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## FUZZY IN LEAN TO EVALUATE THE DECISION DEGREE

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## FUZZY IN LEAN TO EVALUATE THE DECISION DEGREE

### FUZZY EM LEAN PARA AVALIAR O GRAU DE DECISÃO

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#### ABSTRACT:

The research aims to structure hierarchically an approach about the importance in decision making processes in the organizational environment, facilitating the applicability of Lean principles. The proposal was carried out using the Fuzzy - Analytic Hierarchy Process (FAHP). We used the parity and individual matrices between three managers and nine supervisor's experts in production through individual questionnaire application and focal group. The answers were collected through the categorical application, where the moderator role was conducted by the researchers themselves with six constructs and 33 subconstructs in three companies from different branches, having characteristics closely related in the manufacturing sector. As results about the companies' operations and processes, the values that obtained the highest degree of importance were the management construct (23%); capacity (22%) and costs (20%). We conclude for Lean principles these three factors have a 65% impact degree on decisions.

**KEYWORDS:** FAHP, Lean, Manufacturing, Decision Making Processes, Production.

#### RESUMO:

A pesquisa buscou estruturar hierarquicamente uma abordagem sobre a importância em processos decisórios no âmbito organizacional, facilitando a aplicabilidade dos princípios Lean. A proposta transcorreu com o auxílio analítico de Fuzzy - Analytic Hierarchy Process (FAHP). Desse modo, utilizou-se das matrizes paritárias e individuais entre três gestores e nove supervisores especialistas em produção utilizando técnicas de aplicação de questionário individual e grupo focal respectivamente. As respostas foram coletadas por meio da aplicação categórica, na qual o papel de moderador foi realizado pelos pesquisadores, com seis constructos e 33 subconstructos em três empresas de ramos diferentes, mas com características do setor manufatureiro fortemente relacionadas. Como respostas sobre as operações e processos das indústrias no âmbito atual, os valores que obtiveram maior grau de importância foram os constructos gestão (23%); capacidade (22%); e custos (20%). Conclui-se que, para princípios Lean, estes três fatores engajados impactam em um grau de 65% nas decisões.

**PALAVRAS-CHAVE:** FAHP, Lean, Manufatureiras, Processos Decisórios, Produção.

#### INTRODUCTION

In the last decades, the manufacturing system has stopped to be a unique method of transforming products (Silva, Santos Júnior & Correa, 2019). Like labor in the great part of the manufacturing processes, to a multicriterial group of sustainable technological factors, associated to efficient decision-making processes in the production management (Zare, Nouri, Abdoli, Atabi, & Alavi, 2016). In consideration, these notes are

relevant to competent management, in which Shingo (1996) and Krafcik (1998) complement that managers should focus organizational efforts by maximizing strategic processes as differentiation in the attempt to become strong competitively in the market.

With the constant evolution of industrialization, the processes designed to manufacture of the raw material are more complex due to the high standard desired by the customer regarding quality, delivery time among other factors (Przybyla-Kasperek & Wakulicz-Deja, 2016). In this way, the incessant need to continue to apply improvements in technical and technological processes is a competence reported at the managerial level of the company. It is with this bias that organizations need to be aware of factors related to efficient changes (Zare et al., 2016). In this thought of lean improvement in the industrial sector, organizations seek to apply lean production in a global way or by stages related to Lean Manufacturing philosophy. The main function of this philosophy is linked to the operation of mechanisms that reduce production failures. In this context, lean production has become a methodology that generates advantages, both in the systematic quality of production and in the better conditions for analysis and management (Shingo, 1996; Aikhuele, Souleman and Azizi, 2014)

Due to difficulties in developing technical approaches with application in uncertainty studies such as in production management, the Fuzzy-Analytic Hierarchical Process (FAHP) has the ability to identify and sediment information for decision-making agents in management. Thus, an intelligent and ideal system that allows to innovate the operative principles of the organizations, executing them through semantic controls (Somsuk & Laosirihongthong, 2014). Thus, the use of FAHP analysis becomes a convergent technique to the production system through mathematical modeling, when it is involved in manufacturing processes systems by Lean Manufacturing.

The objective of this paper is to demonstrate the importance of decision-making processes to expand Lean Manufacturing in manufacturing industries. Our research question address: What are the parameters that best define hierarchization as a degree of managerial importance in decision-making processes for expansion of Lean philosophy in the manufacturing industries on demand? In this way the research was conducted by a multicase approach with three companies placed in the cities of Nova Esperança do Sul - RS (NE); Santa Maria - RS (SM); Nova Hartz - RS (NH) in which the average of the threeresponders (peer-to-peer) was used according to Chang's (1996) extension, thus comparing the average of the nine specialists' responses. The data collected analysis for research was followed by the use of the softwares: Assistat®, to perform the Analytic Hierarchy Process calculations; Scilab® for Fuzzy-Ahp; and Statistical Package for the Social Sciences (SPSS®) to perform Cronbach's Alpha.

## LITERATURE REVIEW

In this chapter arguments will be made in order to present theories about Lean Manufacturing in decision-making processes in organizations and theoretical-conceptual discussions about mathematical Fuzzy-Ahp method.

## LEAN MANUFACTURING

According Womack and Jones (2004), Krafcik (1998) and Vinodh and Chintha (2011) the lean production method is a system based on customer, team engagement, standardization and process stability, where interconnection is about optimizing the waste generated by excesses in production processes. The productive sector efficiency in general involves activities such as value-adding activity; auxiliary activities; unnecessary activities; product delivery; worker involvement; continuous improvement; reduced preparation times;

process interruption in moments when something is wrong; error prevention, and total productive maintenance (Lindenau-Stockfisch, Searle & Möckel, 2016).

In this process, its purpose is to keep stability in production, in order to keep the factory always focused on its goals, productive capacity, quality in the processes and offered products, with the view to qualify its employees and to innovate through technological acquisitions to be able to remain more competitive (Womack & Jones, 2004; Aikhuele, Souleman and Azizi, 2014). To that end, organizational and competitive success is understandable in relation to lean production performed by manufacturing. In that the consequence of actions and activities contributes in the quality of the product, quality in the delivery and satisfaction of clients and managers, corroborating with the decision processes.

## DECISION-MAKING PROCESSES IN ORGANIZATIONS

A process can be considered as a set of information collected and processed so that the manager can simulate an environment and thus create alternatives from the objective to the planning (Simon, 1965; Karaaslan, 2016). In this sense, for process quality normalization, it depends very much on the description that will solve a problem, or make a detail to develop a process decision management. In order to implement it, it is necessary to have parameters that work as reference standards, evaluating the performance of the decisions to be made (Hwang & Shen, 2015). To elaborate the processes, it is necessary to integrate some criteria, being structured by five steps according to Abdel-Maksoud, Elbanna, Mahama and Pollanen (2015): (a) problem identification; (b) diagnosis; (c) alternatives generation; (d) decision choice; and (e) decision evaluation.

It is possible to make improvements in the quality of processes with correct decision, being carried out through elaborations in a criteria way. In addition, the quality of the information collected may contribute to corporate management being emphasized, through decisions made as a consequence of the decision-making processes (Gray & Nunamaker, 1993; Rojas-Zerpa & Yusta, 2015). Knowing how to make the right decision is an action that can be measured logically by distinguishing the impacts that can be affected as social, economic and environmental. There are several criteria that involve the decision processes and it is necessary to be understood by the manager taking into account the potential of the company in making the right choice (Verdecho et al., 2012; Gorane & Kant, 2016).

## EXTENSION CHANG FUZZY-ANALYTIC HIERARCHY PROCESS (FUZZY-AHP)

The importance of fuzzy set theory is understood because its results complete the uncertainties and imprecisions composed in several criteria addressed in a problem, simplifying the approach. Even so, this theory derives from some weaknesses as to the prioritization of weights for each criterion. Thus, the method that can influence this approach in identifying the correct weights of these criteria is the Ahp method (Ouma; Opudo & Nyambenya, 2015; Bilgen & Sen, 2012).

Joining Fuzzy-Ahp theories form a structure that proposes a pre-qualification and choosing which criteria will be considered of greater importance. For this, the need was created to elaborate six steps that guide the calculations to identify the criteria weights as shown in Figure 1 (Chou & Yu, 2013).

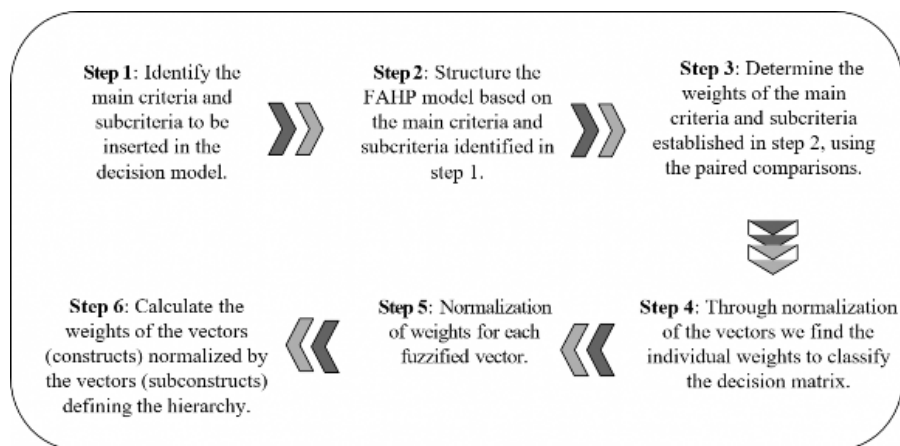


FIGURE 1

## Structure for choosing criteria

Fonte: Adaptado de Zadeh (1965) e Kahraman (2006).

Following these six steps is possible to arrive at a standardization for decision making processes, providing solutions that reduce the flaws in the research proposal, given the uncertainties and inaccuracies not found. With this FAHP structure the advantages are greater, resulting from applications made by fuzzy or Analytic Hierarchy Process individually (Rashid & Husnine, 2014; Wu et al., 2014; Falat, Marcek & Durisova, 2016; Zare et al., 2016).

In this way, the purpose of the studies carried out by the AHP methodology is the hierarchy of the actions that are in the foreground and those of the background to choose the order of decision making. It should be noted that these actions must be in agreement with the Consistency Index (CI), which evaluates the degree of inconsistency of the matrix performed in parallel with Equation 1 (Zare et al., 2016).

$$IC = \frac{|\lambda_{\max} - N|}{N-1} \quad (1)$$

After this, the Consistency Ratio, RC is performed, allowing to consider the inconsistency, according to the judgments made, through Equation 2, which should be <0.10.

$$RC = \frac{IC}{IR} \quad (2)$$

The fahp theories improve structures which qualify the decision-making processes for problems or suggestions, chosen through criteria that are considered of greater importance. Therefore, Van Laarhovem and Pedrycz (1983) suggest that four application steps can be developed for the application of FAHP. Before starting the proposed steps mentioned in the previous paragraph it is necessary to organize the process of transformation of scales. First the AHP scales (odd values) are organized and later transformed to a fuzzy scale, as shown in Table 1.

TABLE 1  
Conversion Scale

| Scale                   | AHP-Evaluation | AHP-Inverse | Fuzzy-Evaluation | Fuzzy-Inverse |
|-------------------------|----------------|-------------|------------------|---------------|
| Extremely preferred     | 1              | 1           | (1,1;3)          | (1/3;1;1)     |
| Very strongly preferred | 3              | 1/3         | (1;3;5)          | (1/5;1/3;1)   |
| Strongly preferred      | 5              | 1/5         | (3;5;7)          | (1/7;1/5;1/3) |
| Moderately preferred    | 7              | 1/7         | (5;7;9)          | (1/9;1/7;1/5) |
| Equally preferred       | 9              | 1/9         | (7;9;9)          | (1/9;1/9;1/7) |

Source: Kahraman et al. (2006).

Using the extension method of Chang (1996) are calculated according to the steps considered in the sequence, which are:

Step 1: Transformation of the original values (crisp) of the original ahp model into fuzzy numbers and the matched comparison of each criterion and subcriteria in a matrix. This operation can be viewed by the following mathematical expression:

$$(M_{g1}^j)_{n \times n} = \begin{bmatrix} M_{g1}^1 & M_{g1}^2 & \cdots & M_{g1}^m \\ M_{g2}^1 & M_{g2}^2 & \cdots & M_{g2}^m \\ \vdots & \vdots & \vdots & \vdots \\ M_{gn}^1 & M_{gn}^2 & \cdots & M_{gn}^m \end{bmatrix}$$

$$\begin{bmatrix} (1,1,1) & (a_{12},b_{12},c_{12}) & \cdots & (a_{1m},b_{1m},c_{1m}) \\ (a_{21},b_{21},c_{21}) & (1,1,1) & \cdots & (a_{2m},b_{2m},c_{2m}) \\ \vdots & \vdots & \vdots & \vdots \\ (a_{n1},b_{n1},c_{n1}) & (a_{n2},b_{n2},c_{n2}) & \cdots & (1,1,1) \end{bmatrix}$$

Step 2: The value of the fuzzy synthetic measure with respect to the object is defined by equations 3, 4, 5 and 6.

$$S_i = \sum_{j=1}^m M_{gi}^j \otimes [\sum_{i=1}^n \sum_{j=1}^m M_{gi}^j]^{-1}$$

$$\sum_{j=1}^m M_{ij} = (\sum_{j=1}^m l_{ij}, \sum_{j=1}^m m_{ij}, \sum_{j=1}^m u_{ij}), i=1, 2, 3, \dots,$$

$$\sum_{i=1}^m \sum_{j=1}^n M_{gi}^j = \left( \sum_{i=1}^m \sum_{j=1}^n l_{ij}, \sum_{i=1}^m \sum_{j=1}^n m_{ij}, \sum_{i=1}^m \sum_{j=1}^n u_{ij} \right)$$

$$[\sum_{i=1}^m \sum_{j=1}^n M_{gi}^j]^{-1} = \left( \frac{1}{\sum_{i=1}^m \sum_{j=1}^n l_{ij}}, \frac{1}{\sum_{i=1}^m \sum_{j=1}^n m_{ij}}, \frac{1}{\sum_{i=1}^m \sum_{j=1}^n u_{ij}} \right)$$

(3)(4)(5)(6)

Step 3: The degree of possibilities of  $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$  is defined by the equation:

$$V(M_2 \geq M_1) = \sup_{y \geq x} \left[ \min \left( \mu_{M_2}(x), \mu_{M_1}(y) \right) \right]$$

(7)

$$V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1, & \text{se } m_2 \geq m_1 \\ 0, & \text{se } l_1 \geq l_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{cc} \end{cases}$$

(8)

The formulation of this work followed the original method of Chang (1996), so the first and third conditions of equation (8) were used:

Step 4: The degree of possibility for a convex fuzzy number to be greater than convex fuzzy numbers can be defined by Equation 9.

$$V(M \geq M_1, M_2, \dots, M_k) = V[(M \geq M_1)] \text{ e } (M \geq M_2) \text{ e } \dots \text{ e } (M \geq M_k) =$$

(9)

Equation (9) takes the form of Equation (10) evaluating the minimum of possibilities:

$$d^{(A_i)} = \min V(S_j \geq S_i)$$

(10)

$$W_i = \frac{w_i}{\sum_{i=1}^n w_i}$$

(11)

Step 5: Through normalization, the weight vectors are obtained by Equation (11) where W it is a non-fuzzy number.

Step 6: Calculate global weights for subcriteria. The global weights of subcriteria are calculated by multiplying the local weight of each subcriterium by the weight of the criterion to which it belongs. The latter procedure defines the final hierarchization of all subcriteria by means of their obtained weights.

## RESEARCH METHOD

This section relates which scientific components are important for conducting the research, in which it serves as a basis for identifying problems, following the proposed objectives.

## RESEARCH DESIGN

The present study is emphasized as descriptive exploratory and normative axiomatic. An exploratory research is properly characterized on occasions when there is a linear problem established with little information. Thus, exploratory research establishes as objective, to describe determinant actions in a population or phenomena, based on several variables (Cervo & Bervian, 2002; Ruiz, 2008; Roesch, 2013). Descriptive research seeks to observe, record and analyze facts or variables without manipulation. This approach is mainly related in cases that wish to raise problems should be examined. A normative axiomatic study is a method that aims to develop actions to improve results available in the literature, seeking solutions to problems identified as new through mathematical programming. It is an approach that contributes to the development of new methodologies and to potentiate existing models for new knowledge techniques.



## TECHNICAL AND DELIMITATION OF THE SUBJECT IN QUESTION

For the technique used for research, it is necessary to identify the target audience, as people, information-causing events that will serve to answer the questions related to the study (Collis & Hussey, 2005; Cooper & Schindler, 2011). The techniques are the use of skills for precepts or norms of their purposes, thus obtaining a direct documentation through search of data. It is important to point out that the research was based on a bibliography of elaborate material, formally composed of books and scientific articles (Gil, 2008; Marconi & Lakatos, 2010; Miguel, 2012).

In this sense, for the elaboration and technical analysis of the work, softwares were used, such as, Assistat®, Statistic®, Scilab® and SPSS® for data computation. The adjustment of the theme proposal was first integrated through the application of joint questionnaires together with the three managers and nine specialists of production line and quality of the manufacturing sector. In which the questionnaire was structured according to Lean Manufacturing waste. The choice of respondents sought common profiles.

To this end, managers in hierarchical issues within organizations are CEOs making decisions regarding improvement or investment in manufacturing processes, both in strategic and tactical levels. The specialists are professionals with the task of helping the employees at shop-floor level, i.e., the specialists are responsible for identifying risks, failures, improvements in shop-floor operations as well as proposing decisions to managers of what should be done in the line. Another relevant detail to be highlighted is the segmentation of the companies under study. All of them work on demand, with the task of receiving raw material and transforming it into an almost finished or finished good. The finishing phase is reported as the transformation of certain parts, e.g., “shoes to be assembled in other units”. Additionally, the surveyed companies have as support the outsourcing of these products, i.e., they work with the logistics of delivery of these materials to other companies (service contractors). In relation to their size, all the studied companies are medium-sized (between 100 and 500 employees).

## CHARACTERISTICS OF THE STUDIED COMPANIES

The three companies that agreed to participate in the survey are from the manufacturing sector on request. Companies that perform on-demand activities tend to get more difficult in complex markets because of their volatility. In this continuity, the study sought to simplify decision-making in this systematic niche. The first company to be studied was from the city of Nova Esperança do Sul - RS, whose main activity is to produce shoes and outsource services and products. The company of Santa Maria - RS, second to be studied has as its branch develop projects of the metal sector, providing services and products in order to outsource its activities. The third company to be studied was from the city of Nova Hartz - RS, which provides services for the assembly of footwear. The three organizations are considered medium-sized because they have between 90 and 130 employees directly and indirectly and with processes considered linear.

## FOCUS GROUP TECHNICAL ANALYSIS

The field of study whenever it involves a qualitative approach can be constituted on several methodological probabilities, allowing, thus, more dynamic processes made to the focal group way. This technique of data collection allows the group interaction, promoting the wide problematization on a particular theme or specific focus (Gondim, 2003; Backes, Colomé, Erdmann & Lunard, 2011). The focus group technique is widely used at moments when it is desired to explore participant conceptions and experiences, thus prevailing not to examine only what people think, but how they are reasoning, and why they act in that specific way (Sellitto, 2006). It is necessary that the composition of the focal group consider that the responding members



can obtain common characteristics on the topic addressed. These characteristics should be determined by the objective of the study, with an intentional sample (Backes et al., 2011; Reis; Ladeira & Fernandes, 2013). In order to do this, an essential number of groups must be worked out to the research objectives proposed by the researcher, that is, a technical approach that can be used in environments where the main focus is in group analysis.

## DATA COLLECTION INSTRUMENTS

As a method of searching for data, a questionnaire was applied in an interview with first-line production and quality specialists. As a method of data selection, questionnaires of a colloquial nature were applied to managers and specialists of the first line of production and quality. Thus, we have related the constructs (Appendix A) to be used, described in published literature: processes, inspection, storage, capacity, costs and management. This set of indicated criteria was referenced with theoretical basis in articles that directly potentiate the use of these factors and proposed openness to elaborate the sub-constructs. Moreover, we followed the below procedures:

- 1- Respondents were presented to all criteria (Appendix A) and what each one corresponded within the company;
- 2- Each respondent should weigh each of the constructs;
- 3- For the managers, it was about 3 hour's interviews;
- 4- For supervisors about 2 hour's interviews;
- 5- All interviews were after work hours.

## RESULTS AND DISCUSSION

The emphasis of this section emerges to present the results obtained in the application of questionnaires to managers and supervisors in different companies. In this context, a dynamic and efficient response is sought to simplify the application of the Lean Manufacturing methodology in the manufacturing sector as evidence to facilitate the sizing of the results found in the research.

## RELIABILITY STATISTICS

In situations when work with the application of questionnaires it is necessary to establish a field pre-test. In this case, the research was carried out by 3 specialists from the manufacturing area of different companies (different from the companies used in the research), in which a standard questionnaire was developed for application, after making some necessary adjustments. A reliability analysis was important for the standardization of this questionnaire. This analysis was performed based on the Statistical Package for the Social Sciences (SPSS®) using Cronbach's Alpha. This statistical tool measures the reliability of the data found. In this sense, the consistency between the answers obtained in the study was satisfactory, as can be seen in Table 2.

TABLE 2  
Reliability Statistics

| Cronbach's Alfa | Based on standardized items | Number of used items |
|-----------------|-----------------------------|----------------------|
| 0,853           | 0,866                       | 33                   |

The demonstration of Table 2 with the alpha value of 0.853 indicates that the research obtained an acceptable degree of reliability among the questions. In which, it can be noted that both the responding managers and supervisors of the three different companies are on a fairly logical axis of reasoning.

## NORMALIZATION OF CONSISTENCIES

In this context, after the normalization found by Cronbach's Alpha in Table 2, the next step is to calculate the consistency ratio values, which according to the literature should be  $\leq 0.10$ , of the constructs and sub-constructs. In this stage of the research the results obtained are based on the information of the managers and not supervisors.

These calculations were performed according to the FAHP extension of Chang (1996) presented according to the previously mentioned explicit equations in the literature. When performing the categorization of the matrices, the first statistical operation to be performed is the consistency ratio (CR) analysis that obtained values lower than 0.10. In this way, the consistencies between the constructs are reliable, which is exposed in Table 3 for each organization between the cities (NE); (SM) and (NH).

TABLE 3  
Consistency ratio and lambda on the matrices constructs

| Company (NE)       | Company (SM)       | Company (NH)       |
|--------------------|--------------------|--------------------|
|                    | Constructs         |                    |
| (CR) 0.066         | (CR) 0.093         | (CR) 0.056         |
| (IR) 0.082         | (IR) 0.115         | (IR) 0.070         |
| ( $\lambda$ ) 6.41 | ( $\lambda$ ) 6.57 | ( $\lambda$ ) 6.35 |

## FAHP HIERARCHICAL DEFUZZIFICATION

After applying the questionnaires and calculations, according to the equations, the matrices of importance of each construct and sub-construct were elaborated, discussing the structuring of the FAHP performance weighted in Table 4. In this way, Table 4 structures and measures the capacity on the first and second order respectively, the constructs and sub-constructs being these calculated specifically by the FAHP. The information to be used is deferred over the column (constructs) and (relative importance). The applications involved in Table 4 indicate the performance of each matrix, and the technical specifications used, which was constituted by Equation (12). This equation weighs the defuzzification, which will rank and present the FAHP gaps, according to Table 4.

$$\sum_{i=1}^{33} ai.ci$$

(12)

Decisions for any organizational environment involve many intangible situations that need to be studied. To understand these facts, these intangibilities need to be measured and tangibly evaluated in order to meet the goals of the decision maker (Saaty & Shih, 2009). In this way, in contrast to Table 4, two approaches can be argued as a result goes against the objective of this research. The first one is restricted to the constructs that, in terms of degree of importance, the managers considered management, costs and capacity as being more

attention when it comes to decision making. That is, in terms of evaluation, the first steps to be structured and evaluated in a product systematization is the management construct with (23%). The subconstruct in focus is the development of leaders (35%). Many organizations consider this subconstruction as a key to good organizational management (Elassy, 2015). Capacity with (22%) has as its operational highlight control in processes and operations (30%). In the construct costs (20%) carry out in investments in infrastructure got the most importance with (25%).

TABLE 4  
Contextualization of FAHP performance

| Constructs     | Concepts  | Relative importance            | Decision degree    |
|----------------|---|--------------------------------|--------------------|
| Process 18%    | Cell application by manufacturing 24% Use of the manufacturing cell 18%Use operational control (raw material) 15% Application of departmentalization 16% Application of environmental sustainability 25%Innovation in processes 2%                          | 4,32%3,24%2,70%2,88%4,50%0,36% | 8°15'20"17°7'32°   |
| Inspection 14% | Inspection by employee 20% Use of indicators 8% Chronoanalysis 14%Floating adjustment in production 14% Inspection of productive capacity 19% Ergonomicsapplication 25%   | 2,80%1,12%1,96%1,96%2,66%3,50% | 19°26'23"24°21'13° |
| Stocking 3%    | Demand control versus capacity 21% Use of security stocks 7%Innovation with automation in process 36% Preventive maintenance 10%Corrective maintenance 26%  | 0,63%0,21%1,08%0,70%0,78%      | 31°33'27"29°28°    |
| Capacity 22%   | Control in process and operations *global) 30% Control in process and operations (isolado) 10% Layout característico aos processos 23% Characteristic layout to operations 13% Application of setups by product 16%Use of industrial statistical systems 8% | 6,60%2,20%5,06%2,86%3,52%1,76% | 2°22'5"18°12'25°   |
| Costs 20%      | Transport of lots automation 19% Infrastructure investment 25%Investing in intelectual capacity for inspection 15% Investing in intelectual capacityfor supervision 21% Controlling cost formanufacturing orders 20%  | 3,80%5,00%3,00%4,20%4,00%      | 11°6'16"9°10°      |
| Management 23% | Execute systems with computational modules 15%Offer differentiated solutions 22% Application of environmental management in production 3%Employee training 25%Leaders developing 35%  | 3,45%5,06%0,69%5,75%8,05%      | 14°4'30"3°1°       |

Theoretical Therm: Mathematical approaches to lean system applications Lean 100%

For the second approach, which is linked to constructs that are no less important but which are weighted less than the others in terms of hierarchy and evaluation as decision making by managers and supervisors, are processes with (18%) obtaining the application of environmental sustainability (25%) as argument to give more attention due to how to deal with discard methods of raw material refuse. Following this process line, the inspection construct with (14%) has as its main relevance in its matrix the question about the application of ergonomics (25%). Justifying this factor by the repetition of activities that the Lean systematization impacts on the staff. And lastly decision making, stocks with (3%). This construct is given less attention because companies do not operate with significant inventories. Being companies that provide services and perform it on demand is unfeasible if they have stock of material in their premises.

We can highlight two large groups in Table 4. The first consists in management; capacity; costs and processes. This shows the importance that teams give to these constructs due to the interviewed companies are practically companies with a large focus on outsourcing, both in offering and to receiving, and this strongly implies the relationships mentioned for this first group. This relationship is explained because it is a convergence point where organizations can control their entire business.

In group two, which is made up of inventory and inspection, they are not so relevant for organizations when compared to group 1 as they do not need these features so much in the foreground, as their raw materials are often provided by the contracting companies in which they aim at the quality of the final delivery. Thus, inventories and inspections are performed by the contracting companies. Moreover, inspection had a relative significance (14%), but we characterized in group 2 due to the high relationship with stocking (3%) during our interviews.

## CONCLUSION

The main contribution of the study was to propose an improvement assessment approach in decision processes in companies with systematic approaches in order to facilitate future applications of Lean Manufacturing. This approach was carried out through multi-criteria bases, applying questionnaires to managers and supervisors of production. Using mathematical models to emerge a new philosophical approach, which paths are necessary and, fundamental, for the fulfillment of a new management in decision making in the manufacturing sector.

Thus, a study in situations that is portrayed in a linguistic way, through the collection of data in questionnaires of scales, the researcher must always have in question that the probability of the decision answer of the manager and supervisor can undergo changes constantly, even with expert respondents in the area. This is a normal factor when there are jobs of such importance.

The results presented in the development of the work is perceived to the quality in applying mathematical methods for techniques that involve linguistic purposes, such as the management area. The Fuzzy-Ahp technique results in projections of reasoning aimed at the emergence of reliable productions. In support of this logical approach, by allocating values for linguistic terms and using techniques such as triangular FAHP, the dimensions of multivalued decision output responses remain with an acceptable degree of reliability.

It is concluded that the use of FAHP can be related in researches that approach lean manufacturing, in the search to help as a decision support through the elaboration of new action scenarios. On the other hand, the practical contribution made in this study is to propose a better knowledge of these tools applied to Lean systems in the analyzed sample.

Most of the problems in decision-making are in human subjectivity and the imprecision of the real world. Several methods and tools are used to approximate the uncertainties of future events in the manufacturing sector that go through limitations to constantly improve the management system. It is from this point that

the number of decision-makers inserted in the research was not enough, limiting them to carry out studies with a more precise diffuse conclusion.

Although FAHP is a widely used tool in several articles in the academic world, its relevance as a decision making is still quite efficient. It is a tool that seeks to get close to the context of human reasoning in what would be the best decision to make. However, some considerations as future proposals would be to use the final results of the FAHP as input to make simulations and to compare scenarios that may occur in the organizational sector proposing improvement in the current project. This tool that can perform these simulations is the Fuzzy Sets analysis. By integrating these two tools, is possible to check how Lean Manufacturing is being applied in organizations? What is being used of lean in the productive systems? And what can be improved with the complexity and dynamism of the market?

## REFERENCES

- ABDEL-MAKSoud, A.; ELBANNA, S.; MAHAMA, H.; POLLANEN, R. The use of performance information in strategic decision making in public organizations. *International Journal of Public Sector Management*, v. 28, n. 7, p. 528-549, 2015.
- AIKHUELE, D. O.; SOULEMAN, F. S.; AZIZI, A. Application of Fuzzy AHP for ranking critical success factors for the successful implementation of Lean production technique. *Australian Journal of Basic and Applied Sciences*, v. 8, n. 18, p. 399-407, 2014.
- BACKES, D. S.; COLOMÉ, J. S.; ERDMANN, R. H.; LUNARDI, V. L. Grupo focal como técnica de coleta e análise de dados em pesquisas qualitativas. *O mundo da saúde*, v. 35, n. 4, p. 438-42, 2011.
- BILGEN, B.; ŞEN, M. Project selection through fuzzy analytic hierarchy process and a case study on Six Sigma implementation in an automotive industry. *Production Planning & Control*, v. 23, n. 1, p. 2-25, 2012.
- CERVO, A. L.; BERVIAN, P. A. Metodologia científica. 5 ed. São Paulo: Pearson, 2002.
- CHANG, D-Y. Applications of the extent analysis method on fuzzy AHP. *European journal of operational research*, v. 95, n. 3, p. 649-655, 1996.
- CHOU, C-C.; YU, K-W. Application of a new hybrid fuzzy AHP model to the location choice. *Mathematical Problems in Engineering*, v. 2013, 2013.
- COLLIS, J.; HUSSEY, R. Pesquisa em Administração: um guia prático para alunos da graduação. 2. ed. Porto Alegre: Bookman, 2005.
- COOPER, D. R.; SCHINDLER, P. S. Métodos de pesquisa em administração. 10. ed. Porto Alegre: Bookman, 2011.
- ELASSY, N. The concepts of quality, quality assurance and quality enhancement. *Quality Assurance in Education*, v. 23, n. 3, p. 250-261, 2015.
- FALAT, L.; MARCEK, D.; DURISOVA, M. Intelligent Soft Computing on Forex: Exchange Rates Forecasting with Hybrid Radial Basis Neural Network. *The Scientific World Journal*, p. 15, 2016.
- GIL, A. C. Como elaborar Projetos de Pesquisa. São Paulo: Atlas, 2008.
- GORANE, S.; KANT, R. A case study for predicting the success possibility of supply chain practices implementation using AHP approach. *Journal of Business & Industrial Marketing*, v. 31, n. 2, p. 137-151, 2016.
- GRAY, P.; NUNAMAKER, J. Group decision support systems. *Decision support putting theory into practice*, v. 3, 1993.
- GONDIM, S. M. G. Grupos focais como técnica de investigação qualitativa: desafios metodológicos. *Paidéia*, v. 12, n. 24, p. 149-161, 2003.
- HWANG, B-N.; SHEN, Y-C. Decision making for third party logistics supplier selection in semiconductor manufacturing industry: a nonadditive fuzzy integral approach. *Mathematical Problems in Engineering*, v. 2015, 2015.
- KAHRAMAN, C.; ERTAY, T.; BÜYÜKÖZKAN, G. A fuzzy optimization model for QFD planning process using analytic network approach. *European Journal of Operational Research*, v. 171, n. 2, p. 390-411, 2006.



- KARAASLAN, F. Soft Classes and Soft Rough Classes with Applications in Decision Making. *Mathematical Problems in Engineering*, p. 11, 2016.
- KRAFCIK, J. F. Triumph of the lean production system. *MIT Sloan Management Review*, v. 30, n. 1, p. 41, 1988.
- LINDENAU-STOCKFISCH, V.; SEARLE, J.; MÖCKEL, M. POCT in emergency rooms: one key factor for process streamlining with lean management. In: *Conference Papers in Science*. Hindawi Publishing Corporation, 2013.
- MIGUEL, P. A. *Metodologia de pesquisa em engenharia de produção e gestão de operações*. 2. ed. 2012.
- OUMA, Y. O.; OPUDO, J.; NYAMBENYA, S. Comparison of fuzzy AHP and fuzzy TOPSIS for road pavement maintenance prioritization: methodological exposition and case study. *Advances in Civil Engineering*, v. 2015, 2015.
- PRZYBYŁA-KASPEREK, M.; WAKULICZ-DEJA, A. Global decision-making in multi-agent decision-making system with dynamically generated disjoint clusters. *Applied Soft Computing*, v. 40, p. 603–615, 2016.
- RASHID, T.; HUSNINE, S. M. Multicriteria group decision making by using trapezoidal valued hesitant fuzzy sets. *The Scientific World Journal*, v. 2014, 2014.
- REIS, L. P.; LADEIRA, M. B.; FERNANDES, J. M. Contribuição do método analytic hierarchy process (ahp) para auxílio ao processo decisório de terceirizar ou internalizar atividades no contexto de uma empresa de base tecnológica. *Produção Online*, Florianópolis, v. 13, n. 4, p. 1325–1354, 2013.
- ROESCH, S. M. A. *Projetos de estágio e de pesquisa em administração. Guia para estágios, trabalhos de conclusão, dissertações e estudos de caso*. 3. ed. 2013.
- ROJAS-ZERPA, J. C.; YUSTA, J. M. Application of multicriteria decision methods for electric supply planning in rural and remote areas. *Renewable and Sustainable Energy Reviews*, v. 52, p. 557-571, 2015.
- RUIZ, J. A. *Metodologia Científica: Guia para eficiência nos estudos*. 2008.
- SAATY, T. L.; SHIH, H-S. Structures in decision making: On the subjective geometry of hierarchies and networks. *European Journal of Operational Research*, v. 199, n. 3, p. 867-872, 2009.
- SANTOS, A. M.; SANTOS JÚNIOR, J. C. F.; CORREIA, A. M. M. Avaliação das práticas de produção da cachaça em um engenho na Paraíba, a partir das dimensões da produção enxuta. *Revista Gestão e Desenvolvimento*, RGD v. 16, n. 1, p. 99-128, 2019.
- SELLITTO, M. A.; WALTER, C. Avaliação do desempenho de uma manufatura de equipamentos eletrônicos segundo critérios de competição. *Production*, v. 16, n. 1, p. 34-47, 2006.
- SIMON, H. *Comportamento Administrativo. Estudo dos Processos decisórios*. 1965.
- SHINGO, S. *O sistema Toyota de produção do ponto de vista da engenharia industrial*. 1996.
- SOMSUK, N.; LAOSIRIHONGTHONG, T. A fuzzy {AHP} to prioritize enabling factors for strategic management of university business incubators: Resource-based view. *Technological Forecasting and Social Change*, v. 85, p. 198–210, 2014.
- VAN LAARHOVEN, P. J. M.; PEDRYCZ, W. A fuzzy extension of Saaty's priority theory. *Fuzzy sets and Systems*, v. 11, n. 1-3, p. 229-241, 1983.
- VERDECHO, M-J.; ALFARO-SAIZ, J. J.; RODRIGUEZ-RODRIGUEZ, R.; ORTIZ-BAS, A. A multi-criteria approach for managing inter-enterprise collaborative relationships. *Omega*, v. 40, n. 3, p. 249-263, 2012.
- VINODH, S.; CHINTHA, S. K. Leanness assessment using multi-grade fuzzy approach. *International Journal of Production Research*, v. 49, n. 2, p. 431-445, 2011.
- WOMAK, P. J.; JONES, T. D. *A mentalidade enxuta nas empresas lean thinking: elimine o desperdício e crie riqueza*. Rio de Janeiro. 2004.
- WU, J-T.; WANG, J. Q.; WANG, J.; ZHANG, H. Y.; CHEN, X. H. Hesitant fuzzy linguistic multicriteria decision-making method based on generalized prioritized aggregation operator. *The Scientific World Journal*, v. 2014, 2014.
- ZADEH, L. A. Information and control. *Fuzzy sets*, v. 8, n. 3, p. 338-353, 1965.

ZARE, R.; NOURI, J.; ABDOLI, M. A.; ATABI, F.; ALAVI, M. The integrated fuzzy AHP and goal programming model based on LCA results for industrial waste management by using the nearest weighted approximation of FN: aluminum industry in Arak, Iran. *Advances in Materials Science and Engineering*, v. 2016, 2016.

## Appendix A

| Constructs | Concepts  |
|------------|---|
| Process    | Cell application by manufacturing Use of the manufacturing cell Use operational control (raw aterial) Application of departmentalization Application of environmental sustainability Innovation in processes                          |
| Inspection | Inspection by employee Use of indicators Chronoanalysis Floating adjustment in production Inspection of productive capacity Ergonomics application  |
| Stocking   | Demand control versus capacity Use of security stock Innovation with automation in process Preventive maintenance Corrective maintenanc   |
| Capacity   | Control in process and operations *global) Control in process and operations (isolado) Layout caracteristico aos processos Characteristic layout to operations Application of setups by product Use of industrial statistical systems |
| Costs      | Transport of lots automation Infrastructure investment Investing in intelectual capacity for inspection Investing in intelectual capacity for supervision Controlling cost for manufacturing orders                                   |
| Management | Execute systems with computational modules Offer differentiated solutions Application of environmental management in production Employee training Leaders developing  |