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ARTICLES

STUDY FOR DECENTRALIZATION OF NAVAL POWER IN THE BRAZILIAN NAVY: STRUCTURING AND MATHEMATICAL MODELING IN THE LIGHT OF THE ELECTRE-MOR METHOD

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ABSTRACT. The Brazilian Navy (BN) has its combatant force concentrated in an area with only one exit to the sea. Nevertheless, Brazil has an extensive coast that needs to be patrolled and, in case of any kind of conflict, the BN must be able to defend the sovereignty and interests of the country. For this purpose, a robust and decentralized naval force is necessary, which allows the fulfillment of its mission. This paper aims to classify the most suitable cities in Brazil to be established as naval bases by applying the ELECTRE-MOr hybrid method. Seventeen cities were analyzed, which have an opening to the sea and a pre-existing minimum port structure. The alternatives were evaluated by specialists from the BN, with more than twenty years of active service, in the light of operational, economic and strategic criteria. As a result, five alternatives were classified as the most indicated headquarters for the decentralization of the naval power: Belém/PA, São Luis/MA, Fortaleza/CE, Recife/PE and Aratu/BA. This article presents relevance to academia and society, as it represents the application of a method in the state of the art to support the decision-making process in a significant problem for the sovereignty of Brazil, presenting a methodology that can be applied in issues of tactical, operational, strategic and political levels.

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1 INTRODUCTION

The National Defense Strategy (NDS), enacted in 2008 and updated in 2012, aims to prepare and apply the Naval Power, considering the means, obstacles and objectives to be fulfilled, to achieve and maintain the goals of the National Defense Policy (NDP). In this sense, the preparation of the Naval Power consists of a set of activities performed to strengthen it. The efficiency of such practice depends on policies and strategies that provide the necessary conditions for the country's development process (Marinha do Brasil, 2019).

The NDS was also developed to meet the equipment needs of the Military Commands, reorganizing the defense industry so that the most advanced technologies are under national control and instituting medium and long-term strategic actions aimed at modernizing the national defense structure (National Defense Policy (NDP)/National Defense Strategy (NDS), 2012).

The NDP also establishes as a priority area the Brazilian strategic environment, which includes the South Atlantic, and covers the Blue Amazon. According to the objectives and guidelines constituted by this document and the NDS, which form the high-level documents that condition the preparation and use of the Armed Forces, the Brazilian Navy (BN) is responsible for using the Naval Power. According to Vilela (2020), this power must provide sufficient capacity and credibility to dissuade enemy forces from carrying out actions in the Blue Amazon (a maritime area in the Atlantic Ocean that Brazil has for economic activities).

The BN's Mission was updated in 2016, having as references Article 142 of the Brazilian Federal Constitution (FC) and Complementary Law No. 97/99, and the following statement was established: "Prepare and employ the Naval Power to contribute to the Defense of the Homeland; for the guarantee of constitutional powers and, on the initiative of any of these, law and order; for the fulfillment of the subsidiary attributions provided for by law; and for support for foreign policy".

The Naval Power must have means capable of detecting, identifying and neutralizing actions that pose a threat in Brazilian Jurisdictional Waters (BJW). Furthermore, the intensification of the occurrences of illegal acts at sea (such as piracy, drug and human trafficking, illegal fishing, environmental crimes, among others) demand the state presence under the international law with which Brazil has committed itself. To this end, the Naval Power should also maintain security in maritime communication lines with national interests (Brazilian Navy 2019).

According to Leal Ferreira (2019), over the last few years, much has been discussed about the constitution of the so-called Second Squadron, supported by a Naval Base capable of meeting the logistical needs arising. Numerous reasons justify a more significant presence of the Brazilian Naval Power in the Blue Amazon.

Therefore, it will be of great value for the BN to establish another headquarters for its squadron, which would provide a tactical, operational, and strategic military gain for Brazil. However, given the continental dimensions of the country and many coastal cities, the decision process to select the most suitable city is involved in complexity and subjectivity.

In this context, the Multiple Criteria Decision Analysis (MCDA) is a set of formal approaches which seek to take explicit account of multiple criteria in helping stakeholders and groups explore decisions that matter (Belton & Stewart, 2002). These decisions almost universally involve numerous conflicting objectives, costs and benefits accruing to various individuals, businesses, groups and other organizations (Keeney et al., 1993).

Despite the diversity of MCDA approaches, methods and techniques, their essential elements are a finite or infinite set of actions (alternatives, solutions, courses of action, etc.), at least two criteria, and at least one Decision-Maker (DM). Thus, MCDA is an activity that helps make decisions, mainly in choosing, ranking, or sorting the actions (Greco et al., 2016) and gained traction in academic and industry practices for effective decision-making (Basílio et al., 2022).

In this sense, Almeida et al. (2021) conducted a study to choose a headquarter for the second Brazilian fleet in the light of operational criteria and related to the maintenance structure, considering cities with a previously established base structure. This article presents an extension of the research conducted by those authors, with the following additional contributions:

1. We considered cities that cover practically the entire Brazilian coast, including alternatives that do not present an established basic structure.
2. We considered economic criteria, considering the hypothesis of building a basic structure in the cities chosen to be the basis of the second fleet; and
3. Considering that the choice of headquarters for the decentralization of Brazilian naval power takes into account economic, political and strategic factors, in this article, our objective is to establish a group of more indicated cities, and not just an alternative, as done in the research made by Almeida et al. (2021).

In short, the objective of this article is to classify alternative bases for the decentralization of the naval power of the Brazilian Navy, by applying the ELECTRE-MOr multicriteria method. Furthermore, this application aims to establish the clusterization of alternatives, presenting those cities that the naval administration should prioritize as possible bases for the second Brazilian squadron.

The relevance of this research is due to the application of a method in the state of the art to support the decision-making process in a highly significant problem for the sovereignty of Brazil, presenting relevance for naval administration, academia, and society because the methodology presented can be applied in problems of tactical, operational, strategic and political levels.

2 LITERATURE REVIEW

The academic literature contains many examples of the application of MCDA in the military field. Costa et al. (2022a) presented a literature review on the main military applications of MCDA, highlighting that most of the problems in this area refer to the strategic level, more specifically logistical aspects and acquisitions of military equipment.

Costa et al. (2022a) also analyzed the most applied MCDA methods in military problems (Table 1) and concluded that the Analytic Hierarchy Process (AHP) is the most used MCDA method in military problems, corroborating the findings of Vaidya and Kumar (2006) and Santos et al. (2021).

Table 1 – Distribution of MCDA methods. Source: Costa, et al., 2022a.

MCDA method	Percentage
AHP	43.80%
Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)	22.17%
Analytic Network Process (ANP)	6.30%
Condorcet	3.56%
Preference Ranking Organization Method for Enriching Evaluations (PROMETHEE)	3.56%
ELimination Et Choix Traduisant la REalité (ELECTRE)	3.56%
Decision Making Trial and Evaluation Laboratory (DEMATEL)	3.01%
Organísation, rangement et synthèse de données relarionnelles (ORESTE)	3.00%
VIseKriterijumska Optimizacija I KOmpromisno Resenje (VIKOR)	2.44%
Borda	2.06%
Verbal Decision Analysis (VDA)	1.13%
Multiattribute Utility Theory (MAUT)	1.10%
THOR	0.94%
Reference Ideal Method (RIM)	0.56%
Full Consistency Method (FUCOM)	0.56%
Simple Multi Attribute Rating Technique (SMART)	0.56%
REGIME	0.56%
TODIM	0.38%
Utility Additive (UTA)	0.38%
FITradeoff	0.38%
Copeland	0.38%

According to Santos et al. (2021), the preponderance of the AHP is justified by its modeling, which involves concepts of hierarchy and compensatory decision rules, which are following the military culture. These features facilitate analysis by military experts.

The literature review carried out in this research allowed us to verify that most applications of MCDA methods in the military field refer to the strategic level (about 60% of documents), mainly dealing with logistical, personnel and acquisition problems (Bastian et al., 2016; Jardim et al., 2020; Jou et al., 2016; Koban & MacDonald Gibson, 2017; Moreira et al., 2023; RC. APereira et al., 2022; Wang & Zheng, 2012). On the other hand, operational/tactical levels can be represented by threat assessment, military operations planning, war tactics, among others (Frini et al., 2017; Han et al., 2014; Weir et al., 2014).

Regarding the trends in publications on the topics analyzed, there was a growing number of logistical applications and acquisitions of military assets, most of them with a high level of technology and added value.

Problems related to site selection contain many conflicting criteria, and increasingly such a decision is part of the military strategic management activity (Oztaysi et al., 2019). In this sense, we analyzed the main MCDA applications in location selection problems for military contexts (Table 2).

Table 2 – MCDA applications in location selection problems for military contexts.

Authors	Source	Methods
(Sennaroglu & Varlik Celebi, 2018)	Transportation Research Part D: Transport and Environment	AHP, PROMETHEE and VIKOR
(Farahani & Asgari, 2007)	European Journal of Operational Research	TOPSIS
(Gigović et al., 2016)	Sustainability	DEMATEL and ANP
(Bozanic et al., 2018)	Decision Making: Applications in Management and Engineering	AHP and Multi-Attributive Border Approximation Area Comparison (MABAC)
(Akgün & Erdal, 2019)	Computers & Industrial Engineering	AHP and TOPSIS
(Lai, 2019)	Applied Soft Computing	AHP
(Curran et al., 2014)	Procedia Engineering	Multi-Attribute Value Theory (MAVT) and PROMETHEE II

The literature review revealed several applications combining MCDA methods to support the decision-making process in military problems, in most cases applying a method to obtain the weights of the criteria and another one to evaluate the alternatives, taking advantage of each method's characteristics. The modeling presented in this paper distributes the alternatives into pre-defined categories, offering some differences from the other ELECTRE methods, such as the input of ordinal weights, multiple DM, and evaluating quantitative and qualitative criteria (Costa et al. 2021).

Also, the ELECTRE-MOr method presents two ways of obtaining the lower limits of pre-defined classes, providing two distributions of the alternatives. According to Souza et al. (2018), showing two ordinations after applying the method allows a sensitivity analysis of the result, giving greater transparency and robustness to the decision-making process.

2.1 Multicriteria Decision Analysis

The usefulness of the outranking model comes from the fact that it is based on relatively weak mathematical assumptions. It attempts to enrich the dominance relation by strongly established preferences, accepting incomparability and neither imposing completeness nor transitivity of preference: indifference, weak preference, strict preference, and incomparability. Sometimes is not an easy task for a decision-maker because it requires fixing a precise numerical value for such parameters as importance coefficients (weights) of criteria (Greco et al., 2011). Real-world decision problems are rarely mono-criterion-based. They generally incorporate a variety of criteria, often contradictory. In many practical situations, alternatives must be ranked given multiple, conflicting criteria of preference (Silva et al, 2018).

Considering a real decision-making problem, uncertainty is intrinsic (Moreira et al., 2021). According to Kou et al. (2014), ordinal and cardinal inconsistencies are essential and popular research topics in studying the decision-making process. Methods used as decision aid should enable an integrated algorithm, permitting qualitative and quantitative data (Malloy et al. 2017). In decision analysis, uncertainty regarding evaluating a problem is recurrent, considering that obtained information can present a lack of complete data or certainty (Dong et al., 2018).

Among the various MCDA methods available, we verified that the ELECTRE-MOr method has good adherence to the problem. It distributes the alternatives in pre-defined classes and analyses a set of alternatives considering both quantitative and qualitative criteria, structuring the weights of criteria by ordinal inputs.

Therefore, this paper aims to propose an action plan based on applying the ELECTRE-MOr method, which facilitates DMs' expression of preference relationships, contributing to transparent and reliable decision-making.

2.2 ELECTRE-MOr method

The ELECTRE-MOr, proposed by Costa et al. (2021), is a new multicriteria sorting method with ordinal weight input that includes multiple decision-makers and distributes the alternatives into pre-defined categories.

For the establishment of preference relationships, the method establishes three fundamental situations of comparison between alternatives and pre-defined class limits (Costa et al. 2022b):

Weak Preference / Indifference threshold (q): The indifference threshold, q, between two performances, is the largest performance difference that is judged compatible with an indifference situation between two actions with different performances. This difference (which is by definition non-negative) can be equal to zero and it is at most similar to the preference threshold (Roy et al. 2014);

Strict preference (p): the preference threshold, p, between two performances is the smallest performance difference that, when exceeded, is judged significant of a strict preference in favour of the action with the best performance. This difference (which is by definition non-negative) can be equal to zero (which corresponds to the case of the true-criterion model) (Roy et al. 2014);

Veto (v): Limit defined for each criterion that sets a value for the difference gj(b)-gj(a) (difference concerning criterion j and discordant of the statement aSb), from which the proposition aSb will not be accepted (Gomes et al. 2010; Gomes & Gomes 2019).

To obtain the weights and evaluate qualitative criteria, the ELECTRE-MOr method uses an adaptation of the SAPEVO-M method (Gomes et al. 2020), transforming ordinal preferences of criteria into a vector of criteria weights and integrating the preferences of different DMs, by applying the scale of pairwise comparisons presented in Table 3.

Table 3 – Relationship and scale.

Relationship	Scale
is much less important than	− 2
is less important than	− 1
is as important as	0
is more important than	1
is much more important than	2

This relationship associated to a scale allows transforming the matrix $D_K = [\delta_{ij}]$, where k = decision-makers, into a column vector [v_i], such that (Costa et al., 2021) (1):

$$\sum_{j=1}^{m} (c_i)\,, \, for \; i = 1,\ldots,m \wedge k = 1,\ldots,n \tag{1}$$

Where c_i represents the degrees assigned in the pairwise evaluation of the criteria, according to the scale presented in Table 3. Once the matrix integration process is finished, the resulting vector is normalized, which ensures the generation of non-negative values (2):

$$\overline{c_i} = \left(\frac{a_{ij} - \min a_{ij}}{\max a_{ij} - \min a_{ij}} \right) \tag{2}$$

From the study of the ELECTRRelationship and scale.E methods, the indices of concordance, discordance and credibility were developed:

a) Concordance index (3):

The condition (p>q) must be met so that the result of the calculation is not equal to zero.

$$c_j(a,b_h) = \begin{cases} 0 \text{ if } g_j(b_h) - g_j(a) \geq p_j(b_h) \\ 1 \text{ if } g_j(b_h) - g_j(a) \leq q_j(b_h) \\ \text{ if } p_j \geq g_j(b_n) - g_j(a) > q_j \\ 1 - \left(\frac{-g_j(b_h)+g_j(a)+q_j}{-p_j - q_j} \right) \end{cases} \tag{3}$$

b) Comprehensive concordance index (4):

$$c(a,b_h) = \frac{\sum_{j \in F} w_j c_j(a,b_h)}{\sum_{j \in F} w_j} \tag{4}$$

c) Discordance index (5):

The condition (v>p) must be met so that the result of the denominator calculation is not equal or minus to zero.

$$d_j = \begin{cases} 0 \text{ if } g_j(a) - g_j(b) \leq p \\ 1 \text{ if } g_j(a) - g_j(b) > v \\ \text{if } v > g_j(a) - g_j(b) \geq p \\ \left(\frac{g_j(a) - g_j(b) - p}{v - p}\right) \end{cases} \tag{5}$$

d) Credibility index (6):

$$\sigma(a, b_h) = c(a, b_h) \prod_{j \in F} \frac{1 - d_j(a, b_h)}{1 - c(a, b_h)} \tag{6}$$

e) Lower limit classes b_h and b_n:

The classes in C are delimited by two ways of obtaining profiles:

- set Bh = $\{bh_1, bh_2, \ldots, bh_p\}$; and
- set Bn = $\{bn_1, bn_2, \ldots, bn_p\}$.

The bh threshold is obtained considering the number of profiles p established by the DM, dividing the interval between each criterion's maximum and minimum values into p+1 equal parts. Let g_j^* and g_j^- be the maximum and minimum values, respectively, presented by the alternatives in each criterion. Then, Costa et al. (2021) define the interval h_j between consecutive profiles (7), (8).

$$h_j = \frac{g_j^* - g_j^-}{p+1} \tag{7}$$

$$bh_i = g_j^- + i * h_j; \quad i = 1, \ldots, p \tag{8}$$

Figure 1 illustrates the establishment of class profiles obtained through the bh procedure.

The bn procedure establishes profiles for each criterion so that each subclass has the same number of alternatives. Let n be the number of alternatives. In procedure bn, a decreasing pre-order of the alternatives is established, such that $a_i = \{a_1, a_2, a_3 \ldots, a_n\}$, where a_1 represents the score of the alternative with the best performance in a given criterion, and a_n, the worst score. For the definition of bn thresholds, we calculate a parameter k, which serves as a basis for obtaining the indices and values of the profiles (9).

$$k = \frac{n}{p+1} \tag{9}$$

After defining the value of k, we obtain the bn profiles, such that $bn_i = \{bn_p = a_k, bn_{p-1} = a_{2k}, \ldots bn_1 = a_{pk}\}$, where p is the number of profiles, bn_p represents the lower limit of the highest class (Class 1), and bn1, the upper limit of the worst class (Class p+1). Figure 3 shows the establishment of class profiles obtained through the bn procedure.

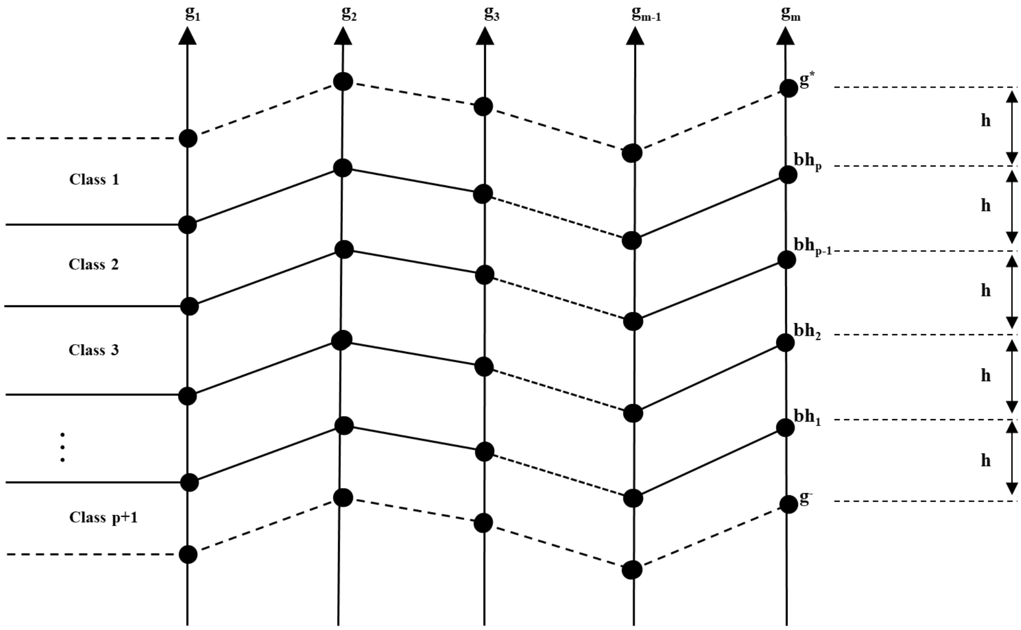

Figure 1 – The bh procedure of the ELECTRE-MOr method (Costa et al., 2022b).

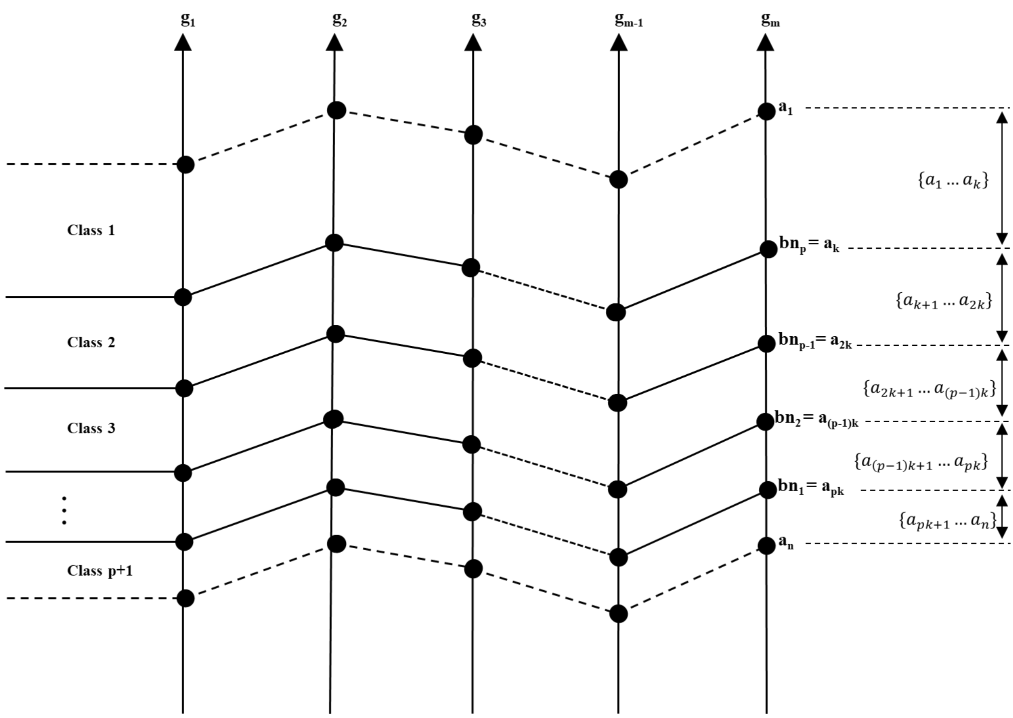

Figure 2 – The bn procedure of the ELECTRE-MOr method (Costa et al., 2022b).

f) Cutting level:

The aSb_h statement means that “the alternative to does not perform worse than the bh profile”. In validating the aSb_h statement, a credibility index σ (a, bh) is calculated, which expresses the degree of confidence of the statement “a is no worse than bh”. To define the outranking ratio, the cut-off level λ (9) is adopted.

$$b_n aSb_h \leftrightarrow \sigma(a,b_h)\geq\lambda \tag{10}$$

The distribution is carried out through two procedures:

(a) Optimistic: it consists of comparing the alternative successively to alternative b, from the last profile (category, class);

(b) Pessimistic: It compares alternative a successively to alternative b, starting from the first profile (category, class), the most demanding classification.

The ELECTRE-MOr has some advantages over the other methods of the ELECTRE family (Costa et al. 2022b):

- The elicitation of weights of the criteria by an ordinal form, since this is not an easy task for a DM, requires establishing a precise numerical value for such parameters as the importance coefficients of criteria. Besides, the method allows the evaluation of the criteria by multiple decision-makers.
- Two ways of obtaining the lower limits of the classes (bh and bn), which provides 4 different sorts (2 optimistic and 2 pessimistic), allowing a more robust and reliable sensitivity analysis of the results.

As recent and relevant applications of the ELECTRE-MOr method, one can cite: classification of the OECD Countries (Pereira et al., 2022); classifying flying hospitals (Costa et al., 2021) and vaccines (De Paula et al., 2022) against COVID-19; additive manufacturing (Drumond et al., 2021); course portfolio management (Costa et al., 2022b); Risk analysis related to the corrosion of atmospheric storage tanks (Moreira et al., 2023); algorithm for personnel selection (Costa et al., 2022c).

3 MATERIALS AND METHODS

Problem Structuring Methods (PSM) are stages of the decision-making process that aims to organize issues, questions and dilemmas for which decision propositions are sought (Costa et al., 2020). PSM is widely accessible in Operational Research (OR) and the movement of systems for understanding and structuring complex problems (Rosenhead & Mingers, 2001).

Every model has validity only within a particular managerial context, which, in addition to taking into account the specificities of the organization studied, also has a “space-time” validity (Santos, 2018).

Among the most used PSM, this paper will use the Soft Systems Methodology (SSM) (Checkland, 1981), which has been explored in a variety of research fields and serves equally diverse practical interests.

SSM presents seven stages of application (Checkland, 1981), which two of them will be addressed in this paper for the problem structuring:

1. explore an unstructured problematic situation; and
2. express it by making a rich picture.

In the first stage, the brainstorming technique was used by the authors to demonstrate the perceptions of the group about all possible information, without interference or judgments to define the problem. In the second stage, a rich picture was constructed (Figure 3) to express all relevant aspects of the problem.

According to Checkland (1981), the rich picture is a simple SSM tool, helpful in opening the discussion around individual perceptions towards a broad view of the different issues affecting the situation. They are created freely and unstructured to capture the participants' interpretation of a real situation (Rose, 1997).

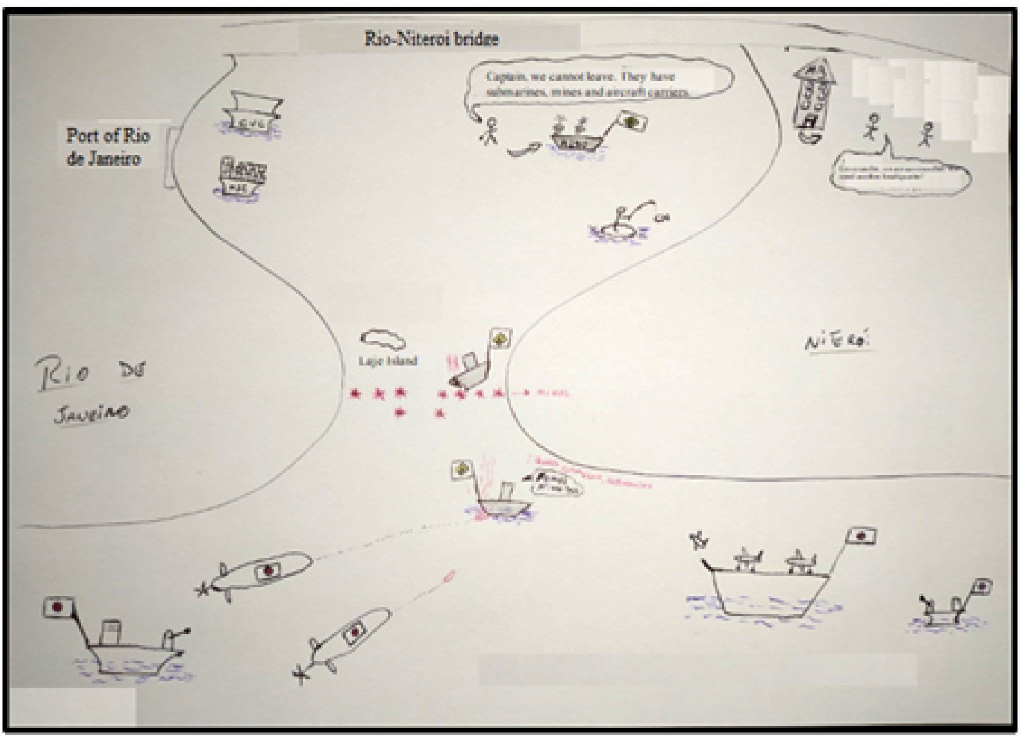

Figure 3 – Rich picture, entitled "Need for a second Fleet" (Almeida et al., 2021).

The rich figure shows difficulty for the Brazilian Navy if multiple coordinated attacks are distributed along the Brazilian coast. This deficiency is caused by the fact that the BN Squadron is based in the interior of Guanabara Bay, facilitating the action of hostile means in creating some blockade, which would prevent ships from leaving their base. This possibility makes it impossible the permanence of an entire squadron in a single place.

After analysing the rich picture and consulting three BN officers (specialists) with more than 20 years of experience, we established seven criteria: Distance from Rio de Janeiro by sea (C1), Exit Width (C2), Distance to the Sea (C3), Square Meter Value (C4), Port structure (C5), Preexisting Naval Base (C6) and City Infrastructure (C7).

Also, seventeen alternatives of cities to be established as the headquarters were chosen to compose the problem studied in this paper: Santana/AP, Belém/PA, São Luís/MA, Luís Correia/PI, Fortaleza/CE, Natal/RN, Cabedelo/PB, Recife/PE, Maceió/AL, Aracajú/SE, Aratu/BA, Porto Seguro/BA, Vitória/ES, Santos/SP, Paranaguá/PR, Itajaí/SC and Rio Grande/RS.

3.1 Presentation of criteria

- C1 - Distance to Rio de Janeiro by the Sea (NM): It is known that the Brazilian coast is extremely extensive and that there is a need to cover as much area as possible. Because of this, the further away from Rio de Janeiro these possible facilities for Decentralization of the Naval Power, the better it will be to enable the coverage of the coast.
- C2 - Output Width (Mts): The width for access to the sea is an essential point in the site strategy, since the greater this exit, the greater the difficulty of the possible enemy generates some kind of dam or blockade in this location.
- C3 - Distance to the Sea (KM): This is the approximate distance from the possible place where the naval base will be established in each city to the area where it is considered the smallest area necessary to maneuver with the vessels in safety.
- C4 - Square Meter Value: The average values of the square meter of these cities were considered, aiming at the worst situation that would be the need to purchase some area and later the need to build some physical basis for the operation of these new structures. The data was released in December/2020 and acquired according to the website FipeZap (2021);
- C5 - Port Structure: It was established by surveying some characteristics such as Spaces for mooring, the possibility of support with water network and receiving energy through electrical cables.
- C6 - Preexisting Naval Base: For this criterion, a binary system was established where “0” is inserted for cities that do not have a Naval Base and “1” for those cities that have it; and

- C7 - City Infrastructure: The situation for each city was analyzed concerning the population with their respective offers of specialized labor and industries that are somehow present in the selected cities.

We emphasize that, despite the problem addressed in this paper being strategic, our analysis also considered tactical criteria, such as the Output Width, because this characteristic is relevant to the decision-making process for classifying possible headquarters. Also, as a limitation, we emphasize that military data can be confidential, so only ostensible data were used in the present study.

3.2 Presentation of alternatives

After selecting the criteria and evaluating the cities with the potential to be the host for the second Brazilian squadron, the specialists have chosen seventeen cities that cover practically the entire navigable area of Brazil. Table 4 presents the attributes of the cities in each criterion.

Table 4 – Data from the cities evaluated.

Alternatives	C1	C2	C3	C4	C5	C6	C7
A1 - Santana/AP	2544	607	165	5890	2	0	1
A2 - Belém/PA	2217	1200	100	5213	4	1	4
A3 - São Luís/MA	1910	4700	15	5291	4	0	5
A4 - Luís Correia/PI	1731	170	4	5921	0	0	1
A5 - Fortaleza/CE	1505	1000	1.7	5882	3	0	5
A6 - Natal/RN	1233	200	5.5	5177.5	3	1	4
A7 - Cabedelo/PB	1165	1300	2	4473	2	0	3
A8 - Recife/PE	1086	300	4	6176	4	0	6
A9 - Maceió/AL	972	500	2.3	5101	2	0	4
A10 - Aracajú/SE	875	750	4	4013	0	0	3
A11 - Aratu/BA	755	450	27	5191	4	1	5
A12 - Porto Seguro/BA	539	470	1	5970	0	1	3
A13 - Vitória/ES	252	140	7.3	6993	5	0	5
A14 - Santos/SP	220	300	11	5512	7	0	6
A15 - Paranaguá/PR	350	2100	25	3521	5	0	4
A16 - Itajaí/SC	389	240	4.5	6382	6	0	5
A17 - Rio Grande/RS	755	500	18	3488	4	0	4

The alternatives will be evaluated in light of the five established criteria and will be distributed into three classes, i.e.:

- Class A: Cities that the high naval administration should prioritize, considered the most indicated to be the basis for the second fleet.

- Class B: Intermediate cities, which can be chosen if there are no alternatives in class A or those are not considered at the will of the decision-maker.
- Class C: Cities can be excluded as options because they have the worst classification among the alternatives.

4 RESULTS AND DISCUSSION

4.1 Evaluation of criteria

The initial part for applying the method is to obtain the weights of the criteria through the scale presented in Table 3, equations (1) and (2). Then, the opinions of the same decision-makers who defined criteria and alternatives were considered, thus obtaining the values of the weights according to Table 5.

Table 5 – Weights of the criteria, obtained by applying the ELECTRE-MOr method.

Criterion	Weights	
C1	Distance to Rio de Janeiro by the Sea	1.8
C2	Output width	3
C3	Distance to the Sea	1.6
C4	Square Meter Value	1.4
C5	Port Structure	2.6
C6	It has a Naval Base	2.1
C7	City Infrastructure	2.3

After the experts' analysis, we noted that the criterion with the most significant weight was the Width of the Exit, followed by the Port Structure, the City Infrastructure and the fact that it has a pre-existing Naval Base. The Criterion Square Meter value, which refers to the acquisition and construction of a structure for support, obtained the lowest value. The results are very coherent because the Exit Width, infrastructure aspects of the city and port are crucial points for a military base, which justifies the higher weights of these criteria.

4.2 Evaluation of alternatives

Table 6 presents the performance matrix used in evaluating the alternatives in the light of each criterion.

We applied the same methodology to obtain the weights of the criteria to evaluate the qualitative criteria C5 - Port Structure and C7 - City Infrastructure, because it is an arduous task to define, among 17 alternatives, a cardinal scale of preferences. Criterion C6 – Pre-existing Naval Base was evaluated on a binary scale, where the value 1 represents the existence of a Naval Base in the described city and the value 0 the absence. The criteria C3 - Distance to the Sea and C4 - Value of the Square Meter are negative because the best occurrence is the decrease of its parameters:

Table 6 – Performance matrix.

	C1	C2	C3	C4	C5	C6	C7
A1	2544	607	-165	-5890	2	0	1
A2	2217	1200	-100	-5213	4	1	4
A3	1910	4700	-15	-5291	4	0	5
A4	1731	170	4	-5921	0	0	1
A5	1505	1000	-1,7	-5882	3	0	5
A6	1233	200	-5,5	-5177.5	3	1	4
A7	1165	1300	-2	-4473	2	0	3
A8	1086	300	-4	-6176	4	0	6
A9	972	500	-2,3	-5101	2	0	4
A10	875	750	-4	-4013	0	0	3
A11	755	450	-27	-5191	4	1	5
A12	539	470	-1	-5970	0	1	3
A13	252	140	-7.3	-6993	5	0	5
A14	220	300	-11	-5512	7	0	6
A15	350	2100	-25	-3521	5	0	4
A16	389	240	-4.5	-6382	6	0	5
A17	755	500	-18	-3488	4	0	4
q	150	100	15	1000	1	0.5	1
p	300	200	50	2000	2	1	3
v	1200	500	120	5000	5	2	5
Weight	1,8	3	1.6	1,4	2,6	2,1	2,3
$\mathbf{b_{h2}}$	1769.33	3180.00	-52.33	-4656.33	4.67	0.67	4.33
$\mathbf{b_{h1}}$	994.67	1660.00	-108.67	-5824.67	2.33	0.33	2.67
$\mathbf{b_{n2}}$	1233.00	750.00	-4.00	-5177.50	4.00	0.00	5.00
$\mathbf{b_{n1}}$	755.00	300.00	-15.00	-5890.00	2.00	0.00	4.00

the lower, the better. After a meeting and consensus among the decision-makers, the thresholds of Strict Preference (p), Weak Preference (q) and Veto (v) were established. After the application of (7) and (8), bh and bn values were obtained.

4.3 Results

Completing all the steps of ELECTRE-MOr, for a cut-off level of 0.65, we obtain the optimistic and pessimistic classifications for the two forms of normalization bh and bn. This cut-off value was applied because it presents good discrimination regarding the sort of alternatives, shown in Table 7.

Table 7 – Results obtained after the application of the ELECTRE-MOr method.

bh			bn		
Alternative	**Pessimist**	**Optimist**	**Alternative**	**Pessimist**	**Optimist**
A1	C	B	A1	C	A
A2	C	B	A2	A	A
A3	A	A	A3	A	A
A4	C	B	A4	C	C
A5	C	B	A5	A	A
A6	C	C	A6	B	B
A7	B	B	A7	A	A
A8	C	B	A8	A	A
A9	C	C	A9	B	B
A10	C	C	A10	B	B
A11	C	B	A11	A	A
A12	C	C	A12	B	B
A13	C	B	A13	B	B
A14	C	B	A14	B	B
A15	B	B	A15	A	A
A16	C	B	A16	B	B
A17	C	C	A17	A	A

After analyzing the results, we verified four types of classification. To cluster the alternatives, providing the category into the three pre-defined classes, we have adopted the following parameters:

1. Any alternative with the same classification two, three or four times will be allocated in that determined class. So, for example, A3 will be distributed in Class A, because all its ratings have been A.
2. An alternative with two one-level and two lower-level rankings will be allocated in the lowest rank. For example, A17 will be allocated in Class C because two classifications are in Class A and two in Class C.

At the end of the process, we obtained the result, shown in Table 8.

Observing the results, we found that the cities A2, A3, A5, A8 and A11 obtained classification A. These cities can be prioritized by the Naval High Administration as the localities with the greatest possibility of implementing a support structure for ships because they presented, after the application of the ELECTRE-MOr method, the best performances among all alternatives. We highlight that, among the seventeen options, only five obtained performance that justified implementing a structure to support ships.

Table 8 – Distribution of alternatives in the pre-defined classes.

	Cities	Class
A2	Belém/PA	A
A3	São Luís/MA	
A5	Fortaleza/CE	
A8	Recife/PE	
A11	Aratu/BA	
A7	Cabedelo/PB	B
A13	Vitória/ES	
A14	Santos/SP	
A15	Paranaguá/PR	
A16	Itajaí/SC	
A1	Santana/AP	C
A4	Luís Correia/PI	
A6	Natal/RN	
A9	Maceió/AL	
A10	Aracajú/SE	
A12	Porto Seguro/BA	
A17	Rio Grande/RS	

Alternatives A1, A4, A6, A9, A10, A12 and A17 were allocated in class C, justifying the exclusion of these cities since they obtained the worst classification among all alternatives. Alternatives A7, A13, A14, A15 and A16 obtained classification B and can be considered for a possible application.

4.4 Analysis of results

Analyzing the causes that led the five alternatives to be distributed in the highest class, we note that such cities stand out in the criteria of higher weights, which ratifies the results obtained, presenting much coherence.

The alternatives that achieved the performance classified as B demonstrated a median performance in the evaluated criteria. On the other hand, in some cases, the alternatives obtained high scores on the criteria of higher weights but were balanced with low values in other criteria. For example, the alternative A15 presented the second-highest value in criterion C2 - Width to the Sea but was still classified as B.

For the analysis of the alternatives that obtained lower grades, class C, it is noticeable that, in general, all of them had values below expected in most criteria. Thus, for example, it is possible to highlight the alternative A6 that, even with high values in some criteria, obtained the third-worst value in the criterion C2 - Width for the Sea, which corroborated to obtain such classification.

Comparing the results of this research with the findings of Almeida et al. (2021), we found that the three best alternatives presented by that study obtained class A performance, while the last three presented performance related to the worst class. We emphasize that the set of alternatives evaluated in this study is higher than in that study (17 instead of 6).

4.5 Sensitivity Analysis

The ELECTRE-MOr method also allows sensitivity analysis to be performed, varying the cutting level and verifying the distribution of alternatives (Costa et al., 2022b). In this sense, table 9 summarizes the sensitivity analysis, with the distribution of alternatives after the variation of parameter λ. To verify more demanding and flexible scenarios, we used lower (0.55 and 0.6) and higher (0.7, 0.8, 0.9 and 1) values than the value of λ initially adopted as a reference (0.65).

Table 9 – Sensitivity analysis, varying the cutting level λ.

λ	0.55	0.6	**0.65**	0.7	0.8	0.9	1
A1 - Santana/AP	C	C	**C**	C	C	C	C
A2 - Belém/PA	A	A	**A**	B	C	C	C
A3 - São Luís/MA	A	A	**A**	A	A	A	B
A4 - Luís Correia/PI	C	C	**C**	C	C	C	C
A5 - Fortaleza/CE	A	A	**A**	A	B	C	C
A6 - Natal/RN	C	C	**C**	C	C	C	C
A7 - Cabedelo/PB	B	B	**B**	B	C	C	C
A8 - Recife/PE	A	A	**A**	B	C	C	C
A9 - Maceió/AL	C	C	**C**	C	C	C	C
A10 - Aracajú/SE	B	C	**C**	C	C	C	C
A11 - Aratu/BA	A	A	**A**	B	C	C	C
A12 - Porto Seguro/BA	C	C	**C**	C	C	C	C
A13 - Vitória/ES	B	B	**B**	C	C	C	C
A14 - Santos/SP	B	B	**B**	C	C	C	C
A15 - Paranaguá/PR	B	B	**B**	B	B	C	C
A16 - Itajaí/SC	B	B	**B**	C	C	C	C
A17 - Rio Grande/RS	C	C	**C**	C	C	C	C
Class A	29.41%	29.41%	29.41%	11.76%	5.88%	5.88%	0.00%
Class B	35.29%	29.41%	29.41%	29.41%	11.76%	0.00%	5.88%
Class C	35.29%	41.18%	41.18%	58.82%	82.35%	94.12%	94.12%

We verified consistent results after carrying out the proposed sensitivity analysis. As we increased the value of λ (making the analysis more demanding), there was a tendency towards a decrease in the alternatives in classes A and B, and an increase in the alternatives distributed in class C, corroborating the findings of Costa et al. (2022b).

We observed that only alternative A3 - São Luís remained in class A for the scenarios in which λ= 0.8 and 0.9. Also, we observed that, for the most demanding possible scenario (λ= 1), alternative A3 was allocated in class B, with all others being classified in the worst possible class.

In view of the above, the sensitivity analysis provided additional information to the DM, as it made it possible to verify the changes in the distributions of the alternatives when the cut-off level was varied (from 0.55 to 1). Such analysis allows decision-making based on more flexible or rigorous scenarios. The variation of λ and, consequently, of the distributions, can be used as a way of prioritizing the alternatives that remain in the higher classes with the increase in the cut-off level.

5 CONCLUSION

The application of the ELECTRE-MOr method considered the evaluation of three different specialists. It made it possible to obtain the values of the weights of the criteria, taking into account each opinion, making the analysis more robust and reliable. Considering the objective of the article, which was the support of the high Naval Administration in the decentralization of naval power, the great weight in the operational and strategic criteria is justified since even with the focus on not burdening the possible choices, one cannot leave the military part in low priority.

We emphasize that the method proved to be efficient for the proposed analysis, enabling the entry of ordinal weights, considering the opinion of multiple decision-makers, both in obtaining the weights and elicitation of the preference thresholds, veto and limits of the pre-defined classes. Moreover, the presentation of two classifications allows verifying the behaviour of alternatives in four different scenarios, which makes the analysis much richer, robust and transparent, making the method so useful for solving real problems of various types - tactical, operational and strategic - thus being a tool of great utility to academia and society.

Given the above, this paper's objective was achieved by presenting robust alternatives for choosing the best locations to apply a naval support structure. Finally, we suggest that this distribution model in pre-defined classes of alternatives using ELECTRE-MOr can be expanded in other military applications, seeking more ways to improve the Armed Forces and Public Security processes in Brazil and worldwide.

References

CROES GAAKGÜN İ & ERDAL H. 2019. Solving an ammunition distribution network design problem using multi-objective mathematical modeling, combined AHP-TOPSIS, and GIS. *Computers and Industrial Engineering*, **129**: 512–528. Available at: https://doi.org/10.1016/j.cie.2019.02.004

BASÍLIO MP, PEREIRA V, COSTA HG, SANTOS M & GHOSH A. 2022. A Systematic Review of the Applications of Multi-Criteria Decision Aid Methods (1977–2022). *Electronics*, **11**(11): 1720. Available at: https://doi.org/10.3390/electronics11111720

BASTIAN ND, BOGUCHWAL L, LANGHANS Z & EVANS D. 2016. A multi-criteria, network analytic approach to war game participant selection. *Journal of Defense Modeling and Simulation*, **13**(2): 183–194. Available at: https://doi.org/10.1177/1548512915586883

BELTON V & STEWART T. 2002. *Multiple criteria decision analysis: an integrated approach*. Springer Science & Business Media.

BOZANIC D, TESIC D & MILICEVIC J. 2018. A hybrid fuzzy ahp-mabac model: Application in the serbian army -the selection of thelocation for deep wading as a technique of crossing the river by tanks. *Decision Making: Applications in Management and Engineering*, **1**(1): 143–164. Available at: https://doi.org/10.31181/dmame1801143b

CHECKLAND PB. 1981. Systems Theory. *Systems Practice*.

COSTA IPA, COSTA AP. DE A, SANSEVERINO AM, GOMES CFS & SANTOS M DOS. 2022a. Bibliometric studies on Multi-criteria Decision Analysis (MCDA) methods applied in military problems. *Pesquisa Operacional*, *42*. Available at: https://doi.org/10.1590/0101-7438.2022.042.00249414

COSTA IPA, MAÊDA SM. DO N, TEIXEIRA LFH. DE S. DE B, GOMES CFS & SANTOS M DOS. 2020. Choosing a hospital assistance ship to fight the Covid-19 pandemic. *Revista de Saúde Publica*, *54*. Available at: https://doi.org/10.11606/S1518-8787.2020054002792

COSTA IPA, MOREIRA MÂL, DE ARAÚJO COSTA AP, DE SOUZA DE BARROS TEIXEIRA LFH, GOMES CFS & SANTOS M DOS. 2022b. Strategic Study for Managing the Portfolio of IT Courses Offered by a Corporate Training Company: An Approach in the Light of the ELECTRE-MOr Multicriteria Hybrid Method. *International Journal of Information Technology & Decision Making*, **21**(01): 351–379. Available at: https://doi.org/10.1142/S0219622021500565

COSTA IPA, SANSEVERINO AM, BARCELOS MR. DOS S, BELDERRAIN MCN, GOMES CFS & SANTOS M DOS. 2021. Choosing flying hospitals in the fight against the COVID-19 pandemic: structuring and modeling a complex problem using the VFT and ELECTRE-MOr methods. *IEEE Latin America Transactions*, **19**(6): 1099–1106. Available at: https://doi.org/10.1109/TLA.2021.9451257

COSTA IPA, TERRA AV, MOREIRA MÂL, PEREIRA MT, FÁVERO LPL, SANTOS M DOS & GOMES CFS. 2022c. A Systematic Approach to the Management of Military Human Resources through the ELECTRE-MOr Multicriteria Method. *Algorithms*, **15**(11): 422. Available at: https://doi.org/10.3390/a15110422

CURRAN RW, BATES ME & BELL HM. 2014. *Multi-criteria decision analysis approach to site suitability of U.S Department of Defense humanitarian assistance projects* (SD & VA. (eds.); Vol. 78, pp. 59–63). Elsevier Ltd. Available at: https://doi.org/10.1016/j.proeng.2014.07.039

DE ALMEIDA IDP, CORRIÇA JV DE P, COSTA AP. DE A, COSTA IP DE A, MAÊDA SM. DO N, GOMES CFS & DOS SANTOS M. 2021. Study of the Location of a Second Fleet for the Brazilian Navy: Structuring and Mathematical Modeling Using SAPEVO-M and VIKOR Methods. *ICPR-Americas 2020. Communications in Computer and Information Science*, **1408**: 113–124. Available at: https://doi.org/10.1007/978-3-030-76310-7_9

De Paula NOB, de Araújo Costa IP, Drumond P, Lellis Moreira MÂ, Simões Gomes CF, dos Santos M & do Nascimento Maêda SM. 2022. Strategic support for the distribution of vaccines against Covid-19 to Brazilian remote areas: A multicriteria approach in the light of the ELECTRE-MOr method. *Procedia Computer Science*, **199**: 40–47. Available at: https://doi.org/10.1016/j.procs.2022.01.006

De Souza LP, Gomes CFS & De Barros AP. 2018. Implementation of New Hybrid AHP-TOPSIS-2N Method in Sorting and Prioritizing of an it CAPEX Project Portfolio. *International Journal of Information Technology and Decision Making*, **17**(4): 977–1005. Available at: https://doi.org/10.1142/S0219622018500207

Dong Y, Liu Y, Liang H, Chiclana F & Herrera-Viedma E. 2018. Strategic weight manipulation in multiple attribute decision making. *Omega (United Kingdom)*, **75**: 1339–1351. Available at: https://doi.org/10.1016/j.omega.2017.02.008

Drumond P, Basílio MP, Costa IP de A, Pereira DA. de M, Gomes CFS & dos Santos M. 2021. Multicriteria Analysis in Additive Manufacturing: An ELECTRE-MOr Based Approach. In *Modern Management based on Big Data II and Machine Learning and Intelligent Systems III* (pp. 126–132). IOS Press.

Farahani RZ & Asgari N. 2007. Combination of MCDM and covering techniques in a hierarchical model for facility location: A case study. *European Journal of Operational Research*, **176**(3): 1839–1858. Available at: https://doi.org/10.1016/j.ejor.2005.10.039

FineZap. 2021. *Índice FipeZap registra nova alta no preço de imóveis residenciais em novembro*. Available at: https://fipezap.zapimoveis.com.br/wp-content/uploads/2020/12/fipezap-202011-residencial-venda.pdf

Frini A, Guitouni A & Benaskeur A. 2017. Solving Dynamic Multi-Criteria Resource-Target Allocation Problem Under Uncertainty: A Comparison of Decomposition and Myopic Approaches. *International Journal of Information Technology & Decision Making*, **16**(06): 1465–1496.

Gigović L, Pamuĉar D, Bajić Z & Milićević M. 2016. The combination of expert judgment and GIS-MAIRCA analysis for the selection of sites for ammunition depots. *Sustainability (Switzerland)*, *8*(4). Available at: https://doi.org/10.3390/su8040372

Gomes CFS, Gomes LFAM & Maranhão FJC. 2010. Decision analysis for the exploration of gas reserves: merging todim and thor. *Pesquisa Operacional*, **30**(3): 601–617. Available at: https://doi.org/10.1590/S0101-74382010000300006

Gomes CFS, Santos M dos Teixeira LFH. de S. de B, Sanseverino AM & Barcelos MR dos S. 2020. SAPEVO-M: a group multicriteria ordinal ranking method. *Pesquisa Operacional*, *40*. Available at: https://doi.org/10.1590/0101-7438.2020.040.00226524

GOMES L & GOMES CFS. 2019. *Princípios e métodos para a tomada de decisão: Enfoque multicritério*. São Paulo: Atlas.

GRECO S, FIGUEIRA J & EHRGOTT M. 2016. *Multiple Criteria Decision Analysis: State of art surveys*, v. 37. Springer.

GRECO S, KADZIŃSKI M, MOUSSEAU V & SŁOWIŃSKI R. 2011. ELECTREGKMS: Robust ordinal regression for outranking methods. *European Journal of Operational Research*, **214**(1): 118–135.

HAN D.-H, KIM Y.-D & LEE J.-Y. 2014. Multiple-criterion shortest path algorithms for global path planning of unmanned combat vehicles. *Computers & Industrial Engineering*, **71**: 57–69.

JARDIM RRJ, SANTOS M, NETO E, DA SILVA E & DE BARROS F. 2020. Integration of the waterfall model with ISO/IEC/IEEE 29148:2018 for the development of military defense system. *IEEE Latin America Transactions*, **18**(12): 2096–2103. Available at: https://doi.org/10.1109/TLA.2020.9400437

JOU Y.-T, YANG K.-H, LIAO M.-L & LIAW C.-S. 2016. Multi-criteria failure mode effects and criticality analysis method: a comparative case study on aircraft braking system. *International Journal of Reliability and Safety*, **10**(1): 1–21.

KEENEY RL, RAIFFA H & MEYER RF. 1993. *Decisions with multiple objectives: preferences and value trade-offs*. Cambridge university press.

KOBAN LA & MACDONALD GIBSON J. 2017. Small-unit water purifiers for remote military outposts: A new application of multicriteria decision analysis. *Journal of Multi-Criteria Decision Analysis*, *24*(3–4), 146–161. Available at: https://doi.org/10.1002/mcda.1606

KOU G, ERGU D & SHANG J. 2014. Enhancing data consistency in decision matrix: Adapting Hadamard model to mitigate judgment contradiction. *European Journal of Operational Research*, **236**(1): 261–271. Available at: https://doi.org/http://dx.doi.org/10.1016/j.ejor.2013.11.035

LAI C.-M. 2019. Integrating simplified swarm optimization with AHP for solving capacitated military logistic depot location problem. *Applied Soft Computing Journal*, **78**: 1–12. Available at: https://doi.org/10.1016/j.asoc.2019.02.016

LEAL FERREIRA EB. 2019. *The second fleet, the Amazon and the South Atlantic*. Bonifácio. Available at: https://bonifacio.net.br/a-segunda-esquadra-a-amazonia-e-o-atlantico-sul/

MALLOY TF, ZAUNBRECHER VM, BATTEATE CM, BLAKE A, CARROLL WF, CORBETT CJ, HANSEN SF, LEMPERT RJ, LINKOV I, MCFADDEN R, MORAN KD, OLIVETTI E, OSTROM NK, ROMERO M, SCHOENUNG JM, SEAGER TP, SINSHEIMER P & THAYER KA. 2017. Advancing alternative analysis: Integration of decision science. *Environmental Health Perspectives*, **125**(6): 1–12. Available at: https://doi.org/10.1289/EHP483

MARINHA DO BRASIL. 2019. *Naval Policy*. Available at: https://www.marinha.mil.br/politicanaval

MOREIRA MÂL, COSTA IP DE A, PEREIRA MT, DOS SANTOS M, GOMES CFS & MURADAS FM. 2021. PROMETHEE-SAPEVO-M1 a Hybrid Approach Based on Ordinal and Cardinal Inputs: Multi-Criteria Evaluation of Helicopters to Support Brazilian Navy Operations. *Algorithms*, **14**(5): 140. Available at: https://doi.org/10.3390/a14050140

MOREIRA MÂL, GOMES CFS, PEREIRA MT & DOS SANTOS M. 2023. SAPEVO-H2 a Multicriteria Approach Based on Hierarchical Network: Analysis of Aircraft Systems for Brazilian Navy. In *Lecture Notes in Mechanical Engineering* (pp. 61–74). Springer. Available at: https://doi.org/10.1007/978-3-031-09360-9_6

MOREIRA ÉP, COSTA IP DE A, MAINIER FB, GOMES CFS & DOS SANTOS M. 2023. *Risk Analysis Related to the Corrosıon of Atmospheric Storage Tanks: A Multimethodological Approach Using the FRAM and the ELECTRE-MOr Methods* (pp. 245–257). Available at: https://doi.org/10.1007/978-981-19-2840-6_19

NATIONAL DEFENSE POLICY (NDP)/NATIONAL DEFENSE STRATEGY (NDS). 2012. *Pub. L. No. 818/13*. Available at: https://www.gov.br/defesa/pt-br/arquivos/estado_e_defesa/END-PNDa_Optimized.pdf

OZTAYSI B, ONAR SC, GOZTEPE K & KAHRAMAN C. 2019. A multi-expert interval-valued intuitionistic fuzzy location selection for the maintenance facility of armored vehicles. *Journal of Multiple-Valued Logic and Soft Computing*, *32*(1–2), 149–173. Available at: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85071254349\&partnerID=40\&md5=ef70a5bc90dde1facd3b1a2e1c721564

PEREIRA DA DE M, SANTOS M DOS COSTA IP DE A, MOREIRA MAL, TERRA AV, ROCHA C DE S & GOMES CFS. 2022. Multicriteria and statistical approach to support the outranking analysis of the OECD countries. *IEEE Access*, 1–8. Available at: https://doi.org/10.1109/ACCESS.2022.3187001

PEREIRA RCA, MOREIRA MÂL, COSTA IP DE A, TENÓRIO FM, BARUD NA, FÁVERO LP, AL-QUDAH AA, GOMES CFS & SANTOS M DOS. 2022. Feasibility of a Hospital Information System for a Military Public Organization in the Light of the Multi-Criteria Analysis. *Healthcare*, **10**(11): 2147. Available at: https://doi.org/10.3390/healthcare10112147

ROSE J. 1997. Soft systems methodology as a social science research tool. *Systems Research and Behavioral Science: The Official Journal of the International Federation for Systems Research*, **14**(4): 249–258.

ROSENHEAD J & MINGERS J. 2001. *Rational analysis for a problematic world revisited: Problem structuring methods for complexity, uncertainty and conflict*. Wiley Chichester.

ROY B, FIGUEIRA JR & ALMEIDA-DIAS J. 2014. Discriminating thresholds as a tool to cope with imperfect knowledge in multiple criteria decision aiding: Theoretical results and practical issues. *Omega*, **43**: 9–20. Available at: https://doi.org/https://doi.org/10.1016/j.omega.2013.05.003

SANTOS M DOS. 2018. *Proposta de Modelagem Atuarial aplicada ao setor militar considerando influências econômicas e biométricas*. Tese de Doutorado. Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal Fluminense, Niterói RJ.

SANTOS M DOS;, COSTA IP DE A & GOMES CFS. 2021. Multicriteria decision-making in the selection of warships: a new approach to the AHP method. *International Journal of the Analytic Hierarchy Process*, *13*(1). Available at: https://doi.org/10.13033/ijahp.v13i1.833

SENNAROGLU B & VARLIK CELEBI G. 2018. A military airport location selection by AHP integrated PROMETHEE and VIKOR methods. *Transportation Research Part D: Transport and Environment*, **59**: 160–173. Available at: https://doi.org/10.1016/j.trd.2017.12.022

VAIDYA OS & KUMAR S. 2006. Analytic hierarchy process: An overview of applications. *European Journal of Operational Research*, **169**(1): 1–29.

VILELA ÉS. 2020. *Amazônia Azul: a estratégia da Marinha do Brasil para a segurança marítima*. Escola Superior de Guerra (Campus Rio de Janeiro).

WANG K & ZHENG YJ. 2012. A new particle swarm optimization algorithm for fuzzy optimization of armored vehicle scheme design. *Applied Intelligence*, **37**(4): 520–526. Available at: https://doi.org/10.1007/s10489-012-0345-0

WEIR JD, HENDRIX J & GUTMAN AJ. 2014. The triage method: Screening alternatives over time with multiobjective decision analysis. *International Journal of Multicriteria Decision Making*, **4**(4): 311–331. Available at: https://doi.org/10.1504/IJMCDM.2014.066871

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