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Neutrosophic Analysis of Ethics in a Supply Chain

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Abstract. The present study aimed to conduct a neutrosophic analysis of internal and external ethical factors affecting the supply chain of a painting company in the city of Quito. To achieve this, the SWOT method was applied, coupled with the neutrosophic AHP method for prioritizing and weighting the most influential factors. The results obtained allowed for the identification of the factors that had the greatest impact on the system, as per the opinions of the consulted experts. The combination of the neutrosophic AHP and SWOT analysis methods has proven to be a powerful tool for addressing ethical challenges in business decision-making, and the results obtained can serve as a guide for implementing effective ethical strategies in the supply chain.

Keywords: business ethics, supply chain, SWOT analysis, neutrosophic AHP.

1 Introduction

Ethics in the supply chain is an essential component of organizational management, playing a crucial role in the viability and sustainability of an organization. It refers to the implementation of ethical principles and values at all stages and activities involved in the supply chain, from the procurement of raw materials to the delivery of products or services to the end consumer. This perspective implies the consideration and respect for fundamental issues such as labor rights, environmental sustainability, transparency, and corporate social responsibility.

Ethical supply chain management is vital to ensure the survival of an organization in an increasingly complex and globalized business environment. Firstly, ethics in the supply chain contributes to building and preserving the company's reputation. Ethical practices in the supply chain convey an image of responsibility and social commitment, which can attract consumers and business partners who value these ethical aspects in their purchasing decisions and collaborations.

Furthermore, ethical supply chain management reduces legal and financial risks [1]. Compliance with ethical regulations and standards prevents fines and lawsuits, helping to prevent reputational crises that can significantly harm the organization's profitability. Ethics in the supply chain also optimizes operational efficiency by avoiding costly disruptions in production or supply due to labor, environmental, or quality issues [2]. This, in turn, enhances the relationship with suppliers, promoting long-term relationships based on trust and mutual collaboration.

In the context of corporate sustainability, adherence to ethical principles promotes sustainable business practices with a focus on responsible management of natural resources and reducing environmental impact [3]. This ethical perspective provides tangible benefits to the organization, including the consolidation of its reputation, greater operational efficiency, regulatory compliance, and ultimately ensuring its persistence and long-term success in the dynamic contemporary business environment. In this regard, the SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) stands as a useful tool to identify ethical risks and opportunities related to the supply chain.[4]

The SWOT analysis, also known as the SWOT matrix, is a strategic planning technique that allows for the identification of an entity's or project's Strengths, Weaknesses, Opportunities, and Threats [5]. When applying this methodology to the supply chain, both the ethical aspects that strengthen the organization and areas of ethical vulnerability can be recognized. Additionally, ethical opportunities and threats within the supply chain can be identified [6]. Strengths and weaknesses are internal attributes, while opportunities and threats represent external factors. An effective strategic plan focuses on leveraging strengths and opportunities, mitigating weaknesses, and preventing threats.

However, it is imperative to emphasize that the SWOT analysis, by itself, does not provide quantitative assessments or specific measures. Therefore, this research is integrated with the Neutrosophic Analytic Hierarchy Process (AHP). The AHP is a multicriteria decision-making technique used to address complex problems. It is a vital

branch of operations research that aims to build mathematical and programming tools for selecting the best alternative from various options based on specific criteria [7].

In the real world, decision-making criteria are often characterized by their imprecise, intricate, and inconsistent nature. This is exacerbated by the uncertainty and the availability of non-definitive information faced by decision-makers. In response to these limitations, several researchers have turned to fuzzy set theory [8]. However, fuzzy set theory focuses only on the notion of the degree of truth-membership, which omits aspects related to falsity and, more crucially, indeterminacy [9].

To overcome these disadvantages associated with both fuzzy sets and the intuitionistic fuzzy set theory introduced by Atanassov, the theory of neutrosophic sets, proposed by Smarandache [10], has been introduced. Neutrosophic sets address uncertainty, indeterminacy, and falsity jointly, making them a more realistic representation of the complexity inherent in real-world situations. Consequently, neutrosophic sets emerge as a more accurate representation of the complexity of reality. As a result, in this research, the Neutrosophic Analytic Hierarchy Process (NAHP) method presented by [11] is implemented to address this context of uncertainty and variability.

The present research aims to conduct a neutrosophic analysis of the internal and external ethical factors that impact the supply chain of a painting company in the city of Quito. The objective is to identify, prioritize, and optimize the ethical components, thereby enabling the organization to make informed decisions based on its ethical strategy, using neutrosophic logical foundations.

2.1 Neutrosophic definitions

Definition 1: The *Neutrosophic set* N is characterized by three membership functions, which are the truth-membership function T_A, indeterminacy-membership function I_A, and falsehood-membership function F_A, where U is the Universe of Discourse and $\forall x \in U$, $T_A(x)$, $I_A(x)$, $F_A(x) \subseteq]^-0, 1^+[$, and $^-0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+$ [10]. Notice that, according to the definition, $T_A(x)$, $I_A(x)$, and $F_A(x)$ are real standard or non-standard subsets of $]^-0, 1^+[$ and hence, $T_A(x)$, $I_A(x)$ and $F_A(x)$ can be subintervals of [0, 1].

Definition 2: The *Single-Valued Neutrosophic Set* (SVNS) N over U is $A = \{\langle x; T_A(x), I_A(x), F_A(x)\rangle : x \in U\}$c, where $T_A: U \to [0, 1]$, $I_A: U \to [0, 1]$, and $F_A: U \to [0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$. The *Single-Valued Neutrosophic Number* (SVNN) is represented by N = (t, i, f), such that $0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Definition 3: the *single-valued trapezoidal neutrosophic number*, $\tilde{a} = \langle (a_1, a_2. a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, whose truth, indeterminacy, and falsehood membership functions are defined in [12].

Definition 4: given $\tilde{a} = \langle (a_1, a_2, a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3, b_4); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued trapezoidal neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

$$\text{Addition: } \tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \quad (1)$$

$$\text{Subtraction: } \tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \quad (2)$$

$$\text{Inversion: } \tilde{a}^{-1} = \langle ({a_4}^{-1}, {a_3}^{-1}, {a_2}^{-1}, {a_1}^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, \text{ where } a_1, a_2, a_3, a_4 \neq 0. \quad (3)$$

$$\text{Multiplication by a scalar number: } \lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3, \lambda a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_4, \lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases} \quad (4)$$

$$\text{Division by a scalar number: } \frac{\tilde{a}}{\lambda} = \left\{ \begin{matrix} \langle (\frac{a_1}{\lambda}, \frac{a_2}{\lambda}, \frac{a_3}{\gamma\lambda}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle \ if\ (\lambda > 0) \\ \langle (\frac{a_3}{\gamma\lambda}, \frac{a_2}{\lambda}, \frac{a_1}{\lambda}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \beta\gamma_{\tilde{a}} \rangle \ if\ (\lambda < 0) \end{matrix} \right\} \quad (5)$$

$$\text{Division: } \frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle (\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \theta\beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \ if\ (a_3 > 0, b_3 > 0) \\ \langle (\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \ if\ (a_3 < 0, b_3 > 0) \\ \langle (\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \ if\ (a_3 < 0, b_3 < 0) \end{cases} \quad (6)$$

2.2 Neutrosophic AHP (N-AHP) in SWOT Analysis

In the application of Neutrosophic AHP, a linguistic scale can be used instead of a numerical scale, which is more natural for experts [13-16]. The original Saaty numerical scale is adapted to a linguistic scale. This allows experts to evaluate ethical elements in the supply chain using linguistic terms, which they find more natural than numerical evaluations. This article will use the Saaty scale translated into a neutrosophic triangular scale, as described in [11-14-15-17].

The SWOT-NAHP involves the execution of the following procedures:

Step 1. Formulate a team of proficient individuals with expertise in conducting SWOT analysis. During this initial phase, the experts utilize questionnaires or interviews to identify both the internal and external factors essential for the SWOT analysis.

Step 2. Establish the hierarchical structure of the problem. The hierarchical structure, in this context, encompasses four distinct stages: The initial stage pertains to the organizational objective that the entity aims to accomplish. The second stage encompasses the four strategic criteria as ascertained through the SWOT analysis, denoted as "criteria." The third stage entails the elements encompassed within each strategic factor identified at the preceding level, referred to as "sub-criteria." The ultimate stage encompasses the strategies that warrant evaluation and comparison, with the understanding that the issue at hand is fundamentally rooted in the ethics of the supply chain. The subsequent phase involves the assessment of the relative importance of factors (criteria), sub-factors (sub-criteria), and strategies (alternatives) based on expert judgments.

Step 3. Construct the neutrosophic pairwise comparison matrix for factors, sub-factors, and strategies as described in Table 1. This process relies on the integration of experts' opinions to quantify the relationships and significance among these elements within the framework of supply chain ethics. The neutrosophic scale is attained according to expert opinion. Matrix $\tilde{A}$ must satisfy condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, based on the inversion operator of Definition 4.

Step 4. Evaluate the coherence of the expert assessments. To ascertain the consistency of the pair-wise comparison matrix, an examination is conducted. If the matrix displays a transitive relationship, specifically when $a_{ik} = a_{ija_{jk}}$ holds for all combinations of i,j, and k, the comparison matrix is deemed consistent. This analysis centers on the lower, middle, and upper values within the triangular neutrosophic numbers found in the comparison matrix.

Step 5. Compute the weights associated with the factors (S, W, O, T), sub-factors {(S_1, …, S_n), (W_1, …,W_n), (O_1, …, O_n),(T_1, …, T_n)}, and strategies/alternatives (Alt_1, …, Alt_n) based on the information contained in the neutrosophic pair-wise comparison matrix. This is achieved by converting the matrix into a deterministic form using the following equations. Let $\tilde{a}_{ij} = \langle (a_1, b_1, c_1), \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ represent a singular triangular neutrosophic number; then,

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (7)$$

and

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

which are the score and accuracy degrees of $\tilde{a}_{ij}$ respectively.

To get the score and the accuracy degree of $\tilde{a}_{ij}$, the following equations are used:

$$S(\tilde{a}_{ji}) = 1 / S(\tilde{a}_{ij}) \quad (9)$$

$$A(\tilde{a}_{ji}) = 1 / A(\tilde{a}_{ij}) \quad (10)$$

Through the evaluation and scoring of each triangular neutrosophic number within the neutrosophic pair-wise comparison matrix, the subsequent deterministic matrix is obtained. As certain the order of precedence, denoted as the Eigenvector X, from the preceding matrix, through the following steps:

- Normalize the values within each column by dividing each entry by the sum of the respective column.
- Calculate the accumulative average for each row.

Step 6. Determine the comprehensive priority for each strategy (alternative) to establish the ultimate ranking of all strategies. The overall weight value for alternative j (□=1, …, □) can be expressed as follows:

$$Tw_{\mathrm{Alt}_j} = w_S * \sum_{i=1}^{n} w_{S_i} * w_{\mathrm{Alt}_j} + w_W * \sum_{i=1}^{n} w_{W_i} * w_{\mathrm{Alt}_j} + w_O * \sum_{i=1}^{n} w_{O_i} * w_{\mathrm{Alt}_j} + w_T * \sum_{i=1}^{n} w_{T_i} * w_{\mathrm{Alt}_j} \quad (11)$$

where (□=1, …, □) and (□□, □□, □□, □□) are the weights of Strengths, Weaknesses, Opportunities, and Threats; (□□□,□□□,□□□,□□□) are the sub-factor weights; and □Alt□ is the weight of the alternative j, corresponding to its sub-factor.

3 Results

The analysis began with the identification of internal and external factors that have a direct influence on the ethical system related to the supply chain of the company under study. In this process, the collaboration of five experts with extensive experience in the system under analysis and a strong track record in supply chain management was sought. To obtain a list of relevant factors, rounds of idea generation were used, and the elements of interest were subsequently selected through consensus. These factors are presented below:

External factors:

1. Changes in ethical regulations that may require adjustments in the company's practices and increase compliance costs.
2. Competing companies that promote higher ethical impact practices.
3. Adherence to ethical standards can increase operating costs, which could affect the company's profitability.
4. Growing demand for ethical and environmentally friendly products.
5. Collaboration with business partner suppliers who share the same ethical values.
6. Gradual opening to international markets with a focus on sustainability.

Internal Factors:

1. Development of programs and adherence to ethical practices during the production process and customer interaction.
2. Strong reputation that builds trust with customers and enhances brand loyalty.
3. Supply chain management under strict ethical standards to ensure efficiency and collaboration with suppliers.
4. Organizational internal culture based on ethical principles that boost employee morale and talent retention.
5. Innovation in sustainable products and processes and transparent supplier selection.
6. Lack of adherence to the company's ethical standards by some key raw material suppliers.
7. Deficiencies in internal disclosure of ethical practices in the supply chain.
8. Waste management shortcomings in the production of paints in some parts of the production process.
9. Lack of ethical awareness among newly hired employees in sensitive areas of the supply chain (warehouses, transportation, and commercial management).

These elements form the basis on which the study was conducted, following the proposed methodology.

Once the internal and external factors that influence the system have been identified, the evaluation of these factors is carried out to determine which of them has a more significant impact on the proper functioning of the system, according to expert judgment. The analysis process unfolds sequentially, starting with the evaluation of each of the components that make up the SWOT matrix, as illustrated in Table 1. Subsequently, an analysis is conducted within each group of factors to establish a hierarchy reflecting their relative levels of importance.

Table 1: Evaluation matrix for the criteria Weaknesses, Threats, Strengths and Opportunities.

	S	W	O	T
S	(1,1,1); 0.5, 0.5, 0.5	(2. 3. 4); 0.3, 0.75, 0.7	(4, 5, 6); 0.8, 0.15, 0.2	(2. 3. 4); 0.3, 0.75, 0.7
W	(1/4, 1/3, 1/2); 0.3, 0.75, 0.7	(1,1,1); 0.5, 0.5, 0.5	(1,1,1); 0.5, 0.5, 0.5	(4, 5, 6); 0.8, 0.15, 0.2
O	(1/6, 1/5, 1/4); 0.8, 0.15, 0.2	(1,1,1); 0.5, 0.5, 0.5	(1,1,1); 0.5, 0.5, 0.5	(2. 3. 4); 0.3, 0.75, 0.7
T	(1/4, 1/3, 1/2); 0.3, 0.75, 0.7	(1/6, 1/5, 1/4); 0.8, 0.15, 0.2	(1/4, 1/3, 1/2); 0.3, 0.75, 0.7	(1,1,1); 0.5, 0.5, 0.5

By using the corresponding calculations on the data presented in Table 1, a numerical matrix is generated, which will be subjected to the standard process of the AHP Method. This process involves verifying the consistency ratio and deriving the weight matrix W corresponding to these criteria. See Table 2.

Table 2: Evaluation matrix for the criteria Weaknesses, Threats, Strengths, and Opportunities

	S	W	O	T
S	0.49	0.55	0.70	0.22
W	0.21	0.20	0.12	0.47
O	0.10	0.20	0.12	0.22
T	0.21	0.04	0.05	0.08

This allowed obtaining the weight vector for this matrix, as presented below.

$$w = \begin{bmatrix} 0.49 \\ 0.25 \\ 0.16 \\ 0.10 \end{bmatrix}$$

A similar analysis was carried out for each of the criteria that make up the SWOT analysis. After this analysis, it was possible to obtain the weight vector for each of the internal and external factors initially identified. Table 3 shows a summary of the results obtained.

Table 3: Matrix of weights of internal and external factors.

	External factors	**Weights**
T1	Changes in ethical regulations that could require adaptations in company practices and increase compliance costs.	0.218
T2	Competing companies that promote practices with a greater ethical impact.	0.218
T3	Adhering to ethical standards may increase operating costs, which could affect profitability.	0.564
O1	The growing demand for ethical and environmentally friendly products.	0.49
O2	Collaboration with business partner suppliers that share the same ethical values.	0.12
O3	Progressive opening to international markets with a focus on sustainability.	0.38
	Internal factors	
S1	Development of programs and adherence to ethical practices during the production process and customer interactions.	0.12
S2	Strong reputation that builds customer trust and enhances brand loyalty.	0.08
S3	Supply chain management under strict ethical standards to ensure efficiency and collaboration with suppliers.	0.28
S4	Internal organizational culture based on ethical principles that boost employee morale and talent retention.	0.09

S5	Innovation in sustainable products and processes and transparent supplier selection.	0.43
W1	Lack of adherence to ethical standards by some key raw material suppliers.	0.16
W2	Deficiencies in internal disclosure of ethical practices in the supply chain.	0.33
W3	Issues in waste management in the paint production process at some stages.	0.40
W4	Lack of ethical awareness among newly hired employees in sensitive areas of the supply chain (warehouses, transportation, and commercial management).	0.12

Based on this data, it is feasible to calculate the overall weight of each of the factors and their direct influence on the system under analysis. The resulting values are presented in Table 4:

Table 4: Vectors of global weights of each of the factors analyzed.

Threats	Opportunities	Strengths	Weaknesses
$\boldsymbol{W_T = \begin{bmatrix} 0.024 \\ 0.024 \\ 0.063 \end{bmatrix}}$	$W_O = \begin{bmatrix} 0.098 \\ 0.025 \\ 0.077 \end{bmatrix}$	$W_S = \begin{bmatrix} 0.059 \\ 0.041 \\ 0.138 \\ 0.046 \\ 0.215 \end{bmatrix}$	$W_W = \begin{bmatrix} 0.029 \\ 0.060 \\ 0.074 \\ 0.021 \end{bmatrix}$

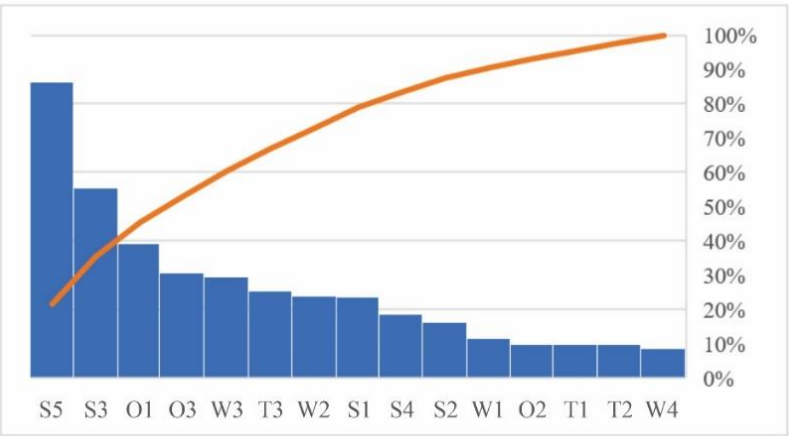
These results allowed the elaboration of a Pareto analysis using the overall weights of the sub-criteria. The Pareto analysis is a technique used to identify and prioritize the most significant factors in a dataset. In this case, the sub-criteria represent different aspects related to ethical factors in the supply chain of the painting company.

Figure 1 allows for identifying which sub-criteria are most influential in the context of the ethical analysis of the company's supply chain. These sub-criteria, including S5, S3, O1, and O3, play a fundamental role and should receive priority attention to strengthen ethics in the supply chain.

Sub-criteria O1, which relates to the growing demand for ethical and environmentally friendly products, highlights the importance of adapting to changing market needs and environmental ethics. Consideration and focus on this aspect can help the company meet the demands of consumers concerned with ethical and environmental issues. Sub-criteria O3, referring to the progressive opening to international markets with a focus on sustainability, indicates that international expansion and sustainability are closely related. Ethics in the supply chain becomes crucial when accessing international markets, and this sub-criterion emphasizes the need to consider ethical aspects in the expansion process.

S3, which relates to managing the supply chain under strict ethical standards to ensure efficiency and collaboration with suppliers, underscores the importance of establishing ethical practices in supply chain operations. Meanwhile, S5, focusing on innovation in sustainable products and processes and transparent supplier selection, demonstrates the relationship between innovation and ethics. Introducing sustainable and transparent practices in the supply chain not only strengthens ethics but can also drive innovation and competitiveness.

Figure 1. Vectors of global weights of each of the factors analyzed.



Taken together, these sub-criteria provide valuable guidance for the company in improving its ethics in the supply chain and in making strategic decisions that effectively address these key aspects.

Conclusion

In the context of this study, a neutrosophic analysis of the ethical factors influencing the supply chain of a painting company located in the city of Quito has been conducted. The methodology applied involved the combination of two approaches: the AHP (Analytic Hierarchy Process) method in its neutrosophic variant and the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. This methodological combination has proven to be highly practical and precise, allowing for addressing the inherent indeterminacy in ethical decision-making processes. The analysis carried out has yielded significant results that are crucial for the organization. It has led to a comprehensive identification of ethical factors, both internal and external, that have a direct influence on the painting company's supply chain. This identification process is an essential component in making decisions based on an ethical strategy. The weighting and ranking of ethical elements enable the organization to focus its efforts on the most critical aspects for strengthening its supply chain from an ethical perspective. This prioritization has been based on neutrosophic logical foundations, adding a layer of rigor and precision to the decision-making process.

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