Pesquisa Operacional (2019) 39(3): 437-456

Printed version ISSN 0101-7438 / Online version ISSN 1678-5142
www.scielo.br/pope
doi: 10.1590/0101-7438.2019.039.03.0437

EFFICIENCY INDICATORS TO EVALUATE SERVICES IN PORT SERVICES: A PROPOSAL USING FUZZY-AHP APPROACH

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Received November 28, 2018 / Accepted September 11, 2019

ABSTRACT. This paper describes a plan to develop a prioritization model of efficiency indicators to evaluate the services provided by seaports to ships in terms ofeconomicity, quality, and reliability. The methodology adopted is applied research, using a case study carried out in a Brazilian seaport. The approach used as an intervention tool in the elaboration of the model is the Fuzzy-Analytical Hierarchy Process. The results suggest the prioritization of economicity over the other two criteria of reliability and quality.

Keywords: Maritime ports; efficiency; fuzzy Analytical Hierarchy Process.

1 INTRODUCTION

In recent decades, port activities have held a prominent position in the world economic scenario. Responsible for the largest share of export and import outflows, ports are today some of the possibilities of indicators of a country's economy, according to the works of Sleeper (2012) and Dwarakish and Salim (2015).

Eurostat data (2017) indicate that cargo movement in European countries is increasing. The Netherlands, Poland, Spain, Portugal, and Greece achieved a growth rate of more than 12% in cargo handling between 2010 and 2016. In Asia, freight handling volumes for Taiwan's seven largest ports; Keelung, Kaohsiung, Taichung, Hualien, Taipei, Suao, and Anping, increased by 5.85% between 2012 and 2016 Taiwan International Ports Corporation [TIPC] (2017). In 2014, the Port of Vancouver, in Canada, was responsible for handling 140 million tons of cargo, valued at 187 billion dollars, according Dworakowska (2016).

According to a report developed by the Ministry of Transport, Ports and Civil Aviation (2017) of Brazil, during the same period, Brazil also registered a gradual increase of 19.1% in cargo movement through seaports.

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One of the ways to efficiently manage operations in a port is through the identification, organization, and measurement of criteria to evaluate the quality, economicity, and reliability of these operations. According to Ensslin *et al.* (2017), performance indicators are one of the most used measures to analyze port performance, second only to data analysis.

According to Ha et al (2017), due to the complexity of port activities and operations, decision makers require an essential understanding of the interdependence between port performance indicators and develop appropriate solutions to improve port performance. Over the past few years, the use of Fuzzy Logic methodologies coupled with the Hierarchical Analytical Process (AHP) has been shown to be efficient for integrating various data on port performance as well as addressing the inherent uncertainties regarding the strategies adopted in port operations. Their use becomes important because they are easy-to-handle tools with extensive bibliography available, especially under conditions of uncertainty (Pereira *et al.*, 2015; Ramalho *et al.*, 2019). Indicators are a mathematical relationship that numerically measure attributes of a process or its outcomes, with the aim of comparing this measure with pre-established numerical goals. According to ANTAQ (2003), port managers use the analysis of performance indicators to organize their goals and to establish new port strategies, that is, the study of indicators is directly linked to efficiency and competitiveness in the port environment.

In Brazil, with the adoption of the indicators proposed by the National Water Transport Agency [ANTAQ] (2003), the study of port performance initially started with the work of Madeira *et al* (2012), who propose the use of an approach based on multi-criteria mathematical modeling. The use of this type of approach (multicriteria) in scenarios of complex realities makes the process of modeling and measuring indicators more robust. Among the several possibilities, the multi-criteria Fuzzy AHP methodology allows the evaluation of indicators using the opinion of specialists as a reference in their analysis.

In this context, the present study proposes a prioritization model of efficiency indicators for the services provided by a seaport located in the southern region of Brazil, which is the New Port of Rio Grande, which is the fourth largest port in Brazil and the only one multimodal region of southern Brazil and which is responsible for the movement of various types of cargo.

The intervention instrument used was the AHP Fuzzy model. Through this instrument, the researchers developed a prioritization model of efficiency indicators for the services provided by the seaport, considering the criteria of economicity, quality, and reliability.

This article is divided into four sections. After the introduction in the first section, the second section presents the theoretical framework that lays the basis for the Fuzzy-AHP methodology within the multi-criteria approaches to operational research. The third, the results obtained by using the defuzzification process of AHP with the port indicators identified in the data are presented. Lastly, section four discusses the final considerations, scope for further study, and limitations.

2 THEORETICAL FOUNDATION

Multi-criteria methods are a set of techniques capable of facilitating the decision process, since their main objective is to reduce the complexity of a problem by including criteria, sub-criteria, and alternatives.

Multicriteria decision making and analysis methods are applied when there is a need to select, sort, classify or describe the present alternatives in a complex decision-making process with multiple criteria and conflicting objectives.Complex environment; conflicting criteria, uncertainties and inaccurate information characterize many decision problems present in the real world. The Multi-criteria decision analysis contributes to make the decision process more rational and efficient (.Kulakowski, 2018) (Fernández *et al,* 2018). The decision analysis process usually considers a variety of alternatives, which must be carefully evaluated so that the "best" decision can be chosen (Cardoso *et al,* 2009).

In addition, they include the judgment and evaluation of specialists in the decision-making process.

Real-world decision problems are rarely mono-criterion based. They generally incorporate a variety of criteria, often contradictory. Regarding decisors' profile; the DM ranks alternatives (A_i) described by criteria (C_j), with a weight criterion (W) and grades (classification) that are given for each alternative, in each criterion (Silva et al, 2018)(Petrović *et al*, 2018).

Mardani *et al.* (2015) state in their study that the judgment of the aforementioned criteria can assume cardinal or ordinal values, that is, this information can be determined in an exact or a diffuse way, using fuzzy logic. In Accordance, Bouyssou *et al* (2006) say that there are a variety of multi-criteria methods; however, one should consider the purpose of the study and identify the most convenient method.

According to Mardani *et al.* (2015), among the main multi-criteria methods, the Analytical Hierarchy Process [AHP] is the most popular in solving problems involving decision making. Hence, the present work will use the AHP method in addition to fuzzy logic, in order to refine the results achieved. Per Emrouznejad and Marra (2017) 8441 published pieces on AHP published between 1979 and 2017.

In a brief review of the literature, recent studies that use Fuzzy AHP to evaluate criteria and performance were found. Calabrese *et al* (2013) apply the Fuzzy AHP methodology to analyze the components of Italian information and communication technology. Taylan *et al* (2016), use the method to support the decision of specialists in choosing the best compressor to be used by the petrochemical industry.

The methodology is also applied to several sectors. For example, Mandic *et al* (2014) have used it to evaluate the performance of the banking sector in Serbia, Shaw*et al* (2012) have used it to choose the supplier that best suits the Indian clothing industry, and Cebeci and Ruan (2007) have used it to verify which Turkish consulting firm achieves the highest customer satisfaction.

Thomas L. Saaty (1980) developed the AHP in the 1970s to facilitate the decision-making process through hierarchical structuring, which enables the visualization of the problem as a whole, and of its components. However, since the method is used in complex decision making, it seems inaccurate and ambiguous due to its reliance on human perception, because the method bases its analysis on the specialist opinions. In this sense, Tang and Lin (2011) claim that the existence of such problems in decisions weakens the effectiveness of AHP.

Peng*et al* (2011) and De Souza *et al* (2018), state that the AHP method, besides having been extensively studied in recent years, has also seen variations in its methodology. The Fuzzy AHP methodology is one such variation.

According to Barros*et al* (2017), Professor Lotfi Asker Zadeh (1970) introduced the fuzzy theory in 1965. Professor Zadeh's main objective was to offer a mathematical treatment for specific subjective linguistic terms, that is, to make them more suitable for defining and measuring uncertainty, through the use of fuzzy numbers.

Saxena *et al* (2010) and Morote and Vila (2011) state that the combination of fuzzy logic and the AHP method is robust, since it considers reality and admits that judgments are not precise, and the variables are relevant to the decision-making environment. Therefore, these variants are minimized with the inclusion of linguistic variables and, consequently, fuzzy logic.

Buckley (1985) argues that the methodology proposed by Saaty (1980) is maintained, but the operations with fuzzy numbers are adapted, which can be seen in the work of Bellman et al. (1970).

The FAHP methodology can be described by 7 steps. The first consists in the decomposition of the problem into a hierarchy that is, composed of objective, criteria, subcriteria and alternatives. In the second step, the hierarchy of the problem in question is created, subdividing it into levels. Figure 1 illustrates the structuring of a problem, exemplified by the case of two criteria, four sub-criteria and two alternatives.

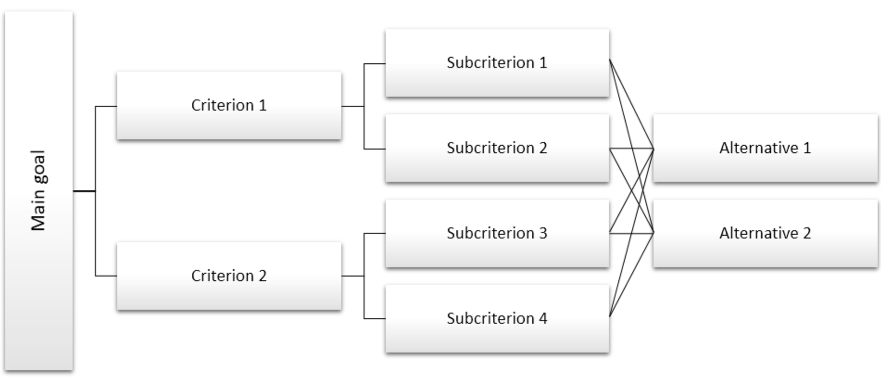

Figure 1 – Hierarchical structure.

The third step is responsible for collecting the judgments alongside the specialists. Experts will make peer-to-peer comparisons of both criteria-based alternatives and sub-criteria against criteria. This comparison is made from the linguistic variables, which are presented in table 1, which presents the expert judgments that were obtained through questionnaires and converted into quantitative indexes. In addition, according to Wang *et al* (2018), in this step the type of fuzzy number to be used in the analysis is reported. In order to incorporate uncertainties in the data (multiples and relative importance), we relied on fuzzy mathematics (Duarte Junior, 2018).

Table 1, adopts the triangular fuzzy number according to the authors Laarhoven and Pedrycz's (1983). The construction of table 1 was determined by m value, which represents the central value of the triangular fuzzy numbers, that is, the one with the greatest relevance. The rules for the definition of the triangular fuzzy number have four variations for the construction:

- $m=1$, the fuzzy number is given by: $\left(\frac{1}{1-\delta},1,1+\delta\right)$
- $m=2,3,\ldots,8$ and the comparison is from i to j, we have: $(m-\delta,m,m+\delta)$
- $m=2,3,\ldots,8$ and the comparison is from j to i, we have: $\left(\frac{1}{m+\delta},\frac{1}{m},\frac{1}{m-\delta}\right)$
- $m=9$ the fuzzy number is given by: $(9-\delta,9,9)$

Where m is the value found in the table of Saaty (1980), which defines the qualitative classifications.

Table 1 – Fuzzy values.

Linguistic variable	Fuzzy Number	The reciprocal number of the Fuzzy Number
Equal	$(1,1,3)$	$(0.3333;1;1)$
Weak	$(1,3,5)$	$(0.2;0.3333;1)$
Strong	$(3,5,7)$	$(0.1428;0.2;0.3333)$
Very Strong	$(5,7,9)$	$(0.1111;0.1428;0.2)$
Absolute	$(7,9,9)$	$(0.1111;0.1111;0.1428)$

In the fourth step, the decision matrices are constructed, which should be: square, reciprocal and positive. The insertion of the elements of the matrices occurs in two ways, the first is when the criterion of column j is greater than that of row i, implies that the element in the matrix will be the inverse of it, as exposed in formalism (1) (2). Another form of insertion is when the criterion is compared with itself, so the matrix will receive the value 1, according to the expression below (3).

$$a_{ji}=1/a_{ij} \tag{1}$$

$$a_{ii}=1,\forall i \tag{2}$$

Therefore the matrix will be as follows.

$$\begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{bmatrix} (1,1,1) & \dots & (l_{1n}, m_{1n}, u_{1n}) \\ (l_{21}, m_{21}, u_{21}) & \dots & (l_{2n}, m_{2n}, u_{2n}) \\ \vdots & \vdots & \vdots \\ (l_{n1}, m_{n1}, u_{n1}) & \ddots & (1,1,1) \end{bmatrix} \tag{3}$$

The fifth step, the defuzzification occurs, that is, the transformation of the fuzzy number into crisp. The most used methods for this process are: Kaufmann and Grupta (1988), Chang (1981) and centroid, discussed in the paper by Bortolan and Degani (1985). In the sixth step, after the defuzzification, the consistency of the matrices is verified as in the AHP method, that is, the maximum eigenvalue obtained in the matrix of the previous step, together with the consistency index (CI) and the consistency ratio (RC), for more details see in Saaty (1980). Thus, if the result obtained is RC <10% the matrix is consistent; otherwise the matrix should be adjusted.

Finally, for the seventh step it is necessary to use the matrix of step 4, which according to Shiu *et al.*(2016) will serve as the basis for the calculation of the synthetic fuzzy measures (S), which are responsible by the hierarchy of the elements of the decision matrix. Given from the calculation $V(S_1 \geq S_2)$, which represents the degree of possibility of S_1 being greater than or equal to S_2, given by (4) and (5):

$$V(S_1 \geq S_2) = \begin{cases} 1, if\ m_1 \geq m_2 \\ \frac{l_1 - u_2}{[(m_2 - u_2) - (m_1 - l_1)]}, otherwise \end{cases} \tag{4}$$

Conforme, Chang (1996).

Priorities are derived from the overall comparison of synthetic measures, which are calculated as follows:

$$d(C_i) = min(V(S_i \geq S_2), \dots, V(S_i \geq S_n)) \tag{5}$$

Thus, the weight vector is obtained through the normalized $d(C_i)$ values.

The table 2 presents a bibliographical review of articles related to the port sector.

The Fuzzy AHP methodology is used in many ways in the port area. Thus, the proposed work contributes, along with the work of the authors mentioned above, to the following aspects:

– in their work, Ding *et al*. (2012) and Chou *et al.* (2013) use the triangular fuzzy number associated with the Chang (1981) method for defuzzification;

– Chiu *et al.* (2014) and Beşikçi *et al.* (2016) apply the triangular fuzzy number. However, they do not comment on the defuzzification method applied;

– Palacio *et al.* (2015) apply the method proposed by Kwong *et al.* (2003) for the defuzzification method associated with the triangular number,

– Hsu *et al*. (2015) apply the Kaufmann and Grupta (1988) method for the defuzzification of the triangular fuzzy number.

Table 2 – Review of the AHP Fuzzy Method.

Authors	Fuzzy AHP Approach	Method
Ding and Tseng (2012)	It was applied to identify and assist port administration with respect to security risks at the container terminal at Kaohsiung Port in Taiwan.	The authors use the triangular fuzzy number and the Chang (1981) method for defuzzification.
Chou and Yu (2013)	It was applied to evaluate the competitive environmental relations among the sites of international distribution centers within the ports of the Asian region.	The authors adopt the triangular fuzzy number and the Chang (1981) method for defuzzification.
Chiu *et al* (2014)	It was used to assist port organizations in choosing the priority attributes of the green port operation, that is, a sustainable port concept that minimizes environmental pollution. The approach was applied to the ports of Kaohsiung, Taichung and Keelung in Taiwan.	The researchers use the triangular fuzzy number. However, they do not comment on the defuzzification method applied.
Hsu*et al* (2015)	It was used in the container terminal at Evergreen Marine Corp. (EMC), in the port of Kaohsiung, to measure the importance, satisfaction, and dissatisfaction of users in relation to the services provided by EMC. In addition, it helps to identify problems and improve the quality of EMC services.	The researchers use the method of Kaufmann and Grupta (1988) for defuzzification and the triangular number that were used in the present study.
Palacio *et al* (2015)	It was used to determine the environmental impacts of container deposits at the Port of Valencia in Spain.	The triangular fuzzy number and the method proposed by Kwong and Bai (2003) are the ones used by the authors.
Beşikçi *et al* (2016)	It was used to calculate the quantitative importance of each factor, prioritizing the operational measures of energy efficiency of ships, and thus, helping the decision-making in the shipping industry.	The triangular number is applied in this work, but the method used for the defuzzification is not mentioned.

Therefore, the present paper, which contributes to the work referenced above, chooses the Wilcoxon test (1945), as the best defuzzification method, associated to the triangular Fuzzy number, since this step is linked to the verification of the consistency of the data, if after this transformation the characteristics of the judgment of the decision maker not to maintain, will imply in a disposal of the decision matrix, besides that it can lose the basic properties of a consistent matrix. The integration of the best defuzzification method and the Fuzzy AHP, applied to the Porto Novo of Rio Grande, in relation to the performance indicators to the services to the ships, makes the present work relevant for the port area.

3 DATA COLLECTION

The Port of Rio Grande is located in the south of Brazil, more precisely in the south of the State of Rio Grande do Sul. Its infrastructure allows access for multimodal freight transport, that is, through waterways, highways, or railroads.

According to Labtrans (2012), the Rio Grande port complex is fragmented into three zones:

- The old port for tourism;
- The new port, reserved for movements of fertilizers, cellulose, vehicles, project cargo, and live cargo,
- And the super port, where the private terminals are located.

The present study is applicable to the New Port, since it is the public dock where a wide movement of ships is concentrated.

According to SUPRG (2019), the Port of Rio Grande handled about 43 million tons in 2018. Until April 2019, it had handled approximately 932 vessels in a total of 10.676.482 tons. Therefore, it is important to note that the aforementioned port is of great importance and, for this reason, there is need to make it more organized and efficient, in order to increase the competitiveness of Brazilian ports.

According to Labtrans (2012), the port moves several cargoes, such as general cargo, fertilizers, containers, frozen items, wood, cellulose, and vehicles. In addition, the New Port serves as a base for the construction of modules for oil prospecting platforms. The wharf of the New Port is also being renovated, to make the port more competitive, by allowing the mooring of ships with a larger volume of cargo.

Due to the great relevance of the New Port of Rio Grande, this study uses the data collected from specialists about the port's performance indicators, with a focus on the services offered to the ships in the New Port of Rio Grande. Based on the organization chart of the port authority and like *Biju et al* (2015), the selection of specialists was based on their general knowledge of ship service indicators, the following specialists were chosen:

- Superintendent Officer;
- Inspector of port operation;
- Head of warehouse division;
- Head of the statistics section;
- Head of the quality, control and contracts division;
- Head of operation division;

- Engineer.

The interaction with the port authorities was through a questionnaire and meetings and debates to explain and assist them in case of doubt.The importance of port indicators, as pointed out by the specialists, was compared peer-to-peer. The proposed scale by Saaty (1980), adapted to Fuzzy logic, is shown in table 1.

The indicators chosen for the present study are the ones used by ANTAQ (2003), which is responsible for assessing Brazilian ports by monitoring prices and performance with the use of the Port Performance System. In addition, reliability indicators, which according to ANTAQ (2003), this indicator can be applied to the analysis of compliance with scales, the incidence of faults and breakdowns as well as the safety of people and the defense and preservation of the environment, focused on the prevention of major environmental impacts were added, since impact of the New Port on environment is of concern.

These indicators were divided according to their definition, as shown in the table 3.

The indicators are presented in a hierarchical order, as depicted in figure 2.

As mentioned earlier, the AHP Fuzzy methodology relies on the consistency of the decision matrix, derived from the opinion of specialists. To verify this consistency, the defuzzification process was carried out, using the methods proposed by Kaufmann *et al*. (1988), Bortolan *et al*. (1985) and Chang (1981), as follows.

The centroid method (Bortolan et al., 1985) transforms a Fuzzy number into a rational number, according to this formula (6):

$$F = \frac{l+m+u}{3} \tag{6}$$

Where:

l: Lower limit; m: Modal value, resulting from the Saaty scale (1980) and u: Upper limit.

For more details see in Bortolan et al., (1985).

The method of Kaufmann and Grupta (1988), it is represented by the following formula (7):

$$F = \frac{l+2m+u}{4} \tag{7}$$

For more details see in Kaufmann and Grupta (1988).

The defuzzification method of Chang (1981) uses the criterion of divergence, or the difference between the limits of the Fuzzy number, this method uses the following formula (8):

$$F = \frac{(u-l)\,(l+m+u)}{6} \tag{8}$$

For more details see in m Chang (1981).

When the Centroid (Bortolan et al., 1985) and Kaufmann and Grupta (1988) defuzzification methods were compared, the sample size criterion for the hypothesis t test was not fulfilled,

Table 3 – Identified Indicators.

Indicators of economicity	C_1	Average port charges for ships	Indicates the port taxes paid by the ship-owners or owners of goods, by the movement of cargoes in the port area.
	C_2	Average price of terminal use by ships	Indicates the average price of the amounts paid by the port operator or owner of merchandise to the lessees for the use of the terminal.
	C_3	Average labor price	Indicates the average value of the single labor employed in the loading / unloading operations, for each terminal or set of cribs.
	C_4	Average price of handling equipment use	Indicates the average value of the rental of equipment used in the loading / unloading operations, in each terminal or set of cribs.
	C_5	Average cost of entry and exit of ships	Indicates the average cost of the ship for each terminal or set of berths.
	C_6	Average handling cost	Indicates the difference between the prices charged by the operator or lessee and the costs incurred in supplementary operations.
Quality indicators – service	C_1	Average waiting time of ships	Indicates the quality of service, in terms of time spent waiting for mooring ships to each terminal or set of berths.
	C_2	Average service index	It reports the relationship between the time the terminal or set of cribs was occupied and the total time of availability.
	C_3	Average level of service	Indicator of promptness of the attendance to the ships, correlated the waiting time with the mooring time or service.
Quality indicators – reliability	C_1	Responsible practices for the consumption of natural resources: qualification, environmental training, education, and environmental awareness.	
	C_2	Use of equipment and products with low energy consumption, reducing environmental impact (efficient consumption, rational use of energy, and others)	
	C_3	Prevention and control of environmental impacts: fines due to environmental accidents.	

because the sample size was less than 20. Thus, following Gehan (1965), the Wilcoxon hypothesis test (1945) was used as the non-parametric alternative to the paired-sample test t, to test the hypothesis that the data medians would be the same against the alternative that they would be different.

For the choice of the defuzzification method that best fits the data of the present study, matrices of order 3 and 6 were used, measured in a single scale, consistent and inconsistent, obtained by the opinion of a specialist. In addition, the three methods described above were applied to these matrices. It should be noted that the data do not have normality, directly implying the choice of the Wilcoxon test (1945).

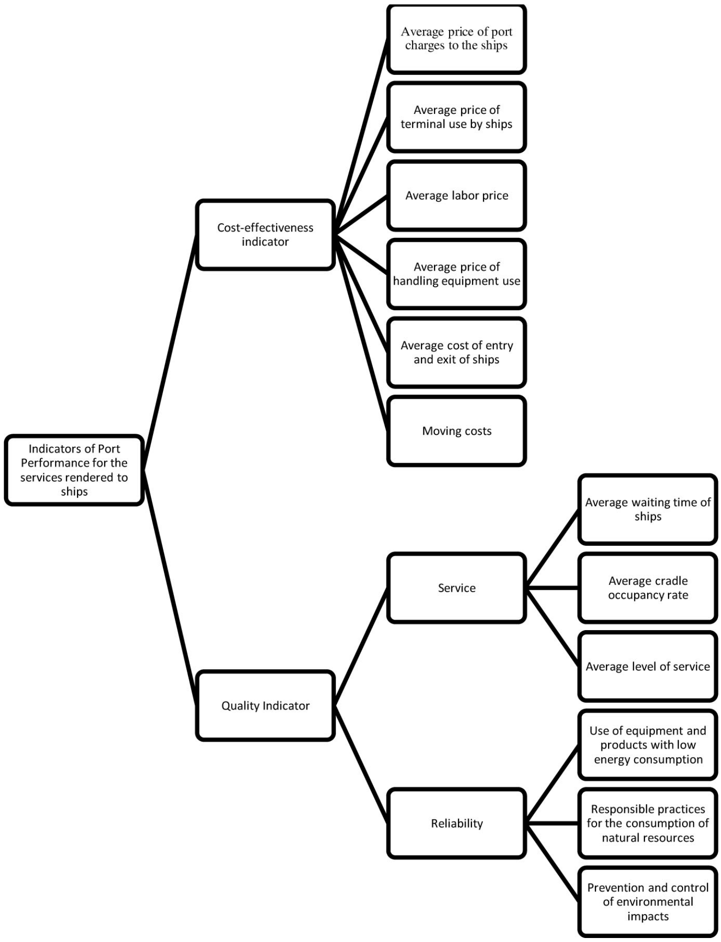

Figure 2 – Hierarchical matrix of port efficiency indicators.

For the Wilcoxon test (1945), a significance level of 5% was adopted, yielding a p value of 0.094 for the consistent matrices and a p value of 0.17 for the inconsistent matrices. The result indicates that there is no significant difference between the medians of the two samples for both the consistent and the inconsistent matrices.

By comparing the method of Kaufmann and Grupta (1988) with that of Chang (1981), through the application of the non-parametric test, we find p equals 0.0087 for the consistent matrices and 0.0088 for the inconsistent matrices. Therefore, these results indicate that there is statistical evidence of significant difference in the medians of the paired samples between the methods under discussion.

To check for the robustness of the results obtained in the first test, the Wilcoxon test (1945) was applied to Chang (1981) and Centroid's (Bortolan *et al*, 1985) methods. The same values were obtained, that is, Kaufmann and Grupta's (1988) result was consistent with that of Chang (1981).

Thus, the robustness of both Kaufmann and Grupta (1988) and for Centroid's (Bortolan *et al*, 1985) methods was supported.

It should be noted that for statistical inference in this study, software R was used for the defuzzification of the values of the matrices adopted. R is free software, created in 1993 by Ross Ihaka and Robert Gentleman, with the purpose of manipulating, analyzing and graphically visualizing the processed results. This work used a spreadsheet developed by the authors.

After choosing the appropriate defuzzification method, the Fuzzy AHP methodology was applied, and the following global decision matrices were found, starting with the matrix listing the indicators of economicity (table 4), followed by quality in terms of service (table 5) and, lastly, quality in terms of reliability (table 6).

Tables 4, 5 and 6 were obtained from the individual decision matrices, these are grouped by calculating the geometric mean in a global decision matrix. This was performed after the defuzzification process. Later the fuzzification process was applied through the rules for m, exposed in the previous sections, i.e., turning the crisp into a triangular fuzzy number again. For this transformation, the formalism of Kaufmann and Grupta (1988) was applied, which was previously verified to be the one that best fits the data of the present study.

Table 4 – Matrix of economicity indicators.

	C_1	C_2	C_3	C_4	C_5	C_6
C_1	$(1,1,1)$	$(0.72;0.99;1.45)$	$(0.66;1.04;1.93)$	$(0.89;1.45;2.59)$	$(1.05;1.89;2.85)$	$(1.30;2.19;3.50)$
C_2	$(0.80;1.04;1.61)$	$(1,1,1)$	$(0,62;0,99;1,87)$	$(0.96;1.58;2.89)$	$(0.70;1.27;2.50)$	$(0.55;0.99;2.08)$
C_3	$(0.59;0.94;1.74)$	$(0.62;0.99;1.87)$	$(1,1,1)$	$(0.62;0.99;2.01)$	$(1.60;2.96;5.36)$	$(1.48;2.50;4.47)$
C_4	$(0.38;0.68;1.10)$	$(0.40;0.63;1.20)$	$(0.49;0.85;1.59)$	$(1,1,1)$	$(1.08;2.53;4.37)$	$(1.18;1.82;3.55)$
C_5	$(0.34;0.52;0.93)$	$(0.35;0.62;1.41)$	$(0.21;0.31;0.72)$	$(0.22;0.39;0.91)$	$(1,1,1)$	$(0.79;1.29;2.76)$
C_6	$(0.28;0.59;0.7643)$	$(0.55;0.99;2.08)$	$(0.25;0.38;0.78)$	$(0.32;0.54;0.98)$	$(0.36;0.60;1.25)$	$(1,1,1)$

Table 5 – Matrix of service indicators.

	C_1	C_2	C_3
C_1	$(1,1,1)$	$(2.9671;5.7755;6.6636)$	$(0.8395;1.1825;2.1084)$
C_2	$(0.1678;0.216;0.3649)$	$(1,1,1)$	$(0.5893;0.8955;1.4839)$
C_3	$(0.5515;0.8395;1.3835)$	$(0.667;1.1118;1.6773)$	$(1,1,1)$

Table 6 – Matrix of reliability indicators.

	C_1	C_2	C_3
C_1	$(1,1,1)$	$(0.8546;1.5217;2.8625)$	$(0.7304;1.4146;2.7282)$
C_2	$(0.4767;0.6524;1.599)$	$(1,1,1)$	$(1.8529;2.5672;4.9854)$
C_3	$(0.5016;0.7007;1.8734)$	$(0.3201;0.3867;0.8629)$	$(1,1,1)$

Following the analysis, the following weights, depicted in descending order, were obtained for each indicator category, according to table 7.

Table 7 – Priorities regarding economicity.

Criterion	Indicator	Weight
C_3	Average labor price	20.43%
C_1	Average price of port charges to the ships	19.47%
C_4	Average price of handling equipment use	18.30%
C_2	Average price of terminal use by ships	17.47%
C_5	Average cost of entry and exit of ships	12.58%
C_6	Average handling cost	11.71%

Table 8 – Priorities regarding service.

Criterion	Indicator	Weight
C_1	Average waiting time of ships	72.12%
C_3	Average level of service	22.49%
C_2	Average cradle occupancy rate	5.38%

Table 9 – Priorities regarding reliability.

Criterion	Indicator	Weight
C_2	Use of equipment and products with low energy consumption, reducing environmental impact (efficient consumption, rational use of energy, and others)	39.24%
C_1	Responsible practices for the consumption of natural resources: qualification, environmental training, education, and environmental awareness	37.67%
C_3	Prevention and control of environmental impacts: fines due to environmental accidents	23.07%

For economicity, the experts determined which of the indicators are most important for port performance. Therefore, it should be noted that between the indicator of average labor costs and that of port taxes on ships, there is no significant difference concerning their importance, implying that these indicators should be prioritized at the time of decision making or even in the analysis of potential improvements for this category.

Table 8 show the importance of the average waiting time of ships as an indicator of port performance efficiency. This was followed by the average level of waiting occupation and average occupancy rate of the cradle.

For reliability pode ser observado na tabela 9, it can be noted that the use of equipment and products with low energy consumption and responsible practices for the consumption of natural resources have a relatively high importance, followed by the prevention and control of environmental impacts.

4 CONCLUSIONS

This study was conducted from the perspective of three defuzzification methods: Centroid (Bortolan *et al*, 1985), Kaufmann and Grupta (1988), and Chang (1981). According to Oyeda *et al* (2012), the Wilcoxon Signed Rank Test, which is applied to paired observations, is based on the difference between these observations. It was verified that there is significant statistical evidence of difference between the methods of Kaufmann and Grupta (1988) and Chang (1981), and between Centroid (Bortolan *et al*, 1985) and Chang (1981). There is no statistical evidence of a difference between the Centroid (Bortolan *et al*, 1985) and Kaufmann and Grupta (1988) methods. It was verified that regardless of the consistency of the matrix, any of the methods could be used in the defuzzification process of the Fuzzy AHP methodology.

The defuzzification methods, in particular that of Kaufmann and Grupta (1988), which was chosen to transform the fuzzy number into crisp, is directly linked to the results obtained, as mentioned in the previous sections, the values obtained are determined by FAHP and verified consistency through this process.

The FAHP method uses subjectivity, which is measured by fuzzy logic with fuzzy numbers, allied to mathematical formalism. This mechanism takes the opinion of decision makers and converts, through fuzzy logic, into hierarchical powers for both criteria and alternatives. Thus, this is the main difference between FAHP and AHP, thus leading to a relevant advantage of using the methodology.

In addition to analyzing the method for defuzzification, computational tests were performed to compare the results obtained by FAHP and AHP without adjustment. According to Bulut and Duru (2017) AHP is very functional and popular in academia and professional life, but AHP methodology has several underlying assumptions, and each assumption needs to be investigated and demonstrated through specific decision-making problems. Eventually inconsistencies imply invalidation of the results obtained. Dong et al (2015) adds by stating that eventually inconsistencies imply invalidation of the results obtained and that consistency is critical for decision problems.

By comparing the methods, it was found that the change in the hierarchy of results was obtained only with respect to the economic indicator. Thus, from the indicators can detect possible deficiencies and dysfunctions, making it possible to align management actions of diagnosis and correction.

The study on the indicators is not exhaustive and is delimited by the particular scenario generated around the Rio Grande Port. The percentages presented by FAHP are closer to the preferences of managers of Porto Novo do Rio Grande not excluding judgments that cause inconsistency.

It was also verified that specialists are concerned with the management of port operations from the perspective of economicity, since according to them, the most prominent indicator is the average price of labor, as labor costs are linked to the cost of qualification through courses, in addition to the high specificity in the execution of tasks. Three of the six criteria presented were related to greater operational vulnerability, implying that they would have an impact on the operational cost.

For the service quality indicators, the results obtained indicate that the professionals are concerned about the waiting time for the ship to dock at the terminal, as this delay compromises overall port management and the port's efficiency and effectiveness.In addition, the waiting time of the ship is directly affected by the problems of logistics, infrastructure and bureaucracy, since like other Brazilian ports, the Porto Novo of Rio Grande is in adaptation to the paperless port project, which is destined to reduce the bureaucracy and the computerization of it.

Finally, the indicators linked to reliability reflected the importance assigned to the environment, because among the indicators presented, the most prominent were responsible practices for the use of equipment and products with low energy consumption, in addition to practices such as environmental training for personnel whose activities would affect the environment.The highlighted indicator exposes the concerns of port management in the conscious consumption, in the mitigation of the environmental impact, in order that it becomes a conscious port.

It is important to note that the contribution of this article in Operational Research is to apply a FUZZY-AHP mathematical model to measure performance indicators, which will contribute to the assessment of port efficiency without the need for complicated equations and difficult to determine their variables.

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