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KPI and Logistics Dashboard Design Using Neutrosophic Statistics

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Abstract. KPIs in logistics are key indicators to measure the evolution of the company and execute continuous improvement actions. This series of data, ratios, and percentages constitute a solid base on which to support our decision-making to achieve logistical excellence, by identifying with greater accuracy the opportunities for improvement to know the problem areas on time and understand the low yields. To ensure that the KPIs fulfill the purpose of generating a practical tool for all logistics professionals who wish to effectively control each of the operations that are implicit in the processes, their integration with the dashboards is necessary. This integration makes it possible to reflect through the graphic representation the KPIs involved in achieving the objectives of a strategy proposed by the company. In addition, this study allows an analysis through neutrosophic statistics and TOPSIS analysis to determine the factors that affect the delivery of products to the customer and determine the possible alternatives based on the use of the logistics KPIs integrated into the dashboard.

Keywords: Logistic KPIs, Neutrosophic Statistics, TOPSIS

1 Introduction

KPI stands for Key Performance Indicators, and its function is to provide indicators that allow measuring various aspects of a company [1], such as; production level, product quality controls [2], the economic and financial situation of the company, the performance of the workers in each of the activities entrusted [3], among others, which are related to the achievement of the organizational objectives of a company, since that is the reason for the study [4-6].

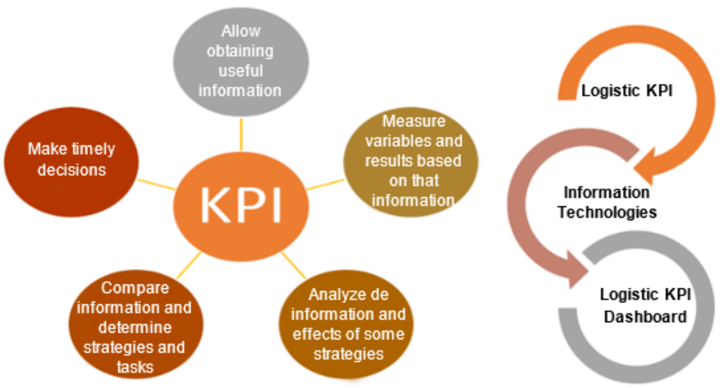

Figure 1. Advantages of KPIs and their integration into technology [7]

With the use of dashboards to visualize KPI metrics, you can get a clearer and more concrete view of what the financial situation of a company is and at what points you can improve production processes and/or administrative processes [7] since both are the ones that set the course of it and its success in the market [8]. For the selection of these parameters, the degree of linkage with the organization's objectives must be analyzed to carry out measurements based on a tangible goal [3, 9].

The KPIs on the dashboard provides strategies to entrepreneurs to boost a business and improve their capabilities in the market. In this sense, income will increase by benefiting partners and workers [4, 7, 10, 11].

Among the significant advantages of having the support of an expert in reading the KPIs [2], is that you will be able to immediately identify any fault detected through this instrument and will plan the most suitable way to attack and correct it, as well as select which are the KPIs with the most significant weight in the study [1]. Consequently, productivity will not be affected but reinforced by these proactive actions [12]. Regarding marketing, KPIs allow identifying in detail the factors that allowed the success or failure of a campaign [13], to improve or discard them for future campaigns [14].

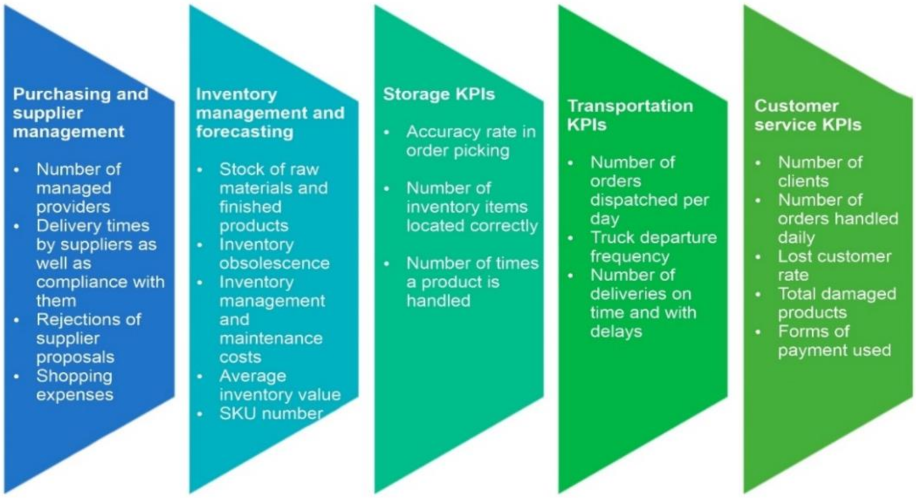

Figure 2. Logistics KPIs at each stage of the process. Source: [10]

The logistics process of a company is one of the most complex ones to monitor [15] since there are a large number of elements to take into account: different states in which the products are, geographical displacement, or stages that go through throughout the process [8, 16].

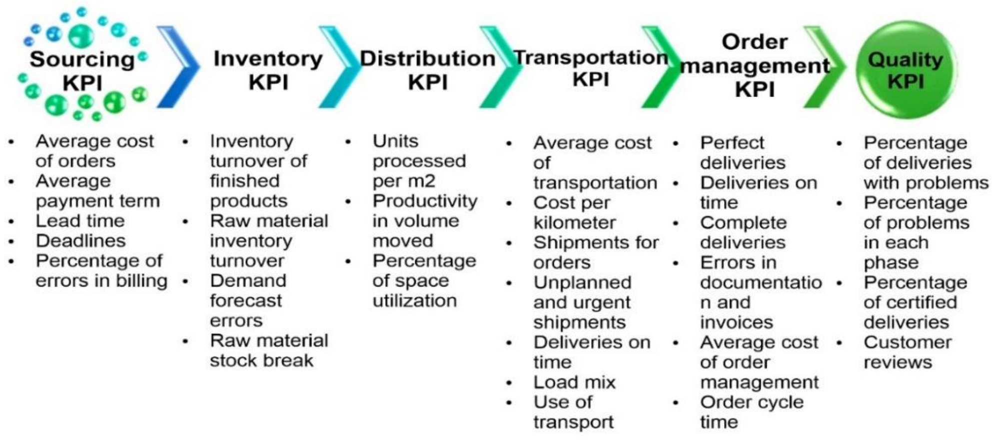

Figure 3. Logistics KPI based on its particularity and planned objective at each stage. Source: [17]

It should be noted that each logistics process has its peculiarities. Therefore, it is essential to set medium/long-term objectives [15, 18-21]. Moreover, the main objective of logistics KPIs is the rapid detection of any failure or deviation [7]. Thus, following up and continuously monitoring these indicators will help reduce costs and optimize the use of material and human resources during the development of the activity [14]. For the analysis of Logistics KPIs, this study defines:

- Problem situation: delays in product deliveries to customers
- The main objective: define the logistics KPI to detect possible deficiencies that influence delays in product deliveries to customers
- Specific objectives:

- Determine the factors that affect the variable analyzed
- Analyze logistics KPIs according to the stages of the process
- Carry out the measurement and modeling of the variable
- Project potential alternatives based on the company's strategy to achieve

From those above, the study is structured according to Figure 4 [22]. It should be taken into account that the analysis of the KPIs will be interrelated with the dashboards [11].

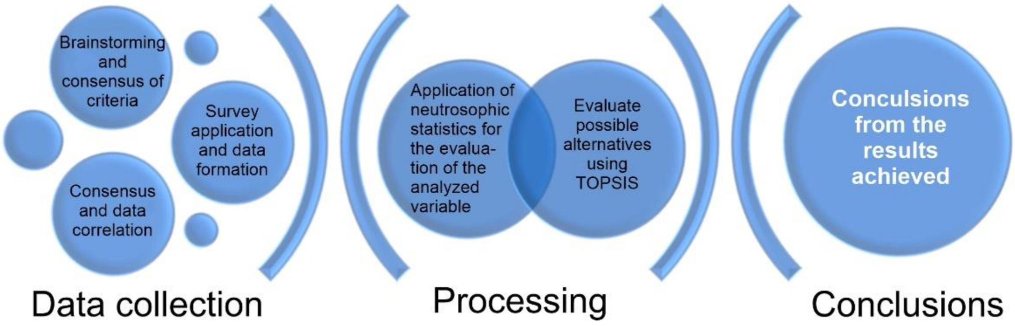

Figure 4. Development of the study of logistics KPIs. Source: Own elaboration.

2 Materials and methods

2.1 Neutrosophic statistics

Neutrosophic probabilities and statistics are a generalization of classical and imprecise probabilities and statistics. The Neutrosophic Probability of an event E is the probability that event E will occur, the probability that event E does not occur, and the probability of indeterminacy (not knowing whether event E occurs or not). In classical probability nsup≤1, while in neutrosophic probability nsup≤3 +. The function that models the neutrosophic probability of a random variable x is called the neutrosophic distribution: $NP(x) = (T(x), I(x), F(x))$, where T (x) represents the probability that the value x occurs, F (x) represents the probability that the value x does not occur, and I (x) represents the indeterminate or unknown probability of the value x.

Neutrosophic Statistics is the analysis of neutrosophic events and deals with neutrosophic numbers, the neutrosophic probability distribution[23], neutrosophic estimation, neutrosophic regression, etc. It refers to a set of data formed totally or partially by data with some degree of indeterminacy and the methods to analyze them. Neutrosophic statistical methods allow the interpretation and organization of neutrosophic data (data that can be ambiguous, vague, imprecise, incomplete, or even unknown) to reveal the underlying patterns [24]. In short, the Neutrosophic Logic, Neutrosophic Sets, and Neutrosophic Probabilities and Statistics have a wide application in various research fields and constitute a new reference of study in full development. The Neutrosophic Descriptive Statistics includes all the techniques to summarize and describe the characteristics of the neutrosophic numerical data [25]. Neutrosophic Numbers are numbers of the form where a and b are real or complex numbers [26], while "I" is the indeterminacy part of the neutrosophic number.$N = a + bI$

The study of neutrosophic statistics refers to a neutrosophic random variable where y represents the corresponding lower and upper level that the studied variable can reach, in an indeterminate interval. Following the neutrosophic mean of the variable when formulating:$X_l\, X_u I_N [I_l, I_u] (\bar{x}_N)$

$$X_N = X_l + X_u I_N;\; I_N \in [I_l, I_u] \tag{1}$$

Where $\bar{x}_a = \frac{1}{n_N} \sum_{i=1}^{n_N} X_{il}\, \bar{x}_b = \frac{1}{n_N} \sum_{i=1}^{n_N} X_{iu}\, n_N \in [n_l, n_u]$ (2)

is a neutrosophic random sample. However, for the calculation of neutral frames (NNS), it can be calculated as follows

$$\sum_{i=1}^{nN} (\bar{X} - \bar{X}_{iN})^2 = \sum_{i=1}^{nN} \begin{bmatrix} min \begin{pmatrix} (a_i+b_iI_L)(\bar{a}+\bar{b}I_L),(a_i+b_iI_L)(\bar{a}+\bar{b}I_U) \\ (a_i+b_iI_U)(\bar{a}+\bar{b}I_L),(a_i+b_iI_U)(\bar{a}+\bar{b}I_U) \end{pmatrix} \\ max \begin{pmatrix} (a_i+b_iI_L)(\bar{a}+\bar{b}I_L),(a_i+b_iI_L)(\bar{a}+\bar{b}I_U) \\ (a_i+b_iI_U)(\bar{a}+\bar{b}I_L),(a_i+b_iI_U)(\bar{a}+\bar{b}I_U) \end{pmatrix} \end{bmatrix}, I \in [I_L, I_U] \tag{3}$$

Where $a_i = X_l b_i = X_u$. The variance of the neutrosophic sample can be calculated by

$$S_N^2 = \frac{\sum_{i=1}^{nN}(X_i - \bar{X}_{iN})^2}{{}^nN}; S_N^2 \in [S_L^2, S_U^2] \tag{4}$$

The neutrosophic coefficient (NCV) measures the consistency of the variable. The lower the NCV value, the more consistent the factor's performance is. NCV can be calculated as follows [27].

$$CV_N = \frac{\sqrt{S_N^2}}{\bar{X}_N} X100;\ CV_N \in [CV_L, CV_U] \tag{5}$$

2.2 TOPSIS method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a technique characterized by its effectiveness and the simplicity of its principle in solving multi-criteria decision problems. The problem is to find the best-evaluated alternative [28]. In the case of TOPSIS, the selection is based on finding the alternative that is closest to the ideal solution, and in turn, it is further away from the worst solution. It allows combining several heterogeneous attributes in a single dimensionless index, and this is because the attributes under evaluation are quite possibly expressed in different units or scales [28-46].

TOPSIS is based on the concept that the selected alternative must have the smallest Euclidean distance to an ideal solution and the greatest Euclidean distance to an anti-ideal solution [47]. Thus, the order of preference of the alternatives can be determined by a series of comparisons of these distances. Both solutions, the ideal and the anti-ideal, are fictitious solutions [27]. The ideal solution is a solution for which all the values of the attributes correspond to the optimal values of each attribute contained in the alternatives; the anti-ideal solution is the solution for which all the values of the attributes correspond to the least desired values of each attribute contained in the alternatives [26]. In this way, TOPSIS provides a solution that is the closest to a hypothetically better solution and the furthest from the hypothetically worst [48]. The process is described below:

1. Determine the objective and identify the attributes to evaluate.
2. Prepare a matrix based on the information available on the attributes. Each row corresponds to an alternative and each column to an attribute. The element in the array represents the non-normalized value of the attribute for the alternative.$x_j j_{th} i_{th}$
3. Calculate the normalized decision matrix. This is obtained by dividing each attribute value by the square root of the sum of the squares of each attribute value XJ. This is mathematically represented by equation (6):$R_{ij} x_j$

$$Rij = \frac{x_{ij}}{\sqrt{\sum_{m=1}^{k} x_{mj}^2}} \tag{6}$$

4. Determine the relative importance or weight for each attribute concerning the objective. This results in a set of weights $w_j\ (para\ j = 1,2,\dots,J)$ such that $\sum w_j = 1$. The weights are generally based on expert judgment and should reflect the relative importance assigned to the performance attributes evaluated. The range of possible values of w_j will only be limited by the ability of the decision group elements to distinguish the relative importance of the performance attributes analyzed. [26].
5. Obtain the normalized and weighted matrix. This is done by multiplying each element in the columns of the matrix by its corresponding weight. Therefore, the elements of the normalized and weighted matrix are expressed by equation 7:$V_{ij} R_{ij} w_j$

$$V_{ij} = w_j * R_{ij} \tag{7}$$

6. Obtain the ideal solution and the anti-ideal: The ideal solution can be expressed as (8) and anti-ideal (9). indicates the ideal value of the attribute considered among the values of the attributes for the different alternatives, while it indicates the worst value of the attribute considered among the values of the attributes for the different alternatives $V_j^+ V_j^-$[27].

$$V^+ = \{V_1^+, V_2^+, V_3^+, \dots, V_j^+\} \tag{8}$$

$$V^- = \{V_1^-, V_2^-, V_3^-, \dots, V_j^-\} \tag{9}$$

7. Calculate the Euclidean distances of each alternative to the ideal and anti-ideal solutions using the following equations:

$$D_i^+ = \sqrt{\sum_{j=1}^{j} (V_{ij} - V_j^+)^2} \quad (10)$$

$$D_i^- = \sqrt{\sum_{j=1}^{j} (V_{ij} - V_j^-)^2} \quad (11)$$

8. The relative closeness Pi of a particular alternative to the ideal solution is expressed by (12):

$$P_i = \frac{D_i^-}{(D_i^+ + D_i^-)} \quad (12)$$

9. In this step, a set of alternatives is generated in descending order according to the value of Pi, with the best alternative being the one with the highest value of Pi.
10. In this article, linguistic terms will be associated with SVNN, in such a way that the experts can carry out their evaluations according to the corresponding scale (Table 1).

Linguistic term	SVNN
Very Weak (VW)	(0.10, 0.75, 0.85)
Weak (W)	(0.25, 0.60, 0.80)
Medium Weak (MW)	(0.40, 0.70, 0.50)
Medium (M)	(0.50, 0.40, 0.60)
Medium Strong (MS)	(0.65, 0.30, 0.45)
Strong (S)	(0.80, 0.10, 0.30)
Very Strong (VS)	(0.95, 0.05, 0.05)

Table 1: Linguistic terms according to the strength of the weight in the alternatives

3 Results

3.1 Data collection

Once the different approaches have been analyzed in the introduction of the document, we apply the techniques above, as follows for a company that aims to deliver and distribute products with a certain level of fragility.

Variable analyzed: product delivery For a sample of n = 150, for each factor (f)

Code	Initials	Factors that affect the compliance and quality of deliveries
a	LARM	Late arrival of raw materials
p	IHP	Incorrect handling of the product
c	BDTC	Breach of delivery times to the customer
d	DP	Damaged products
o	IO	Inventory obsolescence

Table 2. Determining factors in product delivery

For the development of the statistical study, the neutrosophic frequencies of the factors are analyzed to relate to the correct use of logistic KPIs. For each Logistics KPI group, an impact is analyzed in days that make up the logistics impacts in the efficient delivery of products for each factor.

Days	Neutrosophic frequencies				
	LARM	IHP	BDTC	DP	IO
1	[1 ; 2]	[1 ; 2]	[0 ; 0]	[0 ; 0]	[0 ; 1]
2	[1 ; 2]	[0 ; 0]	[0 ; 1]	[0 ; 0]	[0 ; 1]
3	[1 ; 1]	[0 ; 0]	[1 ; 2]	[1 ; 1]	[1 ; 1]
4	[0 ; 0]	[1 ; 1]	[1 ; 2]	[0 ; 1]	[1 ; 1]

5	[1 ; 1]	[1 ; 1]	[0 ; 1]	[0 ; 1]	[1 ; 2]
6	[1 ; 1]	[0 ; 0]	[1 ; 2]	[1 ; 1]	[1 ; 1]
7	[1 ; 1]	[1 ; 2]	[0 ; 1]	[0 ; 0]	[1 ; 1]
8	[0 ; 0]	[0 ; 1]	[1 ; 2]	[0 ; 0]	[1 ; 1]
9	[1 ; 2]	[0 ; 1]	[0 ; 0]	[0 ; 1]	[1 ; 2]
10	[1 ; 2]	[1 ; 1]	[0 ; 1]	[0 ; 0]	[1 ; 1]
11	[1 ; 2]	[0 ; 0]	[0 ; 0]	[0 ; 1]	[0 ; 0]
12	[1 ; 2]	[0 ; 1]	[0 ; 0]	[0 ; 0]	[1 ; 1]
13	[0 ; 0]	[1 ; 1]	[1 ; 1]	[0 ; 0]	[0 ; 0]
14	[1 ; 1]	[0 ; 1]	[1 ; 2]	[0 ; 1]	[0 ; 1]
15	[0 ; 0]	[0 ; 0]	[0 ; 1]	[1 ; 1]	[1 ; 2]
16	[1 ; 1]	[1 ; 2]	[1 ; 1]	[1 ; 2]	[1 ; 1]
17	[0 ; 0]	[1 ; 1]	[1 ; 1]	[1 ; 2]	[0 ; 1]
18	[1 ; 2]	[0 ; 1]	[0 ; 1]	[0 ; 0]	[0 ; 1]
19	[0 ; 0]	[0 ; 1]	[1 ; 2]	[1 ; 1]	[1 ; 1]
20	[1 ; 1]	[1 ; 1]	[1 ; 1]	[0 ; 1]	[1 ; 2]
1-150	**[83 ; 159]**	**[73 ; 140]**	**[72 ; 147]**	**[75 ; 155]**	**[83 ; 150]**

Table 3. Factors affecting order fulfillment and quality

Table 1 studies the factor effects on compliance and quality of deliveries by the logistics part for 150 days, with an occurrence level of [0; 2] for each factor per day with a total indeterminacy level of a = 76, p = 67, c = 75, d = 80, or = 67, with a level of representativeness of [44.66%; 51.61%], on the days that 2 effects per factor are registered, with a higher incidence of 50% in non-compliance with delivery times to the customer and products damaged by improper handling. As a result of the existing indeterminacy, the use of classical statistics is not possible, so it is necessary to use neutrosophic statistics for its better understanding.

3.2 Neutrosophic statistical analysis

The modeling of the data of affectations that influence the delivery of the orders to be controlled by each group of logistics KPIs (table 2). To understand which factor implies a representative mean $\bar{x} = \in [\bar{x}_L; \bar{x}_U]$, the values of the neutrosophic means are calculated and for the study of the variations of the affectations, the values of the neutrosophic standard deviation $S_N \in [S_L; S_U]$.. To determine which affectation requires a higher incidence of the logistic KPIs, the values are calculated $CV_N \in [CV_L ; CV_U]$

Factors	$\bar{x}_N$	*SN*	*CVN*
Breach of supply delivery times by the supplier	[0.553 ; 1.06]	[0.126 ; 0.988]	[0.228 ; 0.932]
Incorrect handling of the product	[0.487 ; 0.933]	[0.125 ; 1.015]	[0.257 ; 1.088]
Breach of delivery times to the customer	[0.48 ; 0.98]	[0.125 ; 0.965]	[0.26 ; 0.985]
Damaged products	[0.5 ; 1.033]	[0.125 ; 1.028]	[0.25 ; 0.995]
Inventory obsolescence	[0.553 ; 1]	[0.126 ; 1.018]	[0.228 ; 1.018]

Table 4. Neutrosophic statistical analysis of incidents in orders

Table 4 shows that non-compliance with delivery times for supplies by the supplier has higher incidence values than the other factors. This means that for the IPEP factor it is on average the one that most affects the fulfillment of order deliveries. In affirmation, the value for this factor is lower compared to the rest. This represents that the result of non-compliance with the delivery dates of the supplies by the supplier has a negative and more significant impact than the other factors in the delivery of the products to the customer (Figure 5).

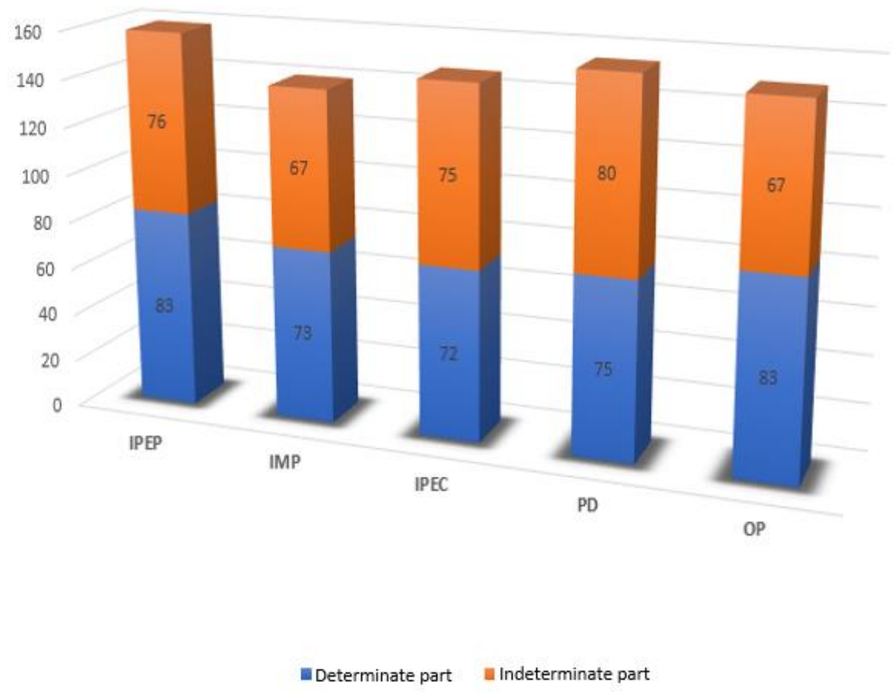

Figure 5. Neutrosophic bar graph of order incidences

3.3 Comparative analysis

To determine the associated referent indeterminacy measure for the form of neutrosophic numbers (Table 5). In the results obtained, it is observed that for the values they go from $\bar{x} = \in [\bar{x}_L; \bar{x}_U], S_N \in [S_L; S_U] CV_N \in [CV_L; CV_U] CV_N$ 0.228 to 0.932 with the indeterminacy measure 75.5 generates a negative impact to comply with the deliveries in the agreed time, as its influence on the other affectations. Logistics KPIs are required to focus on a higher level of monitoring on Supply KPIs.

Factors	$\bar{x}_N$	*SN*	*CVN*
LARM	0.553 + 1.06 I; I ∈ [0; 0.47]	0.126 + 0.988 I; I ∈ [0; 0.87]	0.228 + 0.932 I; I ∈ [0; 0.755]
IHP	0.487 + 0.933 I; I ∈ [0; 0.47]	0.125 + 1.015 I; I ∈ [0; 0.87]	0.257 + 1.088 I; I ∈ [0; 0.76]
BDTC	0.48 + 0.98 I; I ∈ [0; 0.51]	0.125 + 0.965 I; I ∈ [0; 0.87]	0.26 + 0.985 I; I ∈ [0; 0.73]
DP	0.5 + 1.033 I; I ∈ [0; 0.51]	0.125 + 1.028 I; I ∈ [0; 0.87]	0.25 + 0.995 I; I ∈ [0; 0.74]
IO	0.553 + 1 I; I ∈ [0; 0.44]	0.126 + 1.018 I; I ∈ [0; 0.87]	0.228 + 1.018 I; I ∈ [0; 0.77]

Table 5. Neutrosophic forms with the measure of indeterminacy

TOPSIS analysis

To determine the possible alternatives based on using the supply KPI more in line with the given situation, the TOPSIS modeling is used. The strategies to be evaluated are focused on monitoring the supply KPIs integrated into the dashboard and highlighting the following parameters:

- Delivery times. Analysis between the supplier and the company
- Balance between supply and demand. Monitor between what is demanded by the client and what is offered
- Lead time. Monitor the times from the supplier to the warehouse, first stage
- Managed providers. Analysis of suppliers managed to meet demand
- Quality of raw materials. Analysis of the quality management process in the supply stage
- Shopping Costs. Analysis of the costs for the acquisition of raw material

The results are shown in the following tables:

Alternatives	Purchasing and supplier management necessary	Inventory management and forecasting	Storage KPIs	Transportation KPIs	Customer service KPIs	Marketing KPI
Delivery times	(0,95; 0,05; 0,05)	(0,95; 0,05; 0,05)	(0,25; 0,60; 0,80)	(0,95; 0,05; 0,05)	(0,95; 0,05; 0,05)	(0,80; 0,10; 0,30)
Balance between supply and demand	(0,65; 0,30; 0,45)	(0,80; 0,10; 0,30)	(0,50; 0,40; 0,60)	(0,65; 0,30; 0,45)	(0,65; 0,30; 0,45)	(0,65; 0,30; 0,45)
Lead time	(0,95; 0,05; 0,05)	(0,25; 0,60; 0,80)	(0,25; 0,60; 0,80)	(0,95; 0,05; 0,05)	(0,95; 0,05; 0,05)	(0,95; 0,05; 0,05)
Managed providers	(0,65; 0,30; 0,45)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0,80; 0,10; 0,30)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)
Quality of raw materials	(0,95; 0,05; 0,05)	(0,80; 0,10; 0,30)	(0,25; 0,60; 0,80)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)
Shopping Costs	(0,95; 0,05; 0,05)	(0,65; 0,30; 0,45)	(0,50; 0,40; 0,60)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)

Table 6. Table of the weights assigned by the experts to each criterion

Alternatives	Purchasing and supplier management necessary	Inventory management and forecasting	Storage KPIs	Transportation KPIs	Customer service KPIs	Marketing KPI
Delivery times	0.12909	0.03907	0.08025	0.01111	0.01252	0.12867
Balance between supply and demand	0.19466	0.04639	0.04494	0.01676	0.01888	0.16339
Lead time	0.19466	0.01367	0.04494	0.01676	0.01888	0.19402
Managed providers	0.12909	0.00781	0.02568	0.01411	0.00318	0.03268
Quality of raw materials	0.19466	0.03907	0.04494	0.00282	0.00318	0.03268
Shopping Costs	0.19466	0.03077	0.08025	0.00282	0.00318	0.03268

Table 7. Weighted normalized matrix

Alternative	d-	d +	Ri	Order
Delivery times	0.05099	0.06597	0.43595	5
Balance between supply and demand	0.11550	0	1	1
Quality of raw materials	0.11198	0.03272	0.77387	4
Managed providers	0.04739	0.07607	0.38385	6
Lead time	0.11391	0.00732	0.93957	2
Shopping Costs	0.11265	0.01562	0.87818	3

Table 8. Matrix of distances and calculation of Ri for each of the alternatives

According to the results we obtained, it is preferred to enhance alternative 1, monitoring between supply and demand, or alternative 2, lead time, depending on the deficiency to be eradicated (figure 6). The preferred variants to determine and monitor the times in the first stage before reaching the warehouse to improve the precision of the movement of the products from the warehouse to the customer.

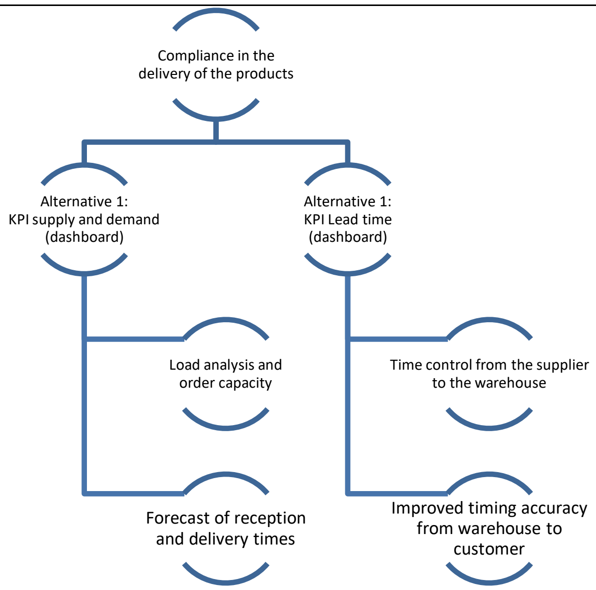

Figure 6. Alternatives implementation priorities.

Conclusions

- Logistics KPIs are highly recognized internationally by companies and institutions, for the level of information they provide in decision-making. The KPIs integrated with the dashboard illustrate the company's log by providing relevant information objectively and truthfully about all the processes that make up the chain. KPIs must be measurable, quantifiable, specific, temporary, and measurable.
- The analysis of the data made to the company determined deficiencies that in the form of a chain reaction affect the deliveries of the products delivered to the customer. When determining the factors that affect the process, the use of neutrosophic statistics is chosen due to the degree of indeterminacy in the analyzed variable, as it is not resolved by classical statistics.
- The neutrosophic statistical analysis shows a lower CV value for the late arrival of raw materials, as a key factor in the fulfillment of product deliveries to the customer. By integrating the result with TOPSIS, it seeks to promote alternatives to improve control in the supply stage, using the KPI of supplies integrated with the dashboard. Among the alternatives to apply, we have: monitoring between supply and demand or lead time according to the objective to be achieved.

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