Application of Analytic Hierarchy Process Considering Artificial Neural Network and ARIMA for Selecting a Chemical Waste Plant

Riciane Bornéo, Mateus Muller Franco, Bruna Caroline Orlandin,
Nathalia Tessari Moraes e Leandro Luis Corso

Abstract

This study defines the best model for a chemical waste plant where the Artificial Neural Network (ANN) and the Integrated Auto Regressive Moving Average Model (ARIMA) were applied as tools for predicting future maintenance cost data. These methods were applied together considering the criteria as follows: plant size, process cost, treatment flexibility, environmental safety and maintenance cost. For this, a decision-making model was developed using the Hierarchical Analysis Method (AHP) with which the company can decide from three alternatives of waste plant models. As a result, the recommendation and solution provide by the multicriteria method was the choice of the alternative 3 of a waste center. This solution indicated the best alternative considering the criteria selected by the company and also the data from RNA and ARIMA In this case, the model presented an index above 70% both in the final aggregation and in the sensitivity analysis.

Keywords

I. INTRODUCTION

Currently, having a good environmental reputation for a chemical industry goes far beyond following guidelines, it is necessary to conduct its production in order to respect the legislation as well as to adopt good practices in the management of its waste. The management of industrial waste has become a major concern for the chemical sector, due to the volume generated and also the dangerousness of these wastes. However, it is possible to be competitive and still implement sustainable practices regarding the management of the process leftovers [1]. The industrial waste should be discarded properly, following strict national and international environmental protection standards. For this, it is necessary to define a waste center in an appropriate place that supports the volume generated and meets the current legislation [1].

This paper aims to define the best design option for a chemical waste plant where the Artificial Neural Network (ANN) and the Integrated Auto Regressive Moving Averages Model (ARIMA) will be applied to forecast future maintenance cost data.

The objective is based on the joint use of the methods, in order to consider five criteria that are; plant size, process cost, treatment flexibility, environmental safety and maintenance cost. In this way, developing a decision-making model through the Hierarchical Analysis Method (AHP). The decision is based on the choice between three alternatives of industrial plants.

It is known that with the fast development of new technologies in relation to the dilemmas of waste management, decision makers must select from a wide field of available alternatives. Multicriteria modeling acts as an element of decision support, since its results provide a crucial understanding of observed environmental problems and can efficiently support environmental decision-making in the public and private sectors [1].

ARIMA models assume that the series are generated from linear processes and are considered more robust and efficient than more complex structural models in short-term predictions [2]. The methods are smoother computation techniques that are very efficient in solving nonlinear problems, being the most accurate and widely used as prediction models in many areas considered quite attractive

mainly in industry [2]. A hybrid model was proposed in [3] combining ARIMA models with ANN since much of the forecasting literature says that no method is the best in all situations, thus complex autocorrelation structures in the data can be modeled more accurately and the model combined is more robust with regard to possible change in the data structure.

Finally, through the AHP, a decision-making model was defined for the problem in question, As mentioned in [1], it is possible to combine AHP and ANN. In [4] the AHP is defined by a decision-making procedure to analyze a multicriteria problem and classify the alternatives through comparisons between pairs. In AHP, the entire decision problem is organized in a hierarchical structure of objectives, criteria and subcriteria where the measurement process occurs at each level of the hierarchy. The goal is to generate a comparison matrix, which can be used in the mathematical process defined by Saaty method [5]. The main use of the ANN and ARIMA methods is to predict the behavior of costs over time, which can direct the decision of the AHP method in this particular case.

II. THE ANN AND ARIMA METHODS AND THE ANALYTIC HIERARCHY PROCESS – AHP

A. The ANN Method

The ANN is a mathematical model that aims to simulate the functioning of the human brain [15]. It consists of neurons represents experimental information. For mathematical neurons, as well as biological neurons, knowledge is acquired through learning process and connections, synaptic weights are responsible for storing that information [15]. Neurons are the basic elements of the structure and act in parallel with each other, they are part of a network in which its three basic elements are described below [16]:

a) Set of input connections: each one has an associated weight, where each input is connected to a given neuron that must be multiplied by its weight;

b) Adder: used to add the multiplication of the input signals by their respective weights, including all connections that connects to the neuron;

c) Activation function: generates an output that is sent to the next neuron in the system. Its goal is to limit the output amplitude of the neuron. The most used functions are sigmoid, linear, step and logistics.

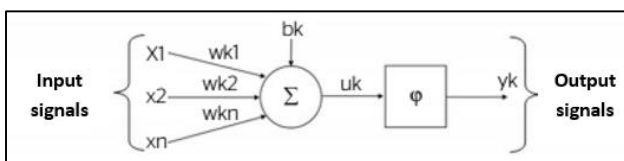The architecture of an ANN is represented in Figure 1.

Figure 1 – Architecture of an Artificial Neural Network
Adapted from Dias et al. (2020)

The equations that make up the structure of the represented networks are Equations (1) and (2) [17].

$$u_k = \sum_{j=1}^{n} \left(w_{kj} \times x_j \right) + b_k \qquad (1)$$

$$y_k = \emptyset \left(u_k \right) \qquad (2)$$

Where:
u_k - state of activation of the artificial neuron;
n - total number of artificial neuron entries;
j - index of an artificial neuron entry;
w_{kj} - synaptic weight of a neuron entry;
x_j - neuron input;
b_k - artificial neuron bias signal;
b_k - output of the artificial neuron;
$\emptyset$ - artificial neuron activation function.

B. The ARIMA Method

The ARIMA method aims to determine future forecasts by analyzing the similarity between the values of a time series or understanding the behavior of the serial correlation between these values [6,7]. It was developed in the mid-1970s by George Box and Gwilym Jenkins in order to describe the changes in time series, through the mathematical approach, the method is also known as Box-Jenkins [8].

By using the method it is possible to describe the behavior of stationary and non-stationary series. ARIMA can be used following the three steps described below [9]:

- Identification: consists on analyzing the data to find out if there is a pattern between them and if necessary, the transformation of the data to achieve stationarity;
- Estimation and testing: in this step the statistical estimates and the test are generated to assess the significance of each parameter in the model, if any parameter is not significant for the model, it can be deleted;
- Application: in the final stage of the method a review of the residuals or errors is carried out, comparing the predicted value with the actual.

The ARIMA methods (p, d, q), where "p" are the parameters of the lag numbers, "d" is the degree of differentiation and "q" the order of the moving average model is based on identification, estimation, diagnosis and forecasting [7,9]. Thus, ARIMA (1,0,0) indicates an autoregressive model that predicts the current data based on the previous observation; the ARIMA (0,0,1) predicts the current data based on observation and previous error and ARIMA (1,1,0) indicates an integrated autoregressive model [9]. Equation (3) depicts this latter model [10].

$$Y_t = \emptyset_1 Y_{t-1} + \theta_0 + \varepsilon_t \qquad (3)$$

Here, $\varepsilon_t = Y_t - \widehat{Y}_t$ is the difference between the actual value and the predicted value of the series. Due to its flexibility and simplicity to represent several varieties of time series, the ARIMA method and its derivatives are often used [11]. The method, can be used to predict complex data

behavior, as shown in [8], [12], [13], [14].

C. The Analytic Hierarchy Process – AHP

The multicriteria decision analysis (MCDA) has been developed rapidly over the last 30 years, and it is able to consider several consequences of proposed solutions of various typologies of problems. A decision-making model should enable the evaluation of all options when taking into account all factors that influence decisions. MCDA can be used to assess decisions related to organization and planning where the most of the methods result in quantitative assessment [1].

MCDA is a systematic methodology that combines information from the parties to classify, select or order the alternatives. It makes use of approaches to discover and quantify judgments and value judgments of decision makers and determining parties, on several relevant factors in the decision-making process [20].

The analytic hierarchy process (AHP) is a decision making-procedure used for analyzing a multicriteria problem and ranking the alternatives by means of pairwise comparisons [18]. When decision problems involve a group of decision makers (DMs), it is necessary to synthesize the individual judgments [4].

This method allows decomposing the problem in a hierarchy of subproblems, which can be more easily analyzed and evaluated subjectively, as illustrated in Figure 2.
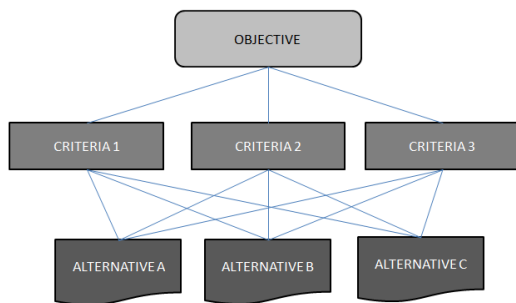

Figure 2 - Hierarchical structure for decision making
Adapted from Saaty (1994)

The AHP prioritizes the alternative in a justified and structured way through a mathematical model as well, it allows the allocation of resources based on priorities and allows the introduction of a cycle of continuous improvement in the company's decision-making process, since all the steps of the implementation of the model, definitions and decision criteria are documented [19].

The sequence of application of the AHP method follows as described by [18], its emphasizes points such as the normalization of the matrices and also the calculation of consistency.

In [19] was emphasized that the comparison should be made, pair by pair, of each element at the same hierarchical level - third, fourth and fifth steps described above. It is necessary to create a square decision matrix of order n, in which n represents the number of elements in each analyzed

level. The decision maker's preference among the compared elements is clearly represented from a pre-defined scale shown in Table 1.

Index	Description
1	Equally preferable
2	Equally moderately preferable
3	Moderately preferable
4	Moderately to strongly preferable
5	Strongly preferable
6	Strongly to very strongly preferable
7	Very strongly preferable
8	Very strongly preferable to extremely preferable
9	Extremely preferable

Table 1 - Fundamental scale of judgment in degree of importance
Adapted from Saaty (1994)

Thus, $\frac{n*(n-1)}{2}$ paired comparisons should be made at all hierarchical levels. According to [19] given the square matrix A (Equation 2), a_{ij} represents the value of the comparison between the decision criteria of row i with column j. By definition $a_{ij} = 1$ if se $i = j$ and $a_{ji} = a_{ij}^{-1}$. The vector of relative priorities P is defined by Equation (4), where A is the square matrix, $\lambda_{máx}$, is the largest eigenvalue of A and P is the associated eigenvector.

$$A = \begin{bmatrix} 1 & a_{12} & ... & a_{1n} \\ 1/a_{12} & 1 & ... & a_{2n} \\ ... & ... & ... & ... \\ 1/a_{1n} & ... & ... & 1 \end{bmatrix} \qquad A.P = \lambda_{máx.}.P \qquad (4)$$

According to [21] the hierarchical analytical process is characterized by being a process that allows calculating the coherence of the pair comparison performed coherence, as there is the possibility of logical inconsistency in the evaluation, and thus, in the performance of the calculations.

The consistency validation of the steps in the application sequence of the method is given by the following mathematical operations:

- Calculate the maximum eigenvalue (λmax): the AHP method searches for λmax, which shows whether the data are logically linked. Thus, the judgment matrix is multiplied by the priority vector of the main focus, after dividing the product of multiplication by the priority vector of the main focus. Next, the λmax is found by means of the arithmetic mean of the auxiliary priorities, that is, the arithmetic means of the division carried out previously. The matrix is considered consistent, if and only if, λmax is equal to the number of rows and columns in the matrix [18].

- Calculate the consistency index (CI): This step must be performed if the matrix is not considered consistent, using the following equation $\frac{\lambda máx - n}{n-1}$, where n is the number of rows or columns of the matrix;

- Calculate the consistency quotient (CQ): The CQ shows the coherence of the paired comparisons, identifying whether a correction of the assessment should be considered [18]. This index can be calculated using the following formula CQ = $\frac{CI}{RC}$, where RC is a random consistency index, which [18] establishes as a fixed value used as a reference and calculated in the laboratory (Table 2).

N	RC
1	0
2	0
3	0,58
4	0,9
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45
10	1,49

Table 2 – Index of random consistency
Adapted from Saaty (1994)

The CQ requires a value less than 0.1, if the result meets the standard, the calculation is accepted, and otherwise it is necessary to improve the consistency, by reassessing the paired comparisons [18].

It was considered in [18] new indexes for the matrix inconsistency assessment standard based on its size. For matrices of order three, the value 0.05 was based, for those of order four, 0.08 and, the rest, remain with the index of 0.1. When the CQ presents an acceptable value, the criteria matrix should be normalized and the local average priorities for each criterion should be found [21].

It is defined in [21], which then calculates the global average priority (GAP), with this, numerical values are found that are organized in the format of a ranking of priorities. The result will indicate which alternative will best meet the needs of the organization, being carried out using the following Equation 3:

$$GAP = \frac{LMP\ criteria}{LMP\ main\ focus} \quad (3)$$

Where:
LMP - local medium priorities;

It was verified in [21] that a widely used methodology for evaluating the results is the analysis of sensitivity, through graphics that can be generated with the use of enabled software, which is used to:

- Make decisions closer to the ideal;
- Realize what data should be refined before opting for an alternative;
- Focus on critical elements during implementation.

In this way, the sensitivity analysis graphs can be generated and interpreted, becoming facilitators, validating the process.

III. METHOD

This research is classified as a case study, of an applied nature, using a combined quantitative and qualitative approach, contemplating the practice in the context of this study [22]. Thus, considering a real application, when choosing a chemical waste center, the combined approach is related to the application of ANN, ARIMA and AHP, considering the subjective and quantitative aspects involved, aiming to facilitate the decision-making process in the addressed problem.

The company's data was multiplied by a factor, in order to maintain their security and confidentiality. In the company's practice, the mentioned volume is given in tons of material. The maintenance cost includes predictive and corrective maintenance over time at the company's current plant. Values from January 2017 to December 2019 were considered in the analysis. However, the factor is considered linear and does not affect the result presented in the present work. Initially, ARIMA and ANN models were created to assess MAPE [9]. The value of the lowest MAPE is what directs the use of the forecast method for the next 2 years. The present study was divided into three stages as shown in Figure 3.
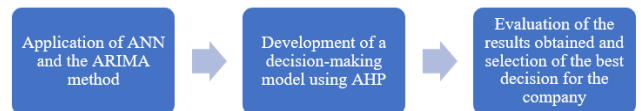
Figure 3 – Study steps
The authors

These steps are described below.

- Application of ANN and the ARIMA method

In this stage, in order to predict future data regarding the company's demand and maintenance costs, two methods were applied, ANN and ARIMA. To evaluate the performance of the statistical models used, the absolute mean percentage error indicator (MAPE) will be analyzed, in order to choose an objective function that minimizes the differences between the results obtained by the model and the data performed.

The methods applied were ARIMA (p, d, q) and a backpropagation neural network (in this particular case it was selected Levenberg-Marquardt algorithm for training, 50 neurons and delay equal 3).

- Development of a decision-making model using AHP

Three types of alternatives of the decision-making model with different characteristics were considered. Each alternative will be evaluated using the criteria listed for this project. The steps of this method were already described at the last chapter.

- Evaluation of the results obtained and selection of the best decision for the company

Finally, after identifying the best method for forecasting demand over the next two years, using ANN and ARIMA and

applying the AHP method, the results obtained were analyzed in order to select the best decision for the company to define a design of a chemical waste plant.

IV. RESULTS

A. Application of the ARIMA and ANN Methods

Based on the definition of the input data, it was possible to apply the forecasting methods. Table 3 shows the respective MAPE values, although the ARIMA method has also been shown to be efficient (relatively low errors). Thus, it was decided to use only ANN to make future projections of volume and maintenance costs.

	Mape ANN	Mape ARIMA
Volume	8,24%	13,06%
Cost	2,47%	4,18%

Table 3 – MAPE values for respective methods and data
The authors

The Figure 4 shows the volume forecast, where it can be seen that the trend is to increase considerably in the next 2 years. The approximation made with the ANN and ARIMA methods also shown, based on this approximation, the MAPE values (Tab. 3) were obtained.

The Figure 4 shows the volume forecast, where it can be seen that the trend is to increase considerably in the next 2 years. The approximation made with the ANN and ARIMA methods also shown, based on this approximation, the MAPE values (Tab. 3) were obtained.
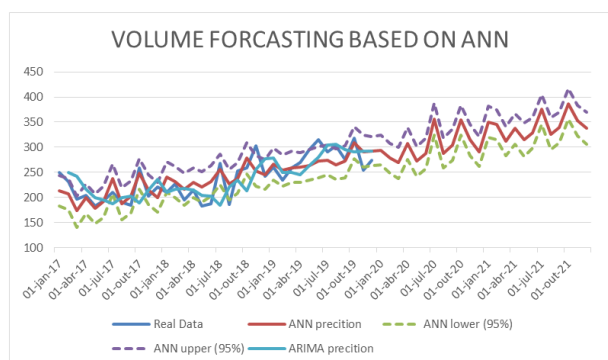

Figure 4 – Demand forecast for ANN and ARIMA x Real Data
The authors

The Figure 5 shows the projection of maintenance costs for the next 2 years, where it can be seen that even with the tendency to increase volume, maintenance costs tend to remain with a parametric behavior. The approximations made by both forecasting methods were also shown.
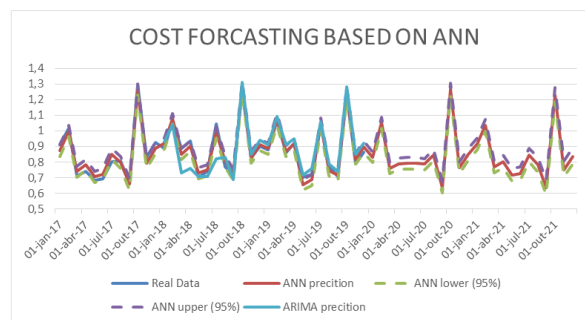

Figure 5 – Maintenance cost forecast for
ANN and ARIMA x Real DataThe authors

Based on this projection, the company made important considerations for the weights to be used in the comparison of the AHP. It can be seen that the weight of the volume of raw material to be processed is much greater than the weight given to the maintenance cost.

B. Application of the AHP Method

The criteria of size, cost of process, flexibility of treatments, environmental safety of process and maintenance was chosen to compose the criteria of this problem of multicriteria decision, considering the nature of application, the context of the studied organization and the relevant factors for the application of this research in this case study.

The size of the plant will be directly related to the company's production volume, which will be considered for the coming years. Artificial intelligence is combined with the ARIMA method to assess the possibility of growth or reduction of the company. The process cost, on the other hand, can be measured with direct values, being linked to the size and level of automation of the company. More larger will be the company, the greater the flexibility of treatments and the possibility of future profitability. Although all alternatives are certified, the larger the plant, the greater the environmental risk, which is why the environmental safety criterion is important. And finally, the maintenance criterion, which can become a critical item if the use of imported equipment could raise the cost of corrective maintenance in this way, a cost projection for the dollar was made in order to estimate future behavior.

In this step, the application of the multicriteria AHP method was divided into six stages, following the description of the theoretical reference and the method. Microsoft Excel software was used to support these processes. As a first stage, it was necessary to build the hierarchical structure of the problem under analysis. For this decision making, the main objective considers the decision criteria and the alternatives, which are considered simultaneously. Thus, Figure 6 presents this application, as a realization of this stage, with the initial phase of application of the AHP.
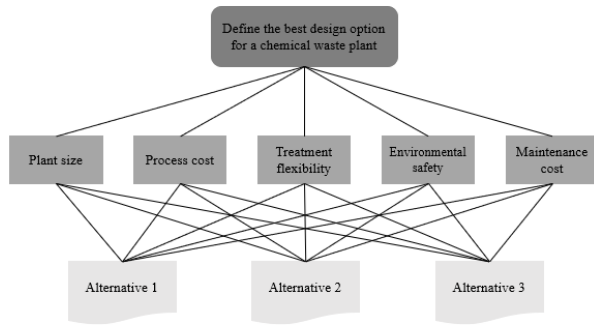
Figure 6 – Hierarchical structuring
The authors

Figure 9 – Autovector
The authors

After that, to consider the normalization of the matrices, in stage 2 of the AHP, it was necessary to create the comparison matrix pair by pair and calculate the relative priorities. In order to create the pairwise comparison matrix, the matching was performed at all levels of the hierarchical structure previously presented. Thus, the judgments were made by the decision maker, using the fundamental scale of Saaty and the paired matrix, both presented in the theoretical reference of the AHP, of this research. For the assessment of relative probabilities, the calculation was developed by dividing each element of the comparison matrix pair by pair, by adding the columns of this matrix. In this way, Figures 7 and 8 shows this application.
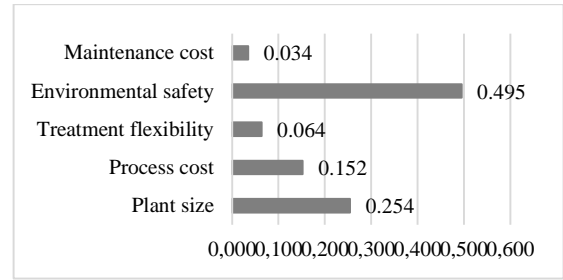
Factor	Plant size	Process cost	Treatment flexibility	Environmental safety	Maintenance cost
Plant size	1.00	3.00	5.00	1/3	7.00
Process cost	1/3	1.00	5.00	1/5	5.00
Treatment flexibility	1/5	1/5	1.00	1/7	3.00
Environmental safety	3.00	5.00	7.00	1.00	9.00
Maintenance cost	1/7	1/5	1/3	1/9	1.00

Figure 7 – Pair to pair comparison matrix
The authors

Factor	Plant size	Process cost	Treatment flexibility	Environmental safety	Maintenance cost
Plant size	0.21	0.32	0.27	0.19	0.28
Process cost	0.07	0.11	0.27	0.11	0.20
Treatment flexibility	0.04	0.02	0.05	0.08	0.12
Environmental safety	0.64	0.53	0.38	0.56	0.36
Maintenance cost	0.03	0.02	0.02	0.06	0.04

Figure 8 – Relative priorities
The authors

In sequence, the autovector was calculated, with the completion of stage 3 of the AHP. This result was made possible by the average of the lines of the matrix of relative priorities, constructed at the beginning of the application of this multicriteria method. Thus, Figure 9 illustrates these results.

Thus, the preferences resulted in the following order: environmental safety, plant size, process cost, treatment flexibility and maintenance cost.

Afterwards, in stage 4, the consistency quotient was found, through the consideration of the pairwise comparison matrix and the eigenvector found in stage 3. That said, Table 4 presents this application.

Factor	Consistency quotient
Plant size	1.436
Process cost	0.827
Treatment flexibility	0.319
Environmental safety	2.776
Maintenance cost	0.178

Table 4 – Consistency quotient
The authors

Continuing with the proposed steps, in stage 5, the calculation of the consistency vector was performed, with the division of the consistency quotient by the eigenvector. In this way, Table 5 shows this application.

Factor	Consistency vector
Plant size	5.645
Process cost	5.424
Treatment flexibility	5.009
Environmental safety	5.609
Maintenance cost	5.155

Table 5 – Consistency vector
The authors

At this stage, the control parameters were calculated, where the n represents the number of criteria and / or alternatives analyzed, the λmax, the consistency index and the final consistency quotient was obtained according to the descriptions of the AHP theoretical reference. The corresponding values in Table 5, related to the consistency

vector, are used to calculate λmax, through the average of the values. Subsequently, this result is also necessary for the calculation of the consistency index. For the application to be valid, the value of the consistency quotient found must be less than or equal to 0.1. Thus, Tables 6 and Figure 10 illustrate these results.

| Parameter	Result
n	5.000
λmax	5.369
Consistency index	0.092
Consistency quotient	0.083

Table 6 – Control parameters

The authors

Finally, with the application of these 6 stages, it was possible to replicate the previous stages, comparing the alternatives versus criteria, completing the application of the conceptual steps of the method and evaluating the results. In this way, Table 6 presents the parameters found, proving the accomplishment of this step.

Parameter	Plant size	Process cost	Treatment flexibility	Environmental safety	Maintenance cost
n	3.000	3.000	3.000	3.000	3.000
$\lambda máx$	3.066	3.029	3.037	3.054	3.066
Consistency index	0.033	0.015	0.019	0.027	0.033
Consistency quotient	0.063	0.028	0.036	0.052	0.063

Figure 10 – Control parameters of the last level
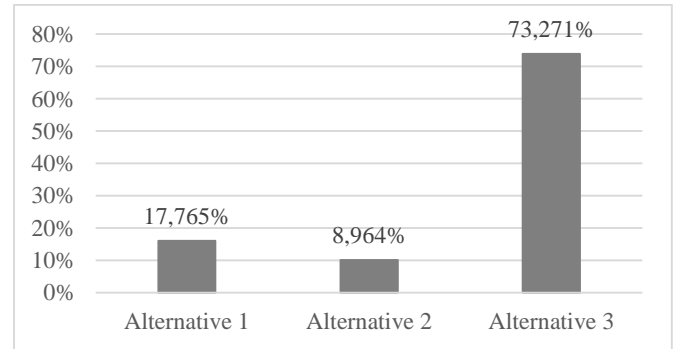
The authors

Therefore, to analyze the results found with stages 1 to 6 of this multicriteria method, the preferred solution could be recommended, with 73,857% preference. The priority results found for the three alternatives, as well as the optimal choice of this decision problem, such as 73.857%, were obtained through the matrix product of two matrices, resulting in a third matrix, with the number of lines in matrix 1 and the number of columns in matrix 2. Thus, the values in matrix 1 refer to the average of the relative priorities at level 2 (criteria versus criteria) and those in matrix 2 refer to the average of the relative priorities at level 3 (criteria versus alternatives) , consistent with the mathematical formulation of the multicriteria method adopted in this research. Thus, the final results, in percentages for each alternative, are obtained, assisting the organization's decision-making process and indicating the alternative that solves the decision problem presented. The Figure 11 illustrates these results. It is important to highlight the preferences of the decision maker and the weights given to each criterion, and their respective influences for the calculation of this final aggregation.
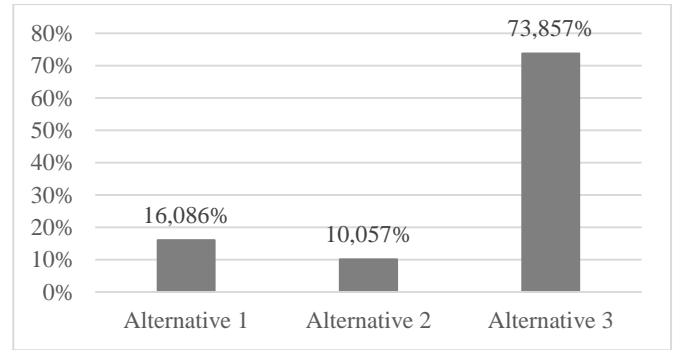
Figure 11 – Final aggregation

The authors

In addition to all the steps already carried out and presented previously, finally, stage 7, refers to the sensitivity analysis.

Here, the decision maker's priorities and their respective weights have been modified to the following order: plant size, environmental safety, treatment flexibility, process cost and maintenance cost. In this way, according to the order of priority established with the modification of the ordering of the criteria, the values were changed to make up the new decision priority. Thus, in the same order as described in the criteria in this sensitivity analysis, the values of 0.494; 0.063, 0.1524; 0.2544; and 0.0344 were used, exactly as described in the change of priority, considering the initial priority for the final result of the application of the AHP. The results were robust, with low variation represented in the final alternatives, as shown in Figure 12.

Figure 12 – Final aggregation with sensitivity analysis

The authors

V. CONCLUSIONS

The future of companies certainly depends on making the right decisions. The main objective of this research focused on the application of the ARIMA method and ANN to support better decision making with AHP.

Through the application of AI and ARIMA it was possible to observe that although the ARIMA method has been shown to be efficient, the application of AI was the best alternative for this study, since it presented a lower percentage of error compared to the ARIMA method. The error obtained with AI was 8.24% in terms of volume and 2.47% in terms of maintenance costs. Based on the application of AI, an upward trend was found in relation to costs and volume.

Based on the AHP mathematical modeling, it was possible to obtain the final rankings of the alternatives. It was considered the evaluation of five criteria. The consistency quotients were considered satisfactory, reaching values less than or equal to 0.1, proving the application's consistencies. As a recommendation and solution for the multicriteria method applied, the choice of alternative 3 is indicated as the optimal option for the problem employed, with 73.857% of preference in the final aggregation of the method. This result was obtained through the defined criteria and the preferences of the decision makers. It was characterized mainly by the high values obtained in environmental safety, plant size and cost of the process. In addition, the sensitivity analysis was carried out, by changing priorities of the decision maker, proving the results found, realizing and recommending the predominance of alternative 3. As a solution, it was found 73.271% of preference when it was compared to the others alternatives. In this way, the AHP subsidized and assisted the decision-making process in the organization of this study. It was considered qualitative and quantitative assessments, subjective considerations and multiple criteria.

Possibly the greatest difficulty encountered throughout this study is related to the maintenance criterion since the company uses imported equipment and maintenance costs tend to be higher in this situation. In this way, it was considered a model of projection of maintenance costs over time through information that the company already has. Bearing in mind that in the case of a positive dollar trend, this point becomes more critical, thus, a currency projection was made to obtain an estimate of future behavior.

As a suggestion for future work, it is indicated to carry out some modifications in the training of ANN, such as, increase the volume of data used for training. This is aimed at improving the mathematical forecasting model.

Finally, it is emphasized that the methodologies employed in this research have the potential to be replicated in other applications, in order to support the best possible decisions in different applications.

VI. References

[1] K. Pazek, J. Prisenk, S. Bukovski, B. Prevolsek and C. Rozman, "Multicriteria Assessment of the Quality of Waste Sorting Centers - A Case Study" *Journal Of Sustainability,* vol. 12, n. 9, p. 37-80, 2020.

[2] A. Adebiyi A., A. Adewumi O., and C. Ayo K. (2014). "Comparison of ARIMA and artificial neural networks models for stock price prediction" *Journal of Applied Mathematics*, p. 1-8, 2014.

[3] P. Zhang G., "Time series forecasting using a hybrid ARIMA and neural network model. *Neurocomputing*, v. 50, p. 159-175, 2003.

[4] P. Amenta, A. Lucadamo and G. Marcarelli, " On the choice of weights for aggregating judgments in non-negotiable AHP group decision making" *European Journal of Operational Research*, p. 294-301, 2020.

[5] M. Bernasconi, C. Choirat and R. Seri, "Empirical properties of group preference aggregation methods employed in AHP: Theory and evidence", *European Journal of Operational Research*, v. 232, n. 3, p. 584-592, 2014.

[6] G.E.P. Box; G.M. Jenkins. "Time Series Analysis: Forecasting and Control," Holden Day, San Francisco. Google Scholar, 1976.

[7] R. Borsato. L. Corso L., "Aplicação de Inteligência Artificial e ARIMA na Previsão de Demanda no setor metal mecânico*." Scientia cum Industria,* v. 7, n. 2, p. 165-176, 2019.

[8] R. Sato C. "Gerenciamento de doenças utilizando séries temporais com o modelo ARIMA" *Einstein (São Paulo),* v. 11, n. 1, p. 128-131, 2013.

[9] A. Linden, J. Adams L., N. Roberts "Evaluating disease management program effectiveness: an introduction to time series analysis" *Disease Management*, v. 6, n.4, p. 243-255, 2003.

[10] A. Adebiyi, A. Adewumi, C. Ayo, "Comparison of ARIMA and Artificial Neural Networks Models for Stock Price Prediction," *Journal of Applied Mathematics,* p. 1-7, 2014.

[11] X. Shuojiang; H. Chan K. and T. Zhang "Forecasting the demand of the aviation industry using hybrid time series SARIMA-SVR approach," *Logistics and Transportation Review*, v. 122, p. 169-180, 2019.

[12] J. Gaudart, O. Toure, N. Dessay, A. Dicko L., S. Ranque, L. Forest, J. Demongeot and O. Doumbo K. "Modelling malaria incidence with environmental dependency in a locality of Sudanese savannah area, Mali" *Malaria Journal,* v.8, 2009.

[13] T. Reichert A., "Influenza and the Winter Increase in Mortality in the United States, 1959-1999" *American Journal Of Epidemiology*, v. 160, n. 5, p. 492-502, 2014.

[14] A. Earnest, M. Chen I., N. Donald G.; S. Leo Y., "Using autoregressive integrated moving average (ARIMA) models to predict and monitor the number of beds occupied during a SARS outbreak in a tertiary hospital in Singapore" *Bmc Health Services Research*, v. 5, n.1, 2005.

[15] S. Haykin, S. "Redes Neurais Princípios e Práticas". 2. ed. *New York: Bookman*, 2001.

[16] L. Ferreira, *et al.* "The use of Artificial Neural Networks as a strategy for forecasting prices in the context of agribusiness" *Review of Administration and Innovation – RAI,* v. 8, n. 4, p. 6-26, 2012.

[17] C. Dias, G., *et al.* "Modelagem e simulação de um sistema inteligente para controle de dosagem da pós-cloração em estações de tratamento de água". *Engenharia Sanitária e Ambiental*, v. 25, n. 2, p. 323–32, 2020.

[18] L. T. Saaty, "How to make a decision: the Analytic Hierarchy Process". *Interfaces*, v. 24, n. 6, p. 19-43, 1994.

[19] M. Padovani, "Apoio à decisão na seleção do portfólio de projetos: uma abordagem híbrida usando métodos AHP e programação inteira" 267 f. *Dissertação (Doutorado) - Curso de Engenharia de Produção*, Universidade de São Paulo, São Paulo, 2007.

[20] A. Ishizaka, P. Nemery, "Multi-criteria decision analysis: methods and software" *John Wiley & Sons*, 2013.

[21] F. Fontanive, F., L. Corso, L., R. Zeilmann, P., and R. R. Biasin, N. "Aplicação do método de Análise multicriterial AHP como ferramenta de apoio a tomada de decisão". *Revista Espacios*, vol. 38, n. 19, p. 6, 2017.

[22] L. Silva, E., M. Menezes, E. "Metodologia da pesquisa e elaboração de dissertação". 4. ed, Florianópolis, 2005.