ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 12, Issue, 11, pp. 59973-59984, November, 2022
https://doi.org/10.37118/ijdr.25595.11.2022

RESEARCH ARTICLE OPEN ACCESS

LOGISTICS MANAGEMENT FOR SUPPLIER EVALUATION IN AN INDUSTRY USING ARTIFICIAL INTELLIGENCE (FUZZY LOGIC) FOR DECISION MAKING

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ARTICLE INFO

Article History:
Received 14th August, 2022
Received in revised form
10th September, 2022
Accepted 19th October, 2022
Published online 30th November, 2022

Key Words:
Quality Management System, Fuzzy Logic, Statistical Data and Supply Chain.

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ABSTRACT

Today's quality is an indispensable requirement when it comes to the production of products or services, because with the highly competitive market, a simple factor that does not please the consumer, can be crucial to generate negative points in business operations. With this, the research carried out in a watch factory X, served to analyze the factors that contribute to the performance and analysis of an international supplier in the year 2019 and 2020, and to reach this objective it was necessary to raise the rejected parts indicators in the process of inspection of receiving process and assembly, as well as the rejection replacement service deadline process in order to evaluate the supplier's performance. The need to carry out this analysis, arose through the experience of one of the members of the group, who works at the company, therefore, this article may contribute to maximize the managers' decision making regarding the approval or disqualification of suppliers to produce watches. A quantitative approach, aiming to measure the variables, the procedure for data collection was through excel spreadsheet documents compiled from the SAP program. At the end of this research, improvement actions were suggested for the company according to the application of the supplier evaluation by the fuzzy logic method. The results achieved in this article, aim to work on the evaluation method and thus try to reduce the losses that generate losses with the process of waiting for information to be collected for decision making.

Citation: ***Ananda Desirée Rondon Fonseca Jana das Neves, Jandecy Cabral Leite and Milton Fonseca Júnior.*** "Logistics management for supplier evaluation in an industry using artificial intelligence (fuzzy logic) for decision making*", International Journal of Development Research*, 12, (11), 59973-59984.

INTRODUCTION

The management of suppliers in factories and companies has little relevance when we disregard variables of the quality management system, it is extremely important to merge data involving the performance of the raw material or product after inspection and quality checking steps (Aron Chibba, 2017). Quality control is an integral part of quality management, where its purpose is to infer product characteristics to satisfy its requirements (Sadikoglu, Esin; Zehir, Cemal, 2010; Oakland, John S., 2014). When choosing a supplier, the item price has become a secondary condition, because with the effect of globalization, it is possible to find a wider range of options with competitive values, with this, other factors have become relevant and important for approval or continuation of the service.

The purchasing and logistics process has become extremely strategic, where it must be fed back with product performance information throughout its entire chain to then make decisions. According to Park *et al*. (2008; SCHÜMANN, Sylvie. 2020), in an integrated SRM (Supplier Relationship Management) structure, the segmentation or use of the supplier portfolio model must occur in the supplier assessment and development stage and enable subsidies for continuous improvement (HADDAD, Cédric; BLOME, Constantin. 2017). The strategic decision depends on documents containing quantitative and qualitative analysis, generated through statistical data, where they are extracted from systems or Excel spreadsheets. Each company has its requirements to consider an excellent supplier, if we have a wide range of options, from quality tests, raw material evaluations and product performance data throughout its chain, gather this data, merge and generate valid information for analysis.

The end can be very time-consuming, diverting the employee from other activities. According to a survey by Kannan and Tan (2002) in Western companies, the selection and evaluation criteria that most corroborate the performance of companies are strategic commitment, honesty and integrity, information sharing and responsiveness. The manager, when evaluating the productivity of each employee, must verify which activities are relevant and necessary, therefore, he will explore options that will reduce the execution time of an operation. The application of fuzzy logic, especially fuzzy logic, is an option for optimizing supplier evaluation processes. According to Aliev, Rafik Aziz (2013), the nebulous sets and the LN enable the generation of effective techniques to solve problems of different natures, and there are authors, such as Chandra, Dubois, Korvin, Siegel, Sriram and others, who report numerous applications in the areas of expert systems, word computing, approximate reasoning, natural language, robotics and in the areas of process control and decision-making. "The proposal of Fuzzy Logic is to assume a premise that varies in degree of relevance, in the range from 0 to 1, which makes the element of the fuzzy set partially true, or partially false" (Dubois,Didier; Prade, Henri, 2001; Klir, George; Yuan, Bo, 1995).

Proposal Formulation: The formulation of this proposal is the development of a computational tool for the application of fuzzy logic to evaluate suppliers in an X watch factory in the Manaus Industrial Pole, analyzing the main supplier variables in an X watch factory in the Manaus Industrial Pole The basis for the study is based on the principle of suppliers in an X watch factory in the Industrial Pole of Manaus and the quality of supply of equipment and parts dispatched by each piece of equipment. Therefore, this work intends not only to monitor these equipment's and parts, but also based on management analysis reports, obtaining fuzzy indicators of their performance. Develop a model for suppliers in an X watch factory in the Industrial Pole of Manaus using a computational tool based on fuzzy logic applied in a watch factory to ensure greater competitiveness and reliability of suppliers in the supply of parts and equipment Implement and evaluate a logistics procedure that enables the correct and adequate planning and control of the supply of parts and equipment to improve their reliability and productivity, through quality fermentation and supplier diagnosis Develop a computational tool using fuzzy logic for logistics according to the technical state of equipment in a watch factory, improving reliability and increasing productivity in this watch Industry.

Contribution and relevance of the study, according to the rules of the model of the Brazilian industrial sector, the unavailability of equipment for any reason is a risk for the entrepreneur, who must bear the losses caused by unavailability at levels higher than those declared. These problems imply financial costs associated with the value of penalties, which include the (decrease in the number of watches that can be sold in contracts due to an unavailability verified above the forecast). However, the poor performance of suppliers seems to indicate that the current regulation is not being effective in inducing an adequate performance of these industries, which is so necessary at this time of prolonged economic crisis. The unavailability of equipment for the watch industry has been relatively high, especially after prolonged periods of idleness, which leads to these aspects being considered by suppliers. This behavior points to the need to study the real dimension of the problem, as well as making it pertinent to study any regulatory changes that allow to mitigate the problem, both for the supply of existing watches and for new projects. The computational implementation of fuzzy logic, using as rules the input parameters of the quality of suppliers, allows the development of a computational tool of supplier conditions for the supply of parts and equipment for operational improvement of the equipment

LITERATURE REVIEW

Robinson and Malhotra (2005) claim that traditional quality management emphasizes the control of improvement of internal processes comprising all sectors of the company, from the beginning of manufacturing to the final process, the finished product.

Companies began to realize that, in addition to the need to implement continuous quality improvement and satisfy the demands of their customers, it was also necessary to compete in a globalized environment, which increases its importance in the context of generality. For Paladini (2009), it is the consumer who assesses quality; to serve you, it must involve everyone in the company on a progressive and permanent basis. As for Garvin, David A. (1988); Nicholas, John (2018), he says that the concept is already quite old. There has been an evolution over time in vision and concept. In the beginning, it was seen under the inspection aspect, through which the measuring instruments, tried to achieve the uniformity of the product; and at another time, it was sought through statistical instruments and techniques to achieve statistical quality control in the next step, quality is more concerned with its own guarantee. Quality management has evolved over the century through the age of product inspection, process control, and quality assurance systems. However, some of its principles, such as the search for customer satisfaction and the continuous improvement of products and processes, have become eternal in view of their economic rationales and their contribution to increasing the company's competitive capacity (Maguad, Ben A. 2006; Ross, Joel E. 2017). In this context, the challenge of survival in the highly interconnected and increasingly competitive market has given rise to new management techniques. They seek to keep organizations in a scenario of constant change, developing agile and strong administrative systems to the standards established in this new economic formation of society (Fernandes, F., 2006; Mootee, Idris., 2013; Tidd, Joe; Bessant, John R., 2020).

Strategic management considers as fundamental the technical, economic, informational, social, psychological, and political variables that form a system of technical, political, and cultural characterization of companies. It also has, as its basic interest, the strategic impact of quality on consumers and the market, with a view to the survival of companies, considering the current competitive society. The competitiveness and performance of organisations are adversely affected in terms of quality and productivity for several reasons. Among them stand out: a) deficiencies in the training of human resources; b) outdated management models, which do not generate motivation; c) decision-making that is not adequately supported by facts and data; and d) postures and attitudes that do not induce continuous improvement (Longo, 1996). Quality assurance is based on the planning and systematization of processes. It is structured in written documentation, which should be easily accessible. What the company wants is the zero defect. All this can be observed in ISOs that are requirements of local customers, and especially of international ones Heras, Inaki; Cilleruelo, Ernesto; Iradi, Jon, 2008; Dale, Barrie G.; Plunkett, James J, (2017). According to Hosmer, Larue Tone, (1994), a quality system implemented based on ISO standards has "a multitude of techniques for optimizing the internal processes of your organization. "In addition, its application becomes relevant, since the standards have flexible postures, all studied and reasoned to ensure organizations greater credibility of their customers and create an additional advantage before their competitors.

Formulation of the Proposal: The formulation of this proposal is the development of a computational tool for application of fuzzy logic for evaluation of suppliers in an X clock factory in the Industrial Pole of Manaus. Analyzing the main variables of suppliers in an X watch factory in the Industrial Pole of Manaus. The basis for the study, part of the principle of suppliers in a factory of X watches in the Industrial Pole of Manaus and quality of supply of equipment and parts shipped by each equipment. Thus, this work aims not only to monitor these equipment and parts, but also based on the management reports of analysis, obtaining fuzzy indicators of their performance. Develop a model for suppliers in an X watch factory in the Industrial Pole of Manaus using computational tool based on fuzzy logic applied in a watch factory to ensure greater competitiveness and reliability of suppliers in the supply of parts and equipment. Implement and evaluate a logistics procedure that allows the planning and control of the supply of parts and equipment in a correct and adequate way to improve their reliability and productivity, through the fermentation of

qualities and diagnosis of suppliers. Develop a computational tool using fuzzy logic for logistics according to the technical state of the equipment in a watch factory improving the reliability and increasing the productivity of this watch industry.

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MATERIALS AND METHODS

The concept of logistics initially covers supply chain management and the distribution of goods and services. However, the theme also encompasses production systems, planning, production control, inventory models and more, managing the flow of information between customers and suppliers. The goal is to deliver the right product on time to the right customer and at the designated location, all while promoting cost reduction. All these goals depend on a series of intermediate procedures, whose operation is essential for the proper functioning of industrial logistics. In this way, it is necessary to strategically manage the acquisitions made, as well as the storage, movement, and distribution of the goods so that it is possible to know how and where each product is. Another process that deserves attention is the processing of orders, which must ensure that orders are separated and sent correctly, thus generating a satisfactory provision of services. With industrial logistics involving a wide variety of systems, information and actions, in addition to all the components already mentioned, it also involves the processes and factors that influence purchasing activities, since it also cares about quality, price, packaging care, handling, product safety, service reliability and its influence on customer loyalty, among others. By applying good practices to improve processes, logistics in industry directs attention to crucial points for business success by reducing unnecessary movements, optimizing space and time, eliminating unproductive operations, and reducing waste and excess inventory, enabling greater use of available resources, which is reflected in increased profitability, more competitive prices and customer predilection.

It's easy to understand how fundamental the logistics chain is to the success of the business and the country's economic growth, isn't it?. Due to the facilities obtained with the high level of technology that comes from the 20th century, the global scenario has become extremely integrated into all existing activity sectors. The industrial landscape has followed this trend and for a company to be competitive today, it is not enough to have control only of its processes, but of all its employees, including suppliers and customers (Wiig, 1997; Van de Vrande, Vareska *et al*., 2009). It is in this context that supply chain management arises. The term originates in the 1980s (Gimenez, Cristina; Ventura, Eva., 2005; Cooper, *et al*., 2016) and therefore still does not have full understanding of its meaning, even though it has been defined by several authors, there are still erroneous interpretations with logistics.

Before talking specifically about GCS, it is necessary to clarify the meaning of supply chain (CS). According to Thorelli (1986) a network, also called chain, is composed of "we", which represent positions taken by companies, factories, business units and other organizations, as well as the flows of information and materials between these links, which are obtained by their interactions. Mentzer *et al*., (2001) proposes a more objective concept, defining as the group of three or more organizations related to the previous and subsequent flows of products, services, funds, and information, starting from the point of origin and ending in consumption. Finally, the Supply Chain Council proposed by Griffin, Abbie *et al*. (1995; Pagh, Janus D.; Cooper, Martha C.,1998; Folinas, Dimitris *et al*., 2004) says that CS covers all stages, from production to product delivery, integrating the first supplier to the final customer. To do so, four processes are needed: Planning, supplying, making, and delivering. The results obtained with a good level of GCS are demonstrated in numbers in the literature. Mertz (1998) shows quantitative and qualitative gains. In relation to the first, the author highlights among other gains: a 50% and 20% decrease in inventory costs, an increase in the accuracy of deliveries by 40%, in addition to the reduction of lead time by up to 27%. About the qualitative highlights: increase of interpersonal relationship and competencies, technical-organizational restructurings, exchange of know-how and technology between the companies that form the network. To obtain these results, Lambert (2004); Ivanov, Dmitry; Sokolov, Boris. (2009) defines eight processes intrinsic to GCS, which must be performed to obtain a high level of maturity of the same. These are shown in Figure 3. It is worth noting that the continuous black arrows represent the flow of materials, while the blue dashed slips are referring to the information. It is clear the importance of the relationship between customer and suppliers, in addition to the segmentation of processes, relating beyond the two already mentioned, demand, orders, manufacturing, returns and commercialization.

The main actions to optimize the logistics sector in an industry and automate processes: control over processes is fundamental to the success of the company. Through mapping, you can improve service efficiency and performance, reduce costs and time spent performing tasks, and eliminate waste, resulting in greater flexibility and agility in the supply chain. The automation of processes integrates all sectors of the company, facilitating access and the search for information, improving the quality of services, making internal actions safer and generating greater customer satisfaction!. Optimize the company space: making the best use of available space is essential to accelerate logistics processes. It is important to keep stocks ordered, considering the input and output logic of products or goods. Inventory control systems can help with this task by facilitating the management of products in the warehouse. Reduce unnecessary handling: Transportation is one of the biggest logistics costs, so good route planning is required to reduce waste and delivery risks. As for internal moves, it is interesting to use layouts, as in assembly lines. In this way, each employee will receive his/her task without having to change his position constantly, avoiding delays in processes and even accidents. Knowing the role of industrial logistics in process improvement, it is important that the logistics company chosen to transport its products adopt measures capable of contributing positively to the growth of your company.

For industrial logistics to integrate between the various areas of your company, it is necessary to face some challenges, such as:

- **Quality control:** it is important to always be attentive to this process so that everything goes as planned, because in addition to verifying if the product is in the standards, this sector should also be responsible for checking the state of the documentation, labels and everything that identifies the product.
- **Provision of services:** because it involves several aspects of the logistics process, often this service leaves to be desired by not giving due attention to each individual process. This affects the reliability of the customer, who does not trust the company.
- **Difficulties with transportation:** in addition to the problems with the precarious conditions of the Brazilian road network,

there is concern about the theft of cargo (which cause great damage to the industry) and the high expenses with fuel.

This learning provides students with a communication environment where they can express themselves freely and favors the processes of tutoring and help within the group. "Each member has defined responsibilities and is co-responsible for learning the other, as the groups constantly evaluate their performance and the quality of their work in order to seek continuous improvement." (Amaya, sd, p.4) Learning allows students to develop skills related to communication and social skills (integration, respect, tolerance, solidarity), which are fundamental for interaction with others (Baumberger-Henry, 2005).
According to Tenutto and Klinoff (2005), one of the main aspects of cooperative learning derives from positive interdependence, since each member of the group has a clear that the efforts, he makes will benefit not only the other members, but also himself. This interdependence manages to promote in the group the convenience that all members have a clear theory so that they can contribute to the group, which means that everyone is up to date. Positive interdependence, Tenutto and Klinoff (2005) typify and exemplify in five inclinations: interdependence of objectives, interdependence of tasks, interdependence of resources, interdependence of functions and interdependence of rewards. The Figure 1 is key to understanding the innovation of this thesis and the methodology used for its development. At the top left, one can appreciate the simplification. In the left center shows the diagnostic activities that allow to know the technical status of the engines to know whether they can be used in the decision-making of suppliers and the lower left shows the reliability analyses, which together with the diagnosis allow knowing when it is possible to hire suppliers. With this data, in the right part of the figure is shown the application of fuzzy logic to make the decision, according to the fuzzy rules that meet the decision-making of the making purchases of each supplier.

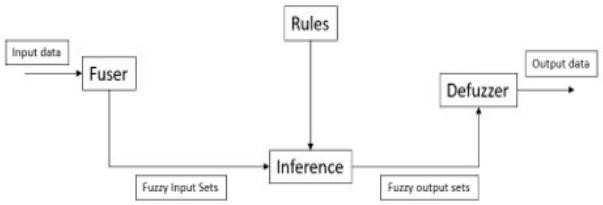
Source: Authors, (2022).

Figure 1. Research Methodology

Fuzzy Logic and its Application: The theory of classical sets is based on the fundamental concept of a set, in which individuals are members or not members. There is a clear, clear and clear distinction between a member and a non-member for any well-defined set of entities in this theory, and there is a very precise and clear limit to indicate whether an entity belongs to a set. Thus, in classical set theory, an element cannot be in a set (1) or a set (0) at the same time. This means that many real-world problems cannot be addressed by classical theory. On the contrary, the theory of diffuse sets accepts values of partial association and, therefore, in a sense, generalizes the theory of classical sets to some extent □□ ∈ [□, +□]..

Fuzzy logic or fuzzy logic: The real world is complex; this complexity often stems from the uncertainty of the events of nature and the future. Human beings have unconsciously managed to solve complex, ambiguous and uncertain problems thanks to the gift of thinking. This thought process is possible because humans do not need the full description of the problem, as they have the ability to infer approximately and draw conclusions and evaluations without having all the data of a particular problem or situation. With the advent of computers and increased computational power, engineers and scientists are increasingly interested in creating methods and techniques that allow computers to work with models with uncertainty. As Prof. Lotfi A. Zadeh suggests by his principle of incompatibility: "How closely one looks at a real-world problem, fuzzy logic becomes the solution", and thus, inaccuracy and complexity are correlated (Zadeh, 1973). Fuzzy Logic, Neural Networks, Expert Systems and Genetic Algorithms are part of a new paradigm known as intelligent systems. These systems seek to provide answers that solve problems, appropriate to the specific situations of these problems, even if they are new or unexpected (Fonseca, Milton *et al*., 2018). Fuzzy logic aims to model the approximate mode of reasoning, trying to imitate the human ability to make rational decisions in an environment of uncertainty and inaccuracy. Thus, fuzzy logic is an intelligent technique, which provides a mechanism for manipulating inaccurate information – concepts of small, loud, good, very hot, cold – and which allows us to infer an approximate answer to a question based on inaccurate, incomplete or not fully reliable knowledge (Tanscheit, 2004). In recent years, there has been a growing interest in diffuse logic, both in industry and academia (Kahraman *et al*., 2016; Ahn *et al*., 2017; Zoghi *et al*., 2017). Current applications include modeling, evaluation, optimization, decision making, control, diagnosis and information (Gottwald, 2013). For example, fuzzy logic has been applied in areas such as predicting nuclear reactor smashing in Europe, forecasting earthquakes in China, and subway control in Japan.

Fuzzy Systems: A system based on fuzzy logic, the Figure 2, can have its action schematized by the following constituent elements: Fuzzificador; Rules, or knowledge base; Inference, or decision-making logic, and Defuzzificador (Larguech *et al*., 2016).



Source: Adapted from (Larguech et al., 2016).

Figure 2. Fuzzy logic-based system

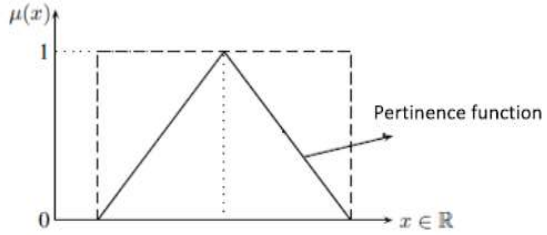
According to (Larguech *et al*., 2016), the "fuzzificador" is responsible for mapping numerical inputs into fuzzy sets and converting them into linguistic variables. "Inference" is performed by mapping incoming linguistic values into outgoing linguistic values using the rules. This uses fuzzy implications for simulation of human decisions, generating control actions, called consequential, starting from a set of entry conditions, called antecedents. This knowledge base represents the system model to be controlled, consisting of a database and a fuzzy linguistic rule base. The "defuzzificator" maps linguistic values and converts them into output numeric values. This function is performed by a defuzzification interface, obtaining a discrete value that can be used in a control action in the real world.

Fuzzy Set Theory: The basis of fuzzy systems is fuzzy set theory. These assemblies are extensions of conventional assemblies, which only allow elements to be true or false (Boolean, bivalent logic). Fuzzy sets allow their elements to have a certain associated "degree of pertinence," which is known as "multivalence". This allows the approximation with the real world that is not bivalent, it is in fact multivalent with a vast number of options rather than just two. Fuzzy logic, then, allows working with such uncertainties of natural phenomena in a rigorous and systematic way (Dubois *et al*., 2014).

The determination of the degree of pertinence, for continuous fuzzy sets, is made by the analysis of "pertinence functions". These functions make it possible to calculate the degree of pertinence according to the value assumed by the variable. They represent the fundamental aspects of all theoretical and practical actions of fuzzy systems (Ganga *et al*., 2011).

Fuzzy pertinence functions: The "Fuzzy Pertinence Functions" represent the fundamental aspects of all theoretical and practical actions of a fuzzy system. A pertinence function is a graphical or tabulated numerical function that assigns fuzzy pertinence value to discrete values of a variable, in its discourse universe represents the numerical range of all possible real values that a specific variable can assume (Mendel, Jerry M., 2017; OglyAliev, Rafik Aziz; Aliev, Rashad Rafik., 2001; Gabriel Filho *et al*., 2011).

$$\mu_A = \begin{cases} 0 \; if \; x \leq a \\ \dfrac{x-a}{b-a} \; if \; a < x \leq b \\ \dfrac{c-x}{c-b} \; if \; b < x \leq c \\ 0 \; if \; x > c \end{cases}$$



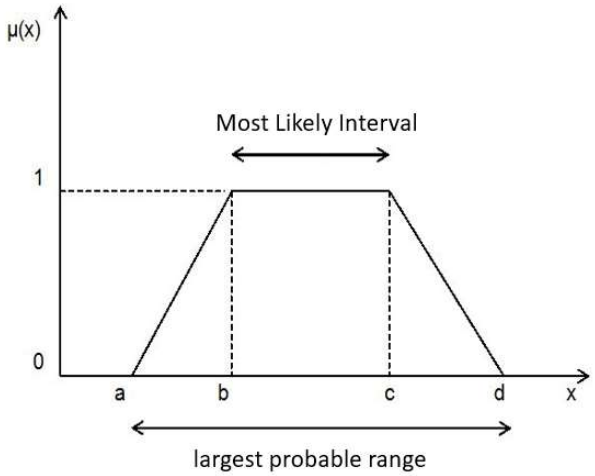
Source: Adapted from (Rodríguez and Huertas, 2016).

Figure 3. Triangular Pertinence function

A diffuse number (in this case, a performance indicator) is a generalization of a regular real number, in the sense that it does not refer to a single value, but rather to a connected set of possible values, where each possible value has its own weight between 0 and 1. This weight is called the join function. Just as Fuzzy logic is an extension of Boolean logic (which uses absolute truth and falsehood only, and nothing intermediate), fuzzy numbers are an extension of real numbers. Calculations with fuzzy numbers allow the incorporation of uncertainty into parameters, properties, geometry, initial conditions, etc. They can be represented by segments formed by attribution to a given function of association index (triangular, trapezoidal, gaussian, bell generalized, sigmoid, gamma, etc.) (Dubois and Prade, 2012). The number of functions in a discourse universe and its format is chosen based on experience, the nature of the process to be analyzed or an interview with the specialized human operator who performs the control functions manually.The graphs of pertinence functions can have different shapes and representations, the most common are triangular, trapezoidal and gaussian.

Triangular Pertinence Functions: The triangular pertinence functions are characterized by a suit (a, b, c), where a and c determine the interval within which the pertinence function assumes values other than zero, and b is the point where the pertinence function is maximum (Zanotelli, Rosana Medina,2020; Saadoud, Djouher *et al*., 2018). Figure 3 displays the curve of a triangular pertinence function where a, b, and c are highlighted. In this figure, the values of the pertinence function and on the horizontal axis are the values of the variable that is to be studied (Justo, Marcio Ribeiro; Bittencourt, João Ricardo. Minuano, 2011).

Trapezoidal pertinence functions: Trapezoidal pertinence functions are characterized by a set of four values of "a", "b", "c" and "d", where "a" and "d" determine the interval within which the pertinence function assumes values other than zero, "b" and "c" determine the interval within which the pertinence function is maximum and equal to 1. Figure 4 shows a trapezoidal pertinence function where points "a", "b", "c" and "d" can be highlighted. In this figure are on the vertical axis the values of the pertinence function and on the horizontal axis the values of the variable that is to be studied.



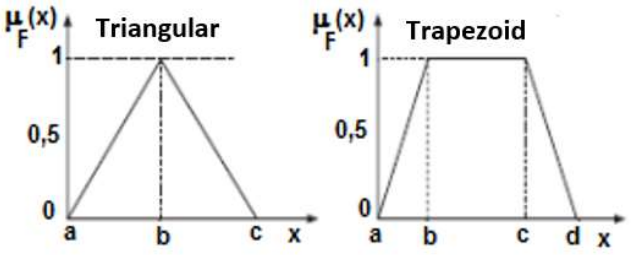
Source: Adapted from (Jones et al., 2012).

Figure 4. Trapezoidal Pertinence function

The and x pressures for the trapezoidal pertinence function are (Justo, Marcio Ribeiro; Bittencourt, João Ricardo. Minuano, 2011).

$$\mu_A = \begin{cases} 0 \; if \; x \leq a \\ \dfrac{x-a}{b-a} \; if \; a < x \leq b \\ 1 \; if \; b \leq x \leq c \\ \dfrac{d-x}{d-b} \; if \; c < x \leq d \\ 0 \; if \; x > d \end{cases} \quad (1)$$

The diffuse triangular and trapezoid numbers (Figure 5) are known for their ability to be adapted, as they reliably formalize many organizational situations (Jones *et al*., 2012).



Source: Adapted from (Jones et al., 2012).

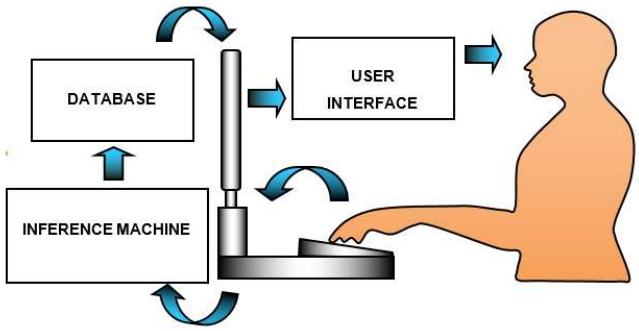
Figure 5. Comparison between trapezoidal and triangular functions

RESULTS AND DISCUSSION

This chapter deals with the application of fuzzy logic for logistics management for evaluation of suppliers in a factory of x watches in the industrial pole of Manaus with application of artificial intelligence (fuzzy logic), evaluated by different variables related to the supplier of parts and equipment.

In the first part are exposed the development of fuzzy rules and the whole inference procedure and in the second part all the evidence to evaluate logistics and suppliers. This tool served as the basis for solving the real problem of parts and equipment supplies to satisfy the rationalized methods of the just in time of an industry on technical conditions of parts and equipment.

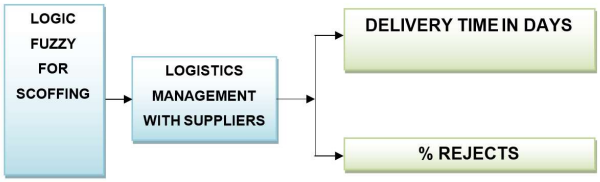
Fuzzy Simulation: The MATLAB is a powerful tool used in numerical computing and in various scientific areas and has become effectively used in engineering to perform mathematical calculations, develop algorithms, modeling and simulation. Through it was confirmed the possibility of optimizing the decision-making process in the pre-dispatch of load with the use of Fuzzy Logic on operating conditions of the generating units. In addition to the main blocks there is a human-machine interface (HMI), which the user or specialist communicates with the system without the assistance of a programmer, Figure 6. The rule-inference or interpreter machine guides the reasoning process through the knowledge base by comparing facts contained in the fact base with the rule set. For a long time, programs that contained general heuristics of how to solve problems were used. However, if knowledge is represented by mathematical logic, the inference machine is the Resolution method (Giarratano and Riley, 2005).



Source: Authors, (2022).

Figure 6. Expert System

Among the most common types of Logistics Management, one can mention suppliers. Figure 7 shows a logistics scheme developed in the industry in the case study, where analyses of % rejects and delivery time are made to support the fuzzy rules, developed as a computational tool to support the decision.



Source: Authors, (2022).

Figure 7. Decision-making

In this session, the results obtained from the collection of data in the research are presented, which supported the analysis of the results obtained. To understand how the data collection process works, it was identified that the assembly company of X watches has as main process of quality, the quality control for receiving raw material, as well as for assembly of watches, everything that is in the form of "tailings" that where through the criteria developed by the company is not in accordance with the criteria, it is forwarded to the quality sector called EAC (stock awaiting components), where the need for spare parts is sent through the system to the supplier. It is also carried out in this sector the evaluation of international suppliers, as well as the decision to continue or not, of the suppliers. The data used for vendor evaluation were:

- % Tailing in the process of receiving parts and assembly.
- Service period of rejected parts.

With these two variables, you can classify suppliers as: very good, good, or insufficient. Data collection, as well as their treatment, was currently done by SAP and transformed into excel spreadsheets, taking an average of 2 weeks to perform every six months or annually of 1 supplier. According to Table 1 and Table 2.

Table 1. The fuzzy logic method was applied based on the data

%REJECT	SERVICE DEADLINE
LOW (0 - 3%)	LOW (0 - 90 DAYS)
REASONABLE (3% - 5%)	
HIGH (5% - 10%)	HIGH (90 - 180 DAYS)

Source: Authors, (2022).

Table 2. The fuzzy logic method was applied based on the data.

LEVEL	VALUE
VERY GOOD	90% - 100%
GOOD	70% - 90%
UNSATISFACTORY	0 – 70%

Source: Authors, (2022).

The fuzzy simulation containing the system variables was performed using the MATLAB 2017 version a tool and the fuzzy model applied in this simulation was by Mamdani. This model is characterized by adopting the semantic rules used for the processing of inferences and is commonly called maximum-minimum inference. Such an inference model applies well to this type of problem since it uses the union and intersection operations between sets. The implementation is made by the Mamdani model applied to this case study according to Table 3. After editing the relevance functions of all variables, fuzzy rules for the inference process, which appear in table 3, were established. Generating the 6 rules proposed by the Matlab system through the application of fuzzy logic:

With this, we can see the information according to the following rules,

- If the % of tailings are low and the service time of rejected parts is low, the supplier's rating is considered "GOOD".
- If the % of tailings are low and the service time of rejected parts is high, the supplier is evaluated as "UNSATISFACTORY".
- If the % of tailings are reasonable and the service time of rejected parts is low, the supplier is evaluated as "BOM".
- If the % of tailings are reasonable and the service time of rejected parts is high, the supplier is evaluated as "UNSATISFACTORY".
- If the % of tailings are high and the service time of rejected parts is low, the supplier is evaluated as "VERY GOOD".
- If the % of tailings are high and the service time of rejected parts is high, the supplier is evaluated as "VERY GOOD".

By applying the data for the year 2019 to the largest supplier of the X watch factory, it was possible to apply the data and defuzzification (Table 4, Figure 8, Figure 9): By checking the annual performance of supplier X, we can see that it was considered "good" when applying defuzzification and considering the full-year performance of 2019 being a class B supplier (Table 5): In the supplier development plan, each classification consists of a range of actions, exemplified below:

- **CLASS A - VERY GOOD:** No negative criteria of supply, issuance of certificate of congratulations and continuation of the service.
- **CLASS B - GOOD:** Sending a statement to the supplier about continuous improvement, without requiring the opening of an action plan and continuation of the service.
- **CLASS C - UNSATISFACTORY:** Request for improvement plan and monitoring of the supplier, blocking for new business, possibility of disaccreditation and start development of alternative supplier.

Table 3. The fuzzy logic method was applied based on the data below

Rules
If (%REJEITO is LOW) and (PRAZO-ATEND is LOW) then (AVALIAÇÃO is GOOD) (1)
If (%REJEITO is LOW) and (PRAZO-ATEND is HIGH) then (AVALIAÇÃO is UNSATISFACTORY) (1)
If (%REJEITO is REASONABLE) and (PRAZO-ATEND is LOW) then (AVALIAÇÃO is GOOD) (1)
If (%REJEITO is REASONABLE) and (PRAZO-ATEND is HIGH) then (AVALIAÇÃO is UNSATISFACTORY) (1)
If (%REJEITO is HIGH) and (PRAZO-ATEND is LOW) then (AVALIAÇÃO is VERY GOOD) (1)
If (%REJEITO is HIGH) and (PRAZO-ATEND is HIGH) then (AVALIAÇÃO is VERY GOOD) (1)

Source: Authors, (2022).

Table 4. The fuzzy logic method was applied based on the data

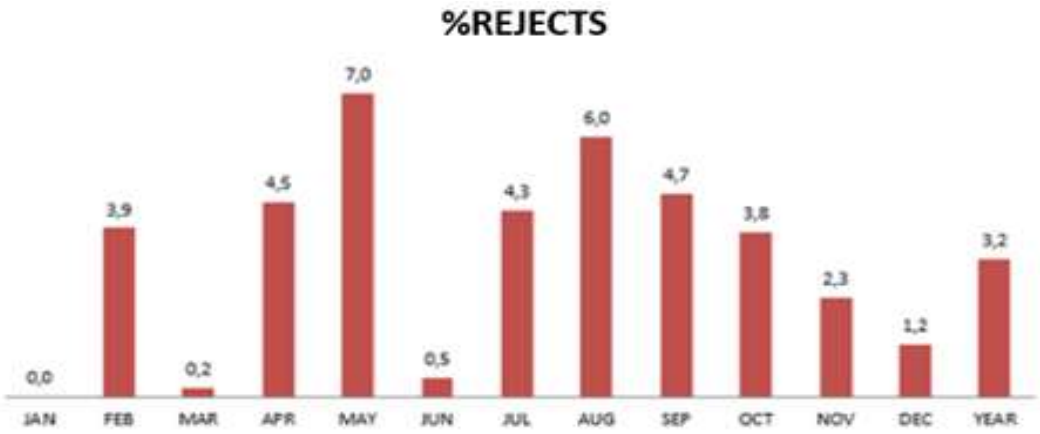
DEVELOPMENT PLAN	JAN	FEB	MAR	APR	MAY	JUN
%REJECT	0,0	3,9	0,2	4,5	7,0	0,5
DEADLINE (DAYS)	0,0	100	30	200	80	190
FUZZY REJECT	LOW	REASONABLE	LOW	REASONABLE	HIGH	LOW
FUZZY DEADLINE	LOW	HIGH	LOW	HIGH	LOW	HIGH
FUZZY RESULT	GOOD	UNSATISFACTORY	GOOD	UNSATISFACTORY	VERY GOOD	UNSATISFACTORY

Source: Authors, (2022).

Table 6. Generating the 6 rules proposed by the Matlab system

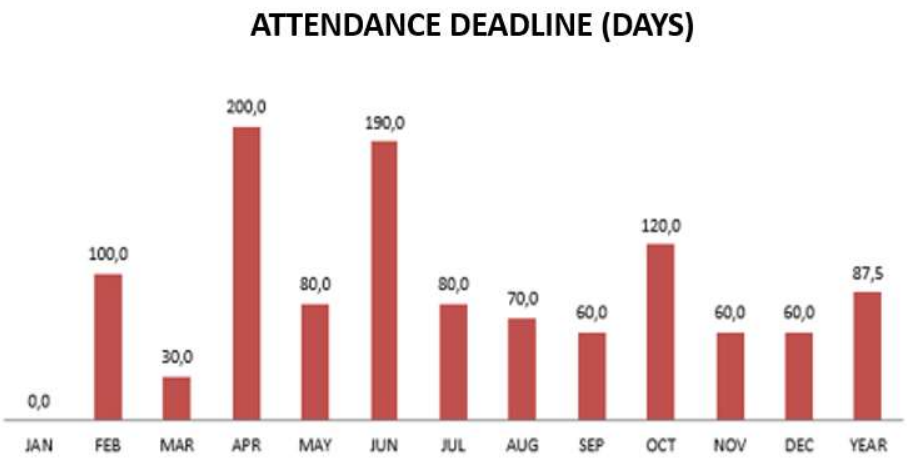
Rules
If(%REJEITO is LOW) and (PRAZO-ATEND is LOW) then (AVALIAÇÃO is GOOD) (1)
If(%REJEITO is LOW) and (PRAZO-ATEND is HIGH) then (AVALIAÇÃO is UNSATISFACTORY) (1)
If(%REJEITO is REASONABLE) and (PRAZO-ATEND is LOW) then (AVALIAÇÃO is GOOD) (1)
If(%REJEITO is REASONABLE) and (PRAZO-ATEND is HIGH) then (AVALIAÇÃO is UNSATISFACTORY) (1)
If(%REJEITO is HIGH) and (PRAZO-ATEND is LOW) then (AVALIAÇÃO is VERY GOOD) (1)
If(%REJEITO is HIGH) and (PRAZO-ATEND is HIGH) then (AVALIAÇÃO is VERY GOOD) (1)

Source: Authors, (2022).



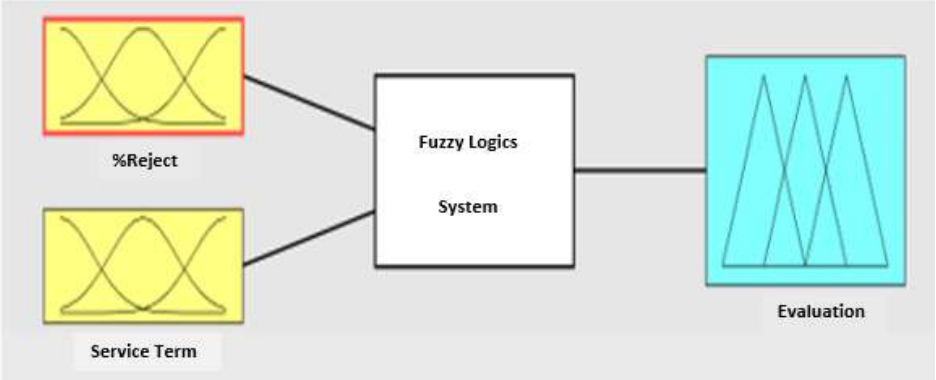
Source: Authors, (2022).

Figure 8. Expert System



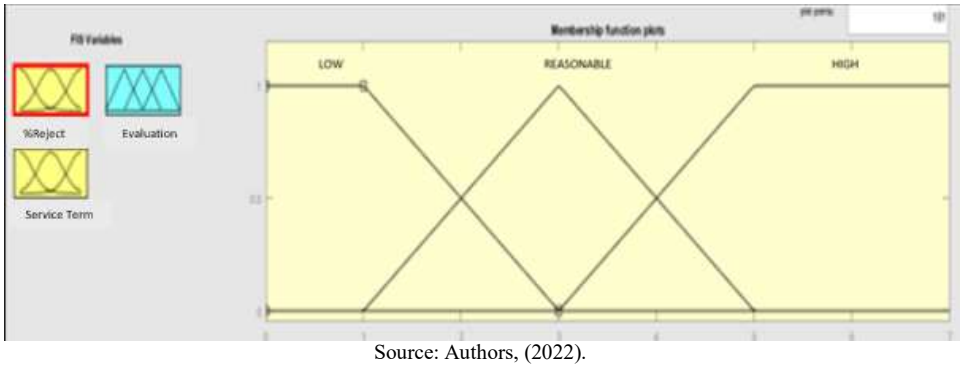
Source: Authors, (2022).

Figure 9. Deadline (Days)



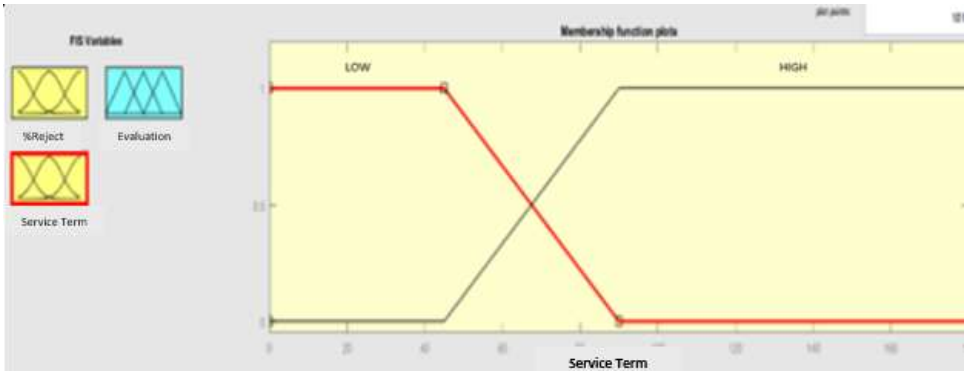
Source: Authors, (2022).

Figure 10 - Mamdani model



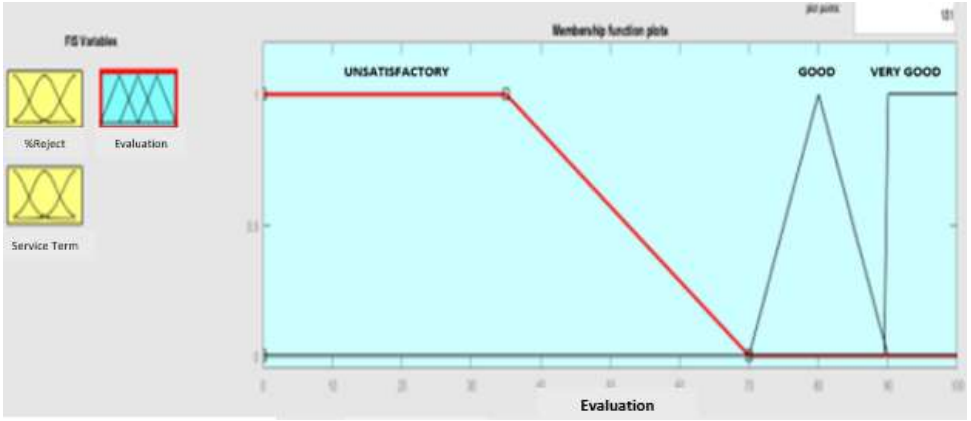
Source: Authors, (2022).

Figure 11. The implementation of all input variables to the fuzz system is presented



Source: Authors, (2022).

Figure 12. The implementation of all input variables to the fuzzy system is presented



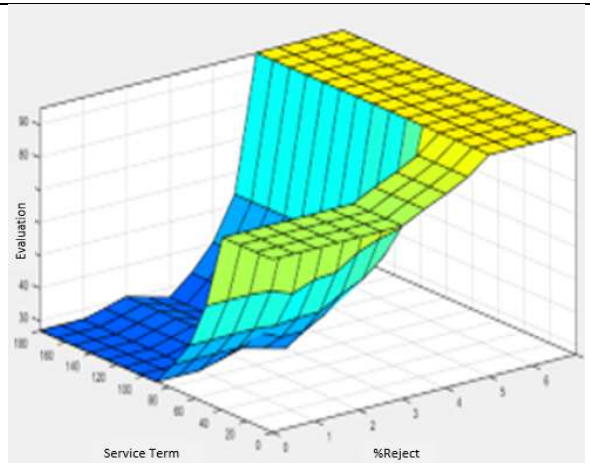
Source: Authors, (2022).

Figure 13. The implementation of all input variables is presented

Table 7. Map D.2019

YEAR	2019		SUPPLIER	TIMEZONE												
Pdf composition	**Weight (%)**	**JAN**	**HALF-YEARLY AVERAGE**	**FEB**	**SEA**	**APR**	**MAI**	**JUN**	**JUL**	**HALF-YEARLY AVERAGE**	**AUG**	**SET**	**OUT**	**NOV**	**TEN**	**AVERAGE YEAR**
Receipt inspection	10%	IN	5	10	IN	10	10	10	10	10	IN	10	0	IN	IN	8,6
Result of rework	30%	IN	0	0	IN	10	0	0	5	3	IN	0	0	IN	IN	2,1
Assembly and finishing inspection	30%	IN	6,5	0	IN	10	10	5	8	6,6	IN	5	8	IN	IN	6,6
Time and quality of replacement of rejected parts	20%	IN	10	10	IN	10	10	10	10	10	IN	10	10	IN	IN	10
TOTAL	90%	IN	0	3	IN	9	6	4,5	6,9	5,9	IN	4,5	4,4	IN	IN	5,5

Source: Authors, (2022).



Source: Authors, (2022).

Figure 14 . Resulting Surface (Service term in day x % Tailings)

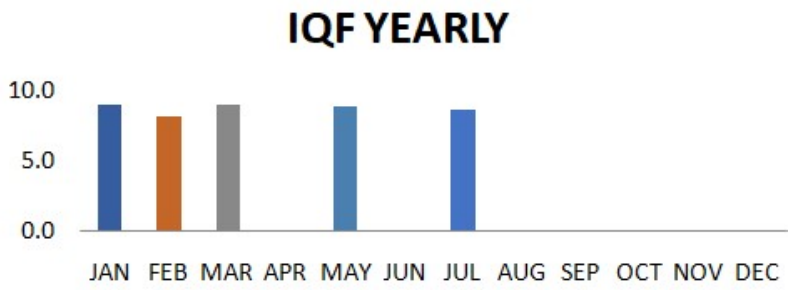
Source: Authors, (2022).

Figure 17. Annual IOF 2019

Table 8. Map D.2020

YEAR	2020		SUPPLIER	TIMEZONE										
PDF	**(%)**	**JAN**	**Feb**	**SEA**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
RECEIPT INSPECTION	10%	10	9,2	10	IN	8	IN	9,1	IN	IN	IN	IN	IN	9,2
RESULT OF REWORK	30%	10	8,3	10	IN	10	IN	9,4	IN	IN	IN	IN	IN	9,6
ASSEMBLY AND FINISHING INSPECTION	30%	10	9,2	10	IN	10	IN	9,7	IN	IN	IN	IN	IN	9,8
TIME AND QUALITY OF REPLACEMENT OF REJECTED PARTS	20%	10	10	10	IN	10	IN	10	IN	IN	IN	IN	IN	10
TOTAL	90%	9	8,2	9	IN	8,8	IN	8,7	IN	IN	IN	IN	IN	8,7

Source: Authors, (2022).



Source: Authors, (2022).

Figure 18. Annual IOF 2020

Table 9. Evaluation of suppliers

MONTHLY REPORT		MONTHLY REPORT						MONTHLY REPORT			
JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC
		ACTION PLAN		IMPROVEMENT				ACTION PLAN		IMPROVEMENT	
		BUY							BUY		

The Inference rules were made according to data elaborated with 512 combinations (% rejects and delivery time in), because table 5.9 presents only 26 combinations as an example. All variables are inserted considering the intervals determined in the inference rules as shown in Table 3.

Application of Fuzzy Logic: In this context, the following groups of information and data are abstracted: input values, called crisp, linguistic variables and fuzzy variables. Fuzzy logic is justified in the solution of this case study as a function of the input variables with better representativeness in fuzzy sets, The variables due to the dimension of the universe of study were divided into inputs and output, all independent of each other.

Procedure for the application of fuzzy logic: The first step was the determination of the variables to be used to establish fuzzy rules, for this we were considered the analysis of % rejects and term of service in days. Based on the classification of the state of these variables, the technical state of the engines was determined according to established fuzzy rules. So, for a demand for the quality of parts and equipment.

Determination of Fuzzy Input Variables: For the determination of each variable, it was convenient to divide into tracks for a closer approximation of the actual situation that is desired to verify:

The input variable "% Rejects and Deadline in Days": The "% tailings and service time in days", measurement that is performed frequently is the first input variable because it is responsible for the quality conditions. The levels of % tailings and service time in vibration days were subdivided into 02 (two) variables, each corresponding to the classification of customer satisfaction levels. Leading to these variables in the fuzzy system, 02 input variables and 1 output variables (inference):

All variables are inserted considering the intervals determined in the inference rules as shown in Figure 10. The evaluation is a product of the relationship between the input variable and the output variable, which make up the pertinence functions expressed in the curves in Figure 13. The values that are produced by this inference can be interpreted by the specialist so that the specialist can verify according to figures 14.

Where the result of processing fuzzy inference rules is displayed across the surface of the 3D chart. In these curves are present all the possible situations that variables can assume within the simulation; the graph is as follows: The upper area of the curve has yellow color, representing the comfort zone of the system, that is, when the variable "Service Term" tends to assume minimum value (normal) or permissible and the "% Rejects" tends to assume minimum value (normal) or permissible the variable "Evaluation" will assume maximum value. The blue area of the curve represents the discomfort zone of the system, that is, when the variable "delivery time" tends to maximum value (critical) or alert and the variable "% Rejects" assume maximum value (critical) or alert the variable "Evaluation" will assume minimum value. Generating the 6 rules proposed by the Matlab system through the application of fuzzy logic: According in Table 6, the combination of some of the linguistic variables is shown, thus forming the antecedents and the consequent ones based on fuzzy inference rules (Table 6). For a better understanding the screen expressed in Figure 13 demonstrates all the possibilities that simulation can produce. Moving the red lines determines the other rule that you want to evaluate. As fines combinations are virtually identical and do not change the output data were performed 120 combinations in Matlab.

With this, we can see the information according to the following rules

- If the % of tailings are low and the service time of rejected parts is low, the supplier's rating is considered "GOOD".
- If the % of tailings are low and the service time of rejected parts is high, the supplier is evaluated as "UNSATISFACTORY".
- If the % of tailings are reasonable and the service time of rejected parts is low, the supplier is evaluated as "BOM".
- If the % of tailings are reasonable and the service time of rejected parts is high, the supplier is evaluated as "UNSATISFACTORY".
- If the % of tailings are high and the service time of rejected parts is low, the supplier is evaluated as "VERY GOOD".
- If the % of tailings are high and the service time of rejected parts is high, the supplier is evaluated as "VERY GOOD".

By applying the data for the year 2019 to the largest supplier of the X watch factory, it was possible to apply the data and defuzzification: The first step when it comes to developing a maintenance program is to direct all efforts in the areas that will bring maximum benefit, and such an approximation can be developed by performing a reliability analysis.

As part of a logistics management, management program and supplier study and monitoring, it is essential to evaluate the development or formation of defects, the size of such defects, the growth of defects, as well as other general weakening of component structures, and characterize and verify the behavior and performance of components and industry as a whole.

Quality Statistics Tools: The main statistical techniques that can be used in an integrated way in cycles of continuous improvement of processes and services are as Table 7, Figure 17, Table 8 and Figure 18. Flowchart, Ishikawa Diagram (Fishbone), Check Sheet, Pareto Diagram, Histogram, Scatter Diagram and Control Charts. These seven tools are part of a group of elementary statistical methods, which should be known to all persons involved with the company, from the president to the employees, and therefore should be part of the basic training programs of organizations (Goetsch and Davis, 2014; Mystica, A.; Bai, J.; Suganthi, Mary, 2015). Some of them will be discussed and implemented throughout this paper. To be able to plan and execute the work developed in this dissertation it was necessary first that everything does an analysis of supplier failures during the years 2021 and 2021. Table 6.1 shows data on the frequency of equipment failures.

Competitiveness has made companies to stay in the market, continue to improve constantly. This is highlighted by the author Paladini (2009), who states that it is necessary to have continuous improvement in the quality of internal processes from its beginning until its end. With this intention the X watch factory, already with the information for supplier evaluation sought to make a survey for the supplier of higher volume and greater impact in the factory for the application of fuzzy logic. With the data exposed in the previous section, the variables % of tailings were extracted in the process of receiving and assembling parts and service time of rejected parts, it was asked how the performance of the year would be and one can see the supplier's performance month by month.

With the application of fuzzy logic in the Matlab system it was clear to notice in a short time the performance of the supplier and what are the rules defined through the variables chosen, after that, the actions for the classifications were constructed:

- **CLASS A - VERY GOOD:** No negative criteria of supply, issuance of certificate of congratulations and continuation of the service.
- **CLASS B - GOOD:** Sending a statement to the supplier about continuous improvement, without requiring the opening of an action plan and continuation of the service.
- **CLASS C - UNSATISFACTORY:** Request for improvement plan and monitoring of the supplier, blocking for new business, possibility of disaccreditation and start development of alternative supplier.

As well, the construction of the supplier evaluation line (Table 9).

RESULTS AND DISCUSSION

It is possible to verify the decrease in data analysis time, survey and acceptance criteria for supplier evaluation leading the plant to a differential when it is necessary to make decisions by managers. According to the facts addressed in this work, we can evidence that currently the technique of "Logistics Management" and applied fuzzy logic computational tool is indispensable for large companies. This is because it provides reliability and productivity to processes and equipment detecting problems still in the early stages. Provided for the logistics sector a good planning of corrective activities in the equipment without harming the company's production plan. Therefore promoting the growth of the same with regard to meeting deadlines consequently an increase in customer satisfaction and reliability shown with increased productivity.

ACKNOWLEDGEMENTS

Thanks to the Institute of Technology and Education Galileo of the Amazon - ITEGAM and the PostGraduate Program Master in Engineering, Process Management, Systems and Environmental (PPG.EGPSA/ITEGAM).

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