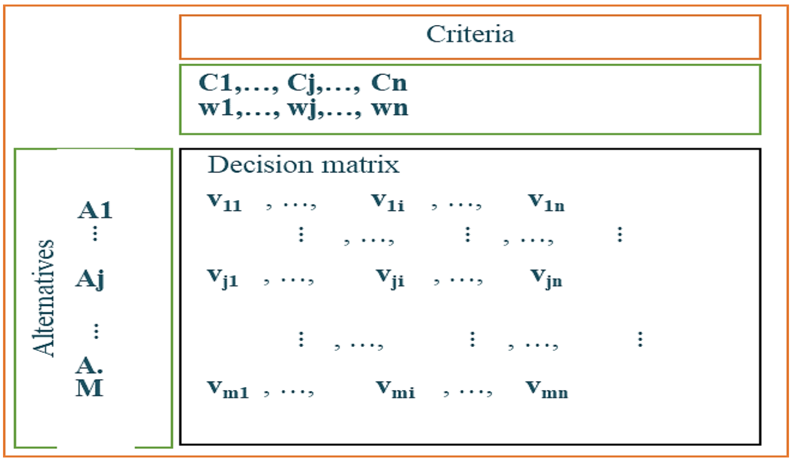

Figure 1. Representation of multicriteria method

Figure 1 shows a representation of a multi-criteria decision-making problem where:

$r_{ij:}$ represents the evaluation of the alternative i against the criterion j.
$w_{i:}$ represents the weight of criterion i.

Each decision-making problem can be different; however, based on the versatility of its nature, a procedure for solving problems can be defined. Figure 2 shows a diagram for solving decision-making problems.

Figure 2. Decision-making problem solving procedure.

For the resolution of various decision-making problems, the proposed multi-criteria methods have been proposed. When you want to issue a weight for a given alternative, the ordering and aggregation methods represent a viable way to apply it.[34-36]. Linear weighting is one of the classic multicriteria methods. The method consists of calculating a global score r_i for each alternative A_i as expressed in Equation 2 [37, 38].

$$R_i = \sum_j W_j \, r_{ij} \quad (2)$$

The linear weighting represents a compensatory method; it is applied after a previous normalization. The method is used in cases where there is a set m of alternatives and n criteria. For each criterion j, the decision maker estimates each alternative "i". The evaluation of the decision matrix that has a cardinal ratio weight is obtained. A weight W_j $(j = 1, \cdots, n)C_j$ of the cardinal ratio type is also assigned for each of the criteria a_{ij}

In the context of multi-criteria methods, neutrosophic numbers are introduced in order to represent the indeterminacy[39, 40]. It constitutes the bases of mathematical theories that generalize classical and fuzzy theories such as neutrosophic sets and neutrosophic logic[41]. A neutrosophic number (N) is represented as follows[42, 43]:

Let $N = \{(T, I, F) : T, I, F \subseteq [0, 1]\}$ be a neutrosophic valuation is a mapping of a group of formulas propositional to N, that is, for each p sentence we have:

$$v(p) = (T, I, F) \quad (3)$$

Where:
T: represents the truth value,
I: represents the indeterminacy value,
F: represents the falsehood value.
Mathematically a Neutrosophic Linear Weighting method can be defined as a 3-tuple (R, W, r) as represented by Equation 4.

$$R_{i(T,I,F)} = \sum_{j} W_{j(T,I,F)}\, r_{ij(T,I,F)} \quad (4)$$

Where:

$R_{i(T,I,F)}$: represents the resulting function that refers to a dimension of the space truth, indeterminacy, and falsehood (T, I, F).

$W_{j(T,I,F)}$: represents the weight of criterion i associated with the criteria that refer to a dimension of the space truth, indeterminacy, and falsehood(T, I, F).

$r_{ij:}$ represents the evaluation of the alternative i with respect to the criterion j that refers to a dimension of the space truth, indeterminacy, and falsehood (T, I, F).

3 Development of the method to evaluate the competencies of mayoral candidates in the execution of government plans

The proposed method is designed to support the process of evaluating the competencies of mayors in the execution of government plans. Its operation is based on multi-criteria, multi-expert techniques where the assessment of competencies is modeled from a set of criteria that represent the competencies to be performed.

It uses in its inference the multicriteria method Linear Neutrosophic Weighting. Figure 3 shows a diagram that illustrates the operation of the proposed method.

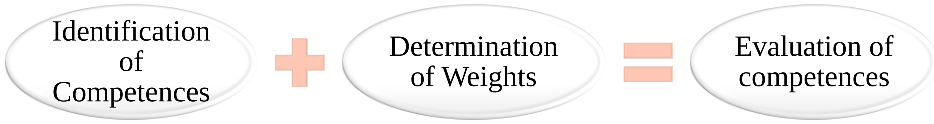

Figure 3: Structure of the proposed method.

The method is designed through a three-stage structure that as a whole determines the assessment of competencies.

Stage 1: Identification of the competences.

It represents the set of competencies that are assessed in the evaluation process for mayoral candidates. It constitutes a multi-criteria approach formalized as:

$C = \{c_1, \dots c_n\}$, n ≥ 2, criteria or competences to be evaluated in the method.

Stage 2: Determination of the weights.

To determine the weights associated with competences, a multi-expert approach is used so that:

$E = \{e_1, \dots e_m\}$, $m \geq 2$, where E, represents the experts involved in the process.

The use of a linguistic scale is recommended, where each of its elements is associated with an SVNN [44-46], as shown in Table 1.

Linguistic term	Value
Not important	(0.10,0.90,0.90)
Less important	(0.20,0.85,0.80)
Slightly important	(0.30,0.75,0.70)
Somewhat important	(0.40,0.65,0.60)
Average importance	(0.50,0.50,0.50)
Important	(0.60,0.35,0.40)
Very important	(0.70,0.25,0.30)
Strongly important	(0.8,0,15,0.20)
Very strongly important	(0.9, 0.1, 0.1)
Extremely important	(1,0,0)

Table 1. Domain of values to assign weight to the criteria.

- Each expert proposes a weight for each criterion, using the scale that appears in Table 1; let's call $\widetilde{w}_{ij}$ the weight assigned by the i-th expert to the j-th criterion.
- $\widehat{w}_j = \frac{1}{m}\sum_{i=1}^{m} \widetilde{w}_{ij}$ is obtained. The weight of the j-th criterion is calculated as $w_j = \frac{s(\widehat{w}_j)}{\sum_{j=1}^{n} s(\widehat{w}_j)}$, where $s(\cdot)$ is the operator that appears in Equation 5.

$$s(\tilde{a}) = \frac{1}{3}(2 + \mathrm{T} - \mathrm{I} - \mathrm{F}) \tag{5}$$

For a neutrosophic number $\tilde{a} = (\mathrm{T}, \mathrm{I}, \mathrm{F})$

Stage 3: Assessment of skills

The evaluation stage represents the processing of the method to emit the result of the proposed inference. The data are processed using the method of linear weighting through Equation 4. As a result, it expresses the value attributed to the competencies of the candidates. This is measured according to the following steps:

- The i-th expert issues an evaluation on compliance with the j-th criterion by the mayor's office. Let's call $\tilde{v}_{ij}$ this value. The evaluation scale is the following given in Table 2:

Linguistic term	Neutrosophic number
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0.15,0.20)
Good (G)	(0.70,0.25,0.30)
Medium good (MDG)	(0.60,0.35,0.40)
Medium (M)	(0.50,0.50,0.50)
Medium bad (MDB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 2. Linguistic terms used.

- The result is calculated with the support of formula 6.

$$\bar{v} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{\mathrm{n}} w_j * \tilde{v}_{ij}}{nm} \tag{6}$$

Where * means the product of a vector by a scalar, "/" is the division of a vector by a scalar and the sum is performed between vectors.

To obtain a more understandable final value on $\bar{v}$, the $s(\bar{v})$ is applied. The closer this value is to 0 the evaluation will be worse, the closer to 1 the evaluation will be better and around 0.5 is an intermediate evaluation.

4 Implementation of method to evaluate the competencies of mayoral candidates in the execution of government plans

For the implementation of the proposed method, a case study was carried out with the government plans presented before the National Electoral Council in the Province of Los Ríos for the mayoral election process in the Babahoyo canton for the 2018-2021 period.

Stage 1: Identification of the competences

For the analysis and operation of the proposed method, 14 competences were used as described in Table 3.

Number	Competences
1	The planning of the canton in accordance with the organization of the superior and inferior governments specifically in relation to land use.
2	The supervision and control of the way the land is used.
3	Address public works related to the streets in urban areas.
4	Take charge of public services.
5	Manage the system of rates and special contributions through ordinances.
6	Manage traffic and urban public transport within the canton.
7	In accordance with the central government is the implementation of schools and health centers, as well as recreational spaces.
8	Assume the preservation and creation of spaces related to architectural heritage.
9	To govern the real estate cadaster system in rural and urban areas.

10	Regulates the use of beaches in the different bodies of natural waters of the canton.
11	Guarantee free access to the natural water banks sources.
12	Control the use of mineral resources present in quarries and aquatic spaces.
13	Manage the fire defense system.
14	Develop international cooperation mechanisms.

Table 3: Competences for the evaluation of candidates.

Stage 2: Determination of the weights

For the stage of determining the weights attributed to the competences, seven experts were consulted who expressed their assessments of the competences. The valuation tables were obtained which were added up in a resulting table. Table 4 shows the result of the evaluation of the criteria once the aggregation process has been carried out.

Competencies	Criterion assessment $\widehat{w}_j$	Criterion assessment w_j
C1	[0.85,0.25,0.25]	0.074132
C2	[0.75,0.25,0.25]	0.070978
C3	[0.55,0.25,0.25]	0.064669
C4	[0.75,0.25,0.25]	0.070978
C5	[0.60,0.25,0.25]	0.066246
C6	[0.80,0.25,0.25]	0.072555
C7	[0.85,0.25,0.25]	0.074132
C8	[0.75,0.25,0.25]	0.070978
C9	[0.60,0.25,0.25]	0.066246
C10	[0.75,0.25,0.25]	0.070978
C11	[0.90,0.25,0.25]	0.075710
C12	[0.85,0.25,0.25]	0.074132
C13	[0.85,0.25,0.25]	0.074132
C14	[0.85,0.25,0.25]	0.074132

Table 4: Weight attributed to the competences of the expert consultation.

Stage 3: Assessment of competencies

Based on the behavior of the weights attributed to the alternatives and the development of the manifestations, the degree of membership to a competence is determined through an aggregation process. Table 6 shows the result of the calculation performed.

Competences	Weights w_j	Average preferences for all experts	$\overline{v}$
C1	0.074132	[1,0.10,0.15]	[0.0741325,0.0074132, 0.0111199]
C2	0.070978	[0.75,0.10,0.15]	[0.0532334, 0.0070978,0.0106467]
C3	0.064669	[0.75,0.10,0.15]	[0.0485016, 0.0064669, 0.0097003]
C4	0.070978	[1,0.10,0.15]	[0.0709779, 0.0070978, 0.0106467]
C5	0.066246	[0.75,0.10,0.15]	[0.0496845, 0.0066246, 0.0099369]
C6	0.072555	[0.50,0.10,0.15]	[0.0362776, 0.0072555, 0.0108833]
C7	0.074132	[1,0.10,0.15]	[0.0741325, 0.0074132, 0.0111199]
C8	0.070978	[0.75,0.10,0.15]	[0.0532334, 0.0070978, 0.0106467]
C9	0.066246	[0.55,0.10,0.15]	[0.0364353, 0.0066246, 0.0099369]
C10	0.070978	[1,0.10,0.15]	[0.0709779,0.0070978, 0.0106467]

C11	0.075710	[0.7,0.10,0.15]	[0.0529968, 0.0075710, 0.0113565]
C12	0.074132	[1,0.10,0.15]	[0.0741325, 0.0074132, 0.0111199]
C13	0.074132	[1,0.10,0.15]	[0.0741325, 0.0074132, 0.0111199]
C14	0.074132	[1,0.10,0.15]	[0.0741325, 0.0074132, 0.0111199]
Index			[0.84298, 0.10000, 0.15000]

Table 5: Weight attributed to demonstrations

The value $s(\bar{v}) = 0.86433$, is close to 1, therefore the evaluation of the mayor's office in its management is "good".

Conclusions

From the research carried out, we obtained a method to evaluate the competencies of the mayoral candidates or the current mayor based on a multi-expert multi-criteria approach. The implementation of the method made it possible to obtain the neutrosophic vectors of weights attributed to the competences through a multi-expert approach. With the application of the method proposed in the case study, it was possible to evaluate the competences of the current mayor in the Babahoyo canton. The proposed case study presents an application of the proposed method, although it is recommended to implement different multi-criteria methods to compare the behavior of the evaluations carried out.

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Method for Treatment and its Incidence in the Change of Social Rehabilitation Regime using Neutrosophic Compensatory Logic

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Abstract. Throughout life, people can make mistakes that lead to custodial sentence. When people pay off their debt to society, they join a social rehabilitation regime. Unfortunately, in all cases a complete rehabilitation is not achieved. This research aims to develop a method for the treatment and its impact on changing social rehabilitation regimen. The uncertainty of this process is modeled using compensatory neutrosophic logic. This is an extension of fuzzy compensatory logic to the neutrosophic framework. A case study is implemented from which a group of people undergoing rehabilitation is analyzed to determine their best treatment. As a result, the status of compliance with the main treatment axes was obtained for the different cases analyzed.

Keywords: Social rehabilitation, compensatory fuzzy logic, compensatory neutrosophic logic.

1. Introduction

Deprivation of liberty constitutes the mechanism used by States to reduce criminal behavior. During the last years, a new legal concept has appeared, worldwide clear standards regarding the deprivation of liberty were obtained [1]. The fundamental objective of this measure is based on the search for a peaceful coexistence among its peoples.

If an individual violates the peace and harmony of a State, this will imperatively be brought before the jurisdictional entity [2, 3]. The jurisdictional entity will apply a sanction against that individual for undertaking an action classified as a criminal offense.

Someone who have been sanctioned to a custodial sentence have the opportunity to be beneficiaries [4, 5]. The benefits are described through the axes of treatment contemplated in the Integral Organic Penal Code. At present, however, it is not possible to quantify the treatment and its incidence in the change of rehabilitation regimen [6].

Problems like the one previously exposed have been addressed in the scientific literature with Soft Computing techniques. It represents a methodology widely used in situations where the data to be considered is not accurate but indeterminate. These indeterminate data are modeled using the fuzzy set theory. Especially Compensatory fuzzy logic results from an axiom obtained from two different theoretic sources: the decision theory and the logic. Its advantage is that it deals with natural language. However, it preserves the limitations of every fuzzy logic theory, where the indeterminacy is implicitly contained. This is why the compensatory neutrosophic logic extends the compensatory logic in the framework of Neutrosophy. In the 1980s, the international movement called Paradoxism [7] , based on contradictions in science and literature, was founded by Florentin Smarandache, who then extended it to Neutrosophy, a science based on contradictions and their neutrals[8-10] .

From the previous analysis, this research aims to develop a method for treatment and its impact on changing social rehabilitation regimen.

The present paper is divided into the following sections: section 2 contains the preliminary concepts, like compensatory fuzzy logic and compensatory neutrosophic logic. Section 3 is exposes the proposed model. Section 4 contains the application of the model in an actual case study. The paper ends with the conclusions.

2. Preliminaries

This section introduces the fundamental elements that facilitate the understanding of the research. The main theoretical references on the social rehabilitation regime and the treatment of the axes of social rehabilitation are proposed.

2.1 Social rehabilitation regime

The National Social Rehabilitation System is administered by the Ministry of Justice, Human Rights and Worship in Ecuador, represents the State in the regulation of custody, internal security and effective rehabilitation of persons deprived of liberty [11].

The Social Rehabilitation System (SRS) comprises a set of principles, regulations, policies, programs and processes that are fully correlated based on the execution of sentences. The penitentiary system seeks to execute programs that guarantee social rehabilitation before a person deprived of liberty can re-enter their family and social nucleus [12].

The treatment axes establish the set of social indicators that guarantee the social rehabilitation of the individual deprived of liberty. People under custodial sentence have the right to social reintegration and The State guarantees their fulfillment[13].

The treatment for persons deprived of liberty, with a view to their rehabilitation and social reintegration, will be based on the axes: labor, education, culture and sport, health, family and social ties, reintegration. The fundamental objective of the axes of rehabilitation is to guarantee comprehensive activities that generate full restoration in society[14-16].

2.2 Compensatory Fuzzy Logic

The Compensatory Fuzzy Logic (CFL) represents a logical model used for the simultaneous modeling of deductive and decision-making processes [17, 18]. The Compensatory Fuzzy Logic (CFL) represents a logical model used for the simultaneous modeling of deductive and decision-making processes[19], [20].

The CFL uses the Fuzzy Logic scale, which can vary from 0 to 1, to measure the degree of truth or falsehood of its propositions. Propositions can be expressed through predicates. A predicate is a function of the universe X in the interval [0;1].

In order to process the CFL, conjunctive operators are used(^), disjunction(∨), negation(¬) and implication(→), defined in a way that restricts the domain [0;1], [21, 22].

An essential property of this logic is the "principle of gradualness" which affirms that a proposition can be both true and false, as long as it is assigned a degree of truth and falsehood. One way to put the principle of gradualness into practice is to define logics where propositions can be expressed by predicates. Precisely the logic of predicates studies the declarative phrases with a degree of detail, considering the internal structure of the propositions.

The different ways of defining operations and their properties determine different multivalent logics that are part of the Fuzzy Logic paradigm [23]. Multivalent logics are generally defined as those that allow intermediate values between the absolute truth and the total falsehood of an expression. So 0 and 1 are both associated with certainty and accuracy of what is claimed or denied and 0.5 with maximum vagueness and uncertainty [24, 25].

3. Materials and methods

The present method is designed for the treatment and its incidence in the change of social rehabilitation regime. This method should show whether a person in the social rehabilitation process maintains socially responsible behavior or not. The method works through Compensatory Fuzzy Logic [18, 26, 27].

CFL is based on the following axioms:

Compensatory Fuzzy Logic (CFL) [15] is a multivalued logic axiomatic approach different from the one based on t-norms and t-conorms. They satisfy characteristics of descriptive approach of decision-making and the normative approaches of the decision-making.

This is based on four logic operators (c,d,n,o). Where c is the conjunction operator, d is the disjunction operator, n is the negation operator and o is a fuzzy-strict ordering.

The following axioms are postulated

I. Compensation Axiom $\min(x_1, x_2, \cdots, x_n) \leq c(x_1, x_2, \cdots, x_n) \leq \max(x_1, x_2, \cdots, x_n)$

II. Symmetry or Commutativity Axiom $c(x_1,x_2,...,x_i,...,x_j,...,x_n)= c(x_1,x_2,...,x_j,...,x_i,...,x_n)$

III. Strict Growth Axiom if $x_1=y_1$, $x_2=y_2$, ..., $x_{i-1}=y_{i-1}$, $x_{i+1}=y_{i+1}$,...., $x_n=y_n$ are different to zero and $x_i>y_i$ then $c(x_1,x_2,...,x_n)>c(y_1,y_2,...,y_n)$

IV. Veto Axiom If $x_i=0$ for any i then $c(x)=0$.

V. Fuzzy Reciprocity Axiom $o(x,y) = n[o(y,x)]$.

VI. Fuzzy Transitivity Axiom If $o(x,y) \geq 0.5$ and $o(y,z) \geq 0.5$, then $o(x, z) \geq \max(o(x,y),o(y,z))$

VII. De Morgan's Laws:

$n(c(x_1,x_2,...,x_n) = d(n(x_1),n(x_2),...,n(x_n))$ $n(d(x_1,x_2,...,x_n) = c(n(x_1),n(x_2),...,n(x_n))$

Implications can be defined in different ways:

S-implication: $S(x,y)=d(n(x),y)$, where d and n are the disjunction and negation operators, respectively.

A particular system is the Geometric Mean Based Compensatory Logic (GMBCL), where conjunction and disjunction operators are expressed by (1) and (2), respectively, when the domain is discrete, [28-30].

$$c(x_1, x_2,..., x_n) = \sqrt[n]{\prod_{i=1}^{n} x_i} = \exp\left(\frac{1}{n}\sum_{i=1}^{n}\ln(x_i)\right) \quad (1)$$

Disjunction is the dual of the conjunction:

$$d(x_1, x_2,..., x_n) = 1-\sqrt[n]{\prod_{i=1}^{n}(1-x_i)} = 1-\exp\left(\frac{1}{n}\sum_{i=1}^{n}\ln(1-x_i)\right) \quad (2)$$

Paradoxism is an international movement in science and culture, founded by Romanian Scholar Florentin Smarandache in 1980s, based on excessive use of antitheses, oxymoron, contradictions, and paradoxes[31]. During three decades (1980-2020) hundreds of authors from tens of countries around the globe contributed papers to 15 international Paradoxist anthologies[32]. In 1995, the author extended the Paradoxism to a new branch of philosophy called Neutrosophy [33] (based on opposites and their neutral), that gave birth to many scientific branches, such as: neutrosophic logic [34], neutrosophic probability and statistics[35], neutrosophic multi-criteria methods [36]. All of them with multiple applications in engineering, computer science, soft sciences etc.[37-39].

Definition 1: A *neutrosophic number* N is defined as follows:

$$N = d + I \quad (3)$$

Where d is called *determinate part* and I is called *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:

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

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

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

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

Definition 2: A Compensatory Neutrosophic Logic (CNL) extends the axiomatic of CFL to the domain of $[0, 1] \cup \{I\}$.

Description of second level compound predicates

SRS(x): The Social Rehabilitation Regime is well valued if it adequately complies with the current legal framework and the indicators of the axes of social rehabilitation. If the report of compliance with the legal framework is somewhat unsatisfactory, it must be compensated with very good compliance with the indexes of the rehabilitation axes.

Expression of compound (third level) predicates associated with second level compound predicates

IL(x): Labor and educational integration.

IC(x): Cultural and sports integration.

VF(x): Family integration.

Expression of second-level predicates in CFL predicates.

From natural or professional language to the CFL predicate, as seen in equation 3:

$$SRS_{(x)} = IL_{(x)} \wedge IE_{(x)}{}^2 \wedge VF_{(x)} \wedge \left(\neg VF_{(x)} \rightarrow \left(IL_{(x)}\right)^2 \wedge \left(IE_{(x)}\right)^3\right) \quad (4)$$

For this work, a relationship is considered $SRS_{(x)} \rightarrow$ "Satisfaction" if the truth of the predicate is ≥ 0.9[40], [41], [20]. From this, the following steps are established:

1. Initial step: Reading the data to perform the discovery.
2. Execution of discovery task.

3. Evaluation of the results considering the sample.
4. Hypothesis approach: Definition of new discovery and evaluation projects under consideration.

Description of third level compound predicates.
IL(x): The prison system has an adequate labor and educational integration.
VF(x): The prison system has an adequate family integration.

Expression of compound (fourth level) and simple predicates associated with third level compound predicates
Associated Predicates *IL(X)*
PT(x): The system enhances access to decent work.
PE(x): The system promotes inclusion in education.

Associated Simple Predicates *VF(X):*
IF(x): The system promotes an adequate family integration.
IS(x): The system promotes adequate social integration.
RS(x): The system promotes an adequate social reintegration.

Expression of third-level predicates in predicates of FCL

$$CIL_{(x)} = PT_{(x)} \wedge PE_{(x)} \quad (5)$$

$$CVF_{(x)} = IF_{(x)} \wedge IS_{(x)} \wedge RS_{(x)} \quad (6)$$

Simple Predicates Evaluation Form.
The simple predicates from which the compound predicates will be evaluated will be measured according to the fulfillment of the analyzed values that arise from the study of the behavior of the indicators of social rehabilitation.
The difference of our approach with the FCL is that we incorporate the indeterminacy, which permits more accuracy using CNL.

4. Results and discussions

The Fuzzy Tree associated with the FCL-based Social Rehabilitation Regime and reflects the relationships between the simple predicates to evaluate, the compound predicates and the final predicate. Figure 1 shows the resulting associated tree.

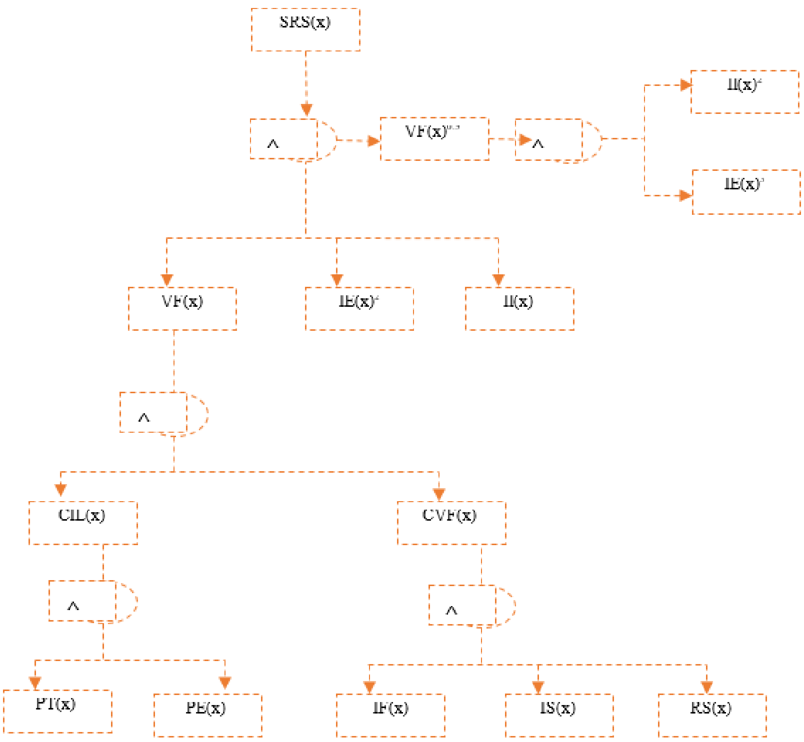

Figure 1. Fuzzy Tree associated with the FCL-based Social Rehabilitation Regime.

To obtain the data to be analyzed, the criteria of 7 penitentiary institutions was used.

Institutions	PT(x)	PE(x)	IF(x)	IS(x)	RS(x)
I_1	[3.00, 3.5]	[2.88, 3.90]	[2.76, 2.78]	[2.92, 2.95]	[0.88, 0.89]
I_2	[2.74, 2.76]	[2.95, 3.00]	[2.67, 3.00]	[2.63, 2.64]	[0.64, 0.65]
I_3	[2.45, 2.46]	[2.13, 2.2]	[2.67, 2.68]	[2.89, 2.90]	[1.52, 1.53]
I_4	[2.96, 3.00]	[1.79, 1.80]	[1.64, 1.67]	[1.85, 1.86]	[1.52, 2.00]
I_5	[2.60, 2.65]	[2.35, 2.37]	[2.47, 2.50]	[2.29, 2.30]	[1.86,1.90]
I_6	[2.75, 2.79]	[2.92, 2.95]	[3.00, 3.01]	[3.00, 3.01]	[2.12,2.14]
I_7	[2.70, 2,75]	[2.90, 2.92]	[2.80, 2.81]	[2.60, 2.62]	[2.00,2.02]

Table 1. Results of the predicates in the 7 institutions analyzed.

Legend:
I: People from penitentiary institutions.

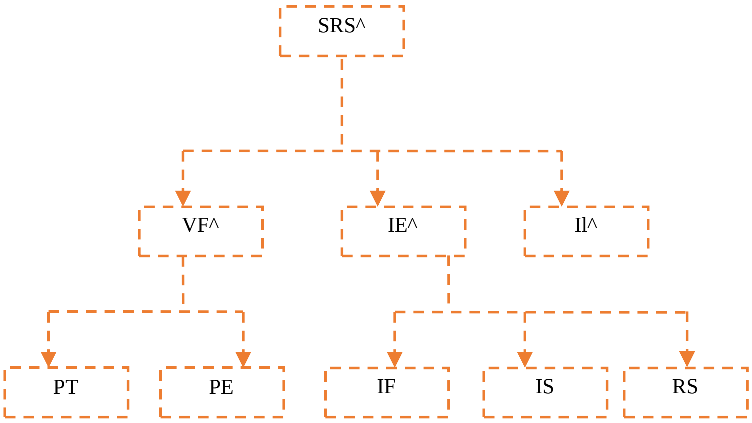

Figure 2. Fuzzy tree of Social Rehabilitation based on FCL.

Other results obtained from the modeling can be seen in Table 2 where the blocks of institutions are located according to their impact on social rehabilitation based on the truth scale determined in the FCL.

State	Scale	Incidence of the social rehabilitation regime	Institution per state of the social rehabilitation
1	0 - 0.2	Inadequate	14 % (1 institution)
2	0.2 - 0.4	Very low	14% (1 institution)
3	0.4 - 0.6	Appropriate	42.8 % (3 institutions)
4	0.6 - 0.8	Good	28.5 % (2 institutions)
5	0.8 - 1	Excellent	

Table 2. Social Rehabilitation Values obtained through data processing.

The analysis of the Social Rehabilitation Regime was developed through the modeling of the Compensatory Neutrosophic Logic that allowed us to evaluate the behavior of compliance with the fundamental axes. 5 penitentiary institutions were used as the object of study.

The use of the Compensatory Neutrosophic Logic for the analysis of Social Rehabilitation showed that:

- A value of 42.8%, representing 3 institutions, comply with Social Rehabilitation in an appropriate way.
- A value of 28.5%, representing 2 institutions, comply with the Social Rehabilitation in a good way.
- However, 14.4%, representing 1 institution, complies with Social Rehabilitation in a very low value.
- A value of 14.4%, representing 1 institution, comply with Social Rehabilitation in an inadequate way.

In the 5 institutions taken as an example for the proposed model, it can be noted that: although the results relation shows how a compound predicate seems to have a good behavior in its internal relations, some variations may occur. Variations are largely conditioned depending on the characteristics of the institution being modeled.

Conclusions

This work is based on the use of information obtained from the social rehabilitation process, for the evaluation of the status of the process. It is an interesting way to link the workers of the penitentiary institutions in the evaluation of the social rehabilitation regime.

The application of a mathematical model based on the Compensatory Neutrosophic Logic constitutes an effective instrument for evaluating the treatment of the Social Rehabilitation System.

For future research, it should result in the formation of knowledge bases on the behavior of treatment in social rehabilitation. This will promote the deepening of knowledge about the subject in question; reference patterns that serve to conduct behavioral analysis.

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Linking Neutrosophic AHP and Neutrosophic Social Choice Theory for Group Decision Making

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Abstract. Analytic Hierarchy Process (AHP) is a decision-making technique that has been widely studied and developed by the scientific community. The interest in this tool is because it combines scientific rigor with the simplicity of its application. Additionally, it has been extended to uncertainty frameworks, such as fuzzy and neutrosophic frameworks. This paper aims to define a new method called NAHP+NSC, where the Neutrosophic Analytic Hierarchy Process (NAHP) is combined with the recently introduced Neutrosophic Social Choice (NSC) theory. Neutrosophy incorporates indeterminacy to both the AHP technique and the SC theory, which is an intrinsic condition of any decision-making process. On the other hand, it is possible to count on a group of experts to carry out the NAHP evaluations, where the chosen alternative is the one with the highest votes. Experts are divided into kind of homogeneous sub-groups called Interest Groups (IG), where each IG conjointly evaluates the proposed alternatives, and then tools of NSC are used for choosing the best alternative. The contribution of this new method is that evaluations and results are more accurate when indeterminacy is incorporated.

Keywords: Neutrosophic Analytic Hierarchy Process, neutrosophic social choice theory, neutrosophic preference relations, group decision-making.

1 Introduction

Analytic Hierarchy Process (AHP) is a technique introduced by Thomas L. Saaty for decision-making, [1]. It is a peculiar technique because the result encloses mathematical and psychology rigor. The decision maker starts from a decision tree with different hierarchical levels, where the top level contains a single leaf that represents the goal of the decision, the intermediate levels represent the attributes and sub-attributes necessaries to make the decision, while the level on bottom contains the alternatives to make the decisions.

The decision maker must compare the relative importance among the attributes, the sub-attributes and finally the alternatives are evaluated with respect to the attributes and sub-attributes, in such a way that the relative importance of each alternative is obtained, which are then ordered so that the preferred one is that with the highest index. These measurements are based on a scale introduced by Saaty. In addition, the consistency of each relative comparison is measured.

This technique has been widely studied for its simplicity and applicability in more or less complex decision-making situations. Additionally, the Saaty's scale has been generalized from crisp numbers to fuzzy numbers, to contain the uncertainty of decision-making, [2, 3]. The extension of the method to a Neutrosophic Analytic Hierarchy Process (NAHP) is also introduced; see [4-9], where the pair-wise comparison is performed with triangular neutrosophic numbers. Neutrosophy allows us to incorporate indeterminacy into the method [10] that is the result of lack of knowledge, inconsistencies or contradictions, which is an essential part of any complex decision-making problem[11].

AHP has also hybridized with other techniques such as SWOT or TOPSIS, [5, 7], to enhance its strength as a decision-making tool. However, due to AHP interest, and its development, some new needs have arisen through classical and non-classical AHP, because more than one expert can make the decision. This makes the method more accurate, and the decision is consensual, but on the other hand AHP theory becomes more complex and that yields some additional questions, such as what are the ways to aggregate the elements of the decision tree of experts or what is the way to consider the evaluations of the experts belonging to different interest groups.

B. Srdjevic in [12], defines a method where the classic AHP hybridizes with tools of the Social Choice Theory, [13-17]. He called this hybridization AHP+SC. The theory of social choice deals with making collective decisions based on the preferences of the individuals that make up a society. Considering a set of social alternatives and a society whose individuals have preferences, these preferences are represented by binary relations over the set of alternatives. Keeping in mind that individuals may have different opinions about social alternatives; the Social Choice theory studies the process of aggregation of individual preferences in a social preference. Collective decisions will be made from the social binary relationship that has been obtained by aggregating individual preferences. That is to say, given a set of social alternatives, a social welfare function assigns to each state of opinion a binary relationship; in general, there is infinity of aggregation processes. Specifically, this theory studies voting methods.

Recently, the theory of social choice has been extended to Neutrosophy, [18], with the intention of applying it to decision-making, where the so-called Neutrosophic Social Choice (NSC) theory was introduced. In that paper, Topal et al. define preferences in a neutrosophic environment. In addition, they use a new form of truth representation of neutrosophic theory called Distributed Indeterminacy Form (DIF), as well as an accuracy function H that serves as a de-neutrosophication method.

In this paper authors are inspired by the method proposed in [12] to introduce a new one in the neutrosophic framework. That is, AHP+SC becomes in NAHP+NSC, where NAHP includes indeterminacy within the AHP technique, which binds with the NSC of Topal et al. Specifically, a group of experts is considered, each of which has its own NAHP evaluation. On the other hand, NSC let us to use voting methods to determine the best alternative by consensus. The method in [12] is based on the division of the group of experts into subgroups called Interest Groups (IG) which for simplicity are considered internally homogeneous. Each of the IGs makes an evaluation jointly, therefore there will be as many evaluations as existing IGs. NSC serves to select the best option among IGs' evaluations. Linking NAHP and NSC in a neutrosophic framework let us incorporate indeterminacy in decision-making.

Next, the main concepts and methods on NAHP and NSC are discussed in Section 2 below. In section 3 the method proposed in this paper is introduced and a simulated example is used as case study. The last section contains the conclusions.

2 Preliminary concepts

This section is structured into two subsections. Subsection 2.1 describes the Neutrosophic Analytic Hierarchy process (NAHP) technique. Subsection 2.2 contains the main concepts of the Neutrosophic Social Choice (NSC) theory.

2.1 Neutrosophic Analytic Hierarchy process

In this subsection, we explain basic concepts of Neutrosophy, like neutrosophic set, single-valued neutrosophic set, and the Neutrosophic Analytic Hierarchy Process (NAHP) technique.

Definition 1: ([19-28]) 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 $\forall x \in U$, $T_A(x), I_A(x)$, and $F_A(x) \subseteq]^{-}0, 1^{+}[$, 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: ([19-28]) 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 $F_A: U \to [0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

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: ([19-28]) 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:

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

$$I_{\tilde{a}}(x) = \quad (2)$$

$$\begin{cases} \frac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \le x \le a_2 \\ \beta_{\tilde{a}}, & a_2 \le x \le a_3 \\ \frac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases}$$

$$F_{\tilde{a}}(x) =$$

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

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: ([19-28]) 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:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
2. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
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 $a_1, a_2, a_3, a_4 \neq 0$.
4. Multiplication by a scalar number:

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

5. Division of two trapezoidal neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle \left(\frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 > 0 \textit{ and } b_4 > 0 \\ \langle \left(\frac{a_4}{b_4}, \frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 < 0 \textit{ and } b_4 > 0 \\ \langle \left(\frac{a_4}{b_1}, \frac{a_3}{b_2}, \frac{a_2}{b_3}, \frac{a_1}{b_4}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 < 0 \textit{ and } b_4 < 0 \end{cases}$$

6. Multiplication of two trapezoidal neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1 b_1, a_2 b_2, a_3 b_3, a_4 b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 > 0 \textit{ and } b_4 > 0 \\ \langle (a_1 b_4, a_2 b_3, a_3 b_2, a_4 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 < 0 \textit{ and } b_4 > 0 \\ \langle (a_4 b_4, a_3 b_3, a_2 b_2, a_1 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 < 0 \textit{ and } b_4 < 0 \end{cases}$$

Where, $\wedge$ is a t-norm and $\vee$ is a t-conorm.

Definitions 3 and 4 refer to *single-valued triangular neutrosophic number* when the condition $a_2 = a_3$ holds [24].

We can find in [4] the theory of AHP technique in a neutrosophic framework. Thus, we can model the indeterminacy of decision-making from applying neutrosophic AHP or NAHP for short.

Equation 4 contains a generic neutrosophic pair-wise comparison matrix for NAHP.

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \tag{4}$$

Matrix $\tilde{A}$ must satisfy condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, based on the inversion operator of Definition 4, according to the scale summarized in Table 1 of triangular neutrosophic numbers.

For converting neutrosophic triangular numbers into crisp numbers, there are two indexes defined in [5], they are the so-called score and accuracy indexes, respectively, see Equations 5 and 6:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{5}$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \tag{6}$$

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	$\tilde{9} = \langle(9,9,9); 1.00, 0.00, 0.00\rangle$
2, 4, 6, 8	Sporadic values between two close scales	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$
		$\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$
		$\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$
		$\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

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

To get the score and the accuracy degree of $\tilde{a}_{ji}$ the following equations are used:

$$\mathbf{S}(\tilde{a}_{ji}) = 1/\mathbf{S}(\tilde{a}_{ij}) \quad (7)$$

$$\mathbf{A}(\tilde{a}_{ji}) = 1/\mathbf{A}(\tilde{a}_{ij}) \quad (8)$$

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

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (9)$$

Next, we determine the ranking of priorities from the previous matrix as follows:

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

The *Consistency Index* (CI) is calculated for matrices in formula 9, which is a function depending on λ_{max}, the maximum eigenvalue of the matrix. Saaty establishes that consistency of the evaluations can be determined by equation $CI = \frac{\lambda_{max} - n}{n-1}$, [1],where n is the order of the matrix. Also, the *Consistency Ratio* (CR) is defined by equation CR = CI/RI, where RI is given in Table 2.

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

Table 2: RI associated to every order.

If CR≤0.1 we can consider that experts' evaluation is sufficiently consistent and hence we can proceed to use NAHP. We apply this procedure to matrices *A* in Equation 9. Consult [4] for more details on NAHP.

2.2 Neutrosophic Social Choice theory

This subsection summarizes the main concepts of Neutrosophic Social Choice theory developed in [18].

Definition 5: ([18]) Let $a = (T_a, I_a, F_a)$ be a single-valued neutrosophic number with truth value T_a, indeterminacy value I_a, and falsehood value F_a. *Distributed Indeterminacy Form* (DIF) of *a* is defined as $a_{DIF} = (T_a - T_aI_a, 0, F_a - F_aI_a)$.

DIF aims to distribute the indeterminacy result on truth and falsehood, thus, this measures the degree of affectation of the truthiness and falsehood, when indeterminacy varies.

Definition 6: ([18]) Let *a* be a single-valued neutrosophic number. An *accuracy function* H of *a* is:

$$H(a) = \frac{1 + T_a - I_a(1 - T_a) - F_a(1 - I_a)}{2} \quad (10)$$

Where for all a, $H(a) \in [0, 1]$. H is an order relation which represents an accuracy score of information of a. If $H(a_1) = H(a_2)$, then $a_1 = a_2$, i.e., they have the same information, whereas, if $H(a_1) < H(a_2)$, then a_2 is larger than a_1.

Let $S = \{s_1, s_2, \ldots, s_n\}$ be a set of alternatives and m be a set of individuals. Each individual declares his or her preferences over S which are represented by an individual neutrosophic preference relation R_k, where N_{R_k} : $S \times S \rightarrow [0,1] \times [0,1] \times [0,1]$ and matrix $R_k = [r_{ij}^k]$, $i, j = 1,2,3,\ldots, n$; $k = 1,2,3,\ldots, m$, where $r_{ij}^k = N_{R_k}(r_i^k, r_j^k)$.

$$R_k = \begin{bmatrix} (0.5, 0.5, 0.5) & r_{12}^k & \cdots & r_{1n}^k \\ r_{21}^k & (0.5, 0.5, 0.5) & \cdots & r_{2n}^k \\ \vdots & \vdots & \cdots & \vdots \\ r_{n1}^k & r_{n2}^k & \cdots & (0.5, 0.5, 0.5) \end{bmatrix}$$

The function H (called *neutrosophic index* or *neutrosophic hesitation function*) assigns each a_{ij} neutrosophic value to a number in $[0, 1]$. Thus, the *neutrosophic index* or *neutrosophic hesitation function* is defined as follows:

$$H(a) = \frac{1 + T(a_{ij}) - I(a_{ij})\left(1 - T(a_{ij})\right) - F(a_{ij})\left(1 - I(a_{ij})\right)}{2} \tag{11}$$

The matrix $R_k^H = [H(r_{ij}^k)]$, $i, j = 1,2,3,\ldots, n$; $k = 1,2,3,\ldots, m$.

$$R_k^H = \begin{bmatrix} H((0.5, 0.5, 0.5)) & H(r_{12}^k) & \cdots & H(r_{1n}^k) \\ H(r_{21}^k) & H((0.5, 0.5, 0.5)) & \cdots & H(r_{2n}^k) \\ \vdots & \vdots & \cdots & \vdots \\ H(r_{n1}^k) & H(r_{n2}^k) & \cdots & H((0.5, 0.5, 0.5)) \end{bmatrix}$$

R_k^H is *quasi-reciprocal* if and only if $H(r_{ij}^k) \leq 1 - H(r_{ji}^k)$. If R_k^H is not quasi-reciprocal, we call k an *irrational individual*.

Other definitions declared in [18] are the following:

$$DIF(R_k) = \begin{bmatrix} (0.5, 0, 0.5) & DIF(r_{12}^k) & \cdots & DIF(r_{1n}^k) \\ DIF(r_{21}^k) & (0.5, 0, 0.5) & \cdots & DIF(r_{2n}^k) \\ \vdots & \vdots & \cdots & \vdots \\ DIF(r_{n1}^k) & DIF(r_{n2}^k) & \cdots & (0.5, 0, 0.5) \end{bmatrix}$$

R_i: preference matrix of the i-th individual,
$DIF(R_i)$: DIF of preference matrix of the i-th individual,
R_i^H: range of preference matrix of the i-th individual under H function,
$r_k^H(ij)$: represents the element at the row i and column j of R_k^H,
$h^k(ij)$: distribution of the kth individual's votes for each pair-wise comparison of alternative's value. It is determined through 0.5 derived from R_i^H,
$[\![h^k]\!]$: the matrix obtained by each element of $h^k(ij)$,
$[\![H_{ij}]\!]$: matrix of the group vote,
A_k: the degree for preference k assigned by the group,
a_{ij}^k: majority determination value for preference k of the group (the element at the row i and column j of $[\![h^k]\!]$,
H_{ij}^k: majority determination value for preference k of the group under H function,

$$h^k(ij) = \begin{cases} 1, \text{ if } r_k^H(ij) > 0.5 \\ 0, \quad \text{otherwise} \end{cases}$$

$H_{\pi_{ij}}$: average majority determination value of the group under H function,
H_π: consensus winner determination matrix,
$C(s_i)$: social aggregation function for the alternative (preference) s_i.

Definition 7: ([18])*:* $s_i \in W$ is called a *consensus winner* if and only if $\forall s_j \neq s_i$: $r_{ij} > 0.5$, where $r_{ij} \in H_\pi$.

Definition 8: ([18]) The *social aggregation average function C* is defined to calculate the order of s_i in the group to the extent that individuals are not against option s_i, using the following equation:

$$C(s_i) = \frac{1}{m-1} \sum_{i \neq j} r_{ij} \tag{12}$$

Where $i, j = 1, 2, \cdots, m$.

3 NAHP+NSC method

In this section we introduce the NAHP+NSC method that is proposed in this paper.

First of all we define for any triangular neutrosophic number $\tilde{a}$, the *triangular accuracy function of* $\tilde{a} = \langle(a_1, a_2, a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}}\rangle$, which is the function **TA** defined as follows:

$$TA(\tilde{a}) = A\Big(\big\langle(a_1, a_2, a_3); DIF\big((\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}})\big)\big\rangle\Big) \quad (13)$$

This is the accuracy degree of Equation 6 calculated for the DIF of the neutrosophic number contained in $\tilde{a}$. DIF is included following the idea in [18], where the accuracy function H also calculates the effect of indeterminacy in the truthiness and falsehood.

Let us note that reciprocal or quasi-reciprocal properties in NSC theory are similar to the reciprocal property in NAHP, from the point of view of the decision maker's rationality.

The method consists of the following steps:

1. The goal of the problem is established, and consequently the group of experts is selected. Next, the attributes, sub-attributes and alternatives are specified.
2. The group of experts is divided into M interest sub-groups, let us denote them by $IG = \{IG_1, IG_2, \cdots, IG_M\}$. We assumed the members of each sub-group form a homogenous decision group.
3. Each expert evaluates his/her own NAHP. However, with respect to every IG_i the equivalent matrices of the members of the sub-group are aggregated using formula 14.

Let $\{\tilde{A}_{i1}, \tilde{A}_{i2}, \cdots, \tilde{A}_{in_i}\}$ be a set of n_i SVTNNs representing the assessment of each member of the i-th sub-group, where $\tilde{A}_{ij} = \langle(a_{ij}, b_{ij}, c_{ij}); \alpha_{\tilde{a}_{ij}}, \beta_{\tilde{a}_{ij}}, \gamma_{\tilde{a}_{ij}}\rangle$ $(i = 1, 2, \ldots, M)(j = 1, 2, \ldots, n_i)$, then the *weighted mean of the SVTNNs* is calculated through the following Equation:

$$\tilde{A}_i = \sum_{j=1}^{n_i} \lambda_{ij}\tilde{A}_{ij} \quad (14)$$

Where λ_{ij} is the weight of $\tilde{A}_{ij}$, $\lambda_{ij} \in [0, 1]$ and $\sum_{j=1}^{n_i} \lambda_{ij} = 1$.

Note that λ_{ij} measures the relative importance of the j-th expert in the i-th sub-group.

Each $\tilde{A}_i$ represents the matrix of pair-wise comparisons of NAHP method in IG_i, to aggregate the matrices of pair-wise comparison of criteria, sub-criteria and alternatives.

$\tilde{A}_i$s are converted into A_is using Equation 13. This process can be repeated until the results are consistent according to the Consistency Ratio of the NAHP method. In accordance with the NAHP method, we obtain a vector of preference of the alternatives.

Here, the Aggregation of Individual Judgments (AIJ) is used because we are interested in measuring the judgments of the sub-group as a synergistic unit.

Let us denote by $O_i = \{o_{i1}, o_{i2}, \cdots, o_{iN}\}$ the position of each alternative $S_i = \{s_{i1}, s_{i2}, \cdots, s_{iN}\}$, when they are evaluated by the members of the i-th sub-group. For example, $O_1 = \{1,1,3,5,4\}$ means that according to the first subgroup, alternatives 1 and 2 are equally preferred, whereas, the next ones are the third, the fifth, and the fourth alternatives, in that order.

4. For each s_{il} $(l = 1, 2, \ldots, N)$, the following triple is formed $V_{il} = (P_{il}, I_{il}, N_{il})$, where $P_{il} = card(\{k \neq l: s_{il} \text{ is strictly preferred over } s_{ik}\})$, $I_{il} = card(\{k \neq l: s_{il} \text{ is equally preferred to } s_{ik}\})$ and $N_{il} = card(\{k \neq l: s_{ik} \text{ is strictly preferred over } s_{il}\})$.
   See that, $V_{il} \in [0, N-1] \times [0, N-1] \times [0, N-1]$ and $P_{il} + I_{il} + N_{il} = N - 1$.
   Finally, $V_l \in [0, 1] \times [0, 1] \times [0, 1]$, $V_l = (P_l, I_l, N_l)$, aggregates the preference of the l-th alternative for all sub-groups, where $P_l = \frac{\sum_{i=1}^{M} P_{il}}{M(N-1)}$, $I_l = \frac{\sum_{i=1}^{M} I_{il}}{M(N-1)}$, and $N_l = \frac{\sum_{i=1}^{M} N_{il}}{M(N-1)}$.
   Note that this is a neutrosophic voting method.
5. $H(V_l)$ $(l = 1, 2, \cdots, N)$ is calculated, and the alternatives are sorted by order of preference, such that V_{l_1} is preferred over V_{l_2} if and only if $H(V_{l_1}) > H(V_{l_2})$. When, $H(V_{l_1}) = H(V_{l_2})$ we say that "V_{l_1} is equally preferred to V_{l_2}".

Below we illustrate this method with an example.

Example 1: (See [29])

Organizations face the problem of how to invest their resources in the different project alternatives. The correct evaluation and subsequent selection of software development projects provides competitive advantages to organizations. The selection of projects in the field of information technology presents multiple challenges, including the difficulty of evaluating intangible benefits, the existing interdependencies between projects, and the restrictions imposed by organizations.

The goal of this decision making problem is to assess three candidates of Information Technology Projects based on three criteria, namely, cost, project time span and profit. We call alternatives by Project 1, Project 2, and Project 3. The decision tree is depicted in Figure 1.

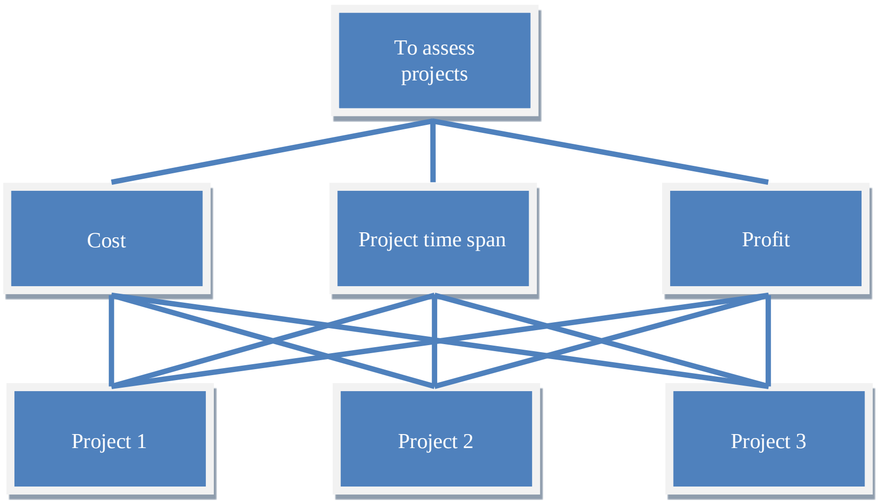

Figure 1: AHP tree of the example. Source [29].

This is a simulated example for illustrating how the NAHP+NSC technique can be applied in a decision-making problem. Suppose a group of 15 experts are selected to make the decision, and three sub-groups are formed, each of them containing 5 members. They are: IG_1 which contains the managers, IG_2 is the sub-group of financial analysts, and IG_3 is the interest group of specialists in information technology.

When the 15 experts give their evaluation according to the NAHP method, matrices of the IG_1 members are aggregated using formula 14, as well as the members of IG_2, and IG_3. Next, the results for each IG are de-neutrosophied using Equation 13, and the NAHP is completed for each interest group. To exemplify these steps, suppose the group assessment of IG_1 is summarized in Table 3 for the pair-wise comparison of the criteria.

	Cost	Project time span	Profit
Cost	$\tilde{1}$	$\tilde{2}$	$\tilde{5}^{-1}$
Project time span	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{4}^{-1}$
Profit	$\tilde{5}$	$\tilde{4}$	$\tilde{1}$

Table 3: Group assessment of criteria by the members of IG_1. Source [29].

Table 4 contains the results to calculate TA(·) according to Equation 13.

	Cost	Project time span	Profit
Cost	0.93750	1.7625	0.18713
Project time span	0.56738	0.93750	0.25157
Profit	5.3438	3.9750	0.93750

Table 4: TA(·) of the group assessment of criteria by the members of IG_1

The calculation of consistency is $\lambda_{max} = 3.02075$, then, CI = 0.010375, and CR = 0.019952<0.1, therefore the group decision of IG_1 is consistent.

The weight of every criterion according to the members of IG_1 is the following, 0.19377 for the cost, 0.11788 for the time span, and 0.68835 for the profit.

Tables 5, 6, and 7 summarize the results of pair-wise evaluating projects 1, 2, and 3 with respect to cost, time span and profit criteria, respectively, collectively by members of IG_1. The numbers in parentheses are the crisp values after calculating TA. The rightmost column contains the priority vector of each project.

	Project 1	Project 2	Project3	Priority vector
Project 1	$\tilde{1}$(0.93750)	$\tilde{2}$(1.7625)	$\tilde{5}$(5.3438)	0.496401
Project 2	$\tilde{2}^{-1}$(0.56738)	$\tilde{1}$(0.93750)	$\tilde{5}$(5.3438)	0.422647
Project 3	$\tilde{5}^{-1}$(0.18713)	$\tilde{5}^{-1}$(0.18713)	$\tilde{1}$(0.93750)	0.080952

Table 5: Reciprocal matrix of the projects related to Cost and their priority vector (rightmost column). The parentheses contain TA values of the triangular neutrosophic numbers.

	Project 1	Project 2	Project3	Priority vector
Project 1	$\tilde{1}(0.93750)$	$\tilde{5}^{-1}(0.18713)$	$\tilde{2}^{-1}(0.56738)$	0.13012
Project 2	$\tilde{5}(5.3438)$	$\tilde{1}(0.93750)$	$\tilde{2}(1.7625)$	0.61860
Project 3	$\tilde{2}(1.7625)$	$\tilde{2}^{-1}(0.56738)$	$\tilde{1}(0.93750)$	0.25128

Table 6: Reciprocal matrix of the projects related to Project Time span and their priority vector (rightmost column). The parentheses contain TA values of the triangular neutrosophic numbers.

	Project 1	Project 2	Project3	Priority vector
Project 1	$\tilde{1}(0.93750)$	$\tilde{5}(5.3438)$	$\tilde{2}(1.7625)$	0.61860
Project 2	$\tilde{5}^{-1}(0.18713)$	$\tilde{1}(0.93750)$	$\tilde{2}^{-1}(0.56738)$	0.13012
Project 3	$\tilde{2}^{-1}(0.56738)$	$\tilde{2}(1.7625)$	$\tilde{1}(0.93750)$	0.25128

Table 7: Reciprocal matrix of the projects related to Profit and their priority vector (rightmost column). The parentheses contain TA values of the triangular neutrosophic numbers.

It is easy to check the consistency of the assessments in Tables 5-7.

Table 8 contains the global weights of the three projects by the members of IG_1.

	Costs	Project time span	Profit	Global Weight
Project 1	0.496401	0.13012	0.61860	0.53734
Project 2	0.422647	0.61860	0.13012	0.24438
Project 3	0.080952	0.25128	0.25128	0.21828
Criterion Weight	0.19377	0.11788	0.68835	1.00000

Table 8: Global weight matrix by IG_1.

Therefore, the members of IG_1 sort the projects in the following order, $p_1 \succ p_2 \succ p_3$.

Suppose that also for IG_2 the order of preference is $p_1 \succ p_2 \succ p_3$, whereas, according to the members of IG_3 the order is $p_1 \succ p_2 = p_3$.

The final results of the method are $V_{11} = V_{21} = V_{31} = (2,0,0)$, which means project 1 is preferred over the rest of projects (two of them), there is not any project preferred over project 1 and it is not equally preferred to another project, for the three IG.

$V_{12} = V_{22} = (1,0,1)$ and $V_{32} = (0,1,1)$, that means for the first and second sub-groups, project 2 is preferred over one project and not preferred over the other one, whereas, for the third IG, project 2 is equally preferred to one project and not preferred over the other one. Additionally, $V_{13} = V_{23} = (0,0,2)$, and $V_{33} = (0,1,1)$.

For each alternative we have, $V_1 = \left(\frac{2+2+2}{2(3)}, \frac{0+0+0}{2(3)}, \frac{0+0+0}{2(3)}\right) = (1,0,0)$, $V_2 = \left(\frac{1+1+0}{2(3)}, \frac{0+0+1}{2(3)}, \frac{1+1+1}{2(3)}\right) = \left(\frac{1}{3}, \frac{1}{6}, \frac{1}{2}\right)$, and $V_3 = \left(\frac{0+0+0}{2(3)}, \frac{0+0+1}{2(3)}, \frac{2+2+1}{2(3)}\right) = \left(0, \frac{1}{6}, \frac{5}{6}\right)$. See that here M = N = 3.

Finally, $H(V_1) = 1$, $H(V_2) = 0.40278$, and $H(V_3) = 0.069444$. Then, project 1 is the preferred one.

Conclusion

This paper introduces for the first time a group decision-making method based on neutrosophic analytic hierarchy process associated with elements of the neutrosophic social choice theory, it is called NAHP+NSC. The advantages of this technique are that it incorporates the indeterminacy as part of the decision-making. So, the result is more accurate than methods where indeterminacy is not explicitly considered. The group of experts is divided into interest groups, therefore the result is consistent, and the hybridization with the neutrosophic social choice theory allow decision makers to rigorously select the best option. Briefly, to combine AHP technique with SC theory in a neutrosophic framework is a complete tool for decision-making. An example is used for illustrating the applicability and the advantages of NAHP+NSC. Future works will consider other voting methods, even modelling with both, offsets [30, 31] and voting game theory as in [32].

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Application of the Neutrosophic AHP Method for the Development of a Training Project on the Adoption Process in Ecuador

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Abstract: Starting from the benefits that can contribute to the people who go through an adoption process, having an adequate knowledge of the current legislation in this respect and a general culture about the impact of this decision in their daily life, their family and especially in the adopted one, this research proposes a training project in child adoption issues in Ecuador. In order to determine precisely which topics the course should be made up of and how much of the total time available should be assigned to each topic, the use of the Analytic Hierarchy Process (AHP) with a neutrosophic approach was used. This approach is justified by the subjective nature of the experts' assessments of the weight of the alternatives for each criterion considered.

Keywords: adoption, training, neutrosophic AHP, SVNS, linguistic term, weighting.

1 Introduction

One of the achievements of contemporary society in the area of human rights is the right to adoption, which, beyond being a legal instrument, is a measure of protection for children and adolescents who are in a state of abandonment. Adoption offers the possibility of forming a family that is not sustained by biological ties; it is a different way of accessing maternity and paternity, where the bond of filiation is symbolically constituted and has the same transcendence as natural reproduction. Its purpose is to provide for the restoration of the child's well-being and security by applying the criteria of unconditional and irrevocable adoption. According to [1] the adoptive parents are committed to caring for their adopted children by instilling in them moral, religious, cultural and social values, providing them with a home full of harmony, love, respect and understanding[2].

The purpose of adoption is to guarantee the right to a family and the integral development of the adopted child by applying the principle of the best interests of the child and ensuring the implementation of public policies that protect and benefit the growth of children and adolescents in an emotional environment that helps them develop physically, psychologically and socially[1]. Adopted children and adolescents are incorporated into families by creating bonds of affiliation and, as a general rule, there is a break in personal, family and legal ties between the children and their biological parents. Adoption as an intervention implies providing the conditions that make possible an adequate psychological development for these children and adolescents because, in essence, this transition can be traumatic[3].

In this sense, some studies have indicated a greater tendency of adopted children to manifest psychological problems. Behavioral problems and the greater presence of adopted children among the clinical population that receives, or has received, mental health treatment have been especially highlighted. A deficit model or a psychopathological model accompanies many of the studies that have been devoted to adoptive samples. Referring to the problems of adoptees is so frequent that one even speaks of the "psychology and psychopathology of adoption" or the "adopted child syndrome"[4]. In recent decades, there has been a significant increase in the number of adoptions worldwide and various ways and criteria have been developed to carry them out, which is legislated in international charters and treaties. The authors [5-7]state that all the regulations in this regard coincide, however, in the need to carry out case studies carefully.

The parent selection process is long and thorough. Applicants may sometimes feel that they are being judged to find their faults, generating doubts and anxiety in the couple. However, this exhaustive assessment is part of the institutional protection system in which the children are found. The evaluating professional must guarantee that these minors will not be victimized again and above all ensure that they are provided with a stable family environment that is capable of covering their needs and therefore their well-being[8] .

The overall characteristics of psychosocial assessment mean that the process involved is not one hundred percent accurate, since even when the criteria to be assessed are clear, it is difficult to recognize the presence or absence of certain qualities, which is why the criteria must be assumed in a flexible manner, always taking into account the characteristics and needs of children. One of the central questions that agitates the discussions, and that mobilizes the main actors, consists in rethinking the place assigned to the families of origin, sometimes called the biological families of the children given up for adoption.

In Ecuador, the adoption procedure lasts eleven months[9]. This period is divided into 90 days, after the application is received, for the application of the adopter, who must be declared suitable by the Ministry of Economic and Social Inclusion (MESI), and up to eight months while waiting for the placement of a child or adolescent. During this process, it is essential that the adopters have the right to adopt through various psychological tests to see if they are capable of gaining a new member of their family. This requires a high level of knowledge of the family and social context, as well as the norms and rules that control the process. That is why, among other aspects, the training process plays a preponderant role for both the adoptee and the adopte[10]r.

For this reason, this research aims to design a training course project on the current legislation regarding adoption in the country, psychological and sociological foundations of the family context and the treatment of children and adolescents in the process of adoption, for people who are going through, or intend to start, an adoption process in Ecuador. In order to determine the specific topics to be included in the course, as well as the distribution of the hours to be taught on each topic, according to its importance in achieving a successful adoption, the use of the Analytic Hierarchy Process (AHP) with a neutrosophic approach is proposed[11-13].

2 Materials and methods

In this section, we expose the basics concepts of Neutrosophy and the AHP method tha were used.

2.1 Some basic concepts of Neutrosophy

Neutrosophy is a mathematical theory developed by Florentin Smarandache to deal with indetermination [14-16]. It has been the base for the development of new methods to handle indeterminate and inconsistent information as the neutrosophic sets and the neutrosophic logic and, especially, in decision-making problems[17-19] .

Let $N = \{(T, I, F): T, I, F \subseteq [0,1]\}n$, be a neutrosophic evaluation of a mapping of a group of formulas propositional to N, and for each sentence p you have:

$$v(p) = (T, I, F) \tag{1}$$

In order to facilitate the practical application to decision-making problems, the use of single-value neutrosophic sets (SVNS) [20, 21] was proposed, through which it is possible to use linguistic terms, in order to obtain a greater interpretability of the results.

Let X be a universe of discourse, a SVNS A over X has the following form:

$$A = \{\langle x, u_a(x), r_a(x), v_a(x)\rangle : x \in X\} \tag{2}$$

Where

$u_a(x): X \to [0,1], r_a(x): X \to [0,1]\ y\ v_a(x): X \to [0,1]$

With $0 \leq u_a(x), r_a(x), v_a(x) \leq 3, \forall\, x \in X$

The intervals $u_a(x), r_a(x)$ and $v_a(x)$ denote the memberships to true, indeterminate and false from x in A, respectively. For convenience a Single Value Neutrosophic Number (SVNN) will be expressed as A = (a, b, c), where a, b, c ∈ [0.1] and satisfies 0 ≤ a + b + c ≤ 3[22].

Let $\{A_1, A_2, \dots, A_n\}$ ∈ SVNS (x), where $A_j = (a_j\,, b_j\,, c_{\,j})$ (j = 1, 2, …, n), then, the Single Valued Neutrosophic Weighted Average Operator is defined by[23]:

$$P_w(A_1, A_2, \dots, A_n) = \langle 1 - \prod_{j=1}^{n}\left(1 - T_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(I_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(F_{A_j}(x)\right)^{w_j}\rangle \tag{3}$$

Where: $w = (w_1, w_2, \dots, w_n)$ is vector of $\mathrm{A_j}(j = 1,2, \dots, n)$ such that $w_n \in [0,1]$ y $\sum w_j = 1$.

Let A = (a, b, c) be a single 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[24, 25]:

$$S(A) = 2 + a - b - c \tag{4}$$

Where $S(A) \in [-1,1]$

2.2 AHP Method

Developed by Thomas Saaty, the AHP (Analytic Hierarchy Process) method essentially consists of formalizing our intuitive understanding of complex problems using a hierarchical structure[26-28]. It has three fundamental concepts: the structuring of the complex decision problem as a hierarchy of objectives, criteria and alternatives, comparisons by pairs of elements of the same level of the hierarchy with respect to each criterion of the superior level, and finally in a vertical way the judgments on the different levels of the hierarchy are synthesized . The application of the AHP method is supported in the structuring of the problem hierarchy in a visual way (Figure 1), where a hierarchy of attributes is constructed containing the purpose or objective of the problem, the different decision criteria and the alternatives[29, 30].

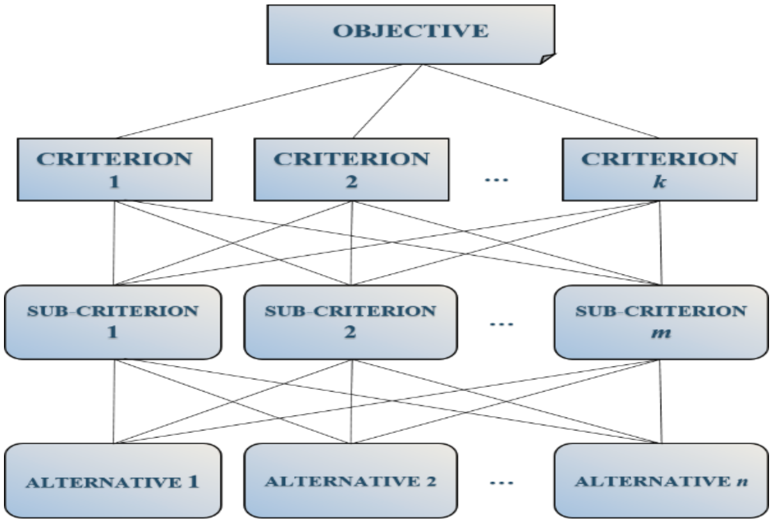

Figure 1. Tree diagram of the elements needed to apply the AHP method

For its application, the following steps are executed:

Step 1. Define the problem and decision criteria in the form of hierarchical objectives

The hierarchy is structured in different levels, starting at the top with the definition of the main objective of the hierarchy process, then the intermediate levels are defined (criteria and sub-criteria to be evaluated) and finally, at the lowest level the alternatives to be compared are described.

Step 2. Evaluate (weigh) the different criteria, sub-criteria and alternatives according to their corresponding importance at each level

Qualitative and quantitative criteria can be compared using informal judgments to obtain weights and priorities. For qualitative criteria, the AHP technique uses simple comparisons (pairwise) to determine the weights and evaluate them. In this way the analyst can concentrate on only two criteria at the same time and indicate how many times one element is more important than another element, with respect to the criterion or property with which they are being compared. In fact, the AHP technique is based on the assumption that the analyst (decision maker) can more easily choose a comparison value than an absolute value. Verbal judgments are translated into a rating scale (Table 1) proposed by [31].

Numerical scale	Verbal scale
1	Both criteria or elements are of equal importance
3	Weak or moderate importance of one over the other
5	Essential or strong importance of one criterion over the other
7	Demonstrated importance of one criterion over the other
9	Absolute importance of one criterion over the other
2, 4, 6, 8	Intermediate values between two adjacent trials, which are used when an average between two of the above intensities is necessary

Table 1. Saaty after determining the values of the comparisons for each level: “Pairwise Comparison Matrix” [8].

Step 3. Determine the weights of each sub-criterion with respect to the previous criterion

In order to calculate them, the columns of the Pair Comparison Matrices are normalized by dividing each number of a column by its total sum, and from these values the average value of the values of each row is obtained, which correspond to the values of the main vector that reports the priority weights of the criteria or sub-criteria. The AHP method allows the analyst to evaluate the congruence of the judgments with the radius of inconsistency. Before determining an inconsistency, it is necessary to estimate the consistency index of a trial matrix, where it is defined by **[32]**:

$$CI = \frac{\lambda max - n}{n-1} \quad (5)$$

Where λmax it is the maximum self value of the matrix.

In this way it is defined by:

$$RI = \frac{CI}{R_i} \quad (6)$$

Where R_i it is a random average value of for a matrix. The values of are shown in table 2.

N	*1*	*2*	*3*	*4*	*5*	*6*	*7*
R_i	0	0	0,52	0,89	1,11	1,25	1,35

Table 2. Values of R_i for different order matrices proposed by [16]

Judgments may be considered acceptable if it is less than or equal to 0.1. In cases of inconsistency, the evaluation process for the evaluated matrix is immediately repeated. Inconsistencies greater than 0.1 or more justify further investigation of the criteria evaluated.

Step 4. Construct Alternative Payment Matrix

In this matrix, for each last level criterion, an assessment of the consequences of the alternatives is made. There are 2 options [8]:

If the data of the alternatives vs. criteria (payment matrix) are available, equation 3 is used, where the values are normalized Z_i to values A_i for each criterion i.

$$\sum_{i=1}^{n} A_i = 1 \quad (7)$$

If the payment matrix is not available, the decision maker makes comparisons to form a n x n matrix of relative importance between alternatives, similar to that of the criteria.

Step 5. Determine total evaluations of the alternatives

The definitive evaluation of each alternative is obtained by using equation 8 for each last level criterion j:

$$V_j(A_k) = \sum_{i=1}^{q} p_i \times a_{ki} \quad (8)$$

Where:

V_j: Is the evaluation of the alternative A_k

A_k: Is the alternative $k, (k = 1,2, \dots, n)$

p_i: Is the priority weighting of the criterion or sub-criterion $i, (i = 1,2, \dots, q)$

a_{ki}: Corresponds to the value of the alternative evaluated with respect to the Z_i.

This calculation must be performed for each criterion at other levels, until the main hierarchy node is reached.

2.3 Neutrosophic AHP Method

Neutrosophic AHP has several advantages over classical AHP, for example, it presents the user with a richer frame structure than classical AHP, fuzzy AHP and intuitionist fuzzy AHP. It describes the expert's judgment values by efficiently handling vagueness and uncertainty about fuzzy AHP and fuzzy intuitionist AHP because it considers three different degrees: degree of membership, degree of indeterminacy, and degree of non-membership. Another advantage is that it is calculated from linguistic terms, which allows for more natural communication with experts [33].

Neutrosophic AHP consists of applying the following steps:

Step 1. Select the experts and measure their weight according to their level of knowledge in the analyzed topic.

To determine the weight of the experts, the selected specialists self-evaluate their level of knowledge in the topic to be analyzed according to a linguistic scale associated with SVNS values, as shown in Table 3.

LINGUISTIC TERM	EVALUATION	SVNS
EXTREMELY HIGH	EH	(1; 0; 0)
VERY VERY HIGH	VVH	(0.9, 0.1, 0.1)
VERY HIGH	VH	(0,8; 0,15; 0,20)
HIGH	H	(0.70,0.25,0.30)
NOT VERY HIGH	NVH	(0,60; 0,35; 0,40)
MEDIUM	M	(0,50; 0,50; 0,50)
BETWEEN LOW AND MEDIUM	BLM	(0,40; 0,65; 0,60)
LOW	L	(0.30,0.75,0.70)
VERY LOW	VL	(0,20; 0,85; 0,80)
VERY VERY LOW	VVL	(0.10,0.90,0.90)
EXTREMELY LOW	EL	(0; 1; 1)

Table 3. Linguistic terms for the evaluation of experts

If $A_t = (a_t, b_t, c_t)$ is the SVNS corresponding to the t-th decision maker (t = 1, 2,..., k), the weight of each expert is calculated by the following formula:

$$\lambda_t = \frac{a_t + b_t\left(\frac{a_t}{a_t+c_t}\right)}{\sum_{t=1}^{k} a_t + b_t\left(\frac{a_t}{a_t+c_t}\right)} \quad (9)$$

Where:

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

Step 2. Define the problem and decision criteria in the form of hierarchical objectives.

This step is accomplished in the same way as in the classic AHP method. The experts must design an AHP tree, specify the criteria, sub-criteria and alternatives to perform the evaluation.

Step 3. Evaluate (weigh) the different criteria, sub-criteria and alternatives according to their corresponding importance at each level.

In order to create the matrices for each level of the tree, according to the experts' evaluations, these must be expressed in SVNS form, for which the original Saaty numerical scale is adapted to a linguistic scale as can be seen in Table 4.

SAATY'S SCALE	DEFINITION	SVNS
1	Equally important	$(0.50, 0.50, 0.50)$
3	Moderate importance	$(0.30, 0.75, 0.70)$
5	Strong importance	$(0.80, 0.15, 0.20)$
7	Very strong or proven importance	$(0.90, 0.10, 0.10)$
9	Extreme importance	$(1, 0, 0)$
2	Sporadic values between two scales close to each other	$(0.40, 0.65, 0.60)$
4		$(0.60, 0.35, 0.40)$
6		$(0.70, 0.25, 0.30)$
8		$(0.85, 0.10, 0.15)$

Table 4. Adapting the Saaty scale for SVNS use

The neutrosophic decision matrix is obtained by combining equation (3), (4) and (9), is defined as:

$$D = \begin{vmatrix} sa_{11} & sa_{12} & \dots sa_{1n} \\ sa_{21} & sa_{22} & \dots sa_{2n} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ sa_{n1} & sa_{n2} & \dots sa_{nn} \end{vmatrix},$$

where $sa_{ij} = 3 - \prod_{t=1}^{k}\left(1 - T_{A_{ij_t}}(x)\right)^{\lambda_t} - \prod_{t=1}^{k}\left(I_{A_{ij_t}}(x)\right)^{\lambda_t}, - \prod_{t=1}^{k}\left(F_{A_{ij_t}}(x)\right)^{\lambda_t}$ (10)

Step 4. Determine the weights of each sub-criterion with respect to the previous criterion
The consistency of the assessments for each matrix is verified, and then step 5 of the traditional AHP is applied.

3 Results

A total of 15 experts were selected to apply the AHP method in the design of the training course:

- Five of them are judges from the Family, Women, Children and Adolescents Unit of Quito City
- Three are judges from the National Court of Justice
- Four are professors of law at the Central University of Ecuador
- Three are freelance lawyers with extensive professional experience in the field.

The experts evaluated their own knowledge on the subject analyzed from the scale shown in table 1 and determined its weight by means of equation 9.

As a second step, the experts were asked to make a proposal of the issues and criteria they considered fundamental for the successful achievement of an adoption process. From the processing of this first information provided by the experts, the following proposals were elaborated, which were sent to them again and were approved by all. These are the proposed themes and criteria:

Themes (decision alternatives)

1. The family and its characteristics. Psychological and sociological foundations of the family context.
2. Ecuadorian Code of Childhood and Adolescence. Theoretical and methodological bases of the adoption process.
3. Psychology of the adoption.
4. Adoption in Ecuador, procedures and requirements.
5. Adoption in the National Legislation of Ecuador.
6. Principles and guarantees of the adoption. Rights of the adopters and rights of the adoptee.

The criteria on which the alternatives were evaluated were focused on the objectives to which the level of knowledge reached in the matters could contribute:

1. Successful completion of all stages of the adoption process
2. To guarantee the integral development of the adopted child
3. To guarantee the adopted child or adolescent a family environment with harmony, love, respect and understanding
4. Be better prepared to meet the challenge of adoption.

The results of the application of the Neutrosophic AHP Method are shown below.

Applying (9), the values of for each expert were obtained, which were used as a weighting coefficient for each of the aggregated matrices. Each of the elements of the matrices are shown as SVNS, but all the weigths were calculated by applying (10) and then, step number 3 of the AHP Classic Method. Table 5 shows the matrix of pairwise comparisons between the criteria.

Criteria	**Pairwise SVNS Comparison Matrix**				**Weight**
	Criterion 1	Criterion 2	Criterion 3	Criterion 4	
Criterion 1	1	(0,523 ; 0,381 ; 0,429)	(0,518 ; 0,416 ; 0,469)	(0,577 ; 0,343 ; 0,387)	0,362
Criterion 2	(0,188 ; 0,754 ; 0,851)	1	(0,499 ; 0,419 ; 0,472)	(0,518 ; 0,429 ; 0,484)	0,266
Criterion 3	(0,189 ; 0,755 ; 0,851)	(0,196 ; 0,74 ; 0,835)	1	(0,21 ; 0,715 ; 0,806)	0,171
Criterion 4	(0,17 ; 0,765 ; 0,863)	(0,189 ; 0,736 ; 0,83)	(0,478 ; 0,483 ; 0,545)	1	0,202

Table 5. Pairwise Comparison Matrix

As can be seen, the most important criterion is number 1, followed by 2, 4 and 3 in that order. The matrix is consistent with an RI=0.015 so these weights per vector will be used for the final comparison between the alternatives.

The components of the priority or hierarchy vectors for each alternative according to each criterion are shown from table 6 and up to table 10.

Alternative	**Aggregated SVNS matrix**						**Priority Vector**
	1	2	3	4	5	6	
1	1	(0.779, 0.244, 0.253)	(0.845, 0.153, 0.159)	(0.903, 0.098, 0.102)	(0.943, 0.106, 0.11)	(0.98, 0.084, 0.087)	0,322
2	(0.149, 0.91, 0.945)	1	(0.169, 0.882, 0.915)	(0.745, 0.265, 0.275)	(0.857, 0.181, 0.188)	(0.875, 0.181, 0.188)	0,176
3	(0.133, 0.923, 0.958)	(0.658, 0.359, 0.372)	1	(0.748, 0.31, 0.322)	(0.841, 0.22, 0.228)	(0.904, 0.137, 0.142)	0,213
4	(0.122, 0.929, 0.965)	(0.152, 0.904, 0.939)	(0.153, 0.896, 0.93)	1	(0.77, 0.252, 0.261)	(0.883, 0.16, 0.166)	0,131
5	(0.122, 0.931, 0.967)	(0.132, 0.919, 0.954)	(0.14, 0.916, 0.95)	(0.15, 0.908, 0.943)	1	(0.194, 0.855, 0.888)	0,073
6	(0.122, 0.937, 0.972)	(0.131, 0.92, 0.955)	(0.129, 0.928, 0.963)	(0.13, 0.924, 0.959)	(0.583, 0.455, 0.472)	1	0,086

Table 6 Pairwise comparison matrix for the alternatives according to criterion 1

According to the previous results, the theme 1 of the course: "The family and its characteristics. Psychological and sociological foundations of the family context" has a higher priority according to the criterion: "Successful completion of all stages of the adoption process".

Alternative	**Aggregated SVNS matrix**						**Priority Vector**
	1	2	3	4	5	6	
1	1	(0.832, 0.231, 0.24)	(0.821, 0.182, 0.189)	(0.881, 0.19, 0.198)	(0.899, 0.168, 0.174)	(0.907, 0.141, 0.146)	0,315
2	(0.144, 0.915, 0.95)	1	(0.172, 0.884, 0.917)	(0.75, 0.282, 0.293)	(0.797, 0.203, 0.211)	(0.895, 0.178, 0.185)	0,175
3	(0.14, 0.92, 0.955)	(0.681, 0.37, 0.384)	1	(0.759, 0.289, 0.3)	(0.768, 0.264, 0.274)	(0.851, 0.184, 0.191)	0,212
4	(0.138, 0.923, 0.958)	(0.151, 0.901, 0.935)	(0.156, 0.904, 0.938)	1	(0.766, 0.237, 0.246)	(0.846, 0.189, 0.196)	0,133
5	(0.129, 0.923, 0.958)	(0.137, 0.913, 0.948)	(0.147, 0.904, 0.938)	(0.146, 0.909, 0.943)	1	(0.191, 0.858, 0.891)	0,076
6	(0.132, 0.929, 0.964)	(0.13, 0.922, 0.957)	(0.133, 0.919, 0.953)	(0.136, 0.919, 0.954)	(0.596, 0.448, 0.465)	1	0,089

Table 7. Pairwise comparison matrix for the alternatives according to criterion 2

According to criterion 2 the same hierarchical order is maintained for the course topics.

Alternative	**Aggregated SVNS Matrix**						**Priority Vector**
	1	2	3	4	5	6	
1	1	(0.825, 0.243, 0.252)	(0.844, 0.222, 0.231)	(0.848, 0.199, 0.206)	(0.823, 0.184, 0.191)	(0.858, 0.16, 0.166)	0,310
2	(0.146, 0.913, 0.948)	1	(0.169, 0.889, 0.922)	(0.763, 0.272, 0.283)	(0.828, 0.219, 0.228)	(0.873, 0.18, 0.187)	0,177
3	(0.142, 0.917, 0.951)	(0.689, 0.348, 0.361)	1	(0.732, 0.296, 0.307)	(0.814, 0.257, 0.267)	(0.799, 0.243, 0.252)	0,213
4	(0.14, 0.92, 0.955)	(0.154, 0.906, 0.94)	(0.159, 0.901, 0.935)	1	(0.754, 0.286, 0.297)	(0.737, 0.268, 0.278)	0,130
5	(0.136, 0.918, 0.953)	(0.139, 0.914, 0.949)	(0.149, 0.911, 0.946)	(0.153, 0.902, 0.936)	1	(0.191, 0.857, 0.89)	0,077
6	(0.133, 0.923, 0.958)	(0.135, 0.922, 0.957)	(0.146, 0.911, 0.945)	(0.151, 0.903, 0.937)	(0.602, 0.455, 0.472)	1	0,092

Table 8. Pairwise comparison matrix for the alternatives according to criterion 3

Once again topics 1 to 3 are the most important according to this criterion and the rest is kept in the same order with topic 5 evaluated as the least important for the course.

Alternative	Aggregated SVNS Matrix						Priority Vector
	1	2	3	4	5	6	
1	1	(0.796, 0.24, 0.249)	(0.829, 0.18, 0.187)	(0.841, 0.171, 0.178)	(0.915, 0.138, 0.143)	(0.962, 0.088, 0.091)	0,319
2	(0.149, 0.913, 0.947)	1	(0.173, 0.883, 0.916)	(0.707, 0.3, 0.312)	(0.792, 0.22, 0.229)	(0.893, 0.12, 0.125)	0,178
3	(0.133, 0.917, 0.952)	(0.659, 0.364, 0.378)	1	(0.743, 0.311, 0.323)	(0.811, 0.236, 0.245)	(0.822, 0.205, 0.213)	0,213
4	(0.139, 0.923, 0.958)	(0.159, 0.897, 0.931)	(0.158, 0.898, 0.932)	1	(0.757, 0.255, 0.265)	(0.218, 0.839, 0.871)	0,107
5	(0.132, 0.93, 0.965)	(0.142, 0.912, 0.947)	(0.147, 0.914, 0.948)	(0.147, 0.905, 0.939)	1	(0.208, 0.853, 0.885)	0,076
6	(0.12, 0.934, 0.969)	(0.124, 0.927, 0.962)	(0.142, 0.918, 0.952)	(0.523, 0.503, 0.521)	(0.557, 0.47, 0.488)	1	0,108

Table 9. Pairwise comparison matrix for the alternatives according to criterion 4

Once all the necessary vectors to establish the comparison between the alternatives were obtained, the vectorial decision matrix was constructed, which includes the weight vector of the criteria q obtained at the beginning of the application of this method. The results are shown in table 10.

Alternative	Criteria				Hierarchical Index
	Criterion 1	Criterion 2	Criterion 3	Criterion 4	
1	0,322	0,315	0,310	0,319	0,317
2	0,176	0,175	0,177	0,178	0,176
3	0,213	0,212	0,213	0,213	0,213
4	0,131	0,133	0,130	0,107	0,127
5	0,073	0,076	0,077	0,076	0,075
6	0,086	0,089	0,092	0,108	0,092
Weigth	0,362	0,266	0,171	0,202	

Table 10. Decision matrix for Alternatives

From the values of the previous table it was possible to establish the hierarchical order of the topics of the course, as well as the index of hierarchy that they present for the assignment of class hours that are programmed. The order and the respective indexes for each topic are as follows:

1. The family and its characteristics. Psychological and sociological foundations of the family context (31.7%)
2. Psychology of adoption (21.3%)
3. Ecuadorian Children and Adolescents Code. Theoretical and methodological bases of the adoption process (17.6%)
4. Adoption procedure in Ecuador, procedures and requirements (12.7%)
5. Principles and guarantees of adoption. Rights of adopters and rights of adoptees (9.2%)
6. Adoption in Ecuador's National Legislation (7.5%)

Conclusions

- The training course project on the current legislation regarding adoption in the country, psychological and sociological foundations of the family context and the treatment of children and adolescents in the process of adoption, is designed to be useful to people who are going through, or intend to start, an adoption process in Ecuador.
- The course is designed to enhance the knowledge that directly contributes to the successful completion of all stages of the adoption process, as well as to guarantee the integral development of the adopted child in a family environment with harmony, love, respect and understanding.
- The application of the neutrosophic AHP method from the information provided by the experts consulted, allowed the establishment of a hierarchical order for the topics of the course according to their relevance, as well as to estimate the proportion of time that should be assigned to each topic in correspondence with its hierarchy index.

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Neutrosophy for Survey Analysis in Social Sciences

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Abstract. The survey is a research procedure used in sociology to determine the thoughts and feelings of a social group at a given time and context. Within the survey, the questionnaire is considered as a very useful instrument used to measure the state of opinions of social groups. Although it has been demonstrated that fuzzy responses to questionnaires are more appropriate than crisp ones, there may be indeterminacy and thus fuzzy processing does not accurately capture the thought that the respondent wants to express, due to doubts, unclear and vague thoughts, among others. Modeling such scenario by means of neutrosophic sets provides respondents a greater range of possible responses and hence it is more appropriate. In this paper, we propose a method to design single-valued neutrosophic sets from questionnaires to social groups. This method, inspired by another fuzzy one, allows us to create membership functions of truthfulness, indeterminacy and falseness through experimental data, which will let us find the essence of the thought of the human group under study to be captured with greater accuracy.

Keywords: Neutrosociology, survey, questionnaire, single-valued neutrosophic set.

1 Introduction

Sociology is the social science that studies the collective phenomena produced by the social activity of human beings, within the historical-cultural context in which they are immersed. In sociology, multiple interdisciplinary research techniques are used to analyze and interpret from different theoretical perspectives the causes, meanings and cultural influences that motivate the appearance of various behavioral trends in the human being, especially when it is in social coexistence and within a shared habitat. One of the most widely used research methods is the survey.

A survey is a research procedure, within descriptive research designs (not experimental) in which the researcher seeks to collect data through a previously designed questionnaire or an interview with someone, without modifying the environment or the phenomenon where the information is collected (just like in an experiment), [1]. The data are obtained by carrying out a set of standardized questions addressed to a representative sample or to the total set of the statistical population under study, often made up of people, companies or institutional entities, in order to know states of opinion, ideas, characteristics or facts. The researcher must select the most suitable questions, according to the nature of the investigation.

On the other hand, a questionnaire is a research instrument that consists of a set of questions and other indications to obtain information from those consulted [1,2]. Although they are often designed to allow statistical analysis of responses, this is not always the case. The questionnaire is a document formed by a set of questions that must be drafted in a coherent way. Those questions must be organized, sequenced and structured according to a certain planning, so that answers can offer us all the required information.

The survey is often carried out based on a questionnaire, which is therefore the basic document to obtain information in the vast majority of research and market studies. Questionnaires have advantages over other types of surveys in that they are inexpensive, do not require much effort on the part of the respondent, such as oral or telephone surveys, and often have standardized responses that make data tabulation simpler.

In sociology, surveys are usually designed such that the possible responses to the questionnaires are fixed values. An example of a sociological questionnaire is the opinion on the number of children that an ideal family should have, which can force respondents to answer with a number (2, 3, 4) even though the respondent wishes to answer more exactly, although imprecise as in interval form such as 2 to 4, [3]. Some authors have studied and demonstrated the fuzzy rather than crisp essence of surveys, [3-7]. Fuzzy sets have been proven more effective in dealing with measurements related to human thought than classical sets.

In this paper, we defend the thesis that neutrosophic sets are even more suitable than fuzzy sets to represent the possible responses to questionnaires. The former one allow the surveyed person to be able to express even more accurately and also with greater indeterminacy about their true thoughts and feelings, due to the indeterminacy membership function [8], which allows modeling the lack of knowledge, doubts or contradictions that may exist in the responses of any human being.

Neutrosophic Sociology or Neutrosociology is the study of sociology using neutrosophic scientific methods, [9-13], because the data of sociology can be vague, incomplete, contradictory, hybrid, biased, ignorant, redundant, superfluous, meaningless, ambiguous, and unclear, among others. In this new approach to the study of sociology, the concepts are represented in the form of <A>, which is the primary concept, <Anti A>, which is its opposite, and <Neut A>, which represents those that are neither <A> nor <Anti A>.

In this paper, we are inspired by a method in [4] for the construction of fuzzy membership functions [14,15] to construct neutrosophic sets as a result of the responses of a survey by a group of individuals under study. To design a priori fuzzy membership functions or neutrosophic sets is not sufficient and yet it is of great interest finding a more adequate application of these theories. With the use of neutrosophic sets instead of fuzzy sets, greater accuracy of the results is obtained, since the single-valued neutrosophic sets allow a greater range of expression of the thoughts and feelings of the respondents, since they cannot only express their ideas, but also what they consider false and what they consider indeterminate. This method, like its predecessor, stands out for its simplicity and applicability.

This paper is structured into the following sections: Section 2, which recalls the main concepts of Neutrosophy that will be used in the proposed method. In Section 3, we introduce the method proposed in the paper and we develop two illustrative examples. The last section contains the conclusions.

2 Basic concepts of Neutrosophy

This section describes the main concepts of Neutrosophy, such as neutrosophic sets, single-valued neutrosophic sets, and single-valued neutrosophic numbers, among others. In addition, the main definitions of neutrosophic statistics are described.

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

Definition 2: (8]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is a set of the form:

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

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∈X. $u_A(x), r_A(x)$ and $v_A(x)$ denotes the membership functions of truthfulness, indeterminate and falseness of x in A, respectively. For convenience a *Single-Valued Neutrosophic Number* (SVNN) will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$ and satisfy $0 \leq a + b + c \leq 3$.

Definition 3: (8]) A *neutrosophic number* N is defined as a number in the following expression:

$$N = d + I \qquad (2)$$

Where d is called *determinate part* and I is called *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:

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

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

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

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

Neutrosophy studies triads, where if <A> is an item or a concept then the triad is (<A>, <neut A>, <anti A>),[9,10]. Neutrosociology is based on triads. E.g., the concept A = imperialist society, has an antiA = communist society, and neutA = neutral society.

Neutrosophic Statistics extends the classical statistics, such that we deal with set values rather than crisp values, [16-22]. Neutrosophic Statistics can be used as a quantitative research method in sociology for testing social hypotheses.

Neutrosophic Descriptive Statistics is comprised of all techniques to summarize and describe the neutrosophic numerical data characteristics.

Neutrosophic Inferential Statistics consists of methods to allow the generalization of a neutrosophic sampling to a population from which the sample was selected.

Neutrosophic Data is the piece of information that contains some indeterminacy. Similar to the classical statistics, it can be classified as:

- *Discrete neutrosophic data*, if the values are isolated points.
- *Continuous neutrosophic data*, if the values form one or more intervals.

Another classification is:

- *Quantitative (numerical) neutrosophic data*; for example: a number in the interval [2, 5] (we do not know exactly), 47, 52, 67 or 69 (we do not know exactly);
- *Qualitative (categorical) neutrosophic data*; for example: blue or red (we do not know exactly), white, black or green or yellow (not knowing exactly).

The *univariate neutrosophic data* is a neutrosophic data that consists of observations on a neutrosophic single attribute.

Multivariable neutrosophic data is neutrosophic data that consists of observations on two or more attributes.

A *Neutrosophic Statistical Number* N has the form $N = d + i$, like Equation 2.

A *Neutrosophic Frequency Distribution* is a table displaying the categories, frequencies, and relative frequencies with some indeterminacies. Most often, indeterminacies occur due to imprecise, incomplete or unknown data related to frequency. Therefore, relative frequency becomes imprecise, incomplete, or unknown too.

Neutrosophic Survey Results are survey results that contain some indeterminacy.

A *Neutrosophic Population* is a population not well determined at the level of membership (i.e. not sure if some individuals belong or not to the population).

A *simple random neutrosophic sample* of size n from a classical or neutrosophic population is a sample of n individuals such that at least one of them has some indeterminacy.

A *stratified random neutrosophic sampling* the researcher groups the (classical or neutrosophic) population by a strata according to a classification; afterwards the researcher takes a random sample (of appropriate size according to a criterion) from each group. If there is some indeterminacy, we deal with neutrosophic sampling.

3 Application of neutrosophic theory in sociological surveys

In the study carried out by Li in [4] about how to measure the people's thoughts, the author acknowledges the existence of possible responses like "1 or 2 (sorry)" with respect to the size of an small family, whereas other answer is "not an exact age" for the question about the exact age of a "young person". Thus, it is necessary to include the indeterminacy like a possible result of a survey. On the other hand, Li deals with indeterminacy when the range of responses is an interval rather than a single value.

In this section, we deal with indeterminacy based on single-valued neutrosophic sets and Neutrosociology concepts. The method consists of the following aspects:

1. Firstly, the sociologist must determine the primary concept he/she wants to measure, e.g., A = "small family". Next, he/she determines anti A, e.g. "big family", and neut A, e.g. "optimal family". In addition, he/she establishes the social group to analyse.
2. He/she asks to the group the questions he/she designed aiming to have information about the triad (<A>, <neut A>, <anti A>). Every question should have three variants, one of them related to one of the three elements of the triad.
   The ambiguous or vague answers like "I don't know", "certain number", and so on are associated with <neut A>, even though they were responses for questions of <A> or <anti A>.
   The interviewer remarks that the responses can be given in form of intervals in case it makes sense or if respondent considers it better corresponds to his/her opinions.
   Questionnaires can also include answers in form of linguistic values.
   The respondent should feel free to write what he/she thinks on the subject of the questions.

Let us denote as $X_j = \{x_i^j\}_{i=1}^{m_j}$ the set of possible responses to question q_j (j = 1, 2,…, n).

The frequency of every possible response is calculated for every element of the triad, let us call them $f_{<A>}(x_i^j)$, $f_{<neut\ A>}(x_i^j)$, and $f_{<anti\ A>}(x_i^j)$.

If N is the size of the social group to study, we calculate the following probabilities:

$$p_{<A>}(x_i^j) = \frac{f_{<A>}(x_i^j)}{N} \quad (3)$$

$$p_{<neut\ A>}\left(\mathrm{x_i^j}\right) = \frac{\mathrm{f}_{<neut\ A>}\left(\mathrm{x_i^j}\right)}{\mathrm{N}} \tag{4}$$

$$p_{<anti\ A>}\left(\mathrm{x_i^j}\right) = \frac{\mathrm{f}_{<anti\ A>}\left(\mathrm{x_i^j}\right)}{\mathrm{N}} \tag{5}$$

The properties of $p_{<A>}\left(\mathrm{x_i^j}\right)$, $p_{<neut\ A>}\left(\mathrm{x_i^j}\right)$, and $p_{<anti\ A>}\left(\mathrm{x_i^j}\right)$ are the following:

- For every $\mathrm{X_j}$ then $p_{<A>}\left(\mathrm{x_i^j}\right), p_{<neut\ A>}\left(\mathrm{x_i^j}\right), p_{<anti\ A>}\left(\mathrm{x_i^j}\right) \in [0,1]$.
- For every $\mathrm{X_j}$ then $\sum_{i=1}^{\mathrm{m_j}}\left(p_{<A>}\left(\mathrm{x_i^j}\right) + p_{<anti\ A>}\left(\mathrm{x_i^j}\right)\right) \leq 1$.
- For every $\mathrm{X_j}$ then $\sum_{i=1}^{\mathrm{m_j}}\left(p_{<A>}\left(\mathrm{x_i^j}\right) + p_{<neut\ A>}\left(\mathrm{x_i^j}\right) + p_{<anti\ A>}\left(\mathrm{x_i^j}\right)\right) \geq 1$.

Let us remark that the probabilities $p_{<A>}\left(\mathrm{x_i^j}\right)$ and $p_{<anti\ A>}\left(\mathrm{x_i^j}\right)$ should satisfy the property of subjective probability approach, [23], whereas, when $p_{<neut\ A>}\left(\mathrm{x_i^j}\right)$ is included then the sum can exceed the unity. This is because of $p_{<neut\ A>}\left(\mathrm{x_i^j}\right)$ and the others two may have common answers for some individuals.

Now, for every concept A the sociologists have a single-valued neutrosophic set defined as follows:

$$A = \left\{\left\langle \mathrm{x}, \min_{\mathrm{j}}\left(p_{<A>}\left(\mathrm{x_i^j}\right)\right), \max_{\mathrm{j}}\left(p_{<neut\ A>}\left(\mathrm{x_i^j}\right)\right), \max_{\mathrm{j}}\left(p_{<anti\ A>}\left(\mathrm{x_i^j}\right)\right)\right\rangle : \mathrm{x} \in \Pi_{\mathrm{j=1}}^{\mathrm{n}}\mathrm{X_j}\right\} \tag{6}$$

Let us note that Π is the Cartesian product and the set A contains the definition of n-norm, [17]. Also, let us remark we are using neutrosophic statistics with neutrosophic data.

The single-valued neutrosophic set A can be de-neutrosophied to a crisp set where the elements of the triad are reduced to numerical values using the scoring function or a precision index.

A scoring function $\mathrm{s}: [0,1]^3 \to [0,3]$ is defined in Formula 7, it is an adapted scoring function from the one defined in [24].

$$\mathrm{s(a)} = 2 + \mathrm{T} - \mathrm{F} - \mathrm{I} \tag{7}$$

Where a is a SVNN with values (T, I, F).

The definition of precision index is given in Equation 8.

$$a(\mathrm{a}) = \mathrm{T} - \mathrm{F} \tag{8}$$

Where $a: [0,1]^3 \to [-1,\ 1]$.

Below, we illustrate the method through two examples.

Example 1

Here, we revisit the example appeared in [4]. The survey aims to investigate what people considers is an ideal family size, thus <A> = <ideal family size>, <anti A> = <non- ideal family size>, and <neut A> = <indeterminate ideal family size>. Let us note we are dealing with three variants of the same concept instead of only one of them. Here, we use only one question, which is:

1. Use any number (0, 1,2,...) or any range (1-4, 2-3,...) to indicate your perception of:
   1.1. the ideal family size.
   1.2. you cannot determinate it is neither ideal nor not an ideal family size.
   1.3. non- ideal family size.

Let us assume that the population contains 6 respondents, which answer in the following way, where $R_i = \left(R_i^{<A>},\ R_i^{<neut\ A>},\ R_i^{<anti\ A>}\right)$, correspond to the responses given by the i-th respondent for the triad $(< A >, < neut\ A >,\ < anti\ A >)$, respectively:

$$R_1 = (\{1,2,3,4\},\{5\},\{0,6,7,8,9,10\})$$

$$R_2 = (\{2\},\{3,4\},\{0,1,5,6,7,8,9,10\})$$

$$R_3 = (\{2,3\},\{1\},\{0,4,5,6,7,8,9,10\})$$

$$R_4 = (\{1,2\},\{0\},\{3,4,5,6,7\})$$

$$R_5 = (\{0\},\emptyset,\{x: x > 0\})$$

$$R_6 = (\{2,3,4\},\{5,6\},\{1,7,8,9,10\}).$$

That means, e.g., the first respondent thinks the ideal family size (number of children) is from 1 to 4, whereas to have not child or more than 6 is not ideal, however, 5 children is indeterminate for him/her. Contrarily, respondent 5 is against to have any child.

Table 1 summarizes the frequency of each possible response in the example:

Responses X_1	$f_{<A>}(x_i^1)$	$f_{<neut\ A>}(x_i^1)$,	$f_{<anti\ A>}(x_i^1)$.
0	1	1	3
1	2	1	2
2	5	0	1
3	3	1	2
4	2	1	3
5	0	1	4
6	0	1	5
7	0	0	6
8	0	0	5
9	0	0	5
10	0	0	5

Table 1: Frequencies of the responses.

The probabilities are obtained dividing the frequencies by N = 6. The truthfulness, indeterminacy and falseness membership functions are depicted in Figure 1.

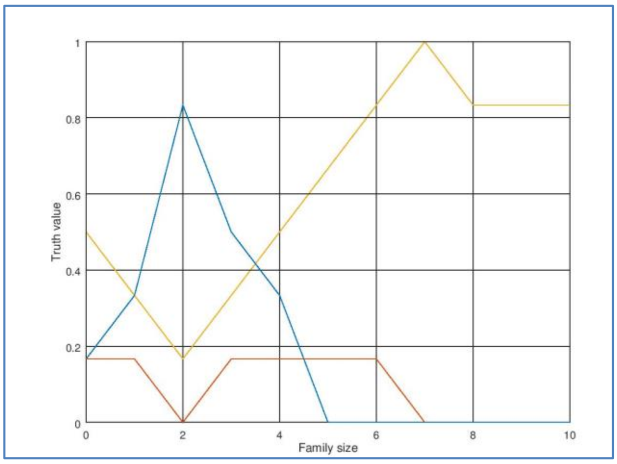

Figure 1: Truthfulness-membership function in blue lines, indeterminacy-membership function in red lines, and falseness-membership function in yellow lines, for the concept "ideal family size".

In Figure 2 shows the scoring function using Equation 7 for the possible responses about the concept "ideal family size".

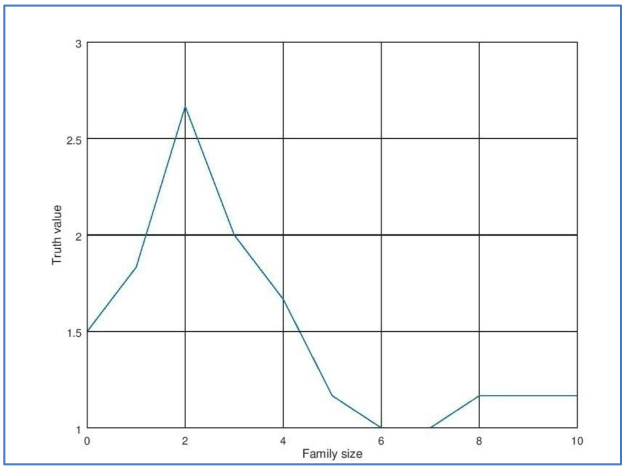

Figure 2: Scoring function of the single-valued neutrosophic set in Figure 1.

Evidently, the ideal family size can be considered equal to 2 for this social group.

Example 2

In a community, sociologists want to know how members perceive two concepts: *young* and *educated*. To do this, they design a questionnaire, one where the triad is that of (<young>, <middle-aged>, <old>), while the second triad is (<instructed>, <borderline instruction>, <unlearned>).

Questions are:

1. How old must a person be to be considered:
   1.1. young?
   1.2. middle-aged?
   1.3. old?
2. ¿What level of education must a person have to be considered:
   2.1. instructed?
   2.2. borderline educated?
   2.3. not educated?

For the first question, the possible answer is an age between 0 and 120 years old, it can also be expressed in the form of intervals, that is, $X_1 = \{G: G \subset [0, 120]\}$.

For the second question, the possible answers are: "primary level of education", "secondary level of education", "upper secondary level of education", "higher level of education", and "MSc. or PhD degrees ”, these are the elements of X_2.

Suppose the population of study consists of 180 members. The results are shown in Figure 3:

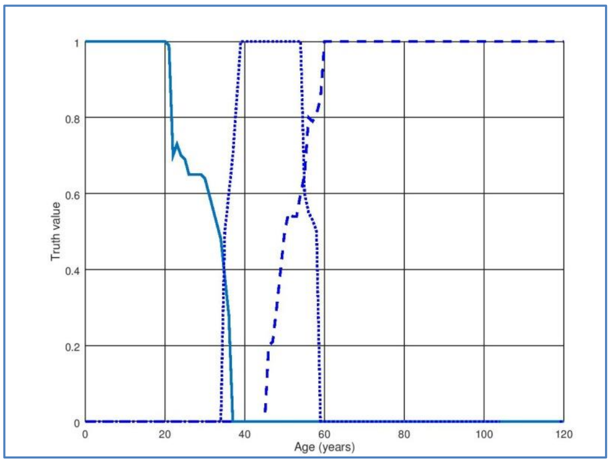

Figure 3: Truthfulness-membership function in solid lines, indeterminacy-membership function in dotted lines, and falseness-membership function in dashed lines, for the concept “young”.

In Figure 4 it is depicted the scoring function of the triad related with young people.

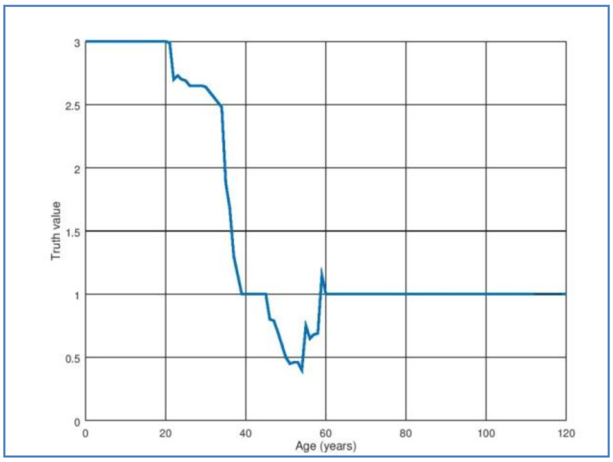

Figure 4: Scoring function for the single-valued neutrosophic set in Figure 3.

Regarding the level of instruction, let us assume that the results were the following:

- Primary level of education has the triple $(0, 0.01, 0.93)$,

- Secondary level of education has the triple $(0.1, 0.6, 0.8)$,
- Upper secondary level of education has the triple $(0.6, 0.4, 0.1)$,
- Higher level of education has the triple $(1, 0.1, 0)$, and
- MSc. or PhD degrees has the triple $(1,0,0)$.

Thus, to define the conjunction of young and instructed person, it is necessary to obtain the Cartesian product between the pair age and education level, where the n-norm of the triple of each of them is calculated. E.g., one young 20 years old person AND having a primary level of instruction has a triad value obtained since the n-norm between $(1, 0, 0)$ for young and $(0, 0.01, 0.93)$ for educated, which results in $(0, 0.01, 0.93)$ for this combination. Calculating the scoring function we have the value -0.94, thus it is very low.

Conclusion

This paper introduces a neutrosophic method for survey analysis in social sciences. The new method is inspired by another one where fuzzy sets were used. The advantage of the neutrosophic approach is that the respondents can express more accurately their thoughts and feelings, because indeterminacy is considered as well as an independent membership function of falseness. The method consists of designing a single-valued neutrosophic set from the collected data. This set serves to evaluate the satisfaction of a concept by a social group. The method is also based on the Neutrosociology theory, where the set A includes the notion of the triad of the aforementioned theory. This neutrosophic approach is applied to questionnaires where both discrete numerical and linguistic responses are possible.

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Neutrosophic Sociogram for Group Analysis

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Abstract. The sociogram is a technique of sociometry widely used in the field of sociology due to its simplicity and effectiveness. The purpose of this method is the graphical visualization of the relationships among the members of a social group. The sociogram has been extended to the fuzzy framework to include uncertainty in the so-called fuzzy sociograms. However, there could be indeterminate relationships among some members of the group, because they have not experience in performing some activities together, although potentially either future links or disagreements could be established among them. In this paper, we propose a neutrosophic sociogram, which allows representing the indeterminacies in the relationships among some members of a group. The advantage of neutrosophic sociograms over fuzzy sociograms is that the representation and calculation considering indeterminacy, allow us to achieve greater accuracy in the results, and a greater approach to the potentialities of the group in terms of the future bond among the members. A hypothetical example is proposed to illustrate the applicability of the method.

Keywords: Sociogram, neutrosophic sociogram, Neutrosociology, group analysis, sociometry analysis.

1 Introduction

The sociogram is a data analysis technique that focuses its attention on the way in which social relationships are established within any group, [1]. Jacob Levy Moreno, a Romanian psychiatrist, developed the technique in the mid-30s of the 20th century as a tool for exploratory and diagnostic purposes. Since its creation, sociometry appears as one of the most advanced and ordered strategies to describe and measure group dynamics, since it allows the quantitative study of interpersonal relationships in groups. The sociogram is an important example within sociometry.

In essence, the sociogram allows us to study the existing interpersonal preferences in a group of people. Currently it is widely used in various organizational settings, from small schools to large companies. It is also used in intelligence work in order to detect criminal networks. They can be briefly defined as graphics or tools used to determine the sociometry of a social space.

A social bond is a set of social relationships established between two or more individuals, which together, results in a group of social interaction, that is, when several members establish social bonds between them, forming a small social group. The social position is the specific place that every member occupies either in relation to the group of interaction or to the group in general.

This way, when applying a sociometric test or sociogram in a social group, the researcher may have knowledge of the way in which the group is socially related to each other, as well as the benefits and repercussions that this interaction has on each one of the members individually. This is very useful, since many times the degree of integration of an individual directly influences their performance. It is not groups dynamic but an easy-to-apply technique that can help us to better understand the world of relationships that is established in a social group.

Specifically, the sociogram starts from a questionnaire applied to the social group under investigation, where each member of the group specifies, in order of preference, with which other members they would like to carry out the activities asked in the questionnaire. This way, it starts with a matrix that is represented in the form of a graph, where the individual of the group preferred by the others and the isolated individual are determined.

In the classical sociogram, each member evaluates their preference through crisp values; however, some authors introduce the uncertainty that exists in these relationships, by using fuzzy graphs instead of crisp graphs with the so-called fuzzy sociogram, [2, 3]. Others make this type of graph even more complex with the definition of fuzzy graphs for polyfactor analysis, that is, fuzzy graphs that allow us studying more than one relationship between members of the social group. Some of these methods link this tool with classic cooperative game solutions such as Shapley value [2]. Sociograms can be applied in more than one moment to measure the change in relationships within the group.

It is not difficult to accept that the relationships between the members of the social groups may contain indeterminacies. Some members of the group may not know each other well, or may doubt on the behavior of the other in some activity. Therefore, in the classical sociogram and in the fuzzy sociogram it is not differentiated whether there is a mutual rejection between these individuals and therefore there is no possibility of a future relationship, or there is simply a potential bond that has not developed yet.

This fact has motivated the authors to propose a neutrosophic sociogram, where indeterminacy is included as part of the relationships between two individuals, because they are not well known, or there has been no possibility of creating a link between them or they have not determined the impossibility of such relationship.

Neutrosophy has served as the basis for sociology with the so-called Neutrosophic Sociology or Neutrosociology, which is defined as the study of sociology using neutrosophic scientific methods, [4, 5]. There are also neutrosophic graphs that allow us to measure concepts using graphs within the framework of Neutrosophy.

In this paper, neutrosophic sociograms are introduced, where the relationships among the members of a social group are graphically represented and quantitatively measured, including the indeterminacy of these relationships. Indeterminate relationships are considered as potential relationships in short, medium or long term, therefore it is a more accurate indicator than sociograms or fuzzy sociograms, since it guarantees a more precise measurement of group dynamics.

The paper is structured into the following sections: section 2 contains the main concepts related to sociograms and Neutrosophy. In section 3 the method proposed in this paper is introduced and a hypothetical example is used to illustrate how to apply it. The last section contains the conclusions.

2 Preliminaries

In this section, we summarize the main concepts of sociogram and Neutrosophy that will be used in this paper.

2.1 Sociogram

A sociogram is a graph that represents the relationship among the members of a social group. Firstly, the social group is identified. Then the investigator explains to the members the objective of the research. Next, the investigator designs a questionnaire for each member about the other members of the group he/she prefers to join in certain activities. E.g., in a group of students the teacher can ask every one of the members the following three questions [1]:

In order of preference, write the friends with whom
Q_1 : you want to join a quiz program.
Q_2 : you want to study in group.
Q_3 : you want to do volunteer activity.
Let us assume $S = \{s_1, s_2, \cdots, s_n\}$ denotes the set of interviewed. The results are represented in Table 1:

	Q_1	Q_2	Q_3
s_1	S_{11}	S_{12}	S_{13}
s_2	S_{21}	S_{22}	S_{23}
$\vdots$	$\vdots$	$\vdots$	$\vdots$
s_n	S_{n1}	S_{n2}	S_{n3}

Table 1: Generic table representing the relationship among the members of the social group.

The elements of Table 1 are the sets of members $S_{ij} \subset S$ $(i = 1,2, \ldots, n)(j = 1,2,3)$ such that the member s_i has chosen for answering the j-th question (Q_1, Q_2, or Q_3).

The classical sociogram is formed from a square matrix where every member of S is represented in one row and one column, such that elements of the matrix contain one number from 1 to 3, which is used by every s_k to evaluate his/her preference for member s_l.

The results are depicted in a directed graph, where every node represents a member of the social group and the edges E_{kl} represent that k-th member of the group selected the l-th member. An example of sociogram is depicted in Figure 1.

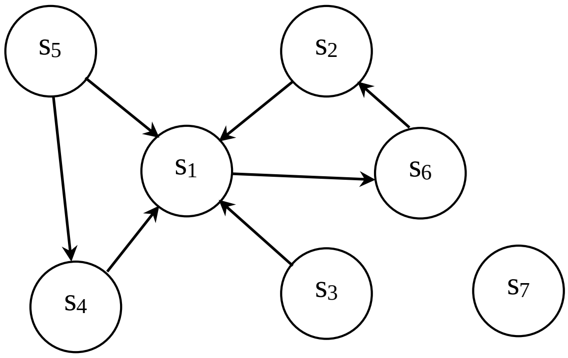

Figure 1: Example of sociogram of a group with seven members.

For example, in Figure 1 a social group of 7 members is investigated, where every node represents a member and every edge represents that one member prefers the other. Let us note in the example most of the members preferred s_1, while s_7 is isolated, he/she does not prefer anybody and nobody prefers him/her.

In the crisp sociogram, the graph is the final result, whereas in fuzzy sociogram the strength of every node (member) is measured with a function. f: $\{1,2,\cdots,n\} \rightarrow [0,1]$, where the closer is f(i) to 0 the more isolated member *i* is, thus it is an unpopular member possibly discriminated by the others, and the closer is f(i) to 1 the more linked member *i* is, then, *i* is a popular member or possibly the group's leader. This function can depend on fuzzy operators like t-norms or compensatory ones.

On the other hand, the preferred member can be selected using Shapley value [2]. Sometimes dendrograms are used to represent the sociogram [3].

2.2 Basic concepts on Neutrosophy

Definition 1: [6] Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow]^-0, 1^+[$, which satisfy the condition $^-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3^+$ for all x∈X. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indetermination and falsehood of x in A, respectively, and their images are standard or non-standard subsets of $]^-0, 1^+[$.

NS are useful only as a philosophical approach, so a *Single-Valued Neutrosophic Set* is defined to guarantee the applicability of Neutrosophy, see Definition 2.

Definition 2: ([6]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (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 $u_A, r_A, v_A : X \rightarrow [0,1]$, satisfy the condition $0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ for all x∈X. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indetermination and falsehood of x in A, respectively. For convenience, a *Single-Valued Neutrosophic Number* (SVNN)[7, 8] will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$ and satisfies $0 \leq a + b + c \leq 3$.

Neutrosophic Logic (NL) extends fuzzy logic. As stated by Florentin Smarandache, its author, a proposition P is characterized by three components; see [9-12]:

$$NL(P) = (T,I,F) \quad (2)$$

Where component T is the degree of truthfulness, F is the degree of falsehood and I is the degree of indetermination. T, I and F belong to the interval [0, 1], and they are independent from each other.

A *neutrosophic number* is formed by the algebraic structure a+bI, where I = indetermination. Below we formally describe some important concepts.

Definition 3: ([13-18]) Let R be a ring. The *neutrosophic ring* $\langle R \cup I\rangle$ 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 $\langle R \cup I\rangle$ and in addition $0 \cdot I = 0$. Also, I^{-1}, the inverse of I is not defined.

E.g., a neutrosophic ring is $\langle \mathbb{Z} \cup I\rangle$ generated by $\mathbb{Z}$, which is the set of integers.

Some operation using I is $I + I + \ldots + I = nI$.

Definition 4: ([19, 20]) A *neutrosophic number* N is also defined as a number:

$$N = d + I \quad (3)$$

Where d is the *determined part* and I is the *indeterminate part* of N.

Example 1. N = 1+I, where 1 is the determined part and I is the indeterminate part, and for I = [0, 1] we have N = [1, 2].

Let $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$ be two neutrosophic numbers, then some operations between them are:

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

2. $N_1 - N_2 = a_1 - a_1 + (b_1 - b_2)I$ (Difference),
3. $N_1 \times N_2 = a_1a_2 + (a_1b_2 + b_1a_2 + b_1b_2)I$ (Multiplication),
4. $\frac{N_1}{N_2} = \frac{a_1+b_1I}{a_2+b_2I} = \frac{a_1}{a_2} + \frac{a_2b_1-a_1b_2}{a_2(a_2+b_2)}I$ (Division).

A *neutrosophic matrix* is a matrix whose components are elements of $\langle R \cup I \rangle$.

Thus, it is possible to generalize the operations between vectors and matrices on R to the ring $\langle R \cup I \rangle$. See Example 2.

Example 2. Given two matrices, $A = \begin{pmatrix} 3 & 9 \\ -1 & 7 \end{pmatrix}$ and $B = \begin{pmatrix} 1 & 8 & I \\ 1 & 3 & 2I \end{pmatrix}$, $AB = \begin{pmatrix} 12 & 51 & 21I \\ 6 & 13 & 13I \end{pmatrix}$.

A *neutrosophic graph* is a graph with at least one neutrosophic edge linking two nodes, that is to say, there is an edge with an indetermination on its two nodes connection, [6, 21-23], see Figure 2.

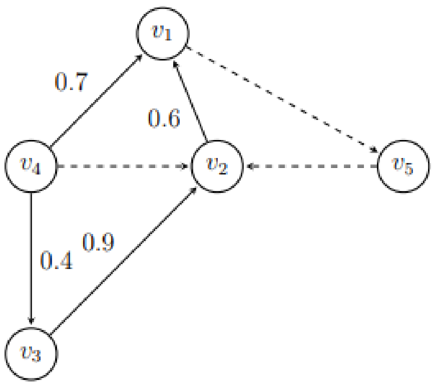

Figure 2: Example of neutrosophic graph. Source [6].

The de-neutrosophication process was introduced by Salmeron and Smarandache in [19], which converts a neutrosophic number in one numeric value. This process provides a range of numbers for centrality using as a base the maximum and minimum values of $I = [a_1, a_2] \subseteq [0, 1]$, based on Equation 4:

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \tag{4}$$

3 Neutrosophic sociogram

In this section, we introduce for the first time the concepts of neutrosophic sociograms. Firstly, the interviewers have to explain to the members of the social group the goal for applying the questionnaire and the type of possible answers required by the researchers[24, 25].

The new questionnaire is a variant of that summarized in Table 1. Now, we have $Q_1, Q_2, \ldots, Q_m$ the questions to be answered. Again, $S = \{s_1, s_2, \cdots, s_n\}$ denotes the set of interviewed.

The possible questions are the following:
In order of preference, write the friends with whom:
Q_1 : you want to join quiz program.
Q_2 : you want to study in group.
Q_3 : you want to do volunteer activity.
Apart, write the members of the group with whom:
Q_1 : you are not sure to join quiz program.
Q_2 : you are not sure to study in group.
Q_3 : you are not sure to do volunteer activity.

With this new method we maintain the elements of Table 1 like $S_{ij} \subset S$ $(i = 1,2, \ldots, n)(j = 1,2, \cdots, m)$ meaning the answers of s_i about his/her preferred members for doing activity asked in Q_j. Additionally, $O_{ij} \subset S$ $(i = 1,2, \ldots, n)(j = 1,2, \cdots, m)$ means the list of the members of the group which s_i is not sure to join in the activity asked in question Q_j, they satisfy $S_{ij} \cap O_{ij} = \emptyset$. Also, interviewer provides a weight to every question, which is denoted by $\Omega = \{\omega_1, \omega_2, \cdots, \omega_m\}$, where $\sum_{j=1}^{m} \omega_j = 1$ and $\omega_j \in [0, 1]$.

Then Table 1 converts into Table 2, where sets O_{ij} are included.

	Q_1	Q_2	$\cdots$	Q_m
s_1	$S_{11}; O_{11}$	$S_{12}; O_{12}$	$\cdots$	$S_{1m}; O_{1m}$
s_2	$S_{21}; O_{21}$	$S_{22}; O_{22}$	$\cdots$	$S_{2m}; O_{2m}$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
s_n	$S_{n1}; O_{n1}$	$S_{n2}; O_{n2}$	$\cdots$	$S_{nm}; O_{nm}$

Table 2: Generic table representing the relationship among the members of the social group for the neutrosophic sociogram.

According to Table 2, the interviewed has also the possibility to include those members of the group whom he/she is not sure to carry out the activity. We consider this indeterminate selected group is the potential extension of the links among the members of the group. The advantage is that we can influence those imprecise relationships to strength the group unity, instead of carrying out some external exercise, e.g. didactic activity in the group class, and later to apply another sociogram to study the dynamical changes in the social group.

Using Table 2 the *evaluation matrix* $R^j = \left(r^j_{kl}\right)$, where r^j_{kl} is the number of times (0 or 1) that s_k selects s_l in Q_j. When k = l we define $r^j_{kl} = 1$.

Thus, $F = \sum_{j=1}^{m} \omega_j R^j$, $F = (f_{kl})$ and if k = l we have $f_{kl} = 1$. f_{kl} means the degree of preference of s_l by s_k. If $f_{kl} = 1$ then s_k strongly prefers s_l and $f_{kl} = 0$ means s_k never prefers s_l.

The *fuzzy amicable degree* g_{kl} between s_k and s_l is calculated through formula 5:

$$\frac{2}{g_{kl}} = \frac{1}{f_{kl}} + \frac{1}{f_{lk}} \tag{5}$$

Where the arithmetic $1/_0 = \infty$ and $1/_\infty = 0$ is used.

Equivalently, $T^j = \left(t^j_{kl}\right)$, where t^j_{kl} is the number of times that s_k selects or hesitates about s_l in Q_j (0 or 1), $T = \sum_{j=1}^{m} \omega_j T^j$. When k = l we define $t^j_{kl} = 1$. Matrix T determines the preferences of s_l by s_k or the possibility that he/she would prefer him/her in the future. Therefore, the *neutrosophic amicable degree* u_{kl} between s_k and s_l is calculated with Equation 6:

$$\frac{2}{u_{kl}} = \frac{1}{t_{kl}} + \frac{1}{t_{lk}} \tag{6}$$

The fuzzy sociogram is represented with the elements of F, whereas the *neutrosophic sociogram* is a neutrosophic graph, such that the elements of the fuzzy sociogram are represented with continuous lines, and the other edges are represented with dashed lines. Every edge of the neutrosophic sociogram is associated with the fuzzy value g_{kl} and the other edges are associated with symbol I. Let us note that we are dealing with non-directed graphs.

The interval of indeterminacy is calculated as $I_{kl} = [g_{kl},\ u_{kl}]$. $\lambda(I_{kl})$ indicates a unique value for representing the amicable relationship between s_k and s_l, according to Equation 4, whereas $I_{kl} = u_{kl} - g_{kl}$ measures the degree of indeterminacy.

The leadership of the k-th member of the group is measured with the following index [2]:

$$\mu(k) = \frac{\sum_l g_{kl}}{\sum_k \sum_l g_{kl}} \tag{7}$$

Additionally, the potential leadership of the k-th member of the group is measured with the following index:

$$\theta(k) = \frac{\sum_l u_{kl}}{\sum_k \sum_l u_{kl}} \tag{8}$$

Below, we use an example for demonstrating how to use neutrosophic sociograms in a simulated case.

Example 3.

A teacher of a group of 10 elementary school students wants to investigate the relationships between the children and the potential links among the group members. To do this, he asks three questions to analyze preferences and possible future links among students. He also uses this study to determine current and potential leaders within the group and if there is any isolated student. That is why he decides to apply the neutrosophic sociogram.

The total questionnaire consists of the following pairs of questionnaires:

Write your friends with whom:

Q_1: you want to join a quiz program.

Q_2: you want to study in group.

Q_3: you want to do volunteer activity.

Apart, write the members of the group in with whom:

Q_1^I : you are not sure to join quiz program.

Q_2^I : you are not sure to study in group.

Q_3^I : you are not sure to do volunteer activity.

We denote by $S = \{s_1, s_2, \cdots, s_{10}\}$ the set of members of the group of class. Results are shown in Table 3.

	$Q_1; Q_1^I$	$Q_2; Q_2^I$	$Q_3; Q_3^I$
s_1	$s_3, s_6, s_8; s_4$	$s_2, s_6, s_{10}; s_4$	$s_3, s_6, s_9; s_4$
s_2	$s_3, s_4, s_5; s_7$	$s_1, s_4, s_9; s_7$	$s_1, s_3, s_4; s_7$
s_3	$s_1, s_2, s_9; s_6$	$s_5, s_8, s_9; s_2$	$s_2, s_6, s_7; s_{10}$
s_4	$s_2, s_5, s_6; s_9$	$s_3, s_6, s_{10}; s_9$	$s_3, s_5, s_6; s_2$
s_5	$s_3, s_7, s_{10}; s_9$	$s_4, s_7, s_8; s_1$	$s_4, s_8, s_{10}; s_1$
s_6	$s_1, s_7, s_8; s_9$	$s_1, s_7, s_8; s_9$	$s_1, s_2, s_9; s_3$
s_7	$s_4, s_5, s_9; s_2$	$s_2, s_4, s_9; s_5$	$s_6, s_8, s_9; s_1$
s_8	$s_5, s_7, s_9; s_3$	$s_4, s_6, s_9; s_7$	$s_1, s_2, s_5; s_3$
s_9	$s_1, s_8, s_{10}; s_2$	$s_2, s_4, s_5; s_1$	$s_1, s_4, s_5; s_2$
s_{10}	$s_2, s_5, s_7; s_9$	$s_2, s_3, s_5; s_4$	$s_2, s_4, s_5; s_8$

Table 3: Preferences and potential links between the members of the group.

In Table 3, for every child in the row, before the semicolon we have the children he/she prefers for performing the activity asked in questions Q_j. After the semicolon there are the children that the student is not sure about to perform activity asked in Q_j^I. Interestingly, student denoted by s_3 prefers to join quiz program with s_2, however he/she is not sure to study in group with s_2. This shows the capacity of the neutrosophic method to model more feelings of the members than its precedents do.

Here we assumed the three questions are equally important, thus, $\omega_j = \frac{1}{3}$ (j = 1,2,3).

Tables 4, 5, and 6 contains the evaluation matrices for Q_1, Q_2, and Q_3, respectively.

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
s_1	1	0	1	0	0	1	0	1	0	0
s_2	0	1	1	1	1	0	0	0	0	0
s_3	1	1	1	0	0	0	0	0	1	0
s_4	0	1	0	1	1	1	0	0	0	0
s_5	0	0	1	0	1	0	1	0	0	1
s_6	1	0	0	0	0	1	1	1	0	0
s_7	0	0	0	1	1	0	1	0	1	0
s_8	0	0	0	0	1	0	1	1	1	0
s_9	1	0	0	0	0	0	0	1	1	1
s_{10}	0	1	0	0	1	0	1	0	0	1

Table 4: Evaluation matrix R^1 for Q_1.

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
s_1	1	1	0	0	0	1	0	0	0	1
s_2	1	1	0	1	0	0	0	0	1	0
s_3	0	0	1	0	1	0	0	1	1	0
s_4	0	0	1	1	0	1	0	0	0	1
s_5	0	0	0	1	1	0	1	1	0	0
s_6	1	0	0	0	0	1	1	1	0	0
s_7	0	1	0	1	0	0	1	0	1	0
s_8	0	0	0	1	0	1	0	1	1	0
s_9	0	1	0	1	1	0	0	0	1	0
s_{10}	0	1	1	0	1	0	0	0	0	1

Table 5: Evaluation matrix R^2 for Q_2

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
s_1	1	0	1	0	0	1	0	0	1	0
s_2	1	1	1	1	0	0	0	0	0	0
s_3	0	1	1	0	0	1	1	0	0	0
s_4	0	0	1	1	1	1	0	0	0	0
s_5	0	0	0	1	1	0	0	1	0	1
s_6	1	1	0	0	0	1	0	0	1	0
s_7	0	0	0	0	0	1	1	1	0	1
s_8	1	1	0	0	1	0	0	1	0	0
s_9	1	0	0	1	1	0	0	0	1	0
s_{10}	0	1	0	1	1	0	0	0	0	1

Table 6: Evaluation matrix $R^3$for Q_3.

Table 7 contains the result of F, the fuzzy matrix.

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
s_1	1	0.33	0.66	0	0	1	0	0.33	0.33	0.33
s_2	0.66	1	0.66	1	0.33	0	0	0	0.33	0
s_3	0.33	0.66	1	0	0.33	0.33	0.33	0.33	0.66	0
s_4	0	0.33	0.66	1	0.66	1	0	0	0	0.33
s_5	0	0	0.33	0.66	1	0	0.66	0.66	0	0.66
s_6	1	0.33	0	0	0	1	0.66	0.66	0.33	0
s_7	0	0.33	0	0.66	0.33	0.33	1	0.33	0.66	0.33
s_8	0.33	0.33	0	0.33	0.66	0.33	0.33	1	0.66	0
s_9	0.66	0.33	0	0.66	0.66	0	0	0.33	1	0.33
s_{10}	0	1	0.33	0.33	1	0	0.33	0	0	1

Table 7: Fuzzy matrix.

Table 8 summarizes the matrix G of fuzzy amicable degree.

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
s_1	1	0.44	0.44	0	0	1	0	0.33	0.44	0
s_2	0.44	1	0.66	0.5	0	0	0	0	0.33	0
s_3	0.44	0.66	1	0	0.33	0	0	0	0	0
s_4	0	0.5	0	1	0.66	0	0	0	0	0.33
s_5	0	0	0.33	0.66	1	0	0.44	0.66	0	0.8
s_6	1	0	0	0	0	1	0.44	0.44	0	0
s_7	0	0	0	0	0.44	0.44	1	0.33	0	0.33
s_8	0.33	0	0	0	0.66	0.44	0.33	1	0.44	0
s_9	0.44	0.33	0	0	0	0	0	0.44	1	0
s_{10}	0	0	0	0.33	0.8	0	0.33	0	0	1

Table 8: Matrix of fuzzy amicable degree.

Equivalently, we calculate matrices T^1, T^2, and T^3, which are summarized in Tables 9, 10, and 11, respectively.

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
s_1	1	0	1	1	0	1	0	1	0	0
s_2	0	1	1	1	1	0	1	0	0	0
s_3	1	1	1	0	0	1	0	0	1	0
s_4	0	1	0	1	1	1	0	0	1	0
s_5	0	0	1	0	1	0	1	0	1	1
s_6	1	0	0	0	0	1	1	1	1	0
s_7	0	1	0	1	1	0	1	0	1	0
s_8	0	0	1	0	1	0	1	1	1	0
s_9	1	1	0	0	0	0	0	1	1	1
s_{10}	0	1	0	0	1	0	1	0	1	1

Table 9: Evaluation matrix $T^1$for Q_1.

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
s_1	1	1	0	1	0	1	0	0	0	1
s_2	1	1	0	1	0	0	1	0	1	0
s_3	0	1	1	0	1	0	0	1	1	0
s_4	0	0	1	1	0	1	0	0	1	1
s_5	1	0	0	1	1	0	1	1	0	0
s_6	1	0	0	0	0	1	1	1	1	0
s_7	0	1	0	1	1	0	1	0	1	0
s_8	0	0	0	1	0	1	1	1	1	0
s_9	1	1	0	1	1	0	0	0	1	0
s_{10}	0	1	1	1	1	0	0	0	0	1

Table 10: Evaluation matrix $T^2$for Q_2.

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
s_1	1	0	1	1	0	1	0	0	1	0
s_2	1	1	1	1	0	0	1	0	0	0
s_3	0	1	1	0	0	1	1	0	0	1
s_4	0	1	1	1	1	1	0	0	0	0
s_5	1	0	0	1	1	0	0	1	0	1
s_6	1	1	1	0	0	1	0	0	1	0
s_7	1	0	0	0	0	1	1	1	0	1
s_8	1	1	1	0	1	0	0	1	0	0
s_9	1	1	0	1	1	0	0	0	1	0
s_{10}	0	1	0	1	1	0	0	1	0	1

Table 11: Evaluation matrix $T^3$for Q_3.

Table 12 contains the values of matrix T.

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
s_1	1	0.33	0.66	1	0	1	0	0.33	0.33	0.33
s_2	0.66	1	0.66	1	0.33	0	1	0	0.33	0
s_3	0.33	1	1	0	0.33	0.66	0.33	0.33	0.66	0.33
s_4	0	0.66	0.66	1	0.66	1	0	0	0.66	0.33
s_5	0.66	0	0.33	0.66	1	0	0.66	0.66	0.33	0.66
s_6	1	0.33	0.33	0	0	1	0.66	0.66	1	0
s_7	0.33	0.66	0	0.66	0.66	0.33	1	0.33	0.66	0.33
s_8	0.33	0.33	0.66	0.33	0.66	0.33	0.66	1	0.66	0
s_9	1	1	0	0.66	0.66	0	0	0.33	1	0.33
s_{10}	0	1	0.33	0.66	1	0	0.33	0.33	0.33	1

Table 12: Matrix T.

Table 13 summarizes the values of the amicable degrees in matrix $U = (u_{kl})$

	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
s_1	1	0.44	0.44	0	0	1	0	0.33	0.5	0
s_2	0.44	1	0.8	0.8	0	0	0.8	0	0.5	0
s_3	0.44	0.8	1	0	0.33	0.44	0	0.44	0	0.33
s_4	0	0.8	0	1	0.66	0	0	0	0.66	0.44
s_5	0	0	0.33	0.66	1	0	0.66	0.66	0.44	0.8
s_6	1	0	0.44	0	0	1	0.44	0.44	0	0
s_7	0	0.8	0	0	0.66	0.44	1	0.44	0	0.33
s_8	0.33	0	0.44	0	0.66	0.44	0.44	1	0.44	0
s_9	0.5	0.5	0	0.66	0.44	0	0	0.44	1	0.33
s_{10}	0	0	0.33	0.44	0.8	0	0.33	0	0.33	1

Table 13: Matrix U.

According to Tables 8 and 13 we have that, for example, the relationship between the students s_2 and s_3 and its potentiality is $I_{23} = I_{32} = [0.66, 0.8]$, which means that currently the amicable degree between them is 0.66, however this degree can be potentially increased up to 0.8 in the future. Thus, the teacher should work to strengthen the relationship between these two students, instead of students s_1 and s_2 with $I_{12} = I_{21} = [0.44, 0.44]$, which seems to do not have the opportunity of changing and is weaker than the relationship between s_2 and s_3.

Calculating the leadership index with Equations 7 and 8, we have the following results:

$\mu =$
$(0.127217, 0.102159, 0.084811, 0.086739, 0.135698, 0.100231, 0.088666, 0.111796, 0.077101, 0.085582)$.

Whereas, $\theta =$
$(0.098068, 0.114461, 0.100117, 0.094262, 0.120609, 0.087822, 0.097190, 0.099532, 0.102459, 0.085480)$.

It is interpreted that student 5 is the leader according to $\mu(5) = 0.135698$ that is a maximum; however, potentially his/her leadership can slightly diminish because of $\theta(5) = 0.120609$.

Finally, we depict the neutrosophic sociogram of the example. See Figure 3.

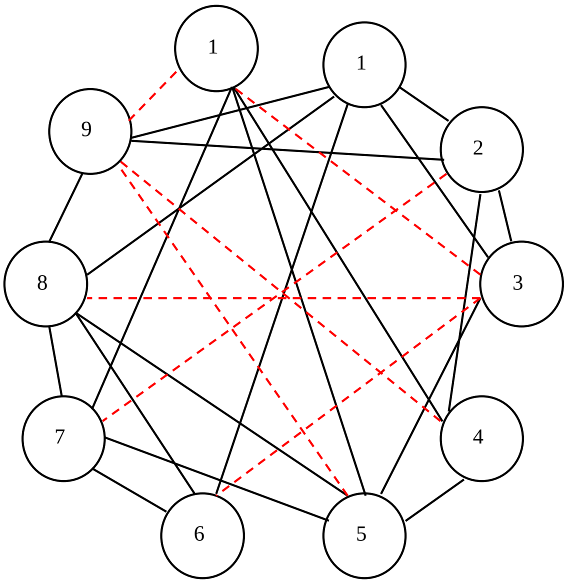

Figure 3: Neutrosophic sociogram of the example.

Let us note that the neutrosophic sociogram in Figure 3 shows in black continuous lines the relationships between the pair of students with fuzzy amicable degree bigger than 0, from Table 8. With dashed lines in red, we represent the edges with amicable degree bigger than 0 in matrix U and null value in matrix G, according to Table 13.

The results represented with continuous lines model the current preferences and the dashed lines represent the potential future links. For simplicity, we omitted in the graph the fuzzy amicable degrees values associated with the edges and the symbol I associated with the lines in red. Let us remark that this is a non-directed graph.

Conclusion

This paper introduces the neutrosophic sociograms. The crisp and fuzzy sociograms only take into account the preference relationships between individuals of the social group under investigation. However, it is possible that there are individuals in the group, especially if it is a large group, where some individuals do not know each other well and therefore are not designated as preferred ones. This type of relationship with lack of knowledge or lack of trust between two members can be consider an indeterminate relationship, where the future of the bond may be a preference relationship or a non-preference relationship, depending on group dynamics. Neutrosophic sociograms consider these indeterminacies, which are measured a possible future relationship. They are non-directed neutrosophic graphs. In this paper, we introduce a method to calculate the matrix of the graph, which is a neutrosophic matrix. The calculations include the weights or importance of each of the questions used to measure the preferred individuals to carry out the activities with. The advantage of defining a neutrosophic sociogram, instead of a crisp or fuzzy sociogram, is that it achieves greater accuracy in the representation of social relationships, and offers a better idea of what group dynamics is like and in which individuals the group cohesion can be strengthened. In future works we will study in depth the relationship of neutrosophic sociograms with Shapley value, taking into account that in the offsets [26, 27] there is an example of a solution for cooperative n-personal games using these neutrosophic sets [28].

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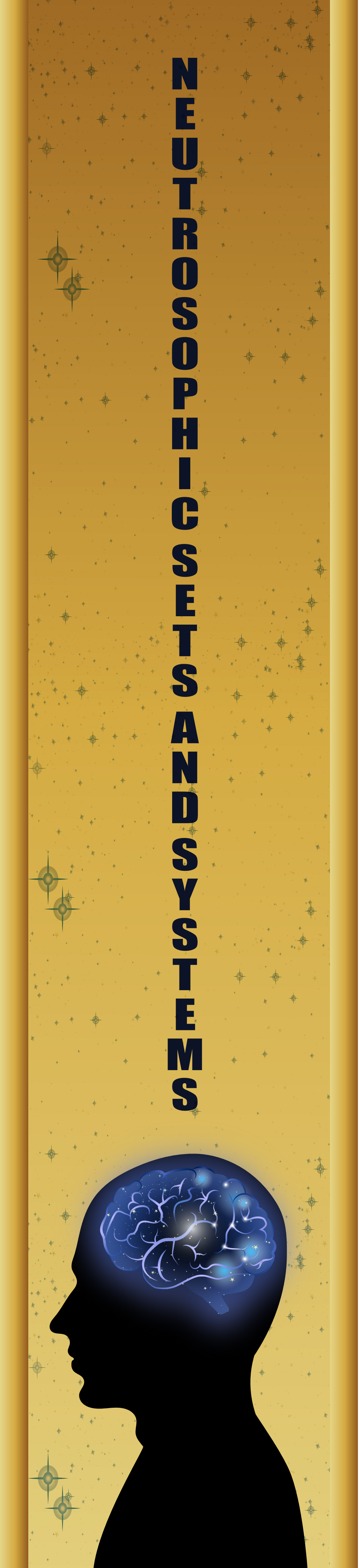

Information about the journal

The main objective of this special issue is to divulge the applicability of the Neutrosophic Theory and to explore the possibilities and advantages of neutrosophic tools, through both the presentation of thorough research and case studies in solving social problems in Latin America. The best presentations discussed at the III International Congress of Educational Research and University Innovation, turned into papers, show us the capacity for socialization of neutrosophic knowledge and its link with this science of validation and consolidation of scientific knowledge. This publication with authors from 11 countries that we place in the hands of the international scientific community, constitutes an example of how in Latin America the Neutrosophy is contributing to complex solutions based on the results of scientific research carried out by teachers and students committed to the social responsibility of continuing to progress for the benefit of humanity.

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