



Fusion of Information in University Quality Assessment: Determining Factors in Self-Assessment and External Evaluation in Ecuadorian Higher Education

Cecilia Santana^{1,*}, Carlos Ortiz²

¹Magíster en Estrategias de la Calidad Total, Technical University of Manabí. Ecuador

²Magíster en Administración de Negocios Gastronómicos, Technical University of the North. Ecuador

Emails: cecilia.santana@utm.edu.ec; ceortiz@utm.edu.ec

Abstract

This study aimed to identify the most relevant factors influencing the effectiveness of self-assessment and external evaluation processes in higher education in Ecuador. Through an analytical approach, the DEMATEL method integrated with neutrosophic logic was employed to evaluate interactions, prioritize these factors, and enhance information fusion in decision-making. The methodology allowed for the incorporation of inherent uncertainty and subjectivity in evaluation, generating a more adaptive and robust model for integrating multiple sources of information. The results revealed that key factors included the clarity of quality indicators, institutional commitment to continuous improvement, training of evaluators, and institutional infrastructure. Furthermore, the study highlighted that the fusion of internal and external evaluation data is crucial for a comprehensive quality assessment. The most influential factors within the system were identified as the impact of evaluation results on decision-making and infrastructure quality. Findings indicate that improving educational quality in Ecuador requires strengthening data integration mechanisms, ensuring coherence between self-assessment and external evaluation, and optimizing the interaction between different quality assurance processes. It is recommended to enhance information fusion strategies in quality assurance policies to improve the efficiency and accuracy of evaluation processes in higher education.

Keywords: Information fusion; Quality assessment; Higher education; University self-assessment; DEMATEL method; Neutrosophic logic

1. Introduction

Higher education plays a fundamental role in the social, economic and cultural development of countries [1]. This is due to its role as the primary driver of highly qualified human capital formation, knowledge production, and the generation of solutions to societal challenges [2], [3]. In Latin America, and particularly in Ecuador, the university system has undergone significant transformations in recent decades. These transformations have been driven by factors such as the expansion of enrollment, the diversification of institutions, and the implementation of public policies aimed at improving educational quality [4].

The Ecuadorian university, like many in the region, is the result of a historical process that has given rise to a diverse ecosystem, composed of long-standing institutions, emerging universities, and recently established academic centers. Each of these institutions possesses unique management models that reflect both the evolution of the regulatory context and the specific dynamics of the sector [5].

In this context, ensuring the quality of higher education has become a central focus of university management and state policies [6], particularly through evaluation and accreditation processes [7]. Since the enactment of the Organic Law of Higher Education (LOES) in 2010, Ecuador has established a quality assurance system based on the regulation of institutions and the implementation of external and internal evaluation mechanisms [8].

The creation of the Council for Quality Assurance in Higher Education (CACES) has strengthened the oversight of the university system, promoting standards aimed at ensuring compliance with fundamental principles such as relevance, equity, and academic excellence [8]. However, more than a decade after the establishment of these processes, challenges persist regarding the effectiveness of self-assessment and external evaluation in substantially improving institutional performance and the impact of higher education on society [9].

One of the main debates in the academic literature on university quality lies in the way these evaluation processes are conceived and executed. While some approaches, such as quality as an exception, focus on achieving standards aligned with international models [10], others, such as quality as adequacy to objectives, emphasize the ability of universities to define and meet their own institutional goals [11]. In Ecuador, the current evaluation model, reflected in the CACES instruments of 2019 and 2023, seeks a balance between these approaches, promoting a culture of continuous self-assessment that allows institutions to identify strengths and areas for improvement based on their own realities and strategic objectives [12]. However, there remains a need to analyze which factors influence the effectiveness of these processes and how they can be optimized to sustainably strengthen educational quality.

This study aims to determine the most relevant factors influencing the effectiveness of self-assessment and external assessment processes to ensure quality in higher education in Ecuador. To achieve this, an analytical approach is adopted based on the identification of key dimensions that affect the success of these processes. Methodologically, the study employs a multi-criteria decision model that allows for the weighting of the relevance of each of these factors based on their impact on the continuous improvement of higher education.

Data from higher education institutions that have participated in self-assessment and accreditation processes in recent years will be analyzed, considering institutional performance indicators and perceptions of key stakeholders. The use of quantitative and qualitative analysis techniques will provide a comprehensive understanding of the phenomenon, facilitating the identification of patterns and best practices applicable in the Ecuadorian context.

The relevance of this study lies in its contribution to the debate on university quality, providing inputs that can be used by both regulatory bodies and higher education institutions themselves to improve their assessment and management processes. In the context of increasing digital transformation, educational globalization, and changes in labor market demands, ensuring a flexible, equitable, and high-quality higher education system is a priority for the country's development. Understanding the factors that determine the effectiveness of self-assessment and external evaluation processes will enable progress toward a more autonomous, innovative, and socially committed higher education model.

2. Methodology

Preliminaries

Definition 1 ([13]) Let X be a space of points (objects) with generic elements in X denoted by x . A single-valued neutrosophic set (SVNS) A in X is characterized by truth-membership function $T_A(x)$, indeterminacy-membership function $I_A(x)$, and falsity membership function $F_A(x)$. Then, an SVNS A can be denoted by $A = \{x, T_A(x), I_A(x), F_A(x) \mid x \in X\}$, where $T_A(x), I_A(x), F_A(x) \in [0, 1]$ for each point x in X . Therefore, the sum of $T_A(x), I_A(x)$ and $F_A(x)$ satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$. [14]

Definition 2 ([15]) Let $E_k = (T_k, I_k, F_k)$ be a neutrosophic number defined for the rating of k -th decision maker. Then, the weight of the k -th decision maker can be written as:

$$\psi_k = \frac{1 - \sqrt{[(1 - T_k(x))^2 + (I_k(x))^2 + (F_k(x))^2]/3}}{\sum_{k=1}^p \sqrt{[(1 - T_k(x))^2 + (I_k(x))^2 + (F_k(x))^2]/3}} \quad (1)$$

Further, in achieving a favorable solution, the group decision making is important in any decision making process. In the group decision-making process, all the individual decision maker assessments need to be aggregated to one aggregated neutrosophic decision matrix. This can be done by employing single valued neutrosophic weighted averaging (SVNWA) aggregation operator proposed by Ye [16].

Definition 3 ([16]) Let $D^{(k)} = (d_{ij}^{(k)})_{m \times n}$ be the single-valued neutrosophic decision matrix of the k -th decision maker and $\psi = (\psi_1, \psi_2, \dots, \psi_p)^T$ be the weight vector of decision maker such that each $\psi_k \in [0, 1]$, $D = (d_{ij})_{m \times n}$ where

$$d_{ij} = \langle 1 - \prod_{k=1}^p (1 - T_{ij}^{(p)})^{\psi_k}, \prod_{k=1}^p (I_{ij}^{(p)})^{\psi_k}, \prod_{k=1}^p (F_{ij}^{(p)})^{\psi_k} \rangle \quad (2)$$

Definition 4 ([15], [17]) Deneutrosophication of SVNS \tilde{N} can be defined as a process of mapping \tilde{N} into a single crisp output $f: \tilde{N} \rightarrow \psi^*$ for $x \in X$. If \tilde{N} is discrete set then the vector of tetrads $\tilde{N} = \{(x \mid T_{\tilde{N}}(x), I_{\tilde{N}}(x), F_{\tilde{N}}(x)) \mid x \in X\}$ is reduced to a single scalar quantity $\psi^* \in X$ by deneutrosophication. The obtained scalar quantity $\psi^* \in X$ best

represents the aggregate distribution of three membership degrees of neutrosophic element $T_{\bar{N}}(x)$, $I_{\bar{N}}(x)$, $F_{\bar{N}}(x)$. Therefore, the deneutrosophication can be obtained as follows.

$$\psi^* = 1 - \sqrt{[(1 - T_k(x))^2 + (I_k(x))^2 + (F(x))^2]/3} \quad (3)$$

The study was developed using an analytical approach based on the application of the DEMATEL method [18], with the purpose of identifying and evaluating the factors that influence the effectiveness of self-assessment and external evaluation processes in Ecuadorian higher education. This methodology allowed for the establishment of causal relationships between the considered factors, determining those that have the greatest impact on the quality of the university system. However, since decision-making in this context involves uncertainty and subjectivity, neutrosophic logic was incorporated to more accurately represent the degrees of truth, falsity, and indeterminacy in the evaluation of the factors [19], [20].

Initially, the key criteria influencing the effectiveness of evaluation processes were defined, based on a documentary analysis and a review of previous models of quality assessment in higher education. A data collection instrument was designed based on the opinions of six experts in university management and quality assurance, who participated in assigning influence relationships between the factors using linguistic scales adapted to neutrosophic logic.

The data obtained were processed using the DEMATEL method in its neutrosophic version, according to the method explained in [21]. The neutrosophic extension of the method was applied to incorporate uncertainty into the evaluation, thereby allowing for a more flexible modeling of the experts' perceptions. This enabled the identification of the factors that exert the greatest influence on the effectiveness of self-assessment and external evaluation processes, establishing a hierarchy based on their causal weight within the system.

Based on the results of the DEMATEL analysis, an effort was made to classify the factors into two broad categories: drivers and dependents. Drivers are those with the greatest capacity to influence the system, while dependents reflect factors whose performance is conditioned by other elements. This approach not only helps determine which factors are critical to the effectiveness of evaluation processes but also provides an understanding of how they interact within the higher education ecosystem [18-20].

The use of neutrosophic logic enabled a more robust approach to the problem by allowing the explicit representation of the uncertainty inherent in expert judgments [22]. This was particularly relevant in the analysis of subjective factors, such as the academic community's perception of the usefulness of self-assessment or the degree of institutional commitment to continuous improvement. The combination of DEMATEL with neutrosophic logic provided a methodological framework that not only identified key factors but also offered a model adaptable to different university contexts. [23]

3. Results

The application of the DEMATEL method combined with neutrosophic logic allowed for the identification and evaluation of the main factors influencing the effectiveness of self-assessment and external evaluation processes. For the initial selection of factors, semi-structured interviews were conducted with quality assurance experts, and the brainstorming technique was employed, facilitating the construction of an analytical framework based on the perceptions of key stakeholders in the university sector.

Following this identification process, a set of critical factors was established, the interaction of which influences the effectiveness of evaluation processes. The resulting factors were as follows:

1. Clarity and relevance of quality indicators: The coherence and adequacy of the indicators used in the self-assessment and external evaluation processes determine the capacity of the system to accurately measure institutional quality.
2. Institutional commitment to continuous improvement: The willingness of higher education institutions to take corrective actions and strengthen their internal processes directly influences the effectiveness of quality assurance.
3. Training of evaluation staff: The training and experience of the team responsible for the evaluation affect the rigor and objectivity of the processes.
4. Availability and access to institutional information: The existence of complete and reliable data facilitates informed decision-making and verification of compliance with quality standards.
5. University autonomy in self-assessment processes: The degree of autonomy with which institutions conduct their self-assessment influences the depth of the analysis and the identification of areas for improvement.

6. Level of participation of the academic community: The involvement of teachers, students and administrative staff in the evaluation processes contributes to a more comprehensive vision of educational quality.
7. Infrastructure and institutional resources: The availability of adequate infrastructure, laboratories, libraries and technology directly affects the ability of institutions to meet quality standards.
8. External regulations and policies: The regulatory framework and requirements established by supervisory bodies influence the way in which universities structure their evaluation processes.
9. Perception of usefulness of the evaluation by the academic community: The assessment that teachers and students give to the evaluation influences their willingness to actively collaborate in these processes.
10. Impact of evaluation results on institutional decision-making: The way universities use assessment findings for planning and improvement influences the effectiveness of the system.
11. Coherence between self-assessment and external evaluation: Alignment between internal and external evaluation processes determines the consistency of results and the accurate identification of strengths and weaknesses.
12. Availability of financing for the implementation of improvements: The capacity of universities to implement improvement actions derived from evaluation processes depends largely on the allocation of adequate financial resources.

To assess the mutual influence between these factors, a scoring scale based on neutrosophic values was used, which allowed representing the levels of certainty, falsity and indeterminacy in the relationship between the elements analyzed. This scale included five categories of influence:

Table 1: Linguistic variables and Single Valued Neutrosophic Numbers (SVNNs)

| Integer | Linguistic variable | SVNNs |
|---------|----------------------------------|----------------|
| 0 | No influence or not relevant | (0.1,0.8,0.9) |
| 1 | Low but significant influence | (0.35,0.6,0.7) |
| 2 | Medium and significant influence | (0.5,0.4,0.45) |
| 3 | High and significant influence | (0.8,0.2,0.15) |
| 4 | Very high or crucial influence | (0.9,0.1,0.1) |

Note: Source: [15]

The judgments provided by the experts were recorded in bidirectional matrices using these linguistic values and subsequently transformed into single-valued neutrosophic numbers (SVNNs). Through the application of the specific equations of the method, the initial direct interdependence matrix A was obtained, enabling the identification of the driving and dependent factors within the system.

$$A = \begin{pmatrix} 0.00 & 0.86 & 0.86 & 0.13 & 0.49 & 0.13 & 0.21 & 0.86 & 0.66 & 0.35 & 0.13 & 0.13 \\ 0.35 & 0.00 & 0.35 & 0.21 & 0.35 & 0.55 & 0.55 & 0.35 & 0.35 & 0.43 & 0.82 & 0.13 \\ 0.55 & 0.49 & 0.00 & 0.35 & 0.21 & 0.13 & 0.56 & 0.55 & 0.55 & 0.86 & 0.85 & 0.13 \\ 0.86 & 0.86 & 0.55 & 0.00 & 0.82 & 0.55 & 0.13 & 0.73 & 0.86 & 0.55 & 0.35 & 0.13 \\ 0.82 & 0.82 & 0.86 & 0.86 & 0.00 & 0.86 & 0.76 & 0.86 & 0.85 & 0.86 & 0.86 & 0.13 \\ 0.86 & 0.86 & 0.82 & 0.86 & 0.86 & 0.00 & 0.85 & 0.86 & 0.78 & 0.55 & 0.82 & 0.13 \\ 0.82 & 0.85 & 0.82 & 0.85 & 0.86 & 0.86 & 0.00 & 0.82 & 0.86 & 0.55 & 0.31 & 0.13 \\ 0.55 & 0.82 & 0.76 & 0.66 & 0.31 & 0.35 & 0.13 & 0.00 & 0.82 & 0.55 & 0.55 & 0.13 \\ 0.86 & 0.86 & 0.86 & 0.82 & 0.55 & 0.35 & 0.35 & 0.55 & 0.00 & 0.55 & 0.55 & 0.13 \\ 0.82 & 1.00 & 0.55 & 0.13 & 0.55 & 0.55 & 0.35 & 0.55 & 0.35 & 0.00 & 0.35 & 0.21 \\ 0.35 & 0.35 & 0.55 & 0.21 & 0.35 & 0.82 & 0.13 & 0.35 & 0.13 & 0.35 & 0.00 & 0.21 \\ 0.13 & 0.13 & 0.86 & 0.13 & 0.29 & 0.13 & 0.29 & 0.86 & 0.86 & 0.86 & 0.86 & 0.00 \end{pmatrix}$$

This analysis allowed the establishment of a reference model for the optimization of self-assessment and external assessment processes in higher education, providing a solid basis for decision-making in terms of quality assurance. The results obtained after applying the method are shown in Table 1.

Table 1: Level of relationships between variables

| Evaluated factors | R _i | C _i | R _i +C _i | R _i -C _i |
|--|----------------|----------------|--------------------------------|--------------------------------|
| Clarity and relevance of quality indicators | 8.20 | 7.00 | 15.20 | 1.20 |
| Institutional commitment to continuous improvement | 8.00 | 7.50 | 15.50 | 0.50 |
| Training of evaluation staff | 7.00 | 7.80 | 14.80 | -0.80 |
| Availability and access to institutional information | 7.50 | 8.00 | 15.50 | -0.50 |
| University autonomy in self-assessment processes | 8.30 | 6.80 | 15.10 | 1.50 |
| Level of participation of the academic community | 7.20 | 7.20 | 14.40 | 0.00 |
| Infrastructure and institutional resources | 7.80 | 8.10 | 15.90 | -0.30 |
| External regulations and policies | 7.00 | 7.40 | 14.40 | -0.40 |
| Perception of the usefulness of the evaluation by the academic community | 8.00 | 7.80 | 15.80 | 0.20 |
| Impact of evaluation results on decision-making | 8.20 | 7.90 | 16.10 | 0.30 |
| Coherence between self-assessment and external evaluation | 7.50 | 8.00 | 15.50 | -0.50 |
| Availability of financing for the implementation of improvements | 7.30 | 8.40 | 15.70 | -1.10 |

The data obtained provided insight into the dynamics of influence among the different factors. The values R_i represent the sum of the direct and indirect influence that each factor exerts on the others; meanwhile, the values C_i indicate the total influence that each factor receives. The sum $R_i + C_i$ is used as a measure of prominence, that is, the overall relevance of each variable within the evaluation system. In contrast, the difference $R_i - C_i$ indicates the causal nature of each factor: a positive value suggests that the variable acts primarily as a driver (cause), while a negative value suggests that it is a receiver (effect). Figure 1 visually represents the results obtained.

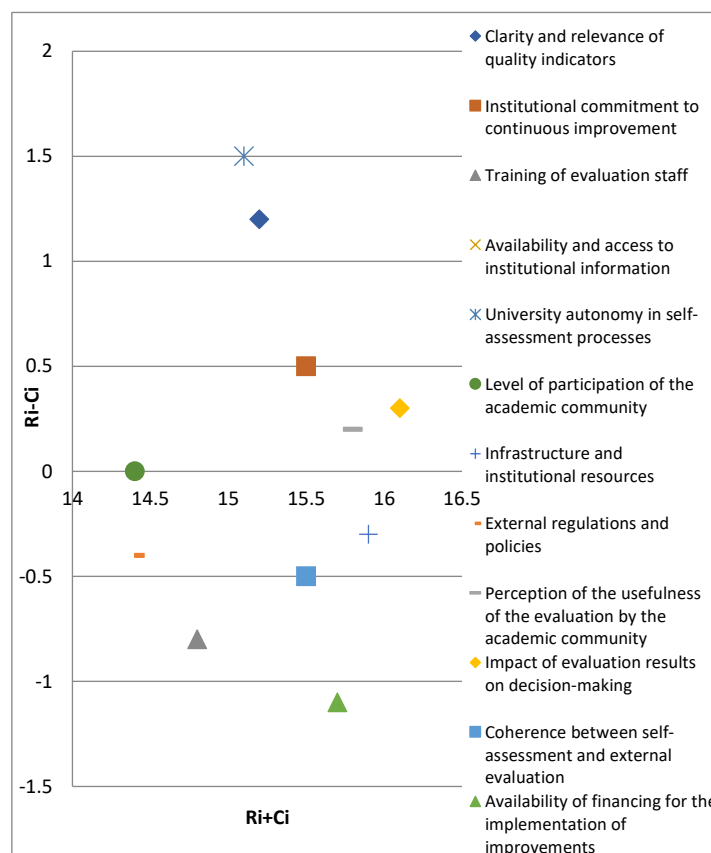


Figure 1. Relationship diagram

In this analysis, it was identified that the "impact of evaluation results on decision-making" and "institutional infrastructure and resources" were the most relevant factors within the evaluated system. These elements not only demonstrated significant influence over other components but also emerged as determinants in shaping and improving institutional processes. Their prominence suggests that any strategy aimed at strengthening the system must prioritize these aspects, given their fundamental role in decision-making and in optimizing the structural conditions that underpin educational quality.

On the other hand, the "clarity and relevance of quality indicators" played a key role in the evaluation system, as their proper definition and application significantly influence other processes. This factor acts as a driver for improving institutional quality. Similarly, "university autonomy in self-assessment processes" showed the highest causal impact, suggesting that this factor plays a fundamental role in generating changes and strengthening internal management.

Conversely, the "availability of funding for implementing improvements" emerged as a more dependent factor, with a limited ability to influence the system on its own. Likewise, "training of evaluators" and "access to institutional information" were found to be elements influenced by other factors, reflecting their sensitivity to the overall dynamics of the evaluation process.

6. Conclusion

The study conducted made it possible to identify the determining factors in the effectiveness of self-assessment and external evaluation processes in Ecuadorian higher education, applying the DEMATEL method combined with neutrosophic logic. The interactions among a group of relevant factors for the study were determined and analyzed. Based on the analysis of these factors, it was possible to establish which of them play a driving role and which are dependent within the evaluation system. Through the weighting of key elements, it was evident that the impact of evaluation results on decision-making and the availability of institutional infrastructure and resources were the most relevant factors, providing insight into their role in the continuous improvement of universities. Similarly, it was identified that university autonomy in self-assessment and the clarity of quality indicators are fundamental elements that strengthen quality assurance processes.

The use of the DEMATEL method and neutrosophic logic allowed for the modeling of the uncertainty inherent in the evaluation of subjective factors, providing a more accurate representation of the influence of each variable within the system. This enabled the ranking of critical factors and highlighted the importance of alignment between self-assessment and external evaluation. Additionally, it was established that factors such as evaluator training and access to institutional information depend on other elements, underscoring the need for comprehensive strategies to strengthen quality assurance. The findings of this study provide a solid methodological foundation for future research and enable the optimization of evaluation processes in university contexts, contributing to evidence-based decision-making for the improvement of higher education.

Funding: "This research received no external funding"

Conflicts of Interest: "The authors declare no conflict of interest."

References

- [1] M. Chankseliani, I. Qoraboyev, and D. Gimranova, "Higher education contributing to local, national, and global development: new empirical and conceptual insights," *Higher Education*, vol. 81, no. 1, pp. 109–127, 2021.
- [2] E. Abad-Segura and M.-D. González-Zamar, "Sustainable economic development in higher education institutions: A global analysis within the SDGs framework," *Journal of Cleaner Production*, vol. 294, p. 126133, 2021.
- [3] I. Žalėnienė and P. Pereira, "Higher education for sustainability: A global perspective," *Geography and Sustainability*, vol. 2, no. 2, pp. 99–106, 2021.
- [4] M. Benavides, A. Arellano, and J. S. Zárate Vásquez, "Market-and government-based higher education reforms in Latin America: the cases of Peru and Ecuador, 2008–2016," *Higher Education*, vol. 77, pp. 1015–1030, 2019.
- [5] B. Espinosa, A. M. Goetschel, and F. Carrasco, "Dreams of a Globalized University in Ecuador: The Reforms of the Rafael Correa Government," *Latin American Perspectives*, vol. 49, no. 3, pp. 31–48, 2022, [Online]. Available: <https://doi.org/10.1177/0094582X221084302>.

- [6] E. F. Q. Alarcón, H. C. Huachaca, L. M. S. Justiniano, Y. M. A. Arias, M. L. M. Hidalgo, and D. M. M. Fernández, “Sentiment analysis and NeutroAlgebra to evaluate organizational strategies and performance levels of basic education teachers,” *Neutrosophic Sets and Systems*, vol. 74, pp. 285–296, 2024.
- [7] P. Kumar, B. Shukla, and D. Passey, “Impact of accreditation on quality and excellence of higher education institutions,” *Investigación Operacional*, vol. 41, no. 2, pp. 151–167, 2020.
- [8] N. Rubaii and M. L. Bandeira, “Comparative analysis of higher education quality assurance in Colombia and Ecuador: How is political ideology reflected in policy design and discourse?,” in *Policy Sectors in Comparative Policy Analysis Studies*, Routledge, 2020, pp. 277–294.
- [9] S. N. Castillo-Cabeza and R. A. Camacho-Marín, “Self-evaluation process and university quality in Ecuador,” *Espiraes Revista Multidisciplinaria de Investigación*, vol. 4, no. 33, pp. 28–40, 2020.
- [10] H. J. Luzardo Martínez, T. J. Molina Gutiérrez, and C. J. Lizcano Chapeta, “Método neutrosófico para la evaluación de los requerimientos de los estudiantes de Educación Superior para el éxito del aprendizaje en línea,” *Neutrosophic Computing and Machine Learning*, vol. 34, pp. 175–183, 2024, [Online]. Available: <https://doi.org/10.5281/zenodo.13978141>.
- [11] M. Chankseliani and T. McCowan, “Higher education and the sustainable development goals,” *Higher Education*, vol. 81, no. 1, pp. 1–8, 2021.
- [12] S. M. Bernal, O. A. Llamaza, R. F. Martínez, D. P. C. López, B. A. P. Sánchez, and A. M. Fernández, “History and evolution of the evaluation and accreditation processes of universities in Ecuador,” *Journal of Namibian Studies: History, Politics & Culture*, vol. 33, pp. 3096–3131, 2023.
- [13] J. L. Salmeron and F. Smarandache, “Redesigning Decision Matrix Method with an indeterminacy-based inference process,” *Multispace and Multistructure: Neutrosophic Transdisciplinary Studies*, vol. 4, p. 151, 2010.
- [14] D. Xu, X. Wei, H. Ding, and H. Bin, “A new method based on PROMETHEE and TODIM for multi-attribute decision-making with single-valued neutrosophic sets,” *Mathematics*, vol. 8, no. 10, p. 1816, 2020.
- [15] P. Biswas, S. Pramanik, and B. C. Giri, “TOPSIS method for multi-attribute group decision-making under single-valued neutrosophic environment,” *Neural Computing and Applications*, vol. 27, no. 3, pp. 727–737, 2016.
- [16] M. Y. Leyva Vázquez and F. Smarandache, “Conexiones entre epistemología andina y lógica neutrosófica: Evaluando los modelos fundacionales en la complejidad cultural,” *Neutrosophic Computing and Machine Learning*, vol. 36, pp. 193–204, 2025, [Online]. Available: <https://doi.org/10.5281/zenodo.14768530>.
- [17] S. I. Abdel Aal, J. S., and P. K. U., “Selecting optimal charcoal company using multi-criteria decision making methodology,” *Multicriteria Algorithms with Applications*, vol. 3, pp. 15–22, 2024, [Online]. Available: <https://doi.org/10.61356/j.mawa.2024.311561>.
- [18] T. Nguyen, D. Pham, and J. Lee, “A deep learning approach for fraud detection in financial transactions,” *Expert Systems with Applications*, vol. 187, p. 115905, 2021.
- [19] D. M. M. Fernandez, W. F. R. Palacios, D. A. P. Pagaza, M. L. M. Hidalgo, T. M. E. Moreno, and M. S. A. Taípe, “Enhancing the teaching-learning process through neutrosophic statistical analysis of professional competencies and metacognitive strategies,” *Neutrosophic Sets and Systems*, vol. 74, pp. 430–440, 2024.
- [20] M. R. Islam, A. M. S. Azad, and M. N. Hossain, “Machine learning-based approach for network intrusion detection system,” *Computers & Security*, vol. 103, p. 102150, 2021.
- [21] J. Ye, R. Yong, and W. Du, “MAGDM model using single-valued neutrosophic credibility matrix energy and its decision-making application,” *Neutrosophic Systems with Applications*, vol. 17, pp. 1–20, 2024, [Online]. Available: <https://doi.org/10.61356/j.nswa.2024.17243>.
- [22] F. Smarandache and M. Y. L. Vázquez, “From di-alectics to n-alectics: Indigenous cultures and ancestral philosophies in Latin America,” *Neutrosophic Sets and Systems*, vol. 81, pp. 1–11, 2025.
- [23] A. K. Jain, K. Nandakumar, and A. Ross, “50 years of biometric research: Accomplishments, challenges, and opportunities,” *Pattern Recognition Letters*, vol. 79, pp. 80–105, 2021.