APPLICATION OF FUZZY LOGIC TO ANALYZE THE PERFORMANCE OF SUSTAINABILITY LOGISTICS IN INDUSTRIAL DEPARTMENTS

Ana Claudia Mota Castilho de Moura (Corresponding author)
Postgraduate Program in Process Engineering – PPGEP/ITEC/UFPA
Belém, Pará, Brazil.
Email: anacastilhomoura@gmail.com

Sil Franciley dos Santos Quaresma
Postgraduate Program in Process Engineering – PPGEP/ITEC/UFPA
Belém, Pará, Brazil.
ORCID: http://orcid.org/0000-0003-0088-9631

Maria Inácia Favila Salum
Federal Institute of Sergipe – IFS
Itabaiana, Sergipe, Brazil
ORCID: http://orcid.org/0000-0003-2567-3095

Abstract

Bearing in mind that the improvement of sustainable logistics activities tend to reduce social, environmental and economic impacts, models for measuring the level of sustainability as a support tool in decision making are increasingly relevant to the process of identifying companies/departments, which need sustainable best practice in order to mitigate costs or increase profit. The objective of the research is to analyze the performance of sustainability logistics in departments of three companies in the electronic segment. As a methodology to develop the research, a sustainable analysis is carried out using a Fuzzy inferences model, in order to consolidate an expert agent, who is able to measure or indicate the level of sustainability performance in the Human Resources (HR) departments. Patrimony and Information Technology (IT), the data set for analysis and inference of the input and output variables are in line with the characteristics of activities and practices performed in each department. As a result, it was possible to identify an influence of the "Priority" variable as a function of "Performance", in addition, company 1 in the electronic segment presented a performance of 87.6 for HR, 88.1 for IT and 65.5 for Equity with the level of "Performance" in Sustainability.

Keywords: Sustainability, Performance Evaluation, Logistics, Fuzzy Logic.

1. Introduction

Sustainability is a topic widely discussed in academia and industry, considering that sustainability practices tend to be elements of innovation and inclusion of the company in the competitive market, considering that state and governmental laws are the biggest influencers for new perspectives of strategies implemented in the industry.

The continuous improvement of processes with the concept of sustainable supply logistics, allows the reduction of environmental, social and economic impacts, considering the execution of activities such as: Selection of supplies, Receipt of raw materials, Storage, Transport and Packaging, the trend of The market consists of controlling not only the internal logistics processes, but also the external ones (WANG, HAN and BEYNON-DAVIES, 2019).

The assessment of departments and companies with regard to sustainability is a priority among companies and tends to be one of the pillars to remain in the competitive market. This is due to the fact that with more products being used in a recycled form and renewable energy, for example, spending decreases and enables companies to offer lower prices on their products or increasing the company's profit.

In the literature, some models of sustainability assessment are found, but no one has been found to assess the issue of sustainability in company departments, most of which are only focused on suppliers, in addition, they do not use artificial intelligence techniques such as fuzzy logic to support the assessment. and in decision making (SCHALTEGGER *et al*., 2014; PARIDA, SJÖDIN and REIM, 2019).

Thus, the present research contributes to the development of a computational model to analyze and evaluate the performance of sustainability logistics in three departments of companies in the electronic segment, namely: IT, HR and Heritage, not limited to such, and may be used in other departments, as long as it has the same practices and activities listed in this work, if it does not have the model it must be adjusted for the proper purpose.

2. Literature Review

In a competitive market in which the quality of logistics becomes a determining trend that allows the generation of effective methodologies in reducing costs and optimizing the time for a given product or service, especially with the inclusion and concentration of logistical systems that accompany the development and the economic ecosystem (DA SILVA and FREIRE, 2020; SHEGELMAN, VASILEV and KRUPKO, 2020).

This being one of the managerial concepts widely applied in the industry, logistics becomes at the same time one of the richest and most respected activities that tends to be confused with the beginning of the organized economic activity in which the production and exchange of surpluses were involved, appearing then the primordial and basic activities of a logistical base: storage, stock and transport (KABINGA, 2020).

Not limited to these concepts, logistics has taken advantage of its concepts and has undergone continuous improvements that have met the advancement of the technologies involved bringing the notoriety of topics such as reverse logistics, supplies, sustainability, internal and many others (KABINGA, 2020; MOSTEANU *et. al*., 2020).

2.1 Supply Logistics

Sustainability in the supply chain and logistics has become a fashion feature, drivers can be identified as a notable measure of quality in maintenance, typical operational characteristics of a competitive market structure (MOSTEANU *et. al*., 2020; CHAND, THAKKAR and GHOSH, 2020). Technological resources are significant for managers, since all stakeholders are progressively asking for an analysis of natural and social impacts due to performances and activities (MOSTEANU *et. al*., 2020; KARMAKER *et. al*., 2020). Supply logistics is an area of logistics that allows and tends to be successfully planned for logistical systems, thus it is possible to supply productive processes acting in the supply chain, with all material needs, in addition, it contributes with a significant portion of the company's cost reduction, through price negotiations in search of alternative materials and the development of suppliers (SALUM *et. al*., 2020; DA SILVA *et. al*., 2020).

For Salum *et. al*. (2020) the main objective of the supply is to execute the incoming logistics efficiently, supporting the production, providing purchases in a timely manner and at a lower cost. Follmann *et. al*. (2012) states that in supply logistics, cost control analyzes are carried out in companies that involve not only the price of the product, but also logistical costs such as: order processing, transportation, receipt, quality, stock maintenance, storage and return. That said, some activities in common are cited by the authors and illustrated in Figure 1.

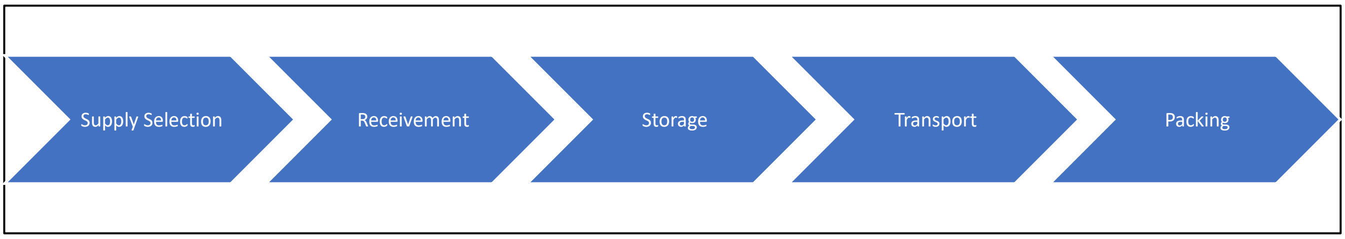

Figure 1. Supply logistics activities.
Source: Adapted from Follman *et. al*. (2012) and Salum *et. al*., (2020).

The selection of supplies comprises good practices in selecting a good supplier through previously raised criteria that are in accordance with the sustainability requirements that are assessed through practices carried out in the environment, in addition, it is considered consultations with stakeholders (BALDASSIN, CAMPANA and DE ANDRADE BERTAZZI, 2020; NAYAK, 2020).

The receipt of raw material comprises assessing material requirements received that meet the company's sustainability criteria and that benefit good logistics practices (NAYAK, 2020).

Warehousing comprises the use of methods and equipment that characterize the application of sustainability logistics, being considered one of the main supply activities for directly impacting logistics costs (PRANANINGTYAS and ZULAEKHAH, 2021).

Transport comprises in the planning and use of logistics systems that evaluate and determine intelligent strategies that directly impact logistics costs, acting mainly in minimizing losses, damages, delivery time, strategic availability of quality products and reducing negative impacts on the environment. (PAUL, MOKTADIR and PAUL, 2020).

The packaging comprises the use of raw material selection criteria that reduce the logistical costs linked to the shipping and packaging of materials, offering protection to the inputs, facilitating the storage and handling of these inputs, maximizing the use of transport equipment (DAVID B, 2020; MOLINA-BESCH and PÅLSSON, 2020).

However, the use of these activities becomes important in dealing specifically with methods for minimizing logistical costs (PAUL, MOKTADIR and PAUL, 2020), including the company in a competitive perspective by adhering to sustainable supply practices, in addition to relating organizational changes that provide economic and environmental improvements (KARAMAN, KILIC and UYAR, 2020).

2.2 Sustainability Logistics

Market trends demand that companies use innovative concepts that take advantage not only of technologies and methodologies that minimize risks and economic losses, but also the mitigation of environmental impacts and an ideal construction of sustainable logistics where several elements within a sector are thought of in this perspective (PETRUCELLI, 2020; DE SOUZA MIGUEL, 2021).

These changes directly imply the attitude of companies both in the awareness of consumers and in local and national legislation when taking responsibility for the environmental and social consequences (DE SOUZA MIGUEL, 2021). Sustainable logistics has become a reality applicable on a large scale aiming at:

- Reduce environmental impacts;
- Improve the use of resources;
- Optimize the use of local labor;
- Increase the useful life of an equipment, work or environment;
- Take advantage of technological resources to amplify and improve the use of natural resources.

Based on the principle that logistics serves the aforementioned purposes, then the concepts of green and reverse logistics arise (KARAMAN, KILIC and UYAR, 2020) which tend to be tools or evolution of logistics to adapt the vision of the company as a whole and adhere to sustainable practices . Thus, sustainable logistics tends to encompass several logistical processes, ranging from the first activity in Supply Selection to Packaging indicating the completion of the process or its return (CENTOBELLI, CERCHIONE and ESPOSITO, 2020).

Green logistics is concerned with producing and distributing goods efficiently without harming or impacting on environmental factors characterizing sustainable practice (SALUM *et. al*., 2020; KARAMAN, KILIC and UYAR, 2020), an example of activity carried out with logistics green is the introduction of healthy principles and strategies in logistical activities when considering energy conservation and reducing its effects on the environment and society, for this the study improves the company's performance by increasing sustainability by reducing waste characterizing GLMPs (AGYABENG -MENSAH, AFUM and AHENKORAH, 2020).

The purpose of logistics is to coordinate activities within a supply chain in such a way that the needs of the beneficiaries are met at the lowest cost to the environment, contributing to a planning approach focused on logistics systems that incorporate sustainability goals (HENRIQUE CECILIANO , SANTANA MOREIRA and DA COSTA VIEIRA, 2020). It is possible to consider as green logistics activities the environmental impact of different strategies, distribution, reduction of water, energy, waste and waste treatment (SALUM *et. al*., 2020).

Considering these approaches to green logistics, an analysis of the effect of logistical activities on the environment can be carried out, where their effects impact on transport, storage, packaging and information processing, acting intensely in reducing logistical costs, mitigating waste problems. natural resources and raw materials and elevates the company's processes (DE SÁ AMORIM *et. al*., 2020).

Reverse logistics considers economic and environmental gains through the reuse of materials previously discarded (Salum *et. al*., 2020). The recycling methodology tends to reduce costs, in many cases helps to reduce polluting emissions with production processes that use machinery with a high rate of labor and energy or biodegradable inputs (PETRUCELLI, 2020).

This method becomes increasingly evident in the manufacturing scenario, aiming at including the company in the competitive market, aiming at operational excellence and service quality in the product. However, a reorganization of processes and operational vision must be listed in the strategic planning, which in several cases tends to have a demand for adaptation (DE SÁ AMORIM *et. al*., 2020). The development of activities aimed at the use of reverse and green logistics methods are essential for the company's inclusion in the concept of sustainable logistics and supplies.

2.3 Fuzzy Logic

Fuzzy logic or fuzzy set theory aims to solve diffuse problems where a sample space presents defined and determined lower and upper limits, by means of this artificial intelligence technique conceptualized and defined by Lofti Asker Zadeh it is possible to level other intervals of definition of a variable where 0 and 1 can have an interval that tends to infinity, these values being defined as degree of relevance (SHAHBAZOVA, SUGENO and KACPRZYK, 2020).

A fuzzy or diffuse set has process integrating elements such as: fuzzifier, inference rules, fuzzy inferences machine and defuzzifier (CARTER, 2021), where:

- **Fuzzifier**: Determines membership values for the definitions of an input or output variable, being possible to use it in the fuzzy system;
- **Inference rules**: rules defined by a specialist who knows the business applied to the cloudy system;
- **Fuzzy inferences machine**: It uses control processes to group the rules and apply them in simulation scenarios that are sent to the defuzzifier;
- **Defuzzifier**: Defines the result of simulations presenting results by means of graphs and an interface that levels the input and output variables according to the processing in the fuzzy system.

Mamdani, who is one of the fuzzy logic controller models, establishes an inference method that has crossed or fuzzy relations through propositions and consequent mathematical logical operators (ABLYAZOV, DRACHEV and TISENKO, 2020; ATANASSOV, 2021) and its rules are described as follows form:

If <property> <operator> <property> ..., then <consequent> (1)

The composition of fuzzy relationships is of fundamental importance in applications, consider R and S two traditional fuzzy relationships known as binary in $U \ x \ V$ and $V \ x \ W$, respectively (SILVA, 2011; ABLYAZOV, DRACHEV and TISENKO, 2020; ATANASSOV, 2021). The composition is a binary fuzzy relationship in $U \ x \ W$ with a pertinence function expressed by equation 2:

$$\varphi RS(u,w) = max_{v \in V}[\min(\varphi R(u,v), \varphi S(v,w))] \quad (2)$$

Where $\varphi R(u,v) = \varphi U(u) \wedge \varphi V(v)$ *and* $\varphi S(v,w) = \varphi V(v) \wedge \varphi W(w)$, being $\wedge$ one t-norm, when the *U*, *V* and *W* sets are finite, then the matrix form of the *R* and *S* ratio given by the max-min composition can be obtained as a multiplication of matrices replacing the product with the minimum and the sum with the maximum (SILVA, 2011; ABLYAZOV , DRACHEV and TISENKO, 2020), equations 3,4 and 5 express a model:

$$U = \{u_1, u_2, \dots, u_m\}; \quad (3)$$

$$V = \{v_1, v_2, \dots, v_p\}; \quad (4)$$

$$W = \{w_1, w_2, \dots, w_n\}; \quad (5)$$

Suppose that:

$$R = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix}_{mxn} \quad e \quad S = \begin{pmatrix} s_{11} & s_{12} & \cdots & s_{1p} \\ s_{21} & s_{22} & \cdots & s_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ s_{m1} & s_{m2} & \cdots & s_{np} \end{pmatrix}_{nxp}$$

Where it is possible to express the definition by equation 6:

$$r_{ij} = \varphi U(u_i, v_j) = \varphi U(u_i) \wedge \varphi V(v_j) \; and \; s_{jk} = \varphi S(v_j, w_k) = \varphi V(v_j) \wedge \varphi W(w_k) \quad (6)$$

For i = 1, ..., m, j = 1, ..., n e k = 1, ..., p.
According to the definition *R* and *S*, the binary fuzzy relationship given by the max-min composition has the following matrix form:

$$T = R \circ S = \begin{pmatrix} t_{11} & t_{12} & \cdots & t_{1n} \\ t_{21} & t_{22} & \cdots & t_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ t_{m1} & t_{m2} & \cdots & t_{mn} \end{pmatrix}_{mxp}$$

Expressed by equation 7:

$$t_{ij} = max_{1 \le k \le n}\left[\min\left(\varphi R(u_i, v_k), \varphi S(v_k, w_j)\right)\right] = max_{1 \le k \le n}[\min(r_{ik}, s_{kj})] \quad (7)$$

The rules are models of inference based on relations or logical operators, composed of fuzzy propositions and can be expressed in linguistic form.

$$Se\ x_1\ \text{é}\ A_1\ e\ x_2\ \text{é}\ A_2\ e\ \ldots e\ x_n\ \text{é}\ A_n$$
$$Então\ u_1\ \text{é}\ B_1\ e\ u_2\ \text{é}\ B_2\ e\ \ldots e\ u_m\ \text{é}\ B_m$$

With the logical construction of each rule provided by a specialist, or technical knowledge about the subject, the set of instructions are cataloged, which will be used in the inferences engine (ESCOTTÁ and BECCARO, 2020).

A fuzzy inference machine translates each fuzzy proposition mathematically, where it is defined which t-norms will have implications and will be used as fuzzy relationships, the ones that model the rule base (SILVA, 2011; ESCOTTÁ and BECCARO, 2020).

There are many defuzzification methods that can be used in a fuzzy inferences model, in this specific research the Centroide or Area Center method is used (SILVA, 2011; JUNIOR *et. al*., 2020), similar to the weighted average for the data distribution, it consists of presenting the average of all the figures that represent the degrees of pertinence of a fuzzy subset, equations 8 and 9 express the discrete and continuous domain.

$$G(C) = \frac{\sum_{i=0}^{n} u_i \varphi C(u_i)}{\sum_{i=0}^{n} \varphi C(u_i)} \tag{8}$$

$$G(C) = \frac{\int_R \ u_i \varphi C(u) du}{\int_R \ u_i C(u) du} \tag{9}$$

Figure 2 illustrates an example of a defuzzification graph, in which it is possible to identify a central line called function G(C) that is expressed by equations 8 and 9, centralization allows to find the average of the sample space (SILVA, 2011; ESCOTTÁ and BECCARO, 2020).

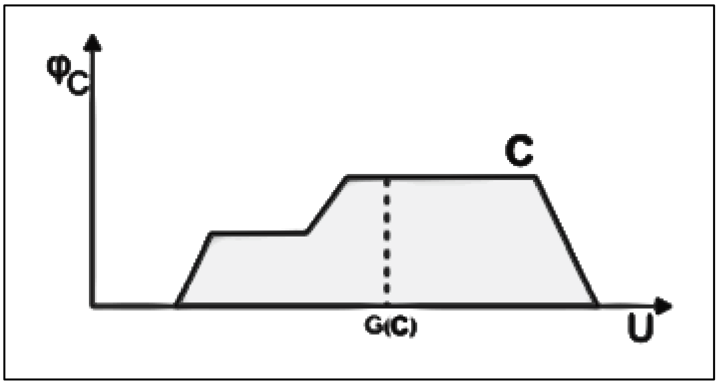

Figure 2. Centroid defuzzification.
Source: Adapted from (SILVA, 2011).

The Takagi - Sugeno - Kang (TSK) model differs from Mamdani in the way it writes the rules of inference and in the process of defuzzification to generate the general output of the system (SILVA, 2011; ESCOTTÁ and BECCARO, 2020), where the output The overall system is expressed by equation 10.

$$u = f_r(x_1, x_2, \dots, x_n) = \frac{\sum_{j=1}^{r} w_j . g_j(x_1, x_2, \dots, x_n)}{\sum_{j=1}^{r} w_j} = \frac{\sum_{j=1}^{r} w_j . u_j}{\sum_{j=1}^{r} w_j} \tag{10}$$

Where the weights w_j they are given by $w_j = \varphi A_{j1}(x_1) \Delta \varphi A_{j2}(x_2) \Delta \dots \Delta \varphi A_{jn}(x_n)$ and Δ it is a t-norm. The weight w_j matches the rule's contribution R_j for the general exit. Suposing that Δ be the minimum t-norm, if the u-value given by equation 11 is taken as a general output.

$$u = \frac{w_1 u_1 + w_2 u_2}{w_1 + w_2} = \frac{w_1 g_1(x_1, x_2) + w_2 g_2(x_1, x_2)}{w_1 + w_2} = f_r(x_1, x_2) \tag{11}$$

Where $w_i = \min\,[\varphi A_{i1}(x_1), \varphi A_{i2}(x_2)]$ matches the weight of the rule R_i in the general output of the process.

Consider a fuzzy controller, with two inputs and an output where the sets involved A_{ij} are triangular fuzzy numbers and the outputs of each rule are given by functions g_i, related lines (SILVA, 2011; COUTINHO *et. al.*, 2020). Figure 3 illustrates an example.

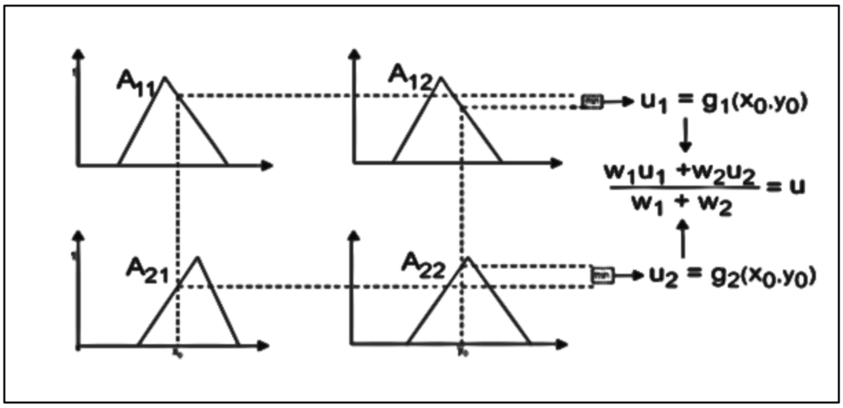

Figure 3. Result of leaving TSK.
Source: Adapted from (SILVA, 2011).

3. Materials and Methods

The research aims to analyze the performance of supply logistics in the departments of an industry in the industrial pole of Manaus, for this it was necessary to survey the history of activities and practices to select the significant variables for the development of the inferences model, finally perform a qualitative and quantitative analysis of performance between the HR, IT and Patrimony. Figure 4 illustrates the stages of activities for the development of the research.

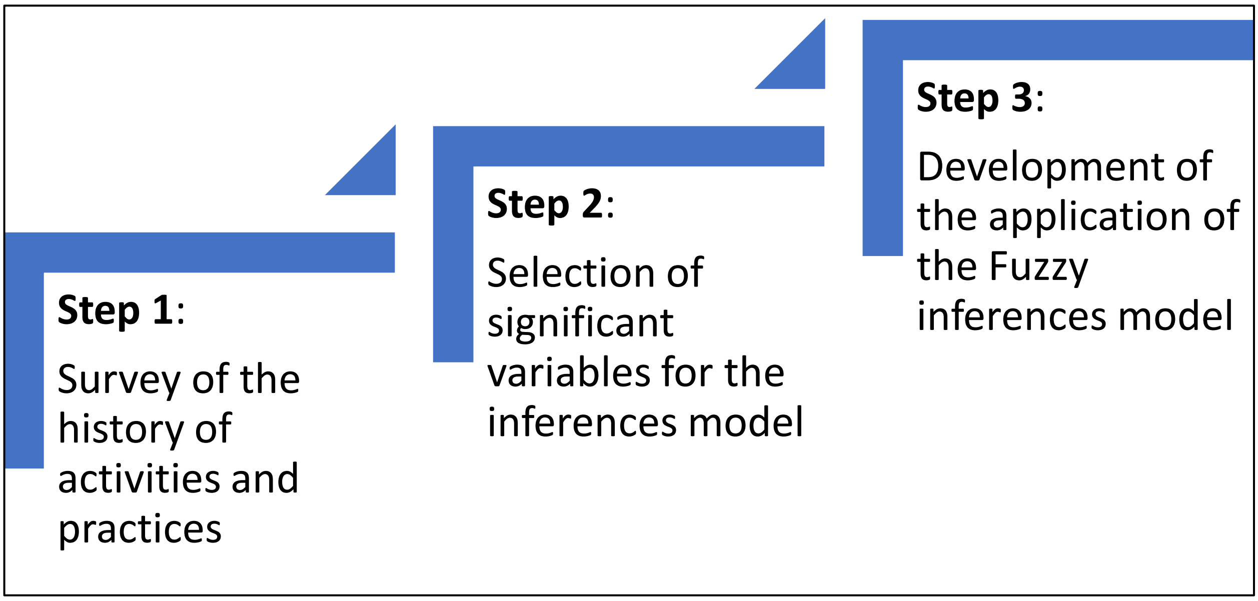

Figure 4. Research steps.
Source: Authors (2021).

3.1 Step 1: Survey of the History of Activities and Practices

The survey of the history of activities and practices was carried out through on-site visits in the industry, with this history it was possible to consolidate a database containing the main elements necessary for the research, this study comprises an evaluation referring to the year 2019.

3.2 Step 2: Selection of Significant Variables for the Inferences Model

With the structured database containing the fields: title name, date of execution of the evaluation, stage of evaluation, sector, number of practices evaluated, note of the practice, dimension of the practice and degree of priority of the practice, it was possible to determine the importance of the and the division between input and output variables to model the inference rules. Table 1 presents the list of variables and their respective linguistic values.

Table 1. Linguistic variables.

Variables	Type	Inference level
Priority	Input	1 - Low priority, 2 - Regular priority, 3 - Medium priority, 4 - Intermediate priority, 5 - High priority
Note	Input	1 - partially performed, 2 - regularly performed, 3 - moderately performed, 4 - frequently performed, 5 - fully performed
Dimension	Input	1 - Low concern, 2 - Regular concern, 3 - Median concern, 4 - Frequent concern, 5 - Total concern
Performance	Output	1 - Critical, 2 - Bad, 3 - Good, 4 - Great, 5 - Excellent

Source: Authors (2021).

The "*Priority*" variable is intended to measure the degree of importance with which the company performs a certain activity in the sector, the "*Note*" aims to define the frequency with which a practice is performed considering the macro activity, the "*Dimension*" defines how concerned, the company is concerned with the activities of sustainability logistics, finally, "*Performance*" allows measuring the logistical level of the sector considering the variables that influence or impact the sustainability stage.

3.3 Step 3: Development of the Application of the Fuzzy Inferences Model

For the development of the model, the *Matlab*® 2016a software was used, in which the fuzzy toolbox tool was used for the modeling and simulation of the scenarios.

The model contains three input variables called "*Priority*", "*Note*" and "*Dimension*", for the output variable "*Performance*" was defined. The modeling had 125 rules, in which each input variable has five levels of inference with a range of equal values in each variable. For the output variable, different values for the inference levels were defined, but the standardization of five levels of inference continued.

Figure 5 shows the model for assessing the performance of supply logistics in sustainability.

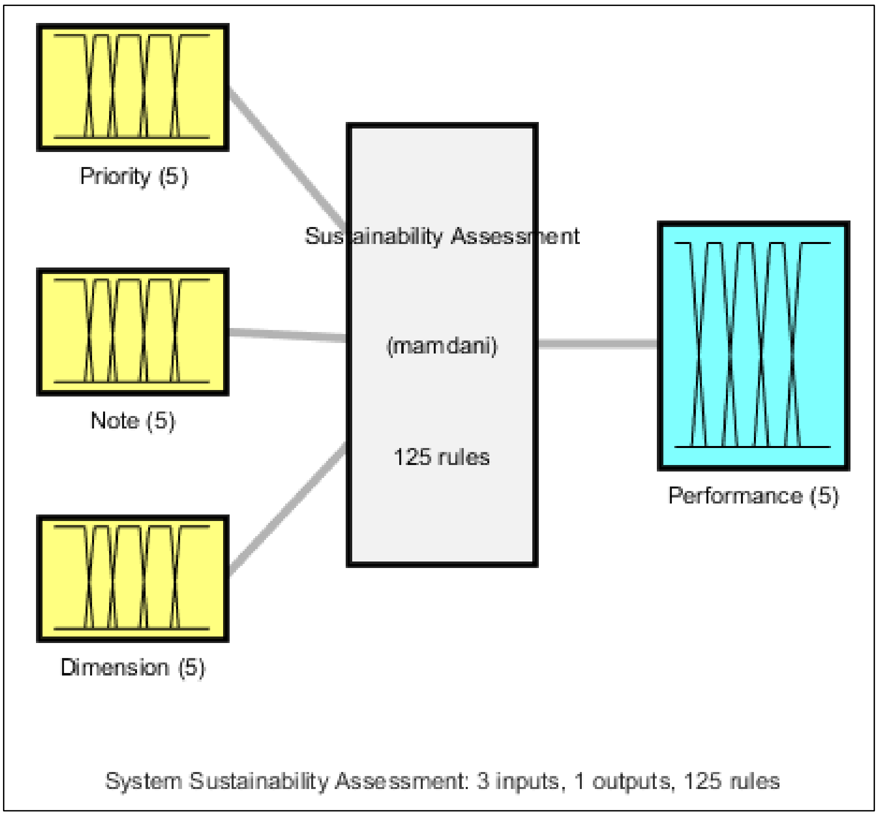

Figure 5. Fuzzy inferences model.
Source: Authors (2021).

3.3.1 Input Variables

Figure 6 shows the input variable called "*Priority*", in which it has five levels of inference:

Low: This level of inference is formed by the range of values from 0 to 25 (horizontal axis), with ranges from 0 to 20 having a maximum relevance, equivalent to 1 (vertical axis), whereas the range from 20 to 25 a relevance decreases linearly until reaching point 25. It consists of a trapezoidal function with the following values (0 0 20 25).

Regular: It consists of the range of values from 20 to 40, with its connection points at (20 26 35 40), where a trapezoidal function was used. From point 20 (horizontal axis) to 26 there is a gradual increase in membership, reaching its maximum value at point 26 and maintaining a constancy in the range 26 to 35, from then on the membership level decreases again until it reaches its low stage reaching the value 0 (null) at point 40.

Median: In this level of inference, a trapezoidal function is used with the points (35 41 55 60) as the definition, with its range being points 35 to 60. The Median inference level has its maximum relevance (1 on the vertical axis) extended by greater interval if compared to the level of inference *Regular*. From point 35 to 41 (horizontal axis) there is an increase in the level of pertinence until reaching the value 1 and it extends in this value until the point 55, where it begins to decrease until reaching the value 0 of relevance.

Intermediate: The Intermediate inference level consists of a trapezoidal function with the points defined in (55 61 75 80). From point 55 to 61 (horizontal axis) there is an increase in the level of relevance reaching its maximum (1 in the vertical axis), in which the level of inference remains constant until point 75 (horizontal axis) and from this point there is a drop in its membership until it reaches point 80 when the membership level is 0.

High: In this level of inference a trapezoidal function is used with the following points (75 81 100 100), with the range of values between 75 and 81 (horizontal axis) increasing relevance reaching a value of 1 (vertical axis), in the range of values between 81 and 100 the pertinence remains constant and maximum.

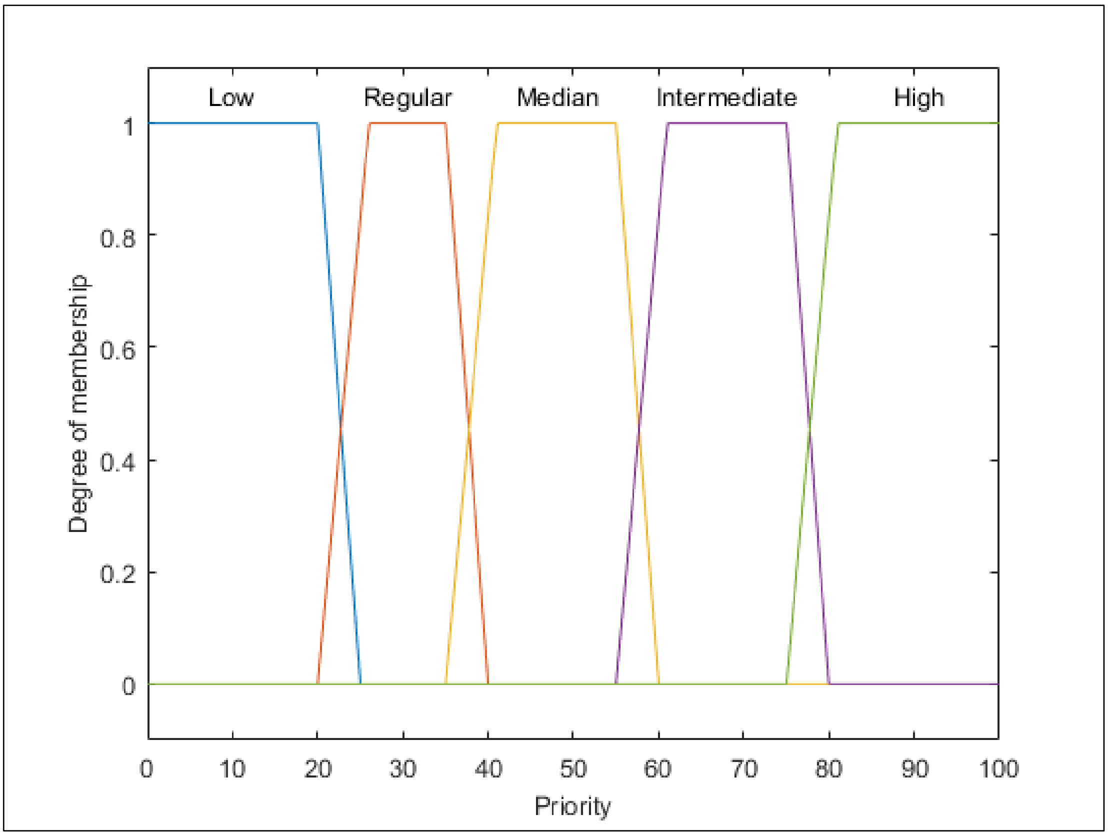

Figure 6. Input variable “Priority”.
Source: Authors (2021).

Figure 7 shows the input variable "*Note*" with its inference levels, having a total of five well-defined levels, such levels can be detailed below:

PartiallyPerformed: This level of inference is composed of a trapezoidal function configured with the following points (0 0 20 25), in which the value range between 0 and 20 (horizontal axis) the relevance remains constant with the value 1 (vertical axis) and in the range of 20 to 25 the pertinence decreases to the point of reaching the value 0.

RegularlyPerformed: At this level it is possible to notice that a trapezoidal function is used, since it has four points (20 26 35 40). From point 20 to 26 (horizontal axis) there is an increase in relevance leaving the value 0 and reaching its maximum point in 1 (vertical axis), in the following points (26 35) the value of relevance remains at 1 and falls to from point 35 until reaching point 40, when the pertinence value is 0.

MidwayAchieved: For this level of inference, a trapezoidal function was used, as in previous levels of inference, with its points established in (35 41 55 60), in which point 35 (horizontal axis) rises to a degree of pertinence of value 1 (vertical axis) at point 41, the interval between 41 and 55 is constant, gradually changing again from point 55 to 60, in which there is a drop in relevance from 1 to 0, with point 60 being the last point of this level of inference.

FrequentlyPerformed: Four points (55 61 75 80) were used, so it is a trapezoidal function. For points 55 to 61 (horizontal axis) there is an increase in the degree of pertinence reaching the maximum value (1 in the vertical axis), the range composed by the values 61 and 75 the degree of pertinence remains the same, and falls from from point 75 reaching a value of 0 (vertical axis) in the degree of relevance in point 80.

FullyRealized: This level of inference is characterized by four points (75 81 100 100) being a trapezoidal function. The interval between points 75 and 81 (horizontal axis) increases the degree of membership reaching 1 (vertical axis), the interval between points 81 and 100 the degree of membership remains at its maximum.

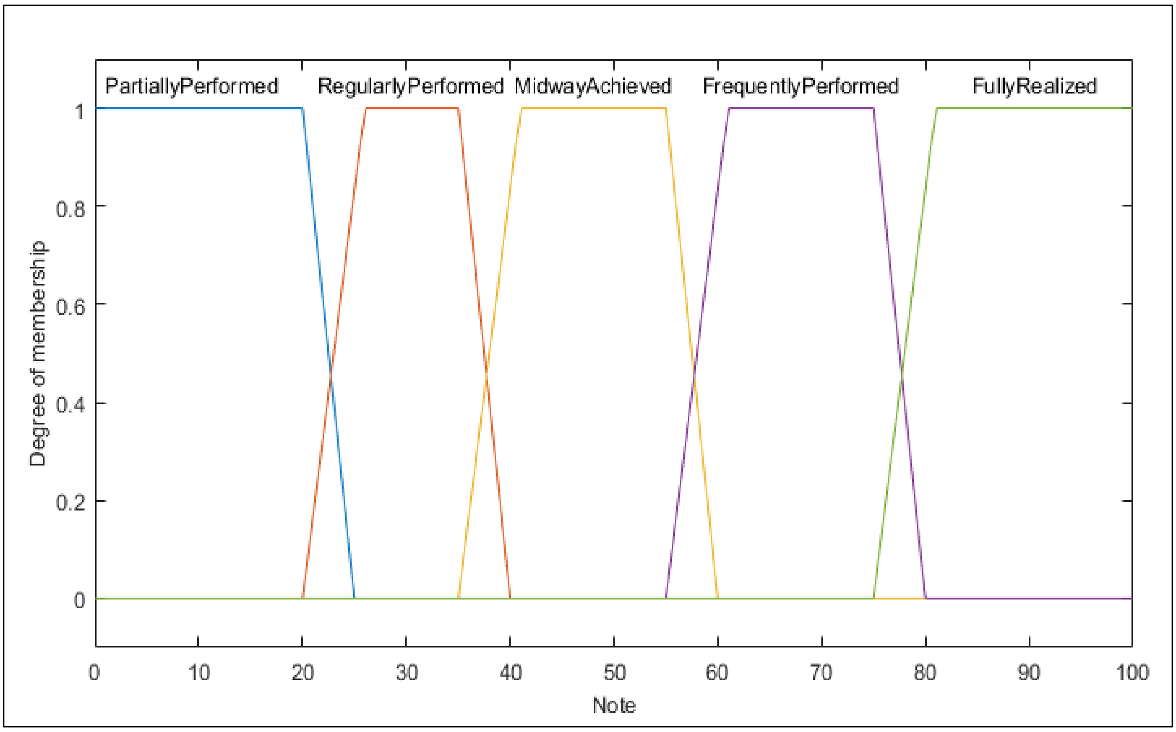

Figure 7. Input variable "Note".
Source: Authors (2021).

In Figure 8, the input variable called "*Dimension*" is observed, where the five levels of inference are observed:

LowConcern: Inference level using a trapezoidal function configured with the following points (0 0 20 25), with point 0 (horizontal axis) to point 20 a constant of relevance equal to 1 (vertical axis). As for the range of points between 20 and 25, the degree of pertinence gradually falls to point 25 (horizontal axis), reaching a pertinence of value 0.

RegularConcern: This level of relevance is characterized by a trapezoidal function that is defined by (20 26 35 40), in which the starting point (20) to point 26 (horizontal axis) increases the degree of relevance (vertical axis) reaching the value 1, from point 26 to 35, there is a regularity in the pertinence remaining at 1. For the segment of points 35 to 40 there is a decrease in the value of the degree of pertinence, reaching the value of 0 in point 40.

MedianConcern: Level of inference that has a trapezoidal function as a configuration element, which are defined in the following points (35 41 55 60). In the interval between points 35 to 41 (horizontal axis) the degree of relevance increases to the value 1 (vertical axis). In the range of values between 41 and 55, the relevance remains unchanged. For points 55 to 60 the relevance drops to the value 0 in point 60.

FrequentConcern: For this level of inference, a trapezoidal function configured with the points (55 61 75 80) is used. For points 55 to 61 (horizontal axis) there is an increase in the degree of relevance that reaches its maximum (1 vertical axis) at point 61. In the point range between 61 and 75 the pertinence remains with the value 1 and from this point on there is a drop to the null value (0 vertical axis).

TotalConcern: For this level a trapezoidal function was used with the points (75 81 100 100), at point 75 the function starts and in the interval between 75 and 81 (horizontal axis) the level of relevance is raised to

1 (vertical axis) remaining constant from this point to point 100.

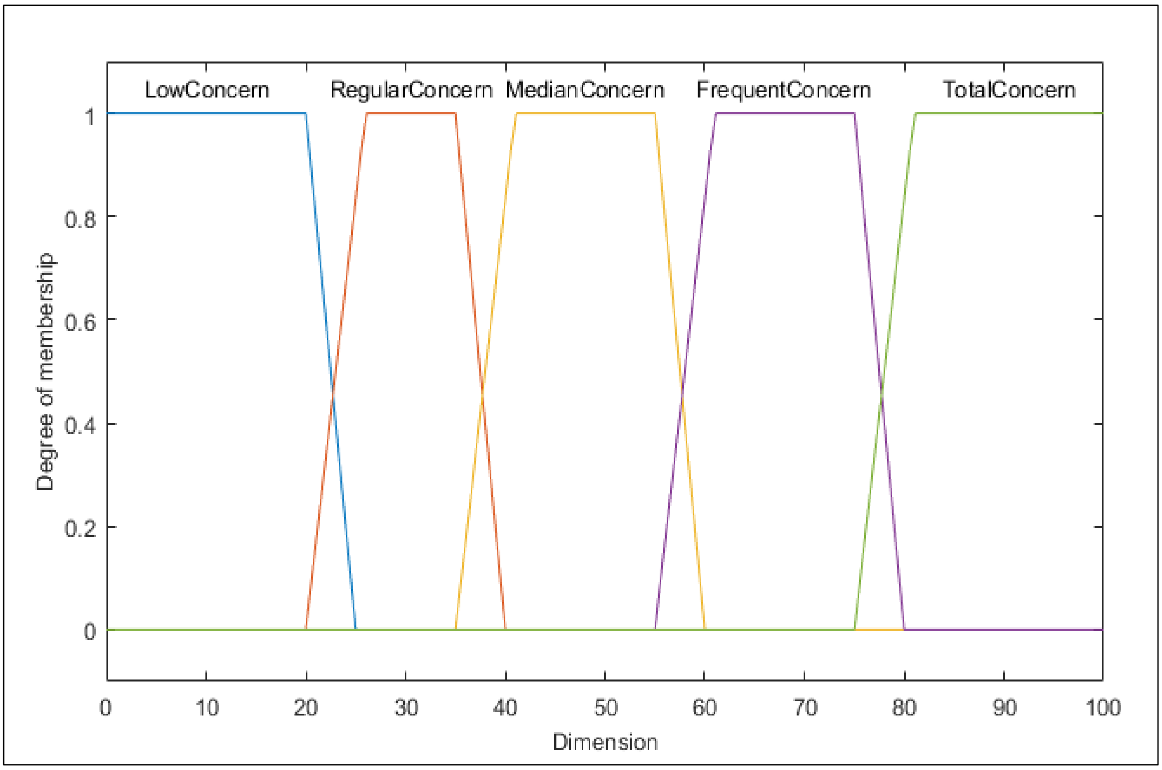

Figure 8. Input variable “Dimension”.
Source: Authors (2021).

3.3.2 Output Variable

For the output variable shown, which is presented in Figure 9, the name “*Performance*” was defined, indicating the final performance of the evaluation of industrial departments in terms of sustainability. The output variable has five levels of inference and are listed as follows:

Critical: Level formed by a trapezoidal function with the values defined in the points (0 0 10 20), in which the relevance value 1 (vertical axis) in the interval between 0 and 10 (horizontal axis) remains constant, already in the interval between values 10 and 20 the relevance of value 1 (vertical axis) drops dramatically to value 0. Indicating the critical level that exists in the performance of the analyzed department.

Bad: Level that there is a trapezoidal function as a model with its values fixed at (11 21 30 40), where the interval between the values 11 and 21 (horizontal axis) has an increasing trend up to point 21, which remains constant until the point 30 with a relevance value of 1 (vertical axis). For the interval between the values 30 and 40 the degree of relevance decreases until reaching its lowest level (0 vertical axis) at point 40.

Good: For this level of relevance, a function with four points (trapezoidal function) was used, which has its values defined in (31 41 50 60), in which the interval between the first two points (31 and 21 on the horizontal axis) there is a gradual increasing degree of relevance, going from 0 to 1 (vertical axis), in the range 41 to 50, the degree of pertinence remains at 1. For the last range of values between points 50 and 60 o degree of pertinence drops to 0 gradually.

Optimal: Level of membership configured with four points (51 61 70 80, trapezoidal function), in which the first interval between the values on the horizontal axis (51 and 61) there is an increase in the degree of membership ranging from 0 to 1 (vertical axis), to follow the interval between the values 61 and 70 there is a maintenance of unchanged values, remaining at 1. From point 70 to 80 the relevance goes down to value 0 (vertical axis) reaching point 80 its lowest value (0).

Excellent: At this level, as well as at all other levels of relevance, a trapezoidal function has four points, which are (71 81 100 100). From point 71 to 81 on the horizontal axis, there is an increase in the degree of relevance from 0 to the value 1 on the vertical axis. For the sequence of points, the relevance remains at value 1.

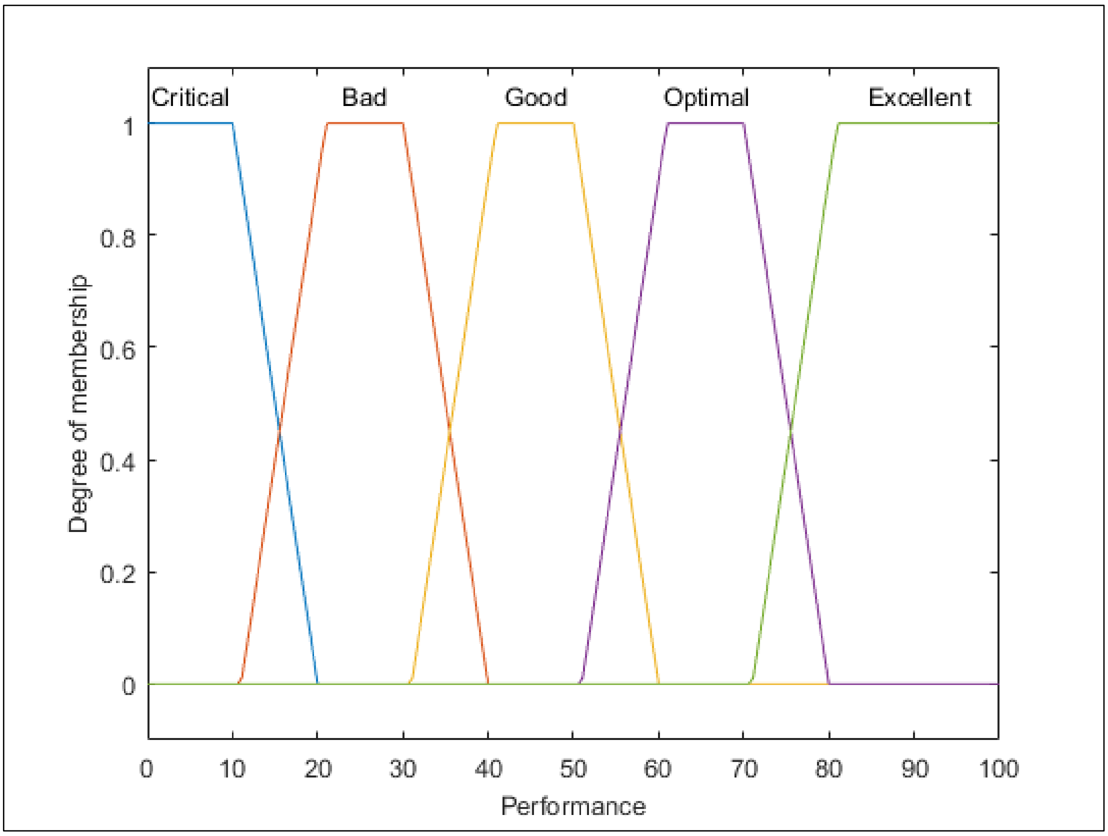

Figure 9. Output variable "Performance".
Source: Authors (2021).

3.3.3 Rules Used for Modeling

Table 2 shows a sample of 11 rules out of a total of 125 that were used in the fuzzy inference engine. Rules that consist of modeling the fuzzy system so that it is able to generate results that would be achieved by specialists in the field. Table 2 shows five columns with the names of the three input variables and the output variable, in addition to the number of the rule imputed in the fuzzy system.

Table 2. Sample of rules used.

Rule number	Input Variables			Output Variable
	Priority	Note	Dimension	Performan

				ce
1	Low Priority	Partially Performed	Low Concern	Critical
7	Low Priority	Regularly Performed	Regular Concern	Bad
20	Low Priority	Frequently Performed	Total Concern	Optimal
28	Regular Priority	Partially Performed	Median Concern	Good
50	Regular Priority	Fully Realized	Total Concern	Optimal
56	Median Priority	Regularly Performed	Low Concern	Good
71	Median Priority	Fully Realized	Low Concern	Good
87	Intermediate Priority	Midway Achieved	Regular Concern	Good
101	High Priority	Partially Performed	Low Concern	Good
119	High Priority	Frequently Performed	Frequent Concern	Excellent
125	High Priority	Fully Realized	Total Concern	Excellent

Source: Authors (2021).

The rules were defined based on the analysis and knowledge of a specialist in the area of industrial process management, in order to bring the system closer to reality, reliable and generic so that it can be used in different types of departments of a company, such as for example: IT department; Logistics; Packing; Supplies; Storage; Production of raw materials, among others.

4. Results and Discussions

4.1 Surface Chart

Figure 10 shows the surface graph generated by the modeled fuzzy inference system, in which it can be seen that it has three dimensions, which are the input variables "*Note*", "*Priority*" and the output variable "*Performance*". On the x axis is located the input variable "*Priority*" with a range from 0 to 100, on the y axis is located the input variable "*Note*" with an interval between 0 to 100 and the output variable "*Performance*" if it is on the z axis, with an interval between 0 to 100, with the same parameters as the input variables, but in Figure 10 it is displayed only up to point 65 of the "*Performance*" variable. The "*Dimension*" variable does not appear in this figure, as it is the variable that has the least influence on the output variable.

As can be seen in Figure 10, the lighter colors correspond to a higher value in the output variable, with the color that represents the highest performance being yellow. The "*Priority*" variable has a greater influence on the output variable, this can be noted due to the values shown in Figure 10 with the rectangular marking in red, in which the value 85 of the "*Priority*" variable causes the performance to exceed the value 65 of the variable "*Performance*", while the variable "*Note*" when it reaches the value 80 still does not guarantee that the variable "*Performance*" exceeds the value 60, this can be noticed by observing the intersection of points 15 to 40 of the variable "*Priority*"Along with points 80 to 100 of the input variable"*Note*"marked by a red circle in Figure 10.

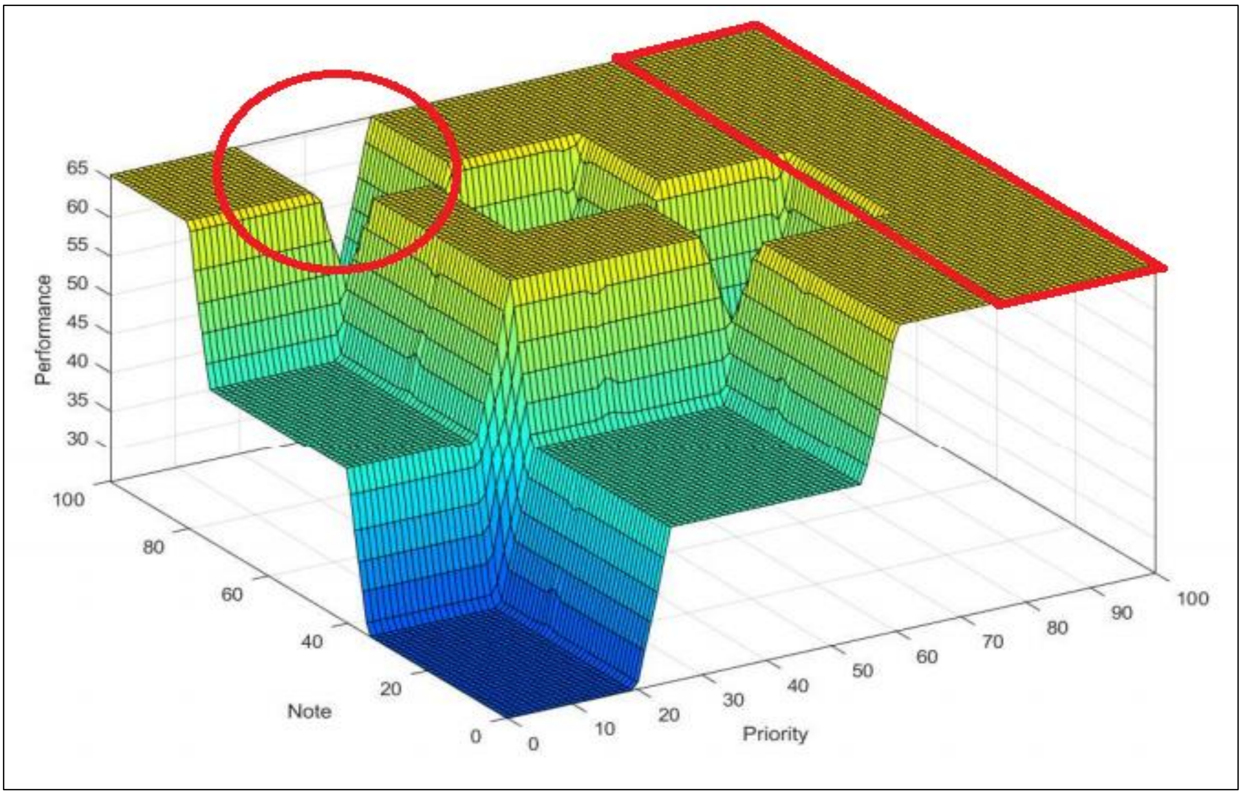

Figure 10. Surface graph.
Source: Authors (2021).

4.2 Sustainability Assessment with the Fuzzy Model

The results were achieved using the *Matlab®* toolbox, which can be seen in Figure 11, which contains the parameters to be filled in for the departments simulation. The simulator serves to add values in the input variables, returning a value in the output variable "*Performance*", which in Figure 11 is 25.5, resulting from "*Priority*" with a value of 12, "*Note*" with 30 and "*Dimension*" with a numerical value of 47.

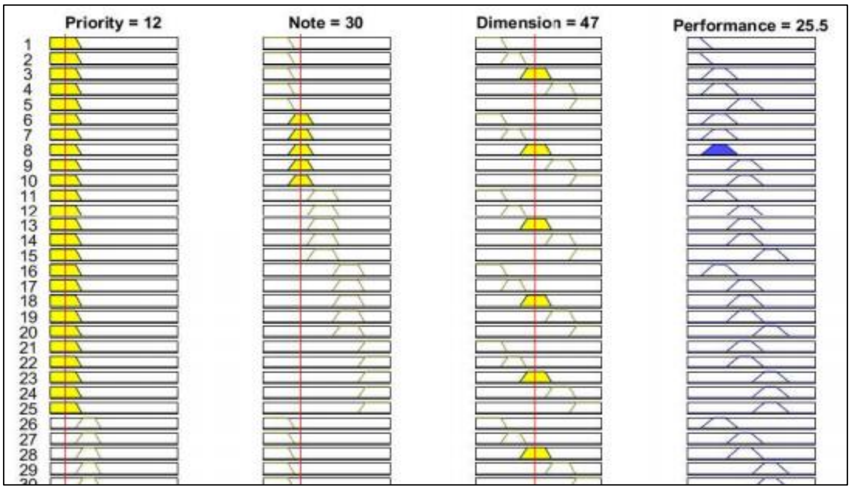

Figure 11. Simulator.
Source: Authors (2021).

Figure 12 shows the results obtained from the evaluation of the equity department of three companies, being called Equity 1 (P1), Equity 2 (P2) and Equity 3 (P3).
It can be seen that the best performance of the patrimony department was P1, since it obtained the best result in the output variable of "*Performance*". It is valid to reaffirm that even though P2 having higher values (68 and 71) in relation to P1 (54 and 61) in the variable "*Note*" and "*Dimension*", the final result in the variable "*Performance*" is higher for P1 (65, 5), this is due to the "*Priority*" variable, which has a greater influence in relation to the "*Note*" and the "*Dimension*".
Even though P2 achieved a final result of "*Optimal*" as well as P1, P1 remains with the best performance, since the numerical value is higher in relation to P2, with P1 having achieved 65.5 of performance in the evaluation and P2 56.5.

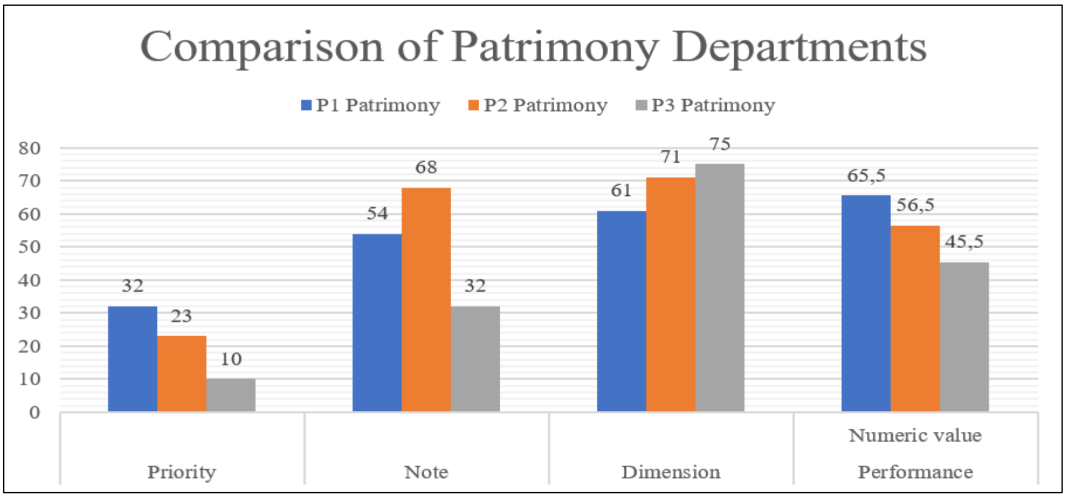

Figure 12. Comparison of Patrimony departments.
Source: Authors (2021).

Figure 13 contains the Information Technology (IT) departments, divided into three departments of different companies, such departments are named as follows: the fictitious name of Information Technology

1 (IT1), Information Technology 2 (IT2) and Information Technology 3 (IT3).

In Figure 13, it can be seen that the best performance among the IT departments analyzed in the companies that were the object of study is IT1, this is due to the input variable "*Priority*" having a higher value than IT2, with IT1 having a value priority 73 and IT2 a value of 66. The two departments have an "*Excellent*" performance, however IT1 is superior due to its higher numerical value compared to IT2 in the "*Performance*" output variable, with IT1 achieving a performance 88.1 and the IT2 a numerical value of 87.0.

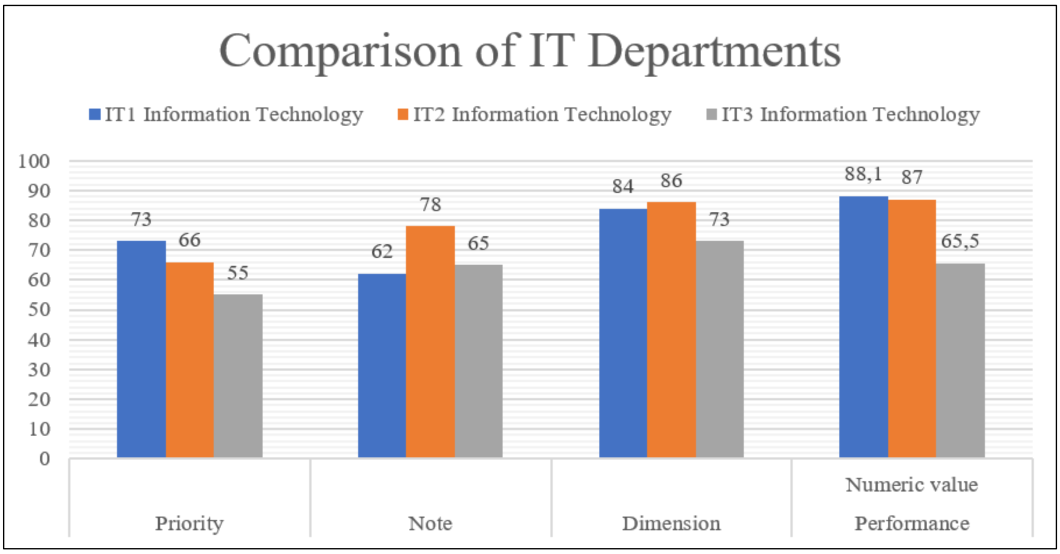

Figure 13. Comparison of IT departments.
Source: Authors (2021).

Figure 14 shows the result of the assessment made for three Human Resource (HR) departments, identified by Human Resource 1 (HR1), Human Resource 2 (HR2) and Human Resource 3 (HR3), in which HR1 had the best performance with a numerical value of 87.6, HR2 had 65.5 performance and HR3 had the worst performance with 25.5.

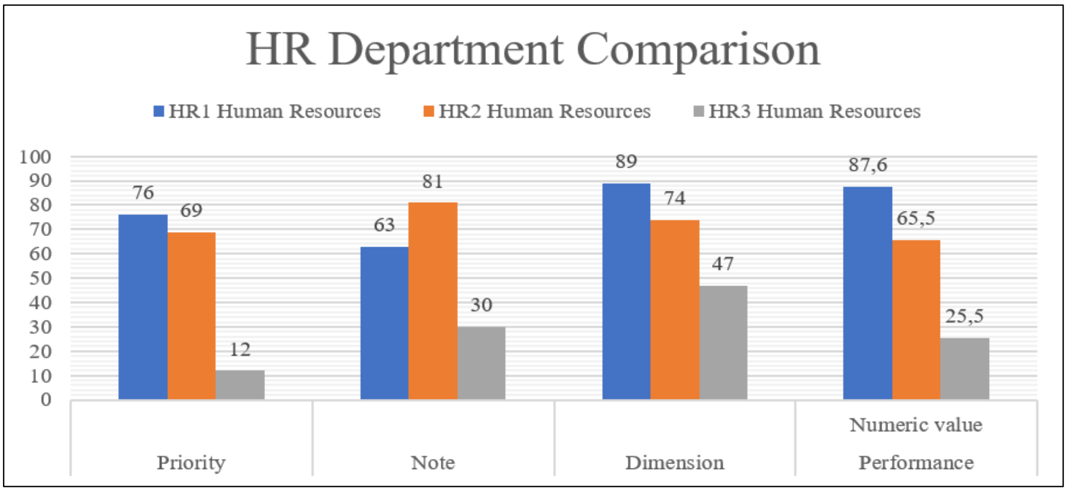

Figure 14. Comparison of HR departments.
Source: Authors (2021).

A single fuzzy inference model was used to assess the three departments (Equity, HR and IT) of different companies, this was due to the practices used being generic and adapting to different types of different departments. Thus, the model can be used to evaluate different departments, as long as they fit the practices used in this model.

5. Conclusion

It is concluded that the present article fulfilled the established objective of analyzing departments of industrial companies in the electronic sector, through a fuzzy inference model. It was observed that when analyzing the performance variables in the initial stage of the research development, the "*Priority*" variable had a greater influence due to the "*Performance*" variable that can be analyzed by the surface graph, the other input variables contribute less influence in "*Performance*".

In the step of selecting the significant variables for the model, it was possible to observe the importance regarding the inferences of the input variables to delimit the degree of performance of sustainable logistics in the analyzed departments, considering that the activities of supply logistics and their practices can be evaluated by means of these characteristics raised.

Therefore, the model is characterized by a basis of inferences that is adapted by a set of common practices and activities of the departments of companies in the electronic segment, and its application allows a comprehensive analysis of the degree of sustainability logistics in the departments, these which are indicated by means of simulations where the different levels of values in the inputs define the final "*Performance*".

Finally, the analysis of the departments indicates that the company in the electronic segment 1 has a high sustainability factor in relation to companies 2 and 3, where the HR, Heritage and IT departments have, respectively, 87.6, 88.1 and 65.5 as sustainable performance.

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