USE OF THE ANALYTIC HIERARCHY PROCESS (AHP) METHOD TO ANALYZE THE ACQUISITION OF RAW MATERIALS IN A METALLURGICAL INDUSTRY

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ABSTRACT

This article aims to analyze how COVID-19 impacted the metallurgical industry and its significant increase in the market. The study's metallurgical company used steel for turning work, and the main concern was the acquisition of raw materials due to scarcity, which resulted in a significant increase in purchase price. Therefore, the objective of this study was to identify, using the AHP method, the best raw material supplier for part production. In terms of nature, it is an applied research with practical interests, and it is considered bibliographic as written materials were used for definitions and understanding of the tool. The application of the method allowed verifying its effectiveness in decision-making support, as the method enables a comprehensive analysis of the problem. Through the application of the model, it was found that the best raw material supplier achieved a composite priority of 37%, the second-place supplier 36%, and the third-place supplier 27%.

KEYWORDS: *Method AHP; Metallurgical industry; Acquisition of raw material.*

I. INTRODUCTION

In the face of COVID-19, companies have had to take adaptation measures regarding the utilization of teams based on the guidelines of the World Health Organization (WHO). The metallurgy sector proposed the development of new products and services. Within the sector, the emergence of

reconfiguring was observed, which refers to the ability to reconfigure in response to market uncertainties arising from the spread of the virus. "To achieve this, it is suggested to increase employee involvement in decision-making, rely on partnerships for strategy formation, encourage internal entrepreneurship, and knowledge management" (WECKER; FROEHLICH and GONÇALVES, 2021). The increase in production in metallurgical companies was due to high demand for steel in the construction industry and the recovery of the international market. However, with the shutdown of the majority of the country, there was a shortage of raw materials and inputs, as well as problems with transportation and distribution logistics (FREITAS, 2021; AIRES, 2021). Metals such as steel, copper, iron, and aluminum, semiconductors, and items used in plastic production are among the main products affected by the rising prices. This trend has also affected consumers, who are facing higher prices for retail products.

In the company under study, which relies heavily on steel as the main raw material and experienced a significant increase in the cost of manufactured products due to its scarcity, the research problem is how to maintain product prices in order to remain competitive in the market. To address this research problem, the following general objective is proposed: to identify the best raw material supplier for part production using the Analytic Hierarchy Process (AHP) method. To achieve this, the following specific objectives are intended: i) identify the criteria to be used for selecting the raw material; ii) demonstrate, through the AHP method, the best alternative for raw material acquisition; iii) evaluate the best raw material acquisition proposal using qualitative and quantitative criteria.

II. LITERATURE REVIEW

2.1. Decision Making

The structuring of the decision-making process dates back to the 18th century. Bana e Costa, Stewart, Vansnick (1997) mention Benjamin Franklin's letter to Joseph Priestly on September 19, 1772, which identified two key phases of decision support: structuring and evaluation. This correspondence also introduced important concepts for decision support, such as conflicting criteria, uncertainty, pairwise comparison, value judgments, trade-offs, weights, aggregations, and more.

It was only in 1969, during the 7th Symposium on Mathematical Programming, that Roy presented a section on the organization of multiple-objective functions. According to Tosoukias (2007), a significant milestone for decision theory occurred in 1976 when Keeney and Raiffa published a book expanding decision theory to incorporate multiple criteria. After the 1970s, new methods specifically tailored for multiple criteria decision-making emerged with different approaches.

The interest in studying the decision-making process has led to significant advancements in this field. Currently, multicriteria methodologies are widely employed in various organizations, utilizing complex decision support systems. Therefore, it is valuable to analyze the elements and stages of the multicriteria decision support process.

To overcome human limitations in analysis, Multicriteria Decision Support (MCDS) has emerged as a field within operations research that encompasses a set of methods applied to problems with multiple objectives. MCDS aims to systematize information and define preferences regarding the attributes of evaluated alternatives (GOMES et al., 2006). The choice of a specific method depends on various factors, such as problem characteristics, context, decision maker's preference structure, and the specific problem at hand (ALMEIDA, 2003).

2.2. Analytic Hierarchy Process (AHP) Method

The Analytic Hierarchy Process (AHP) is one of the earliest and most widely used methods of multicriteria decision support. Created in 1980 by Thomas Saaty, this method is applied in various fields of knowledge due to its ability to incorporate both quantitative and qualitative criteria in the analysis (DA SERRA COSTA, 2020).

According to Oliveira and Belderrain (2008), the main aspects of AHP are: a) the method aims to guide the intuitive decision-making process based on knowledge and experience; b) it relies on expert judgments or decision-makers when there is no quantitative information available on the performance

of a variable with respect to a specific criterion; and c) it results in an overall measure for each potential action or alternative, prioritizing or ranking them.

Vieira (2006) states that the method is based on three principles: i) construction of hierarchies: a complex problem often requires the structuring of criteria in a hierarchy, as it is a natural procedure of human reasoning. The AHP method allows for the structuring of criteria, with the tree structure being the most commonly used, where the highest-level criterion is decomposed into more detailed levels; ii) definition of priorities: these priorities are defined through pairwise comparisons of elements, based on a specific criterion; iii) logical consistency: the method allows for the evaluation of the consistency of priority definitions through the use of consistency indices, which assess the consistency of judgments.

The method is based on pairwise comparisons of different characteristics. By constructing a square matrix, the importance of one characteristic over another is assessed using an appropriate scale. Saaty (1999) proposes the use of the scale shown in Table 1. Once the matrix is filled, the eigenvalue and its corresponding eigenvector are calculated (AMORIM, 2017).

Table 1 - Scale proposed by Saaty

Degree of Importance	Definition	Explantion
1	Equal importance	Both activities contribute equally to the objective.
3	Small importance of one over the other	Experience and judgment favor one activity over the other.
5	Significant or essential importance	Experience or judgment strongly favors one activity over the other.
7	Very significant or demonstrated importance	One activity is significantly favored over the other, and this can be demonstrated in practice.
9	Absolute importance	Evidence strongly favors one activity over the other, with the highest degree of certainty.
2, 4, 6, 8	Intermediate values	When seeking a compromise between two definitions.

Source: Marins,2009.

Among the benefits of the AHP method, Kroenke and Hein (2016) highlight that the AHP method is capable of ranking and forming partial rankings within the structure, as well as an overall ranking considering the entire hierarchical structure established.

The AHP method aids decision-making in choosing between two productive layouts for a fastener painting line, with the aim of increasing production, reducing costs, and eliminating bottlenecks in the delivery of final products that require fasteners before being shipped to end customers (SANTOS, HERMOGENES, and LIMA, 2018).

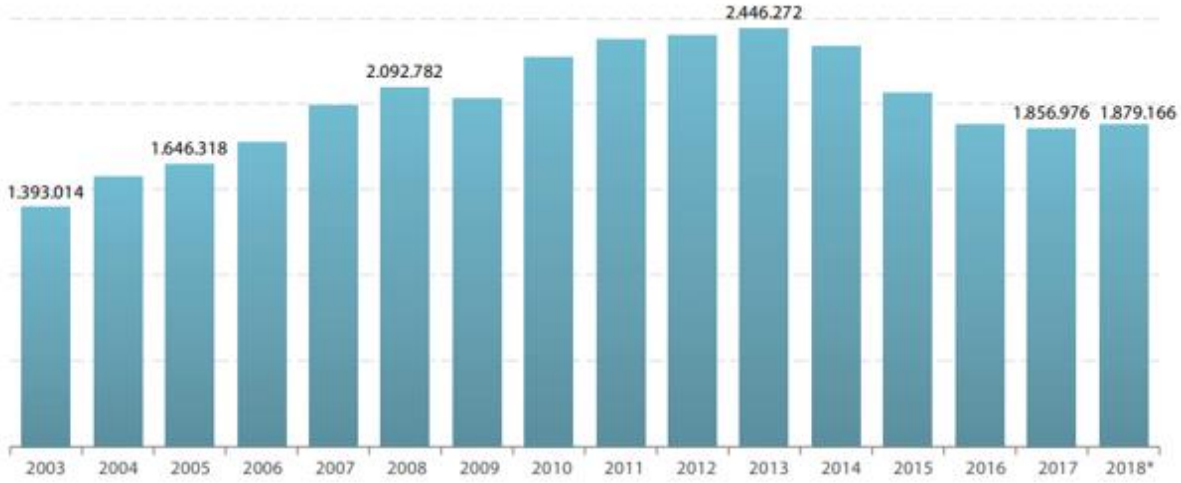
The AHP method can assist in measuring and prioritizing certain entrepreneurial characteristics and profiles, which can be further developed and utilized to support students in their daily work and entrepreneurial development during their academic life (Mendes, Bastos, Souza, and Hernandez, 2014).

The use of the AHP method for hierarchical analysis of processes directs the best option for the physical layout arrangement of a screw and nut painting production line in an industry in Rio de Janeiro. It mathematically demonstrates the optimal path for the decision-maker while minimizing personal interests of those involved in the decision-making process (SANTOS, HERMOGENES, and LIMA, 2018).

2.3 The metallurgical sector

The metallurgical sector is part of the manufacturing industry, where activities involve the transformation of materials, substances, and components to obtain new products. While the metallurgical industry produces tangible goods, it also includes some service activities such as industrial services and assembly of maintenance and repair product components (CARDOSO, 2015).

According to the census, the job market in this sector had 2,446,272 workers, representing 5% of the Brazilian job market. Graph 1 shows the evolution of over 1.1 million jobs between 2002 and 2018 in Brazil (DIEESE, 2019).



Fonte: Rais/MTE

Figure 1 - Employment evolution in the metallurgical sector in Brazil from 2002 to 2013.

According to the CNM (National Confederation of Metalworkers), the steel and basic metallurgy segment has a large production chain and includes both large and small companies in the country, especially in the production of metal artefacts (CARDOSO, 2015).

Like any other sector, cost reduction is a major concern in the metallurgical industry, particularly in relation to production costs, labour, and raw materials. Although Brazil has abundant and high-quality iron ore, the price of this raw material has been increasing in recent years. Between 2005 and 2009, there was a price adjustment of over 300%. As a result, companies adopted strategies to secure a portion of the input through their own mining operations, leading to a rush to acquire mines and promoting self-production of charcoal and electricity for steel production (CARDOSO, 2015).

According to data from S&P Global Platts (2021), the price of Brazilian steel experienced an even greater increase due to the pandemic, with a 46% increase in 2021 and over 130% increase in the last 12 months. International steel prices are also high and subject to further increases, making it challenging to purchase imported materials with delivery in three months due to the lack of control and predictability of exchange rates, freight, and material prices upon arrival.

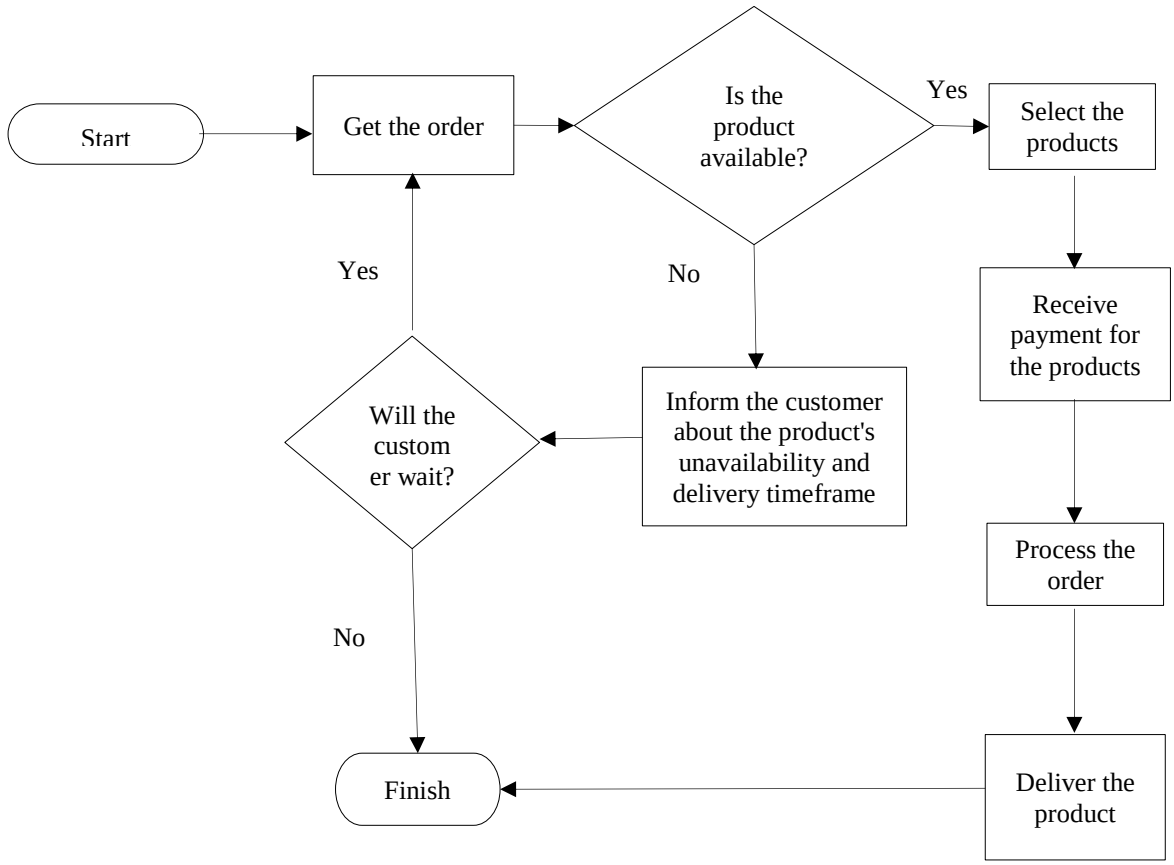
According to the Brazilian Steel Institute (2021), there has been a production deficit since July of last year. From July 2020 to March 2021, the deficit accumulated a total of 981 tons, with consumption reaching 20.41 tons while production stood at 19.42 tons, failing to meet market demand.

III. METHODOLOGICAL PROCEDURES

The research is defined as applied because, according to Marconi and Lakatos (2002), it is characterized by its practical interest, where the results are immediately applied or utilized to solve real-life problems. It can be considered as bibliographic research because written materials are used for definitions and understanding of the tool. According to Sousa, Oliveira, and Alves (2021), bibliographic research involves the survey or review of published works on the theory that will guide the scientific work, requiring dedication, study, and analysis by the researcher conducting the study. Its objective is to gather and analyse published texts.

The research was conducted in a metallurgical company located in the southern region of Santa Catarina, Brazil. The company's main activities are machining and turning services, and its primary products include pulleys, flanges, and couplings for packaging machines, agitators, cargo elevators, belt conveyors, compressors, and extruders.

The company's production process involves the entry of raw materials, machining, finishing, painting, drying, and finally, classification and packaging. The topic addressed in the research is related to the entry of raw materials, as shown in Figure 2.



Source: Authors (2022).

Figure 2 - Raw Material Acquisition Flowchart

Currently, the company purchases its raw materials in the southern region of Santa Catarina. The raw materials, which are mainly metals, are primarily sourced from foundries, and the acquisition criterion is solely related to cost. For this study, the following criteria were considered: product delivery method, price, payment terms, quality, distance, and lead time, for subsequent selection and assignment of importance level for each criterion.

The delivery method criterion refers to the available options for how the raw materials can reach their final destination. Attributes such as the type of vehicle used and whether it is done directly or through third parties are evaluated within this criterion. The price criterion relates to the amount paid to acquire the raw materials. The payment terms criterion considers the form in which the payment will be made, whether upfront or on credit, and whether it can be divided into instalments via invoice, credit card, check, or other payment methods offered by the suppliers.

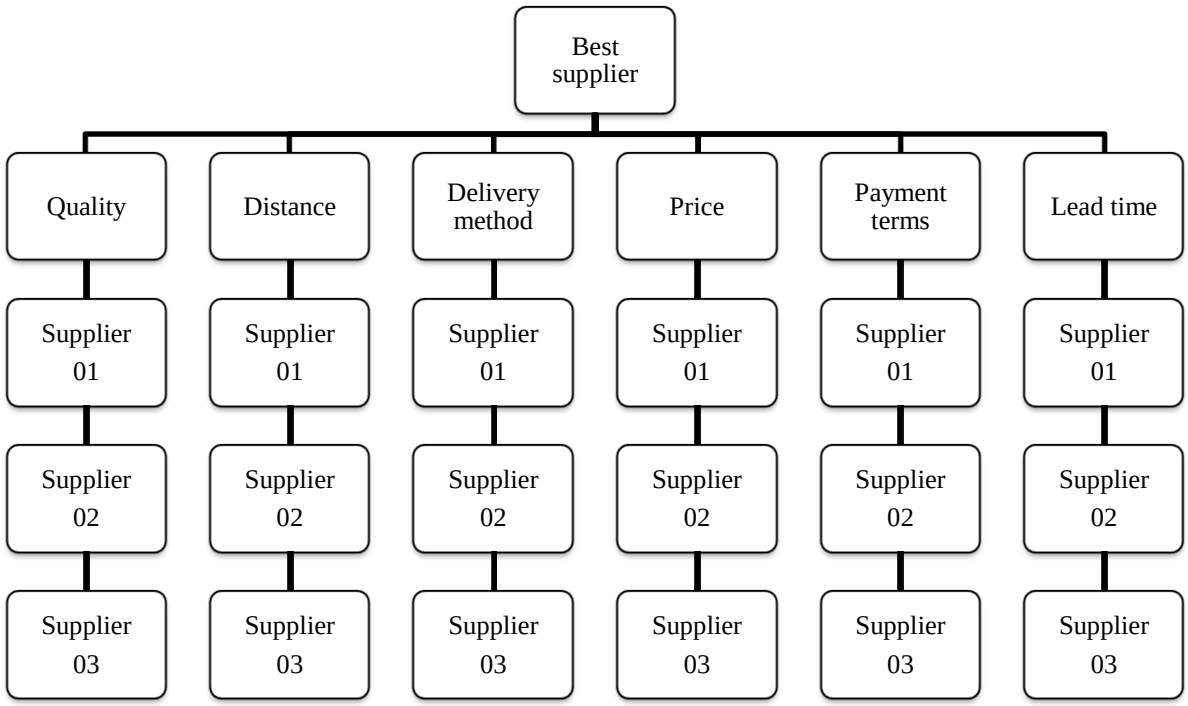
The quality criterion pertains to the quality of the acquired raw materials, which can be classified as high, medium, or low quality for the company's product development. The distance criterion considers the distance that the raw materials will travel to reach the purchasing company, taking into account factors such as lead time, cost, and labour required for the delivery to the final customer. The lead time criterion refers to the time taken for the raw materials to be delivered from the supplier to the receiving location.

In this regard, two foundries from southern Brazil and São Paulo were identified, and data related to the criteria were collected to allow for a comparison between the options for raw material acquisition. Finally, the Analytic Hierarchy Process (AHP) tool was employed using Excel spreadsheets for data

analysis and selection. At the end of the study, a literature review from the past year was conducted to determine whether the pandemic influenced the increase in raw material prices in the metallurgy sector.

IV. PRESENTATION AND ANALYSIS OF RESULTS

To address the raw material acquisition problem, as previously discussed, six evaluation criteria have been identified, as shown in Figure 4, which presents the hierarchical structure of the criteria, implemented following the AHP method's literature.



Source: Authors (2022).

Figure 4 - Hierarchical Structure of Criteria

Later, a pairwise comparison was made between the criteria, according to their respective order of importance, using the Saaty scale. In order to obtain the vector of relative priorities, the criteria were normalized, as shown in Table 2.

Table 2 - Normalized Comparison Matrix

Attribute	Quality	Delivery method	Price	Delivery time	Payment terms	Distance	Relative Priority
Quality	0,19	0,30	0,18	0,08	0,60	0,28	0,2699
Delivery method	0,04	0,06	0,07	0,15	0,06	0,01	0,0664
Price	0,09	0,30	0,37	0,15	0,06	0,28	0,2085
Delivery time	0,09	0,01	0,12	0,31	0,14	0,34	0,1702
Payment terms	0,56	0,30	0,18	0,15	0,12	0,02	0,2230
Distance	0,04	0,02	0,07	0,15	0,02	0,07	0,0620

Source: Authors (2022).

The normalized comparison matrix provides the values that represent the proportion of each attribute's contribution to the total value of each criterion. This allows us to identify which attributes have higher priority and which have lower priority for the comparison to be conducted. The criteria with higher relative priority are quality, price, and payment terms, accounting for 70% of relevance. After structuring the criteria comparison matrix and determining the relative priority of each criterion, it was possible to calculate the consistency ratio and identify that it is below 10%, indicating consistency, as shown in Table 3.

Table 3 - Consistency Index and Ratio

Variable	Result
ʎ max	6,07
IC	0,01
RC	0,01

Source: Authors (2022).

Afterwards, the primary comparison was conducted for each criterion, considering each chosen alternative and its relative priority for the alternatives of each criterion under analysis. Tables 4, 5, 6, 7, 8 and 9 provide the comparisons and analyses carried out between criteria and service providers. Table 3 presents the analysis and comparison between suppliers 01, 02, and 03 in relation to the criterion of quality.

Table 4 – Quality Criterion

Quality	Supplier 01	Supplier 02	Supplier 03	Relative Priority
Supplier 01	0,29	0,44	0,50	0,4101
Supplier 02	0,14	0,22	0,33	0,2328
Supplier 03	0,57	0,33	0,17	0,3571

Source: Authors (2022).

For the quality criterion, there was a predominance of priority for Supplier 01, with a preference of 41.01%, followed by 35.71% for Supplier 03 and 23.28% for Supplier 02. Table 5 then compares the next criterion for analysis, which is the delivery method.

Table 5 – Delivery method Criterion

Delivery method	Supplier 01	Supplier 02	Supplier 03	Relative Priority
Supplier 01	0,29	0,40	0,50	0,3952
Supplier 02	0,57	0,20	0,33	0,3683
Supplier 03	0,14	0,40	0,17	0,2365

Source: Authors (2022).

When analysing the delivery method criterion, it can be observed that Supplier 01 has a priority of 39.52%, followed by Supplier 02 with 36.83%, and finally Supplier 03 with 23.65%. Table 6 shows the comparison of the price criterion for the three suppliers.

Table 6 – Price Criterion

Price	Supplier 01	Supplier 02	Supplier 03	Relative Priority
Supplier 01	0,22	0,40	0,40	0,3407
Supplier 02	0,11	0,20	0,40	0,2370
Supplier 03	0,67	0,40	0,20	0,4222

Source: Authors (2022).

In the price criterion, the values of relative priority were favorable for Supplier 03, with a relative priority of 42.22%, followed by Supplier 01 with 34.07% and Supplier 02 with 23.70%. Table 7 provides the analysis data for the delivery time criterion.

Table 7 – Delivery time Criterion

Delivery time	Supplier 01	Supplier 02	Supplier 03	Relative Priority
Supplier 01	0,17	0,57	0,40	0,3794
Supplier 02	0,50	0,29	0,40	0,3952
Supplier 03	0,33	0,14	0,20	0,2254

Source: Authors (2022).

For the delivery time criterion, Supplier 02 has a relative priority of 39.52%, Supplier 01 has 37.94%, and Supplier 03 has 22.54% of the priority. Table 8 presents the analysis of the payment terms criterion.

Table 8 – Payment terms Criterion

Payment terms	Supplier 01	Supplier 02	Supplier 03	Relative Priority
Supplier 01	0,29	0,10	0,46	0,2824
Supplier 02	0,14	0,30	0,23	0,2245
Supplier 03	0,57	0,60	0,31	0,4930

Source: Authors (2022).

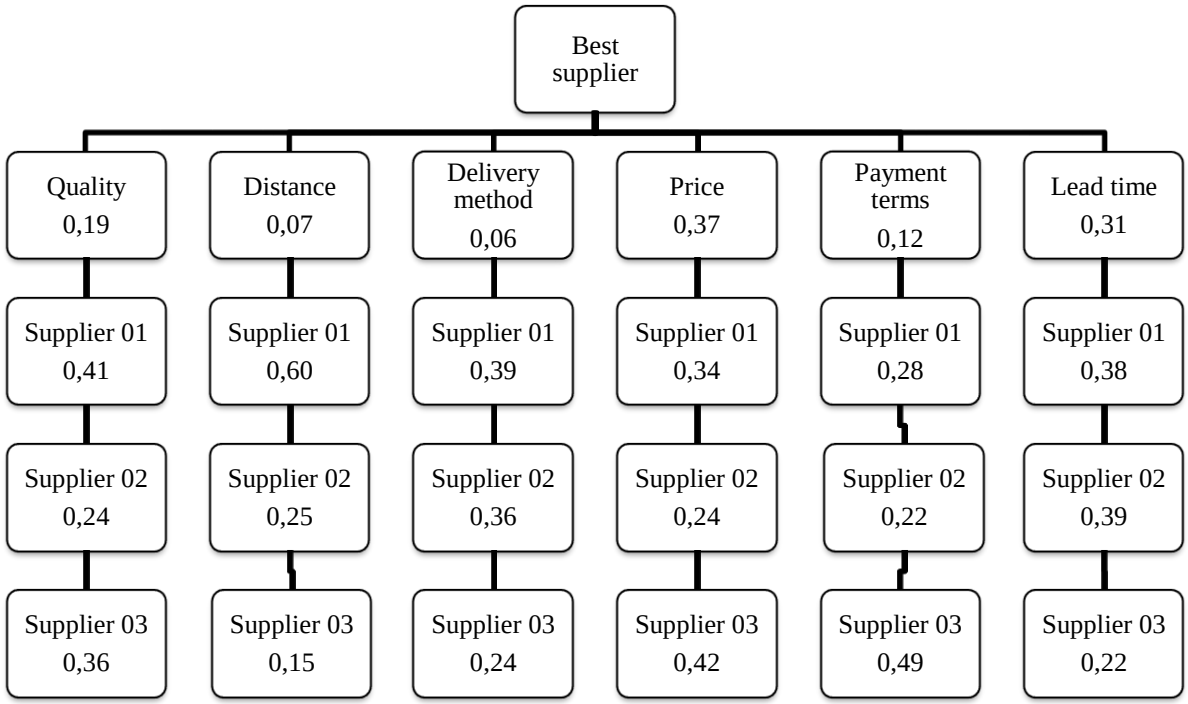
Considering the payment terms criterion, Supplier 03 has a predominance with a relative priority of 49.30%, followed by Supplier 01 with 28.24%, and Supplier 02 with 22.45%. Table 9 presents the analysis of the distance criterion.

Table 9 – Distance Criterion

Distance	Supplier 01	Supplier 02	Supplier 03	Relative Priority
Supplier 01	0,55	0,63	0,63	0,5985
Supplier 02	0,18	0,31	0,25	0,2481
Supplier 03	0,27	0,06	0,13	0,1534

Source: Authors (2022).

The last criterion analysed, distance, showed that Supplier 01 had a relative priority of 59.85%, Supplier 02 had 24.81%, and Supplier 03 had only 15.34%. Based on the results, Figure 5 was created, which displays the hierarchical structure with the respective values of relative priority for the criteria and alternatives.



Source: Authors (2022).

Figure 5 - Hierarchical structure of the criteria with the values of relative priority

Continuing with the AHP method, Table 10 presents the resulting values of the composite priority, which are obtained by multiplying the relative priority values with the criteria priority vector.

Table 10 – Compost Priority

Results	
Supplier 01	0,37
Supplier 02	0,27
Supplier 03	0,36

Fonte: Autores, 2021

According to the data shown in the composite priority, it is possible to highlight that Supplier 1 has a preference of 37%, followed by Supplier 3 with 36%, and Supplier 2 with 27%. The results indicate that these values are close to each other, as many criteria points resulted in similar values. Supplier 1 proved to be the most suitable for purchasing raw materials based on the analysis of the studied criteria. Finally, in discussions with the managers of the company under study and considering the articles published in the last two years about the pandemic's impact on the economy, it is evident that the

metallurgical industry has been greatly affected by the prices of raw materials used in the production process, primarily due to the increase in the dollar exchange rate, shortages of inputs, and logistics issues.

V. CONCLUSION

This study aimed to analyse the feasibility of using a multicriteria decision support tool to select the best raw material supplier for a metallurgical industry in Santa Catarina. The effectiveness of the Analytic Hierarchy Process (AHP) was demonstrated, as it allows decision-making that considers multiple criteria as a whole. Thus, the objective of this study was satisfactorily achieved.

Through the AHP method, the best raw material supplier for the company was identified in the current situation. This involved identifying the qualitative and quantitative criteria of greatest interest for purchasing inputs and analysing the level of importance of each criterion from the perspective of the manager. It is worth highlighting that the method proved to be effective and efficient for the procurement sector.

Furthermore, it was observed that the pandemic presented a new scenario where the metallurgical industry, along with other sectors, had to adapt to new ways of working.

For future research and for the company itself, it is suggested to analyse technology and innovation to reduce costs, improve processes, assess the cost of the produced material, enhance operator performance, and reduce waste/scrap quantity.

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