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Logistical Support to the Military Organizations of the Brazilian Navy Through Cabotage Navigation: Analysis of a Pilot Test with the SAPEVO-M Method

Apoio Logístico às Organizações Militares da Marinha do Brasil por meio da Navegação de Cabotagem: Análise de um Teste-Piloto com o Método SAPEVO-M

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A B S T R A C T

The Brazilian Navy (*Marinha do Brasil*), mostly installed in the city of Rio de Janeiro, has military organizations distributed throughout the national territory, both in the coastal zone and in the more interior areas of the country. In this context, it is necessary to provide logistical support to more distant units through the provision of dry and refrigerated items in addition to those acquired in the local market. The objective of the article is to select a location, through the SAPEVO-M method, to be used in the pilot test, which will be served by cabotage navigation as an alternative to road transport in terms of large consolidated loads. In methodological terms, it is an exploratory research, which sought, through methods and criteria, a proximity to the reality of the object studied. Additionally, the research can be classified as a case study, which enables the deepening of knowledge about a given topic, as well as the investigation of different aspects on the same subject. Four locations - Manaus, Salvador, Fortaleza and Florianópolis - were compared based on logistical criteria. For the interview, three officers of the Brazilian Navy (*Marinha do Brasil*) were selected, who have experience in logistics and load transport. The work can contribute to society in terms of reducing public spending and mitigating the impact on the environment. In addition, it will be able to contribute to the Academy by presenting the application of a recognized method of multi-criteria decision support for the resolution of a concrete problem of load transport in an organization of the Brazilian Navy (*Marinha do Brasil*).

R E S U M O

A Marinha do Brasil, majoritariamente instalada na cidade do Rio de Janeiro, possui organizações militares distribuídas por todo o território nacional, tanto na zona costeira quanto nas áreas mais interiores do país. Nesse contexto, faz-se necessário prestar apoio logístico às unidades mais distantes por intermédio do provimento de itens secos e frigorificados em complemento àqueles adquiridos no mercado local. O objetivo do artigo é selecionar uma localidade, por intermédio do método SAPEVO-M, a ser utilizada no teste-piloto, a qual será atendida pela navegação de cabotagem alternativamente ao transporte rodoviário em matéria de grandes cargas consolidadas. Em termos metodológicos, trata-se de uma pesquisa exploratória, a qual buscou, por meio de métodos e critérios, uma proximidade da realidade do objeto estudado. Adicionalmente, a pesquisa pode ser classificada como estudo de caso, que viabiliza o aprofundamento do conhecimento acerca de determinado tema, bem como a investigação das diversas vertentes sobre um mesmo assunto. Foram comparadas quatro localidades - Manaus, Salvador, Fortaleza e Florianópolis - a partir de critérios logísticos. Para a entrevista, foram selecionados três Oficiais da Marinha do Brasil, os quais possuem experiência em logística e em transporte de cargas. O trabalho poderá contribuir com a sociedade no que diz respeito à redução de gastos públicos e à mitigação do impacto ao meio ambiente. Além disso, poderá contribuir com a Academia ao apresentar a aplicação de um reconhecido método de apoio multicritério à decisão para a resolução de um problema concreto de transporte de carga, em uma organização da Marinha do Brasil.

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Introduction

One of the most relevant decisions in the logistics management of an organization is the choice of the transport modal to be used. In general, managers evaluate various criteria for decision making, often prioritizing the cost and delivery time of the goods. Moreover, the situation becomes more complex in the face of processes involving multiple criteria which are not always easily quantifiable.

Another issue is the increasing level of complexity in the choice of transportation. In past decades, the selection of the modal and the carrier was structured in two stages. First, the modal was chosen and then the carrier to be used. Today, decisions are often made simultaneously, in addition to the fact that innovative strategies, such as just in time, and the increase in quality management have led to the development of numerous approaches that involve not only multiple variables, but also multiple objectives (MEIXEL; NORBIS, 2008).

In the Brazilian case, road conservation conditions and rising fuel prices have made road transport more costly, and increasingly frequent tolls harm organizations. A modal with great efficiency today is the rail. With low energy consumption per ton, it is able to transport large volumes simultaneously, generating considerable savings in scale. Thus, rail freight is significantly lower than the road for the transport of large loads.

On the other hand, rail transport in the country has low operating speeds, losing position to the road modal. Added to this is the fact that the Brazilian rail system is a limited transport, with little flexibility to choose routes. The lines with gauges of different widths and the presence of level crossings, as the crossings between railways and highways are known, makes the railway system demand a strong state investment.

Although not suitable for short distances, watertransport is an alternative for transporting large amounts of load. Having a large functional operation, it is indicated for an immense variety of products, such as: minerals, fuels, grains, automobiles, unitized loads etc.

Another advantage is the possibility of transportation between different countries, through long-haul navigation; local points, by means of cabotage navigation and in inland waters. According to Keedi (2020), cabotage navigation is defined as that performed for transportation within the country, such as a shipment in Rio de Janeiro to Salvador. On the other hand, long-haul navigation will be navigation that unites countries and continents, such as that made from Santos to Rotterdam.

According to Keedi (2020), cabotage navigation should not be confused with coastal navigation. While this may involve one or more countries by navigation near the coast, it must necessarily include points of origin and destination located in the same country. In this context, a navigation from Rio Grande to Buenos Aires, uniting nearby cities located in different countries, will be classified as coastal navigation, because it is carried out near the coast, and long course, because it involves at least two distinct countries.

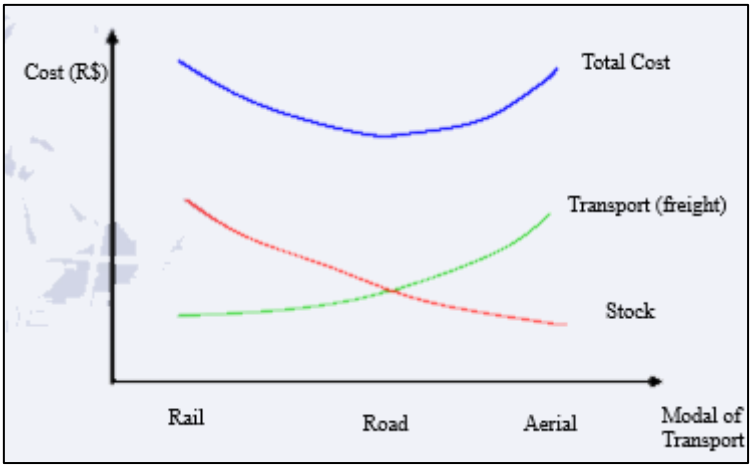
With regard to air transport, it is the most suitable modal for small weight and volume loads, but which have a high added value. The main advantage of this modal over the other ones is the short time it takes for the goods to be transported from the point of origin to the point of destination. On the other hand, given the high cost involved, it should be used for loads that require a privileged transport time or special care, such as samples, organs for donation or small fragile items with high technology shipped.

Faced with information related to transportation, both private companies and public agencies have numerous challenges with regard to logistics aspects. In turn, entities that operate at great distances cannot dispense with a detailed analysis of all the factors involved throughout the logistics chain.

Figure 1 compares transportation costs, inventory costs, and total costs per transport modal. The waterway modal - or waterway - is the one with the lowest transport cost when compared to the others, although it is the one with the highest inventory cost. This is due to the fact that the use of modal is only justified when the carrying capacity of a vessel is used in the best possible way. Thus, operating close to its maximum capacity, costs per ton will be reduced. It is observed that the analysis should be done on a case-by-case basis, because, according to the characteristics of each demand, a distinct modal can be identified as the most advantageous for the situation.

Figure 1.

Trade-off of logistics costs between modals..



Source: Cunha (2017).

In this context the Brazilian Navy (*Marinha do Brasil*), one of the three Armed Forces and with coverage throughout the national territory, is part of the Brazilian Navy (*Marinha do Brasil*).

As a body belonging to the structure of direct public administration, it is subject to the general rules on tenders and administrative contracts. Thus, all purchases of goods and

contracting services must be based on bidding processes, except for the hypotheses provided for by law (BRASIL, 1993).

With most military organizations concentrated in the state of Rio de Janeiro, the Navy Procurement Center (*Centro de Obtenção da Marinha*) in Rio de Janeiro (COMRJ) is responsible for making purchases centrally.

According to Ballou (2006), logistics focuses on all handling and storage activities, with the purpose of enabling the flow of products from the purchase of raw materials to the final consumer, as well as information flows, in order to provide satisfactory service levels to customers at a reasonable cost.

In this context, logistics gains even more significant importance when dealing with public agencies, which are funded with financial resources arising from taxes paid by society as a whole. Thus, in addition to the efficient and effective transportation carried out to contribute to the fulfillment of the public interest with regard to the purpose for which that agency was created, it provides as a positive externality the savings of resources that can be used to meet other demands of the Brazilian population.

The objective of this article is to select a locality, through the SAPEVO-M method, to be used in the pilot test, which will be met by cabotage navigation alternatively to road transport in the field of large consolidated loads.

In methodological terms, this is an exploratory research, which sought, through methods and criteria, a proximity to the reality of the object studied. Additionally, the research can be classified as a case study, which enables the deepening of knowledge about a given theme, as well as the investigation of the various aspects on the same subject.

The next section will deal with the Navy's Distribution and Customs Operations Center.

The Navy´s Customs Distribution and Operations

According to information contained in the Regulation of the Center for Distribution and Customs Operations of the Navy (*Regulamento do Centro de Distribuição e Operações Aduaneiras da Marinha - CDAM*), that Military Organization is the agency responsible for the traffic of all material from Brazilian Navy (*Marinha do Brasil*) deposits located in Rio de Janeiro and destined to military organizations located in other states (MARINHA DO BRASIL, 2018).

For the realization of all load traffic for which it is responsible, the CDAM carries out transport through its own fleet, through the hiring of road transport companies (fractional or closed truck), or through the hiring of air transport companies.

Due to the strategic importance of the activities conducted by this Distribution Center within the Brazilian Navy (*Marinha do Brasil*), periodically ways are rethought to optimize the processes involved. In this context, a discussion has recently begun on an alternative to land transport. The main reason was the need to terminate the contract agreement concluded with

a road transport company. In mid-2018, there was a request for economic and financial rebalancing of the contract because of a truckers' strike. However, the negotiations were frustrated by a lack of documentary evidence that costs would have increased significantly, by forces unrelated to the will of the contracting parties, arising from unforeseeable or incalculable events and incalculable consequences.

Although air transport is already used for small loads that require a priority in service, the aumentioned modal can not be used as an alternative for an inoperability of the land modal due to the loads having high weights and vats.

The alternative transport by rail line was discarded due to the lack of efficient lines for the transport of containers from Rio de Janeiro to the destination points. Just to illustrate, in Brazil, 58% of everything produced in rural areas reaches ports through highways, while only 25% follow trails (ANTF, 2012).

In Brazil, another relevant factor was the existence of approximately twenty-three shipping companies that offer container shipping services on regular lines (SILVINO; ASSIS, 2018).

In order to diversify the possibilities for the transport of large unitized loads by means of containers of twenty or forty feet, studies were initiated to identify a locality for a pilot test for the waterway modal (cabotage navigation). Keedi (2020) points out that, among the characteristics identified, the waterway system is the most suitable for the transport of large amounts of load.

Initially, the locations with the highest frequencies of care were identified for the collection of the necessary data. Among nine locations (Manaus, Belém, Fortaleza, Natal, Recife, Salvador, Vitória, Florianópolis and Rio Grande), the costs of road transport and cabotage were compared. Only three localities (Manaus, Fortaleza and Salvador) presented more advantageous values for cabotage transport.

Although private companies have the freedom to hire carriers, CDAM, because it is a public agency, needs to promote bidding processes that support future expenses. This legal obligation aims to meet some principles, such as legality, morality and the choice of the most advantageous proposal for the administration. For the analysis, we compared the values obtained in Electronic Trading Sessions (*Pregões Eletrônicos*) No. 10/2017 and 33/2019, conducted by the Navy Supply Base (*Base de Abastecimento da Marinha - BAMRJ*), whose objects were the hiring of companies for the performance of road transport and cabotage, respectively.

For each contract, there is the possibility of the adoption of an initial term of twelve months, with successive extensions, provided that there is agreement between the parties, up to the limit of sixty months. To choose the criteria and compare the alternatives, three Navy Officers with experience in logistics and load transport were interviewed. In general, there was

agreement with the criteria and alternatives to be evaluated, although the degrees of preference assigned presented some difference.

Figure 2 shows the location of CDAM - based in the city of Rio de Janeiro - and the three destination points, located in the cities of Manaus, Fortaleza and Salvador.

Figure 2.

Points of origin and destination.

Source: Google Maps.

SAPEVO-M Method

For the analysis of alternatives, the SAPEVO-M method, a Multi-criterion Decision Support (*Apoio Multicritério à Decisão - AMD*) method proposed for multiple decision makers, was used. According to Teixeira, Santos and Gomes (2020), the method is composed of two stages, namely: the ordinal transformation of preference between the criteria, so that their respective weights are established; and the subsequent ordinal transformation of preference between the alternatives.

In the first stage, after the *n* criteria for analysis of alternatives by decision makers are defined, preference degrees will be established for all ordered pairs of criteria (ci, cj), where ci and cj are criteria pertaining to the set of criteria C = {c1, c2, c3, ... , ci, ..., cj, ..., cn}. The degree of preference will be represented by δci cj, such that:

$\delta ci\ cj > 1 \leftrightarrow ci > cj$ *(ci it's better than cj)*

$\delta ci\ cj = 1 \leftrightarrow ci \cong cj$ *(ci it's equivalent to cj)*

$\delta ci\ cj\ < 1\ \leftrightarrow ci < cj$ *(ci it's worse than cj)*

From the degrees of preference established by each decision maker, the points obtained by each criterion will be summed, and then the values will be normalized according to the formula below:

$$v = \frac{(aij - Mín\ aij)}{(Máx\ aij - Mín\ aij)}$$

It is noteworthy that, applying the above formula, we would have a null value representing the importance of the worst evaluated criterion. As all the criteria raised have some degree of importance, even if of reduced value, the authors of the method established that, in these cases, the zero value will be replaced by 1% (one percent) of the immediately higher value.

Chart 1.

Scale of criteria.

Scale 1	Scale 2	Corresponding Linguistic Expression
>>>1	3	Absolutely better
>>1	2	Much better
>1	1	Better
1	0	Equivalent
<1	-1	Worst
<<1	-2	Much worse
<<<1	-3	Absolutely worse

Source: Teixeira, Santos and Gomes (2020).

In the second stage, the decision makers will evaluate each alternative according to the chosen criteria, and matrices of alternatives are formed for each decision maker and each criterion. At the end, the lines will be summed and normalized, as performed in the first stage.

Data Collection

For the survey of primary data related to land and waterway modals, the information contained in electronic trading sessions no. 10/2017 and 33/2019 from BAMRJ, the organ responsible for conducting the bids demanded by CDAM, was extracted. Tables 2 and 3 below show the values used for applying the method:

Chart 2.

Logistics data in the terrestrial modal.

Destiny	Demanded Quantity	Amount per Truck (14 Ton)	Value per Ton	Deadline
Manaus	260 Ton	R$ 19.831,25	R$ 1.416,52	18 days
Salvador	364 Ton	R$ 08.248,74	R$ 0.589,20	03 days
Fortaleza	052 Ton	R$ 15.000,00	R$ 1.071,43	05 days

Source: The authors, from information gathered in the research.

Chart 3.

Logistics data in the waterway modal.

Destiny	Demanded Quantity	Value per container (26 Ton)	Value per Ton	Deadline
Manaus	10 containers	R$ 32.100,00	R$ 1.234,62	22 days
Salvador	14 containers	R$ 10.444,44	R$ 0.401,71	15 days
Fortaleza	02 containers	R$ 14.700,00	R$ 0.565,38	11 days

Source: The authors, from information gathered in the research.

The criteria identified by decision makers were as follows: (a) difference between the price per ton between the terrestrial modal and the waterway modal, as it represents the savings to be obtained; (b) difference between the delivery time of the goods in the waterway modal and in the land modal, due to the longer period of time necessary for the use of the most economical modal; (c) quantity demanded in container quantities; (d) distance from the Military Organization to the port of destination, because in the face of a possible difficulty in transporting the port to the Military Organization through the contracted company, the proximity of the port would facilitate the use of trucks from the MB itself for the transport of containers. The chart 4 presents the criteria used in the model:

Chart 4.

Criteria used.

Destiny	Price[1]	Deadline[2]	Demand	Distance from Port
Manaus	R$ 181,90	04 days	10 containers	13,8 km
Salvador	R$ 187,49	12 days	14 containers	39,7 km
Fortaleza	R$ 506,04	06 days	02 containers	10,1 km

Source: The authors, from information gathered in the research.

Preference among criteria - Decision maker 1

The decision maker 1 evaluated each criterion pair according to the one contained in chart 5. The main diagonal of the square matrix formed by the first four columns is null due to the equivalence between identical criteria. The criterion “price” was evaluated as much better in relation to the criterion “term”, as better in relation to the criterion “demand”, and as “much better” in relation to the criterion “proximity of the port”. The fifth column shows the sum of the values of each row, and finally, the sixth column shows the normalization of the values obtained in the sum. As previously presented, the normalized value of the criterion “proximity of the port” is equivalent to 1% of the immediately higher value, found in the third line.

Chart 5.

Evaluation of the criteria by the decision maker 1.

Criteria	Price	Deadline	Demand	Proximity to the Port	Sum	Normalization
Price	0	2	1	2	5	1,00000
Deadline	-2	0	1	3	2	0,76923
Demand	-1	-1	0	3	1	0,69231
Proximity to the Port	-2	-3	-3	0	-8	0,00692

Source: The authors, from information gathered in the research.

Preference between Criteria - Decision maker 2

Similar to the evaluation performed by decision maker 1, chart 6 presents the preference between the criteria according to the interview conducted with decision maker 2. It is worth mentioning that the square matrix formed by the columns of criteria will always be antisymmetric for all decision makers.

Chart 6.

Evaluation of the criteria by the decision maker 2.

Criteria	Price	Deadline	Demand	Proximity to the Port	Sum	Normalization
Price	0	1	1	2	4	1,00000
Deadline	-1	0	2	2	3	0,88889
Demand	-1	-2	0	1	-2	0,33333
Proximity to the Port	-2	-2	-1	0	-5	0,00333

Source: The authors, from information gathered in the research.

Preference among criteria - Decision maker 3

Chart 7 presents the values corresponding to the interview conducted with decision maker 3. According to this evaluation, the criteria “price” and “term” have the same normalized value. This means that the criteria have the same degree of importance for choosing the alternative to be prioritized.

Chart 7.

Evaluation of the criteria by the decision maker 3.

Criteria	Price	Deadline	Demand	Proximity to the Port	Sum	Normalization
Price	0	1	2	1	4	1,00000
Deadline	-1	0	2	3	4	1,00000
Demand	-2	-2	0	2	-2	0,40000
Proximity to the Port	-1	-3	-2	0	-6	0,00400

Source: The authors, from information gathered in the research.

Assigned Weights

After the establishment of the degree of preference by decision makers, the sum of all normalized values will correspond to the weight assigned for each criterion. Chart 8 represents the weights assigned in the present case study.

Chart 8.

Assigned weights.

Criteria	Decision maker 1	Decision maker 2	Decision maker 3	Weights
Price	1,00000	1,00000	1,00000	3,00000
Deadline	0,76923	0,88889	1,00000	2,65812
Demand	0,69231	0,33333	0,40000	1,42564
Proximity to the Port	0,00692	0,00333	0,00400	0,01426

Source: The authors, from information gathered in the research.

Second Stage

As was performed in the first stage with the criteria, in the second stage the alternatives are compared two to two according to each criterion and the corresponding values are summed and normalized. In this way, we will have four values for each of the three alternatives. At the end, each of the four values of each alternative will be multiplied by the weight obtained corresponding to each criterion and then summed. The sum obtained for each alternative will be used for the formation of the final ranking. Charts 9, 10 and 11 represents the evaluations of the decision makers used in the second stage.

Chart 9.

Evaluation of alternatives by decision maker 1.

Criteria	Manaus x Salvador	Manaus x Fortaleza	Salvador x Fortaleza
Price	Worst	Much worse	Much worse
Deadline	Much worse	Worst	Much better
Demand	Worst	Much better	Much better
Proximity to the Port	Much better	Better	Much worse

Source: The authors, from information gathered in the research.

Chart 10.

Evaluation of alternatives by decision maker 2.

Criteria	Manaus x Salvador	Manaus x Fortaleza	Salvador x Fortaleza
Price	Equivalent	Worst	Worst
Deadline	Much worse	Equivalent	Much better
Demand	Worst	Much better	Much better
Proximity to the Port	Better	Equivalent	Worst

Source: The authors, from information gathered in the research.

Chart 11.

Evaluation of alternatives by decision maker 3.

Criteria	Manaus x Salvador	Manaus x Fortaleza	Salvador x Fortaleza
Price	Equivalent	Much worse	Much worse
Deadline	Worst	Equivalent	Better
Demand	Equivalent	Better	Much better
Proximity to the Port	Much better	Equivalent	Much worse

Source: The authors, from information gathered in the research.

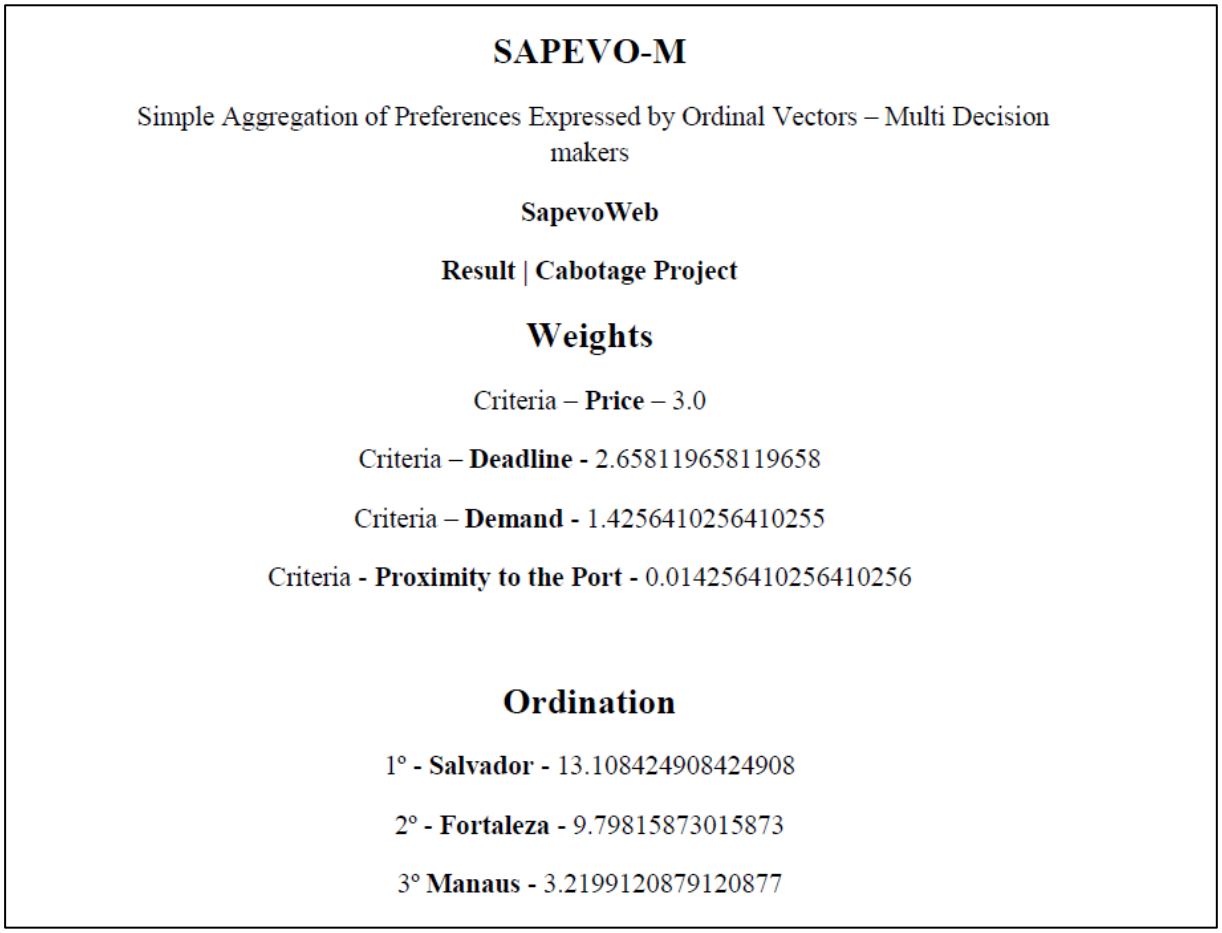
Results Obtained

After demonstrating the steps gradually, figure 3 is shown, which illustrates the application of the SAPEVO-M method, through software available on the www.sapevoweb.com website, developed by Teixeira, Santos and Gomes (2018). From the insertion of data from interviews conducted with decision makers, the software itself performs all the steps automatically. It is possible to observe that the locality of Salvador received approximately

thirteen points, being the city with the highest score. In this context, the city of Salvador should receive higher priority in the choice for the pilot test and the city of Manaus should receive the lowest priority, among the evaluated alternatives.

Figure 3.

Results obtained.



Source: www.sapevoweb.com

In the next section, the final considerations of this study will be addressed.

Final considerations

The objective of this article was to select a locality, through the SAPEVO-M method, to be used in the pilot test, which will be met by cabotage navigation alternatively to road transport in terms of large consolidated loads.

After the application of the SAPEVO-M method, the city of Salvador was identified as the highest priority in the choice for conducting the pilot test for the transport of containers in cabotage navigation.

It was possible to establish the weights between the criteria based on the degree of importance evaluated by the multiple decision makers. Although the method is easy to apply, even without the intesive use of Information and Communication Technology (*Tecnologia da Informação e Comunicação*) tools, the SapevoWeb platform enables people without deep prior

knowledge to solve problems that include Decision Support Systems (*Sistemas de Apoio à Decisão*). Additionally, similar problems with a larger number of decision makers, alternatives or criteria can be easily solved with the use of this software. The tool in question proved advantageous in solving a real transport logistics problem, both with regard to greater agility, and avoiding possible calculation errors in the hypothesis of applying the AMD method manually.

Work can favor society with regard to reducing public spending and mitigating the impact on the environment. In addition, it may contribute to the Academy by presenting the application of a recognized multicriteria support method to the decision for the resolution of a concrete load transport problem in a Brazilian Navy (*Marinha do Brasil*) organization.

Ultimately, it should be highlighted that the research result is attached to the case studied, and its generalization is impossible.

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