



## Analysis of a Supply Chain using the Neutrosophic IOWA-VIKOR Method for Operational Sustainability

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### Abstract

In Ambato, the low availability of suppliers represents a significant challenge for business logistics, directly impacting operational efficiency, legal compliance, and competitiveness. This study aims to analyze the legal implications of business logistics in this region and propose strategies. The Neutrosophic Saaty AHP method was used for the development of the study, identifying the predominant challenge as the "low availability of suppliers," which can lead to legal risks related to contract non-compliance and supply chain issues. To address this challenge, the strategy of promoting the formation of strategic alliances and diversifying supply sources was proposed using the Neutrosophic IOWA-VIKOR method. This allows for the evaluation of suppliers' ability to meet demand and company requirements. The study also highlights the need to address challenges, manage indeterminacies, and optimize logistics chain operations in Ambato's businesses. It concludes that the strategy of strategic alliances and supplier diversification is crucial for overcoming the low availability of suppliers in Ambato.

**Keywords:** Neutrosophic IOWA-VIKOR; Business logistics; challenges; legal implications; Ambato; Operational Sustainability

### 1. Introduction

Business logistics in Ecuador faces unique challenges and opportunities within a constantly evolving legal framework, marked by globalization and the country's economic opening. Legislation, including the Organic Law of Public Enterprises and the creation of regulatory bodies such as the National Agency for Regulation and Control of Land Transport, Transit, and Road Safety (ANTTTTSV), plays a crucial role in defining standards and requirements for logistic operations [1] [2]. These regulations aim to ensure transparency, efficiency, and safety in the supply chain [3], as well as the competitiveness of companies at an international level [4].

However, Ecuadorian business logistics still faces obstacles such as the lack of coordination between government entities and legal risks in supplier selection [5]. The implementation of systems like the Single Window for Foreign Trade (VUCE) has simplified customs processes. Yet problems such as corruption in bidding processes and non-compliance with customs and foreign trade regulations persist, affecting the efficiency and competitiveness of companies. Careful supplier selection and the need for well-defined contracts are crucial to mitigate legal risks and ensure regulatory compliance.

Efficient logistics and compliance with the legal framework are crucial for the competitiveness of companies in Ambato and the rest of Ecuador. Adapting to legal regulations not only prevents operational and financial setbacks but also contributes to the reputation and sustainability of companies in the global market [6]. The interaction between business logistics and law in Ecuador highlights the importance of informed logistical management aligned with legal demands to foster competitiveness and regional economic growth [7] [8]. To achieve this, Ambato must establish strategies and processes that ensure both logistical efficiency and compliance with applicable legal norms. Based on the above, the main objective of this study is to analyze the legal implications and challenges of business logistics in Ambato, Ecuador, and propose strategies to ensure successful business logistics, with the specific objectives:

- Analyze the logistical challenges faced by companies in Ambato and their legal impact.
- Propose strategies to mitigate the most impactful challenges, thereby improving logistical efficiency and legal compliance in Ambato's companies.

The implementation of the IOWA-VIKOR Neutrosophic method in Ambato offers an advanced solution to strengthen the supply chain, integrating multicriteria analysis and handling of indeterminacies to optimize logistical and legal decisions. This strategy promotes alliances and supplier diversification, improving operational resilience and business competitiveness in a complex environment.

## 2. Neutrosophic Methods. Neutrosophic Set.

A neutrosophic set is an extension of classical and fuzzy set theory that allows for the modeling of uncertainty and indeterminacy. An element of a neutrosophic set has three associated parameters: the degree of truth  $T$ , the degree of indeterminacy  $I$ , and the degree of falsity  $F$  of  $x$  in  $Q$ , respectively, and their images constitute standard or non-standard subsets within the range  $\{0,1\}$  [9]. 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  $Q = (T, I, F)$ , where it satisfies the following condition  $0 \leq T + I + F \leq 3$ . To define an ordinary point within the single-valued neutrosophic set (SVNS), the following equation is used [10]:

$$B(Q) = \frac{1 + h - 2i - j}{2} \tag{1}$$

For the development of the study, neutrosophic linguistic scales are determined to establish the weight  $(w_Q) = (w_{Q1}, w_{Q2} \dots w_{Qj} \dots w_{Qn})$  of the criteria (see Table 1). To determine the parameters that allow for the discrimination of alternatives and establish preference of importance, Table 2 is used.

Table 1: Linguistic terms to determine the weight of importance  $(w_Q)$  of the defined criteria and challenges. Source: own elaboration

Linguistic scale	SVNN
Very important	(0.9,0.17,0)
Important	(0.7,0.47,0.25)
Medium	(0.5,0.67,0.5)
Not important	(0.25,0.77,0.7)
Very Not Important	(0,0.95,1)

Table 2: Linguistic terms for evaluating alternatives based on defined criteria. Own elaboration.

SVNN	Criteria					Linguistic term to the ideal point
	CR1	CR2	CR3	CR4	CR5	

(1,0,0)	Very high	Excellent	Very wide	Excellently efficient	Extremely far
(0.96,0.08,0.1)					Very far
(0.86,0.18,0.2)	High	Good	Wide	Very efficient	Very far
(0.76,0.28,0.3)					Far
(0.66,0.38,0.4)	Moderate			Efficient	Medium far
(0.56,0.48,0.5)					Half
(0.46,0.58,0.6)					Fairly close
(0.36,0.68,0.7)	Low	Poor	Limited	Inefficient	Next
(0.26,0.78,0.8)					Very close
(0.16,0.88,0.9)	Very low	Very poor	Very limited	Very inefficient	Very very close
(0,0.98,1)					Extremely close

**A. Neutrosophic IOWASD.**

The Neutrosophic Induced Ordered Weighted Averaging Standardized Distance (IOWASD) operator is calculated through a process that begins with the normalization of disparate criteria data [11]. This initial stage adjusts values to a uniform scale from 0 to 1, with 0 assigned to the least desired value and 1 to the most desirable, allowing for equitable comparisons between them. Subsequently, the procedure progresses with order induction, where the normalized data are reordered, not by their absolute values, but according to a predefined set of variables that indicate the relative importance of each criterion. Finally, aggregation weights are applied to the already ordered data. These weights vary according to the induced order to reflect the strategic importance of each datum, rather than its original magnitude. The general formula for the IOWASD operator is as follows:

$$IOWASD(u_1, f_1, f_{i1}; \dots; u_n, f_n, f_{in}) = \sum_{k=1}^n w_k d_k \tag{2}$$

Where:

- $u_j$ : Order induction variables.
- $f_j^*$  and  $f_j^-$  are, respectively, the best and worst observed values for criterion j.
- $f_{ij}$  is the value of criterion j for alternative i.
- $w_k$  are the weights assigned according to the induced order.
- $d_k$  is the normalized distance between  $f_j^*, f_{ij}$  and  $f_j^-$ , reordered according to  $u_j$ .

**B. Neutrosophic VIKOR. Neutrosophic IOWA-VIKOR**

The IOWA-VIKOR is a multi-criteria method that combines IOWA with VIKOR to effectively choose in contexts of conflicting criteria, aiming for a compromise solution close to the ideal. The Neutrosophic approach of VIKOR enhances decision-making in uncertain situations by considering truth, indeterminacy, and falsehood, thereby optimizing collective well-being and minimizing individual regret [12]. The Neutrosophic IOWA-VIKOR adapts to the diversity of criteria and handles uncertainty to facilitate complex decisions by integrating the advantages of the aforementioned methodologies. For modeling the Neutrosophic IOWA-VIKOR Method, the following steps are defined:

Step 1: Configuration of the Neutrosophic Decision Matrix (see Figure 1):

$$\begin{matrix}
 & & w_{k1}^Q & w_{k1}^Q & \dots & w_{kj}^Q & \dots & w_{kn}^Q \\
 F_j & & Min & Max & \dots & \dots & \dots & \dots \\
 \begin{matrix} Max V_i \\ Min V_i \end{matrix} & \begin{matrix} T_1 \\ T_2 \\ \vdots \\ T_i \\ \vdots \\ T_m \end{matrix} & \begin{bmatrix} m_{11} & m_{12} & \dots & m_{1j} & \dots & m_{1n} \\ m_{21} & m_{22} & \dots & m_{2j} & \dots & m_{2n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ m_{i1} & m_{i2} & \dots & m_{ij} & \dots & m_{in} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ m_{m1} & m_{m2} & \dots & m_{mj} & \dots & m_{mn} \end{bmatrix}
 \end{matrix}$$

$$\begin{matrix} f_{Qi}^* & m_{11} & m_{22} & \dots & \dots & \dots & \dots \\ f_{Qi}^- & m_{i1} & m_{i2} & \dots & \dots & \dots & \dots \end{matrix}$$

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

The various alternatives, which can be numerous, are denoted as  $T_1, T_2, \dots, T_m$ , where each alternative  $T_i$  is subject to evaluation under a set of  $n$  criteria. The rating of each aspect for the alternatives is expressed in neutrosophic terms and is denoted as  $f_{ij}$ , with  $f_{ij}$  being the value of the criterion function  $j$  for the alternative  $T_i$  (see Tables 1 and 2). The number of criteria is  $n$ , and each is associated with an order induction variable that guides the reordering process and weight assignment in the neutrosophic context.

Step 2: Neutrosophic assignment of order induction variables and weights. Neutrosophic IOWASD Aggregation:

Neutrosophic order induction variables are assigned to the criteria to reflect their relative importance, and a set of neutrosophic weights is established. The normalized evaluations are reordered according to the order induction variables, and a layer of neutrosophication is added to the IOWASD calculation. Weights are assigned to the reordered normalized distances to obtain a neutrosophic aggregated score for each alternative.

Step 3: Ranking and selection:

The VIKOR framework, expanded with neutrosophy, is used to rank the alternatives and select a compromise solution that is close to the ideal and results from mutual concessions, all evaluated through a neutrosophic lens. To do this, proceed to:

- I. Calculate the  $f_{Qi}^*$ , and the worst  $f_{Qi}^-$  values of each criterion.

$$\begin{matrix} f_{Qi}^* = \max_i f_{Qij} & f_{Qi}^- = \min_i f_{Qij} & \text{If function } i \text{ represents a benefit} \\ f_{Qi}^* = \min_i f_{Qij} & f_{Qi}^- = \max_i f_{Qij} & \text{If function } i \text{ represents a cost} \end{matrix}$$

- II. Calculate  $S_{Qj}, R_{Qj}$  and  $P_{Qj}$  values for each alternative:

$$S_{Qj} = w_{kj}^Q d_k^Q = \sum_{i=1}^n w_{kj}^Q \frac{f_{Qi}^* - f_{Qij}}{f_{Qi}^* - f_{Qi}^-} \tag{3}$$

Where  $w_k^Q$  are the weights determined after the induced order has been assigned. To do this, the Neutrosophic Induced Ordered Weighted Averaging Standardized Distance (IOWASD) operator is applied according to equation (2) proposed in the study. To determine the weights, the neutrosophic AHP method of Saaty is applied as defined by the consulted references [13].

$$R_{Qj} = \max_i \{w_{kj}^Q d_{kj}^Q\} \tag{4}$$

$$P_{Qj} = v \frac{S_{Qj} - S_Q^*}{S_Q^- - S_Q^*} + (1 - v) \frac{R_{Qj} - R_Q^*}{R_Q^- - R_Q^*} \tag{5}$$

Where:

$$S_Q^* = \min_j S_{Qj}; S_Q^- = \max_j S_{Qj} \tag{6}$$

$$R_Q^* = \min_j R_{Qj}; R_Q^- = \max_j R_{Qj}$$

And  $v$  is introduced as the weight of the maximum group utility strategy, while  $(1 - v)$  is the weight of individual opposition. For this study,  $v \sim 0.5$  or consensus voting is applied.

- III. Alternatives are ranked according to the values of  $S_Q, R_Q$  and  $P_Q$ . Subsequently, the compromise solution is determined as the alternative  $T_b^{(1)}$  which is the best ranked according to the value of  $P_b$  (according to equation 1), that is, with the minimum value of  $P_b$ , if the following two conditions are satisfied:
- Condition 1: Acceptable advantage.  

$$P_b(T_b^{(2)}) - P_b(T_b^{(1)}) \geq DP_b,$$
 Where  $T_b^{(2)}$ , is the second alternative according to the classification of the values of  $P_b$ , and  $DP_b = \frac{1}{N-1}$ , with  $N$  as the number of alternatives
  - Condition 2: Acceptable stability in the decision process.  
 The alternative  $T_b^{(1)}$  must be the best classified according to the list of values of  $S_b$  and/or  $R_b$ , this stable compromise solution within a decision process.  
 If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:
    - ❖ Alternatives  $T_b^{(1)}$  and  $T_b^{(2)}$  if condition 2 is not satisfied.
    - ❖ Alternatives  $T_b^{(1)}, T_b^{(2)}, \dots, T_b^{(m)}$ , and if condition 1 is not satisfied; It is determined by taking into account the relationship  $P_b(T_b^{(2)}) - P_b(T_b^{(1)}) \geq DP_b$ . These alternatives are considered to be close to the ideal solution.

### 3. Results.

Logistical challenges in Ambato can have a legal impact on businesses in terms of breach of contract, customs penalties, lawsuits from dissatisfied customers, and labor issues. It is crucial for businesses to be aware of these challenges and have legal advice to mitigate potential risks and comply with applicable regulations:

D1. Low availability of logistics service providers: The lack of specialized logistics service providers in the area can limit the options available to businesses. This could lead to dependence on a limited number of providers, which in turn could increase the risks of contract breaches or supply chain problems.

D2. Limited transportation infrastructure: Ambato may face limitations in terms of road and transportation infrastructure, which can restrict the efficiency of logistics operations. This can result in delivery delays and difficulties in meeting contract deadlines, which could have legal implications in terms of breach of contract.

D3. Non-compliance with customs and foreign trade regulations. Non-compliance with labor regulations and low staff training: Ambato is a significant commercial center in Ecuador, which implies that local businesses may be involved in foreign trade operations. Customs and foreign trade regulations are complex and constantly changing, which could lead to errors in documentation and customs declarations, in turn resulting in legal penalties. Hiring and training suitable staff for logistics operations can be a challenge. Businesses must comply with labor regulations in terms of contracts, wages, and working conditions, which can have a legal impact if not adequately met.

D4. Inefficient inventory management: Inefficient inventory management can lead to problems such as a lack of products in stock or excess inventory, affecting the businesses' ability to meet delivery deadlines. This could result in legal claims from dissatisfied customers.

D5. Lack of coordination in the supply chain: Lack of coordination among different actors in the supply chain, such as suppliers, carriers, and customers, can result in delays and issues in deliveries. This could affect the businesses' reputation and lead to potential lawsuits for breach of contract.

D6. Low use of technology and information systems: The lack of appropriate information systems and technology can hinder the efficient management of logistics operations. This could result in errors in documentation, loss of information, and lack of visibility in the supply chain, which could have legal implications in case of disputes.

For the analysis of challenges with legal implications affecting the development of business logistics, the Neutrosophic AHP Saaty method is modeled. For the modeling, the resulting table with weights is obtained after having performed the binary comparison matrix (Tables 3 and 4).

Table 3: Determination of criteria weights by applying the AHP Neutrosophic method. Source: own elaboration.

Challenges	D1	D2	D3	D4	D5	D6
D1	(0.9,0.17,0)	(0.9,0.17,0)	(0.9,0.17,0)	(0.9,0.17,0)	(0.9,0.17,0)	(0.9,0.17,0)
D2	(0,0.95,1)	(0.25,0.77,0.7)	(0.7,0.47,0.25)	(0.7,0.47,0.25)	(0.7,0.47,0.25)	(0.7,0.47,0.25)
D3	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0.5,0.67,0.5)	(0.5,0.67,0.5)	(0.5,0.67,0.5)
D4	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)
D5	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)
D6	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)

Table 4: Weight determination and consistency analysis of the paired matrix. Source: own elaboration.

Challenges	A x Weight	Weight	Approximate Eigenvalues
D1	3.95	(0.95,0.15,0)	7.791044776
D2	1.61	(0.50,0.55,0.5)	6.96099844
D3	0.68	(0.25,0.75,0.7)	5.991054313
D4	0.30	(0,0.95,1)	6.164476886
D5	0.30	(0,0.95,1)	6.164476886
D6	0.30	(0,0.95,1)	6.164476886
<b>Eigenvalue = 6.5394214</b>			

The consistency analysis of the method revealed that its eigenvalue is 6.53, with a Consistency Index (CI) of 0.11 and a Random Consistency (RC) of 0.09, thus confirming the correctness of the exercise. Once the weights were calculated, it was determined that the predominant challenge for companies in Ambato in terms of logistics and its potential legal impact is the "low availability of suppliers," with a priority of (0.95,0.15,0). This challenge can have a greater impact on logistics operations and potential legal implications in terms of supplier dependency and risks of contract non-compliance or supply chain issues.

To mitigate this predominant challenge, strategies are proposed to provide a more comprehensive overview for overcoming the low availability of suppliers in Ambato (see Table 5). This includes aspects such as the estimated implementation time and the expected benefits of each strategy.

Table 5: Proposed strategies to overcome the low availability of suppliers in Ambato. Source: own elaboration.

No.	Strategy	Scope	Time	Expected benefits
ES1	Strategic alliances and diversification of supply sources.	Establish alliances and diversify sources to reduce dependence on specific suppliers and improve chain resilience.	3-6 months	Greater supply chain resilience, and reduced dependence on single suppliers.
ES2	Development of a supplier evaluation and certification program.	Implement a program to evaluate and certify suppliers according to capacity, reliability,	6-12 months	Improvement of the quality and reliability of suppliers, reduction of legal and operational risks.

		quality, and legal compliance.		
<b>ES3</b>	Technological integration for supplier management.	Implement technological solutions to optimize supplier management, by including information and automation systems.	6-18 months	Improvements in operational efficiency, data-based decisions, and process optimization.
<b>ES4</b>	Training and development programs for suppliers.	Develop programs aimed at improving the logistical and legal competencies of suppliers.	4-8 months	Raising supplier standards, and improving logistical and legal compatibility.
<b>ES5</b>	Promotion of competitiveness through incentives.	Offer incentives to suppliers that improve their operational efficiency, quality, flexibility, and legal compliance.	Continuous deployment	Stimulation of continuous improvements among suppliers, and promotion of a culture of excellence.
<b>ES6</b>	Proactive management of legal and contractual risks.	Implement proactive risk management by constantly reviewing and adapting contracts with suppliers.	Continuous deployment	Reduction of legal conflicts, improvement in adaptability, and response to regulatory changes.

These strategies provide critical details that allow companies in Ambato to understand the scope, the time required for implementation, and the key benefits of each proposed strategy. These elements are essential for planning and prioritizing actions within an efficient and legally robust supplier management framework.

Once the alternatives have been defined, the criteria designed to evaluate supplier management strategies must be incorporated. This provides an evaluation framework based on neutrosophic linguistic terms and measurement scales that allow for a detailed assessment of each strategy based on its neutrosophic importance. For this study, the following criteria were determined:

- Capacity and Reliability of Compliance (CR1): The ability of suppliers to consistently meet demand and requirements.
- Quality and Reputation (CR2): The quality of the products/services offered and the reputation of the suppliers in the market.
- Operational Flexibility (CR3): The ability of suppliers to adapt to changes in demand and market conditions.
- Diversity of Offer and Contractual Conditions (CR4): Variety of suppliers and favorability of the contractual conditions.
- Cost-Efficiency (CR5): Assessment of the cost of products/services in relation to their value.

Therefore, experts determine 5 criteria that must be evaluated to determine the resulting weight. It is decided to repeat the Neutrosophic Saaty AHP method and consequently model the Neutrosophic OWASD-VIKOR method to determine the resulting strategy (see Tables 6 and 7).

Table 6: Neutrosophic matrix for determining the weights of the criteria. Source: own elaboration.

Challenges	CR1	CR2	CR3	CR4	CR5	Weight
<b>CR1</b>	(0.9,0.17,0)	(0.9,0.17,0)	(0.7,0.47,0.25)	(0.7,0.47,0.25)	(0.9,0.17,0)	<b>(0.9,0.17,0)</b>
<b>CR2</b>	(0,0.95,1)	(0.25,0.77,0.7)	(0.7,0.47,0.25)	(0.9,0.17,0)	(0.7,0.47,0.25)	<b>(0.5,0.67,0.5)</b>
<b>CR3</b>	(0.9,0.17,0)	(0.25,0.77,0.7)	(0.7,0.47,0.25)	(0.7,0.47,0.25)	(0.7,0.47,0.25)	<b>(0.7,0.47,0.25)</b>
<b>CR4</b>	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	<b>(0,0.95,1)</b>
<b>CR5</b>	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	(0,0.95,1)	<b>(0,0.95,1)</b>

Table 7: Analysis of the consistency of the paired matrix. Source: own elaboration.

Challenges	A x Weight	Approximate Eigenvalues
<b>CR1</b>	2.42	6.048304865
<b>CR2</b>	1.19	5.228481071
<b>CR3</b>	1.41	5.214387125
<b>CR4</b>	0.27	5.120584145
<b>CR5</b>	0.26	5.226095529
<b>CR6</b>	2.42	6.048304865
<b>Eigenvalue =5.36757055</b>		

The consistency analysis of the method revealed that its eigenvalue is 5.36, with a Consistency Index (CI) of 0.09 and a Random Consistency Index (RC) of 0.08, thus confirming the correctness of the exercise. The resulting weights prioritize within the neutrosophic set the following priority for  $w_j = \langle(0.9,0.17,0); (0.5,0.67,0.5); (0.7,0.47,0.25); (0,0.95,1); (0,0.95,1)\rangle$ . Here, the CR1 criterion is highlighted as the strongest criterion, followed by CR3 and CR2, while the CR4 and CR5 criteria are considered of lower importance than their predecessors. However, this priority needs to be evaluated based on the induced order of these criteria through the modeling of the OWASD-VIKOR Neutrosophic method and determine the compromise solution or solutions that are closest to the ideal solution (see Table 8-10).

Table 8: Neutrosophic normalization of the decision matrix. Source: own elaboration.

	<b>CR1</b>	<b>CR2</b>	<b>CR3</b>	<b>CR4</b>	<b>CR5</b>
<b>Fj</b>	<b>Max</b>	<b>Max</b>	<b>Max</b>	<b>Max</b>	<b>Max</b>
<b>ES1</b>	(0.66,0.38,0.4)	(0.36,0.68,0.7)	(0.26,0.78,0.8)	(0.46,0.58,0.6)	(0.56,0.48,0.5)
<b>ES2</b>	(0.36,0.68,0.7)	(0.56,0.48,0.5)	(0.56,0.48,0.5)	(0.56,0.48,0.5)	(0.46,0.58,0.6)
<b>ES3</b>	(0.56,0.48,0.5)	(0.76,0.28,0.3)	(0.26,0.78,0.8)	(0.36,0.68,0.7)	(0.26,0.78,0.8)
<b>ES4</b>	(0.36,0.68,0.7)	(0.26,0.78,0.8)	(0.46,0.58,0.6)	(0.26,0.78,0.8)	(0.36,0.68,0.7)
<b>ES5</b>	(0.36,0.68,0.7)	(0.76,0.28,0.3)	(0,0.98,1)	(0.36,0.68,0.7)	(0.66,0.38,0.4)
<b>ES6</b>	(0.36,0.68,0.7)	(0.76,0.28,0.3)	(0,0.98,1)	(0.36,0.68,0.7)	(0.66,0.38,0.4)
<b>Best <math>f_{Qi}^*</math></b>	<b>(0.66,0.38,0.4)</b>	<b>(0.76,0.28,0.3)</b>	<b>(0.56,0.48,0.5)</b>	<b>(0.56,0.48,0.5)</b>	<b>(0.66,0.38,0.4)</b>
<b>Worst <math>f_{Qi}</math></b>	<b>(0.36,0.68,0.7)</b>	<b>(0.26,0.78,0.8)</b>	<b>(0,0.98,1)</b>	<b>(0.26,0.78,0.8)</b>	<b>(0.26,0.78,0.8)</b>

Table 9: Order-inducing variables. Source: own elaboration.

	<b>ES1</b>	<b>ES2</b>	<b>ES3</b>	<b>ES4</b>	<b>ES5</b>	<b>ES6</b>
<b>CR1</b>	(0.95,0.15,0)	(0.95,0.15,0)	(0.50,0.55,0.5)	(0,0.95,1)	(0,0.95,1)	(0.95,0.15,0)
<b>CR2</b>	(0.7,0.35,0.25)	(0.7,0.35,0.25)	(0,0.95,1)	(0.25,0.75,0.7)	(0.50,0.55,0.5)	(0.50,0.55,0.5)
<b>CR3</b>	(0.25,0.75,0.7)	(0.50,0.55,0.5)	(0.95,0.15,0)	(0.50,0.55,0.5)	(0.25,0.75,0.7)	(0.7,0.35,0.25)
<b>CR4</b>	(0.50,0.55,0.5)	(0,0.95,1)	(0.7,0.35,0.25)	(0.95,0.15,0)	(0.95,0.15,0)	(0,0.95,1)
<b>CR5</b>	(0,0.95,1)	(0.25,0.75,0.7)	(0.25,0.75,0.7)	(0.7,0.35,0.25)	(0.7,0.35,0.25)	(0.25,0.75,0.7)

Once the matrix defined in Table 9 is set, weights are assigned according to the induced priority order for  $w_j = \langle(0.9,0.17,0); (0.5,0.67,0.5); (0.7,0.47,0.25); (0,0.95,1); (0,0.95,1)\rangle$  (obtained from the second modeling of the Neutrosophic AHP of Saaty). With this weight vector, the neutrosophic IOWASD is calculated to determine the values of  $S_{Qj}$ ,  $R_{Qj}$ , and  $P_{Qj}$  for each alternative (see Table 10).

Table 10: Index of  $S_{Qj}$ ,  $R_{Qj}$  and  $P_{Qj}$  for each strategy. Source: own elaboration.

<b>IS</b>	$S_{Qj}$	$R_{Qj}$	$v$	$P_{Qj}$	<b>Hierarchy</b>
ES1	(0.36,0.68,0.7)	(0,0.98,1)	0.5	(0,0.98,1)	1
ES2	(0.46,0.58,0.6)	(0.36,0.68,0.7)		(0.56,0.48,0.5)	5

ES3	(0.56,0.48,0.5)	(0,0.98,1)	(0.36,0.68,0.7)	3
ES4	(0.76,0.28,0.3)	(0.36,0.68,0.7)	(0.26,0.78,0.8)	6
ES5	(0.36,0.68,0.7)	(0.26,0.78,0.8)	(0.56,0.48,0.5)	2
ES6	(0.56,0.48,0.5)	(0.26,0.78,0.8)	(0.56,0.48,0.5)	4

For the classification of alternatives, an evaluation is conducted with a consensus vote ( $v \sim 0.5$ ). The results show that among the analyzed strategies, ES1 has the lowest  $P_{Qj}$  value, and based on this criterion, a hierarchy of selection closest to the ideal solution is achieved. However, it is essential to assess whether the best strategy meets the conditions of acceptable advantage and acceptable stability in the decision-making process. This analysis involves examining  $S_{bj}$ ,  $R_{bj}$  and  $P_{bj}$  in Figure 2.

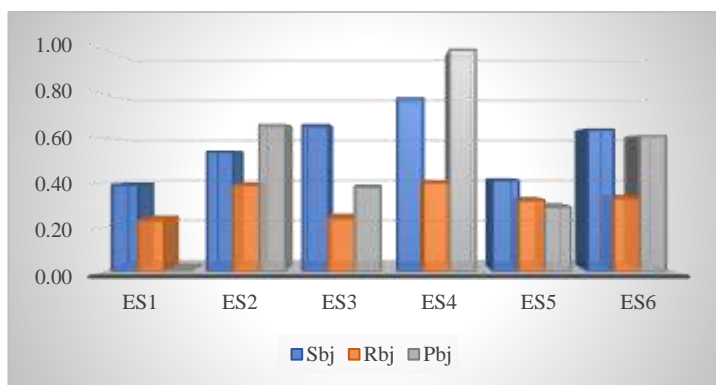


Figure 3: Analysis of  $S_{bj}$ ,  $R_{bj}$  and  $P_{bj}$ . Source: own elaboration.

The graph shows that the alternative ES1 meets the condition of acceptable advantage over alternative ES5, where  $P_b(ES5) - P_b(ES1) \geq DP_b$  for  $0.29 \geq 0.2$ . Therefore, alternative ES1 is defined as the compromise solution and the best-ranked according to the list of  $S_b$  and/or  $R_b$  values. Figure 2 displays a representation of  $S_{bj}$ ,  $R_{bj}$  and  $P_{bj}$  with a value of proximity to the ideal solution of (0,0.98,1).

In summary, the OWASD-VIKOR Neutrosophic analysis has indicated that the ES1 strategy of *strategic alliances and diversification of supply sources* stood out as an *extremely close* compromise solution to the ideal solution to mitigate the challenge of low *availability of logistic service providers*. The ranking of solutions is followed by the ES5 strategy of promoting *competitiveness through incentives* to provide opportunities for suppliers to integrate into the logistics chain.

### 6. Conclusion

The study on Ambato's businesses highlights a significant link between logistical challenges and their legal consequences, particularly emphasizing how the scarcity of suppliers affects contractual and regulatory compliance. It underscores the importance of a holistic strategy that considers both logistics and legal aspects to ensure efficient operational flow and adherence to current laws.

The evaluation of suppliers, focusing on their ability to meet demands and specific requirements, is identified as a key tactic to overcome the limited availability of suppliers. This approach not only minimizes operational and legal risks arising from potential non-compliance but also promotes transparency and informed choice of reliable suppliers, thereby reinforcing trust in business relationships.

Finally, it is concluded that addressing logistical challenges from a legally integrated perspective is essential to increase the competitiveness of businesses in Ambato. The optimal strategy identified promotes the formation of strategic alliances and diversification of supply sources, thereby improving the resilience of the chain, reducing dependence on single suppliers, and ensuring customer satisfaction and operational efficiency. Furthermore, the application of the OWASD-VIKOR

Neutrosophic method to other logistical challenges in different geographical contexts is proposed for future research.

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