



Enhancing Project Selection with Neutrosophic TOPSIS: Navigating Uncertainty in Post-Pandemic Decision-Making

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Abstract

This article explores the implementation of Neutrosophic TOPSIS, an advanced decision-making framework that extends classical and fuzzy set theories to handle the complexities of project selection amid uncertainty and indeterminacy. Neutrosophic sets are characterized by three parameters: truth, indeterminacy, and falsehood, which allow for a nuanced assessment of alternatives against defined criteria. Utilizing neutrosophic scales and expert evaluations, this method prioritizes projects by efficiently balancing multiple truth levels and addressing specific challenges such as judicial process optimization and labor education enhancement. The case study within the article demonstrates the application of Neutrosophic TOPSIS to select the most suitable project for improving labor relations and judicial efficiency in a post-pandemic world. The methodology proved effective in identifying the Digital Platform for Labor Education project as the optimal solution, given its alignment with strategic objectives and potential to handle identified challenges robustly. Future work could integrate Neutrosophic TOPSIS with other decision-making models and expand its application to more complex scenarios, potentially incorporating automated tools for a broader and more dynamic evaluation process.

Keywords: Neutrosophic TOPSIS; project selection; decision-making; uncertainty; labor education.

1. Introduction

Decision-making in project selection faces inherent challenges of uncertainty and indeterminacy, especially in complex and shifting contexts [1,2,3]. In this scenario, the use of neutrosophic sets emerges as a crucial tool for efficiently managing such uncertainties. A neutrosophic set, an extension of classical set theory and fuzzy set theory, provides a framework to model uncertainty through three parameters: truth, indeterminacy, and falsehood [4]. This ability to handle multiple degrees of certainty and their possible overlaps facilitates a more precise evaluation of alternatives and criteria in project selection.

Applying the neutrosophic TOPSIS method [5], it is possible to integrate expert evaluations on various potential projects using neutrosophic scales to determine which project could best handle the identified challenges, such as optimizing judicial processes [6] and improving labor education [7]. This methodology not only allows for a detailed and personalized weighting of importance criteria but also adapts analyses to the complexities of the current environment, especially in post-pandemic situations that demand innovative and effective responses.

This neutrosophic approach is particularly relevant for contexts where decision accuracy is critical for the success and sustainability of proposed initiatives, thus underscoring the relevance of integrating advanced decision techniques in project management and public policy [8].

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Additionally, the versatility of neutrosophic sets in handling the dynamics of project assessment underlines their suitability for real-world applications where traditional binary decisions are insufficient. Neutrosophic TOPSIS provides a robust quantitative framework that allows decision-makers to compare and prioritize projects not only based on their potential benefits but also considering the possible risks and ambiguities associated with each option [9,10]. By employing this method, organizations can navigate the complexities of modern project environments more effectively, ensuring that the selected projects align closely with strategic objectives and are resilient to varying degrees of uncertainty. This strategic alignment is essential in maximizing resource utilization and achieving long-term sustainability in project outcomes.

2. Preliminaries

2.1 Neutrosophic set.

A neutrosophic set is an extension of classical and fuzzy set theory that allows modeling uncertainty and indeterminacy [10]. An element of a neutrosophic set is associated with three parameters: the degree of truth T, the degree of indeterminacy I, and the degree of falsehood F of x in A, respectively, and their images constitute standard or non-standard subsets within the range {0,1}. For this study, the following functions are defined:

- $T = \vartheta_A(x)$ for true membership functions, where $\in \{0,1\}$.
- $I = \eta_A(x)$ for indeterminate membership functions, where $\in \{0,1\}$.
- $F = \delta_A(x)$ for false membership functions, where $\in \{0,1\}$.

Therefore, the neutrosophic number defined for the study is determined as $A = (T, I, F)$, where it satisfies the following condition $0 \leq T + I + F \leq 3$. Whereas to define an ordinary point within the Single-Valued Neutrosophic Set (SVNS), the following equation is used [11]:

$$F(Q) = \frac{1 + T - 2I - F}{2} \tag{1}$$

For the development of the study, evaluations concerning projects based on criteria (challenges) are proposed. For this, a scale of importance for each SVNN is defined as shown in Table 1. Meanwhile, to determine the weight of the experts and the weight of the criteria, Table 2 is used.

Table 1: Linguistic terms representing the weight of the importance of the criteria and the experts.

Linguistic scale	SVNN
Very high importance	(0.92,0.16,0.11)
High importance	(0.72,0.36,0.29)
Medium importance	(0.52,0.56,0.59)
Moderately low importance	(0.22,0.86,0.79)
Very low importance	(0.12,0.96,0.98)

Table 2: Neutrosophic measurement scales for alternatives and evaluation criteria.

Linguistic scale	SVNN
Very high importance	(0.94,0.1,0.15)
High importance	(0.74,0.15,0.25)
Medium importance	(0.54,0.45,0.5)
Moderately low importance	(0.24,0.75,0.75)
Very low importance	(0.14,0.95,0.99)

2.2 Neutrosophic TOPSIS.

The TOPSIS method for SVNN consists of the following [12], assuming that $A = \{\rho_1, \rho_2, \dots, \rho_m\}$ is a set of alternatives and $G = \{\beta_1, \beta_2, \dots, \beta_m\}$ is a set of criteria, the following steps will be carried out:

Step 1: Determine the weight of the experts. For this, specialists evaluate according to the linguistic scale shown in Table 1, and calculations are made with their associated SVNN, let $A_t = (a_t, b_t, c_t)$ be the SVNN corresponding to the t-th decision-maker ($t = 1, 2, \dots, k$). The weight is calculated by equation (2).

$$\lambda_t = \frac{a_t + b_t \left(\frac{a_t}{a_t + c_t}\right)}{\sum_{t=1}^k a_t + b_t \left(\frac{a_t}{a_t + c_t}\right)} \tag{2}$$

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

Step 2: Construction of the aggregated single-valued neutrosophic decision matrix. This matrix is defined by $D = \sum_{t=1}^k \lambda_t D^t$, where $d_{ij} = (u_{ij}, r_{ij}, v_{ij})$ and is used to aggregate all the individual evaluations. Where d_{ij} is calculated as the aggregation of the evaluations given by each expert $(u_{ij}^t, r_{ij}^t, v_{ij}^t)$ (see Table 2), using the weights λ_t of each one with the help of Equation (3). In this way, a matrix $D = (d_{ij})_{ij}$ is obtained, where each d_{ij} is an SVNN ($i = 1, 2, \dots, m; j = 1, 2, \dots, n$).

Let $\{A_1, A_2, \dots, A_n\}$ be a set of n SVNNs, where $A_j = a_j, b_j, c_j$ ($j = 1, 2, \dots, n$), then the Single-Valued Neutrosophic Weighted Average Operator (SVNWAO) over the set is calculated by the following Equation [13]:

$$\sum_{j=1}^n \lambda_j A_j = \left(1 - \prod_{j=1}^n (1 - a_j)^{\lambda_j}, \prod_{j=1}^n b_j^{\lambda_j}, \prod_{j=1}^n c_j^{\lambda_j} \right) \tag{3}$$

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

Step 3: Determination of the Criteria Weight. Suppose that the weight of each criterion is given by $W = (w_1, w_2, \dots, w_n)$, where w_j denotes the relative importance of the criterion $\lambda_t w_j^t = (a_j^t, b_j^t, c_j^t)$. To obtain the neutrosophic weights, the neutrosophic scale (found in Table 1) and equation 3 are used.

Step 4: Construction of the weighted average single-valued neutrosophic decision matrix with respect to the criteria.

Step 5: Calculation of the positive and negative SVNN ideal solutions. The criteria can be classified as cost type or benefit type. Let G_1 be the set of benefit type criteria and G_2 the cost type criteria. The ideal alternatives will be defined as follows [14]:

$$\rho^+ = (a_{\rho^+w}(\beta_j), b_{\rho^+w}(\beta_j), ac_{\rho^+w}(\beta_j)) \tag{4}$$

Denotes the positive ideal solution, corresponding to G_1 .

$$\rho^- = (a_{\rho^-w}(\beta_j), b_{\rho^-w}(\beta_j), ac_{\rho^-w}(\beta_j)) \tag{5}$$

Denotes the negative ideal solution, corresponding to G_2 . Where:

$$\begin{aligned} a_{\rho^+w}(\beta_j) &= \begin{cases} \max_i a_{\rho^+w}(\beta_j), & si \ j \in G_1 \\ \min_i a_{\rho^+w}(\beta_j), & si \ j \in G_2, \end{cases} & a_{\rho^-w}(\beta_j) &= \begin{cases} \min_i a_{\rho^-w}(\beta_j), & si \ j \in G_1 \\ \max_i a_{\rho^-w}(\beta_j), & si \ j \in G_2, \end{cases} \\ b_{\rho^+w}(\beta_j) &= \begin{cases} \max_i b_{\rho^+w}(\beta_j), & si \ j \in G_1 \\ \min_i b_{\rho^+w}(\beta_j), & si \ j \in G_2, \end{cases} & b_{\rho^-w}(\beta_j) &= \begin{cases} \min_i b_{\rho^-w}(\beta_j), & si \ j \in G_1 \\ \max_i b_{\rho^-w}(\beta_j), & si \ j \in G_2, \end{cases} \\ c_{\rho^+w}(\beta_j) &= \begin{cases} \max_i c_{\rho^+w}(\beta_j), & si \ j \in G_1 \\ \min_i c_{\rho^+w}(\beta_j), & si \ j \in G_2, \end{cases} & c_{\rho^-w}(\beta_j) &= \begin{cases} \min_i c_{\rho^-w}(\beta_j), & si \ j \in G_1 \\ \max_i c_{\rho^-w}(\beta_j), & si \ j \in G_2, \end{cases} \end{aligned}$$

Step 6: Calculation of the distances to the positive and negative SVNN ideal solutions. It is calculated using the following Equations [15]:

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

$$s_i^- = \left(\frac{1}{3} \sum_{j=1}^n \left\{ (a_{ij} - a_j^-)^2 + (b_{ij} - b_j^-)^2 + (c_{ij} - c_j^-)^2 \right\} \right)^{\frac{1}{2}} \quad (7)$$

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 [16].

$$\tilde{\rho}_j = \frac{s^-}{s^+ + s^-} \quad (8)$$

Where $0 \leq \tilde{\rho}_j \leq 1$.

Step 8: Determination of the order of the alternatives.

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






4. Case Study

In the pursuit of enhancing labor relations, judicial efficiency, and worker education and protection, five innovative projects have been identified that leverage digital tools and collaborative platforms. These initiatives are designed to streamline judicial processes, facilitate conflict resolution, and promote awareness of labor rights and responsibilities. Below is a detailed overview of the proposed initiatives:

Table 3: Proposed Projects

Code	Description
PAML-001	Create labor advice and mediation centers to resolve labor conflicts efficiently and equitably.
SGJE-002	Implement a comprehensive electronic system for the management of judicial cases, by facilitating the digitalization of the judicial process.
PDEL-003	Develop a digital platform that provides educational resources on labor rights and obligations for both workers and employers.
FDNLL-004	Establish a permanent forum for dialogue between government, employers, workers, and legal experts to review and propose improvements to labor legislation.
IREPL-005	Develop economic support and labor protection programs for workers affected by economic crises and pandemics.

Given that not all projects can be implemented at once and must be incorporated gradually, it is proposed to identify the most important ones. So that they can solve and cover most of the identified challenges. For this purpose, it is proposed to model the Neutrosophic TOPSIS method and classify the best project through neutrosophic evaluation, to determine the scope of improvement to the identified challenges. For the development of this method and the required neutrosophic analysis, it is necessary to work with five criteria. These criteria respond to the main challenges for the performance of the role of legal advisor in Ecuadorian companies in the post-pandemic period:

-  Complexity of the post-pandemic role of legal advisors (CR1).
-  Inadequate application of labor regulations (CR2).
-  Lack of awareness of labor rights among workers (CR3).
-  Need for optimization of judicial digitalization (CR4).
-  Impact of the economic crisis on the protection of labor rights (CR5).

This new criterion (CR5) considers how the economic conditions resulting from the pandemic affect companies' ability to fulfill labor obligations. Furthermore, it examines the subsequent pressure on the legal system to address

these challenges. Once the criteria that evaluate each of these projects have been identified, the neutrosophic TOPSIS is implemented. The modeling is presented in Tables 4 to 11. Equal weight was assigned to all the experts in this case study.

Table 4: Individual evaluations

C1					
Project	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
PAML-001	(0.24,0.75,0.75)	(0.24,0.75,0.75)	(0.24,0.75,0.75)	(0.24,0.75,0.75)	(0.74,0.15,0.25)
SGJE-002	(0.54,0.45,0.5))	(0.74,0.15,0.25)	(0.54,0.45,0.5))	(0.94,0.1,0.15))	(0.24,0.75,0.75)
PDEL-003	(0.94,0.1,0.15))	(0.94,0.1,0.15))	(0.94,0.1,0.15))	(0.94,0.1,0.15))	(0.74,0.15,0.25)
FDNLL-004	(0.14,0.95,0.99)	(0.74,0.15,0.25)	(0.74,0.15,0.25)	(0.24,0.75,0.75)	(0.24,0.75,0.75)
IREPL-005	(0.24,0.75,0.75)	(0.14,0.95,0.99)	(0.74,0.15,0.25)	(0.14,0.95,0.99)	(0.54,0.45,0.5))
C2					
PAML-001	(0.54,0.45,0.5))	(0.24,0.75,0.75)	(0.74,0.15,0.25)	(0.54,0.45,0.5))	(0.54,0.45,0.5))
SGJE-002	(0.74,0.15,0.25)	(0.54,0.45,0.5))	(0.54,0.45,0.5))	(0.14,0.95,0.99)	(0.74,0.15,0.25)
PDEL-003	(0.74,0.15,0.25)	(0.94,0.1,0.15))	(0.74,0.15,0.25)	(0.74,0.15,0.25)	(0.94,0.1,0.15))
FDNLL-004	(0.14,0.95,0.99)	(0.74,0.15,0.25)	(0.14,0.95,0.99)	(0.74,0.15,0.25)	(0.54,0.45,0.5))
IREPL-005	(0.24,0.75,0.75)	(0.14,0.95,0.99)	(0.54,0.45,0.5))	(0.54,0.45,0.5))	(0.24,0.75,0.75)
C3					
PAML-001	(0.74,0.15,0.25)	(0.74,0.15,0.25)	(0.94,0.1,0.15))	(0.24,0.75,0.75)	(0.74,0.15,0.25)
SGJE-002	(0.54,0.45,0.5))	(0.24,0.75,0.75)	(0.54,0.45,0.5))	(0.94,0.1,0.15))	(0.24,0.75,0.75)
PDEL-003	(0.94,0.1,0.15))	(0.94,0.1,0.15))	(0.94,0.1,0.15))	(0.74,0.15,0.25)	(0.94,0.1,0.15))
FDNLL-004	(0.24,0.75,0.75)	(0.14,0.95,0.99)	(0.74,0.15,0.25)	(0.94,0.1,0.15))	(0.74,0.15,0.25)
IREPL-005	(0.74,0.15,0.25)	(0.94,0.1,0.15))	(0.24,0.75,0.75)	(0.14,0.95,0.99)	(0.94,0.1,0.15))
C4					
PAML-001	(0.24,0.75,0.75)	(0.74,0.15,0.25)	(0.94,0.1,0.15))	(0.24,0.75,0.75)	(0.94,0.1,0.15))
SGJE-002	(0.14,0.95,0.99)	(0.94,0.1,0.15))	(0.14,0.95,0.99)	(0.74,0.15,0.25)	(0.14,0.95,0.99)
PDEL-003	(0.74,0.15,0.25)	(0.94,0.1,0.15))	(0.94,0.1,0.15))	(0.74,0.15,0.25)	(0.74,0.15,0.25)
FDNLL-004	(0.94,0.1,0.15))	(0.54,0.45,0.5))	(0.74,0.15,0.25)	(0.14,0.95,0.99)	(0.74,0.15,0.25)
IREPL-005	(0.74,0.15,0.25)	(0.14,0.95,0.99)	(0.24,0.75,0.75)	(0.94,0.1,0.15))	(0.24,0.75,0.75)
C5					
PAML-001	(0.54,0.45,0.5))	(0.94,0.1,0.15))	(0.74,0.15,0.25)	(0.94,0.1,0.15))	(0.74,0.15,0.25)
SGJE-002	(0.24,0.75,0.75)	(0.14,0.95,0.99)	(0.24,0.75,0.75)	(0.54,0.45,0.5))	(0.24,0.75,0.75)

PDEL-003	(0.94,0.1,0.15)	(0.74,0.15,0.25)	(0.94,0.1,0.15)	(0.94,0.1,0.15)	(0.94,0.1,0.15)
FDNLL-004	(0.14,0.95,0.99)	(0.24,0.75,0.75)	(0.14,0.95,0.99)	(0.74,0.15,0.25)	(0.54,0.45,0.5)
IREPL-005	(0.74,0.15,0.25)	(0.74,0.15,0.25)	(0.94,0.1,0.15)	(0.94,0.1,0.15)	(0.14,0.95,0.99)

Table 5: Aggregated single-valued neutrosophic decision matrix.

Project	C1	C2	C3	C4	C5
PAML-001	(0.12;0.96;0.98)	(0.92;0.16;0.11)	(0.72;0.36;0.29)	(0.22;0.86;0.79)	(0.22;0.86;0.79)
SGJE-002	(0.22;0.86;0.79)	(0.22;0.86;0.79)	(0.22;0.86;0.79)	(0.52;0.56;0.59)	(0.12;0.96;0.98)
PDEL-003	(0.52;0.56;0.59)	(0.72;0.36;0.29)	(0.52;0.56;0.59)	(0.92;0.16;0.11)	(0.72;0.36;0.29)
FDNLL-004	(0.72;0.36;0.29)	(0.52;0.56;0.59)	(0.12;0.96;0.98)	(0.72;0.36;0.29)	(0.52;0.56;0.59)
IREPL-005	(0.92;0.16;0.11)	(0.12;0.96;0.98)	(0.92;0.16;0.11)	(0.12;0.96;0.98)	(0.92;0.16;0.11)

To determine the weights of the proposed projects, the importance weights to each criterion is assigned using Equation 2.

Table 6: Weight of the criteria (λ_c).

Groups	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
vector importance	(0.24,0.75,0.75)	(0.54,0.45,0.5)	(0.14,0.95,0.99)	(0.94,0.1,0.15)	(0.74,0.15,0.25)
λ_c	0.1652	0.2096	0.1515	0.2580	0.2158

Once defined, the weighted decision matrix is determined in the sequence of steps of the neutrosophic TOPSIS.

Table 7: Weighted decision matrix of the SVNNS.

Project	C1	C2	C3	C4	C5
PAML-001	(0.00829,0.21855,0.28163)	(0.02136,0.1176,0.11137)	(0.08283,0.0271,0.04207)	(0.14434,0.01815,0.01814)	(0.29203,0.00422,0.00421)
SGJE-002	(0.30046,0.00972,0.00835)	(0.02867,0.12125,0.12775)	(0.03365,0.12812,0.12149)	(0.09103,0.0582,0.07966)	(0.00832,0.33893,0.4006)
PDEL-003	(0.16095,0.00714,0.00847)	(0.09057,0.01476,0.02542)	(0.0337,0.0286,0.03603)	(0.08912,0.01516,0.02627)	(0.292,0.00284,0.00292)
FDNLL-004	(0.02939,0.1735,0.17501)	(0.09841,0.06511,0.09224)	(0.12536,0.04953,0.07203)	(0.19226,0.03091,0.03204)	(0.01499,0.26964,0.35917)
IREPL-005	(0.02014,0.20326,0.18941)	(0.00993,0.32014,0.38386)	(0.02114,0.12986,0.19319)	(0.09676,0.05832,0.07661)	(0.34261,0.00699,0.00678)

Table 8: Positive and negative ideal values by criterion. Source: own elaboration.

Criteria	Ideal value +	Ideal value -
C1	(0.30046,0.00972,0.00835)	(0.00829,0.21855,0.28163)
C2	(0.09841,0.06511,0.09224)	(0.00993,0.32014,0.38386)
C3	(0.12536,0.04953,0.07203)	(0.02114,0.12986,0.19319)
C4	(0.19226,0.03091,0.03204)	(0.08912,0.01516,0.02627)
C5	(0.34261,0.00699,0.00678)	(0.00832,0.33893,0.4006)

Table 9: Determine the distances to the negative and positive solutions.

Project	s_i^+	s_i^-	$\tilde{\rho}_j$	Order
PAML-001	0.274046832	0.2529707	0.4800	2
SGJE-002	0.469772162	0.4317726	0.4789	3
PDEL-003	0.132964498	0.3837689	0.7427	1
FDNLL-004	0.470291508	0.3733643	0.4426	4
IREPL-005	0.345117145	0.1648915	0.3233	5

After calculating the neutrosophic TOPSIS scores, it is observed that the *Digital Platform for Labor Education project* (PDEL-003) obtains the highest score in terms of the proposed evaluation criteria. Therefore, this alternative is the most suitable for managing the identified challenges and promoting the effective protection of labor rights in a world transformed by the COVID-19 pandemic.

6. Conclusion

The application of the Neutrosophic TOPSIS method, as highlighted in the article, has effectively demonstrated its utility in navigating the complexities of project selection within uncertain and indeterminate environments. This technique has successfully identified the Digital Platform for Labor Education project (PDEL-003) as the most suitable initiative in terms of meeting identified challenges, including judicial efficiency and labor education. The neutrosophic approach, by accommodating multiple truth values, enables a more nuanced and comprehensive analysis, thereby enhancing decision-making processes in scenarios where traditional binary logic falls short. Looking ahead, it would be beneficial for future studies to explore the integration of Neutrosophic TOPSIS with other decision-making frameworks to address even more complex scenarios, possibly involving larger datasets or more dynamic criteria. Additionally, the exploration of automated tools for calculating neutrosophic criteria weights and for handling larger-scale evaluations could further streamline the decision-making process. Such advancements would not only refine the accuracy of project evaluations but also extend the applicability of neutrosophic methods to other fields requiring robust decision-making support in the face of uncertainty.

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