Acta Scientiarum

http://periodicos.uem.br/ojs/acta
ISSN on-line: 1807-8672
Doi: 10.4025/actascitechnol.v47i1.66976

CIVIL ENGINEERING

Feasibility analysis of implementing a logistics integration center in amazon region using AHP

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ABSTRACT. The celebrated and constant evolution of operating operations and market companies compensate for the integration of process participants and the need to promote new operating strategies, as well as the integration of process participants, as well as the need for integration of participants in the process resources involved in the supply chain. From this scenario of need for evolution and modification of market relations, the use and implementation of outstanding projects of logistics integration centers as a way of improving the logistics reality. Corroborating this reality, the main objective of this research was to verify the feasibility and benefits generated from the implementation of a Logistics Integration Center in the State of Pará - CILOG, from the perspective of the demand for production flow, availability of modal and location. To verify the feasibility of production for implementation, foam consulted without data regarding load states and load locations in adjacent areas, as well as potential, functionalities and resources of the implementation systems, with flow as the main centers of selection and, systematic and systematic way, of the feasibility and evaluation of the benefits generated from the implementation of the needs of the demand for services of attendance of the neighboring states, as well as of the entrances for the attendance of the neighboring states demand of flow of the production, availability of modals and geographic location. For this, an A-SWOT hybrid methodology was applied to define the HP location criteria and the decision factors that characterize the implementation of logistics such as the Logistics Integration Center (CILOG) in the Amazon Region, as well as the definition of the best for this implementation, based on three local alternatives: Santarém, Alça Viária and Miritituba. With the evaluation, Santarém (on the banks of the Amazon River) was listed as the best location for the installation, from the perspective of locational, operational, relating to capacity and territories

Keywords: Analytic hierarchy process; transport logistics; logistics platforms; multimodal transport.

Received on February 2, 2023.
Accepted on March 25 2024.

Introduction

The changes that have taken place in the organization of the territory, as well as the increase in the extension of supply chains are factors that implement needs to improve the quality of transport, storage and distribution of goods (Qu, Zeng, Li, & Lin, 2020; Wang, Chen, Tseng, Luan, & Ali, 2020). With this, the growing importance of transport logistics, which is a strategic sector for all countries, is fundamental for the Brazilian economy, given that it integrates several sectors and offers subsidies to other markets.

The constant growth in the importance of this sector is intrinsically linked to the increase in cargo movements in the country, establishing a fine line between them (Dočkalíková, Cempírek, & Indruchová, 2020; Liao, Tian, Arentze, Huang, & Timmermans, 2020). This fact increases the demand on the structures responsible for integrating the modes and distributing the loads efficiently and with high performance and this, in turn, eventually depends on their operational and locational characteristics, related to infrastructure and equipment, as well as related to the governance and how they are integrated into logistics chains (Agusdinata, Fry, & Delaurentis, 2011; Filani & Osayimwese, 1978; Woodcock & Tovey, 2020).

According to information from the National Logistics Plan – PNL (2015), the modal division clearly and objectively reflects the disparities that guide interregional cargo transport in the country. In which, it is observed that 65% of cargo movements are carried out by highways through trucks. The railways correspond to 15% within this logistics structure. The waterway modal accounts for only 5% of the amount transported.

Added to these scenarios are the Brazilian industrial and agribusiness growth and consequently the country's economic development, which in turn leads to latent needs for greater investments in the transport and logistics matrix. However, despite numerous studies carried out by various entities interested in the sector in question and some government guidelines implemented over the last few decades, logistical and infrastructural bottlenecks persist today.

For this reason, it is still common to observe the movement of loads and goods of the most diverse types and characteristics over long distances through the road modal. Even this, presenting itself as unfeasible for such, on many occasions, which leads to constant discussions about the use of new options, routes and logistical solutions for this bad weather of the national transport system.

And in this context, the modality that could take the lead in the logistics process, as a dynamism and catalyst for cargo transport, which is the waterway modal, is far below its real possibilities, potentialities and expectations. Even with all the natural vocation available for a large part of this national territory, mainly in the Amazon Basin Region, which in turn, ends up standing out as a true paradox and nonsense to the Brazilian reality.

The waterway transport in a holistic way, is a modality that can be developed by navigation both by inland waterways (the one carried out mainly by potentially navigable rivers), and by maritime cabotage (the one carried out along the Brazilian coast) and by waterways. long haul. Presenting different characteristics, when compared to other modes, such as: low transport costs, great capacity for cargo handling, safety and less impact on the environment.

In this sense, the State of Pará stands out in relation to the other states of the federation, not only for presenting a large territorial extension, but for having natural characteristics that differentiate it, such as its extensive hydrographic network. Composed of long and navigable rivers, which are becoming true cargo export corridors, especially those from agribusiness, with emphasis on the Tapajós River and its navigable route, located in West Pará.

Furthermore, the State also has a vast network of significant transport, with different potentialities and contexts of different uses, intrinsic to the reality of the population. With great use for the transport of passengers. However, with a great potential for loads, which has been increasing in recent years, regarding its use for this purpose.

Multi-criteria decision making (MCDM) or multi-criteria decision analysis (MCDA) can be used as a sub-area associated with operations research responsible for explicitly evaluating various criteria used in decision making from option evaluations with the opinion experts (Chou, 2007; Hsu, Lian, & Huang, 2020; Żak & Węgliński, 2014). MCDM methodologies are associated with the concern with structuring and solving decision and planning problems involving various requirements (Balci, Cetin, & Esmer, 2018; Pallis, Vitsounis, Langen, & Notteboom, 2011). The aim is to support decision makers facing these issues. Typically, there is no unique ideal solution for these problems, and it is necessary to use a decision requirement to differentiate the solutions (Rezaei, van Wulfften Palthe, Tavasszy, Wiegmans, & van der Laan, 2019). To carry out these operational research methodologies with the analysis of process alternatives based on pre-defined criteria, the literature shows the existence of several multi-criteria decision-making methods (MCDM) (Akbayırlı, Deveci, Balcı, & Kurtuluş, 2016; Merkel, 2017; Onwuegbuchunam, 2013; Rodrigue, Comtois, & Slack, 2016; Yeo, Ng, Lee, & Yang, 2014).

In the context of application in engineering problems, there is the existence of the Fuzzy Decision Approach (FDA) based on Fuzzy (Liang & Wang, 1991), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) proposed by Hwang and Yoon (1981), Analytical Hierarchy Process (Saaty, 1977), Analytic Hierarch Process (AHP) by Saaty (2008) and Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) proposed by Bana and Costa (1994).

In view of the aforementioned scenario, the need to implement measures to improve logistics is increasingly presented as something necessary to increase the competitiveness of products (Abrahamsson, Aldin, & Stahre, 2003; Tirachini & Hensher, 2012). Corroborating these needs, it is evident the importance of studies and scientific research capable of identifying ways to improve the efficiency of the transport system using methodological tools that aid in operational processes.

Therefore, starting from the above-mentioned context, the present research has as main cores the verification and evaluation, in a holistic and systematic way, of the viability and the benefits generated from the implementation of a Logistics Integration Center in the State of Pará to attend to the needs to flow the demand for goods produced in the same State, as well as those coming from adjacent states, from the perspective of the demand for the flow of production, availability of modes and geographic location. To this end, an AHP-SWOT hybrid methodology was applied to define the criteria and decision factors that characterize the implementation of a logistics solution such as the Logistics Integration Center (CILOG) in the Amazon Region, as well as the definition of the best location for this implementation, based on three locational alternatives: Santarém (on the banks of the Amazon River), Alça Viária (on the banks of the Guamá River) and Miritituba (on the banks of the Tapajós River).

Material and methods

Analytic hierarchy process method

The AHP decision support multi-criteria judgment method is based on an active assessment methodology, in which multiple relevant characteristics are represented based on their respective importance. This process is characterized by dividing the problem into descending hierarchical levels, starting with the global target, criteria, sub-criteria and possibilities in consecutive levels (Saaty, 1977).

The problem must then be hierarchically structured in such a way that the criteria identified at each level are homogeneous and not redundant. This structure of a simple hierarchy for the AHP method is shown in Figure 1.

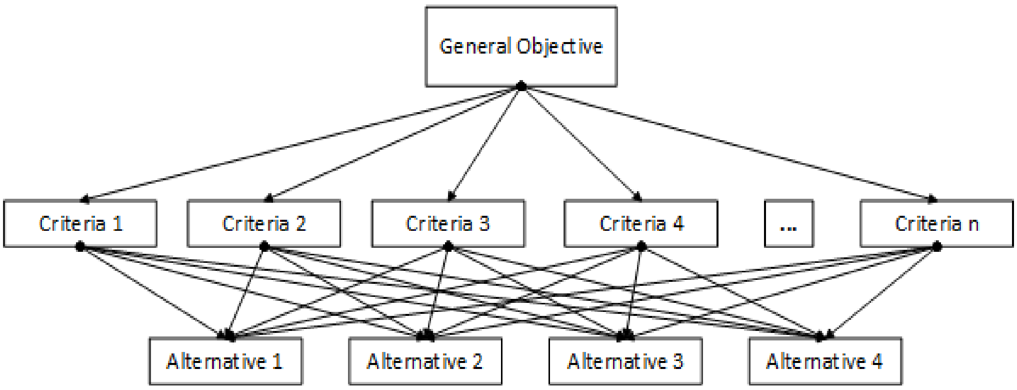

Figure 1. Hierarchical model of AHP method.

Saaty (2008) clarified the AHP methodology to make a decision in order to organize and generate priorities based on stages:

- ✓ Decide the problem;
- ✓ Organize the decision hierarchy and generate the criteria from a set of possibilities;
- ✓ Develop a set of comparison matrices;
- ✓ Employ and weigh the priorities achieved from comparisons.

Using the peer comparison approach, the relative weights of the port selection factors were determined. The experts were informed on how to assess the criteria for selecting ports from Table 1.

Table 1. Fundamental scale of pair-wise comparison.

Intensity of assessment Scale	Assessment scale meaning
1	Equally Important
3	Moderately Important
5	Important
7	Very Important
9	Extremely Important
2, 4, 6 and 8	Intermediate Values of Important

The matrix in pairs was organized in the form of an n x n matrix. The a_{ij} criterion was obtained from expert judgments, using the scale of Table 1 given in Saaty (2008). Based on this, the lower triangular matrix (a_{21}, a_{ji} e a_{j2}) can be calculated using the values of the upper diagonal (a_{12}, a_{ij} e a_{2j}), as illustrated in Equation 1.

$$M = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & a_{ij} \\ \frac{1}{a_{12}} & 1 & a_{2j} \\ \frac{1}{a_{ij}} & \frac{1}{a_{2j}} & 1 \end{bmatrix} \quad (1)$$

a_{ij} represents the elements of the matrix which are the criteria comparison scales, i and j are the rows and columns of the matrix, respectively.

After the matrix organization, the weight value of the comparison between pairs of attributes was calculated based on Equation 2 given in Rahman and Najib (2017).

$$C_k = \frac{1}{n} \sum_{j=1}^{n} \left(\frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}} \right) \quad (2)$$

k is an integer (K = 1, 2, 3, ..., n); a_{ij} represents the input of a given row and column compared to an array of order n.

The validation of the analysis is verified using Consistency Ratio (CR), in which the values referring to this variable must be equal to or less than 0.10 (Yang & Xu, 2002). For the calculation of this index, the Consistency Index (Equation 3) is calculated.

$$CI = \frac{\lambda \max - n}{n-1} \quad (3)$$

λ_{max} is the largest eigenvalue of the filings and (n - 1) is the number of degrees of freedom. From the calculation of the CI value, the CR value can be calculated (Equation 4).

$$CR = \frac{CI}{RI} \quad (4)$$

The Random Consistency Index (IR) shown in Equation 4 can be calculated based on Saaty (2008), from Table 2, being calculated for square n matrices of order n (Dong and Cooper, 2016).

Table 2. Random consistency index, RI of matrix size.

Matrix Order (n)	1	2	3	4	5	6	7	8	9	10	11
RI Values	0	0	0,58	0,9	1,2	1,24	1,32	1,41	1,45	1,49	1,51

The interactions that are involved in this process from the above-defined steps are reproduced multiple times. These interactions admit that the decision is reviewed with a more perfect understanding of the problem through the model that was generated.

Results and discussion

Criteria selection using AHP

This study uses the AHP-based methodology as a decision support tool to carry out an academic study on the potential and feasibility of implementing a Logistics Integration Center (CILOG) in the Amazon region. That said, the methodology in question was initially applied to the selection of fundamental aspects that influence the implementation of a CILOG, in order to understand the relationships between the criteria selected for the objective: Identification of criteria and decision-making factors that characterize the implementation of a CILOG-type logistics solution.

As an important part of achieving the results and for census analysis of the scope of the subject, a questionnaire was made to consult specialists on the importance and hierarchy of the criteria that characterize viable solutions from the locational, operational, territorial and capacity-related perspectives. The questionnaire in question was intended to assess the degree of importance of each criterion, previously selected, when considering the implementation of CILOG in a locality.

The AHP support structure was ordered based on 4 criteria and their immediate sub-criteria. Each one of these is analyzed by the referring sub-criteria, comparing them pair by pair, in a scale of alternating importance among the numerals from 1 to 9 of intensity (SAATY, 2008). The framework of criteria and sub-criteria constituted for the study is shown in Table 3.

Table 3. Criteria and subcriteria table - AHP for criteria selection.

Level 1 - Objective	Level 2 - Criteria	Level 3 - Subcriteria
Identification of criteria and decision-making factors that characterize the implementation of a logistics solution such as the Logistics Integration Center (CILOG) in the Amazon Region	Location Aspects	Waterway Access Road Access Rail Access Distance from Residential Areas
	Operational Aspects	Operations Flexibility Cost and Ease of Services Reliability and Cost in port operations Communication Systems Level
	Aspects related to Capacity	Capacity of Roads and Access Storage Capacity Movement Capacity Port Equipment Capacity
	Territorial Aspects	Disponibilidade de Terras Disponibilidade de Mão de Obra Local Proximidade de Mercado Consumidor Apoio do Governo e da Indústria

AHP for selection of locational alternatives

According to authors Randhawa and West (1995), for locating facilities, the AHP method encompasses four steps: choosing a set of criteria to judge competing sites; define weights that judge the relative importance of each of these in the decision space; weight the location of each criterion; and joining the weights of each criterion into an overall ranking.

The AHP method that subsidizes the decision making in the location of installations is used in several countries, with different objectives, from the location of industrial installations, to the location of a thermoelectric plant. The possibility of merging the use of the AHP method with other methods such as fuzzy logic stands out (Liang & Wang, 1991); the Delphi method; the Quality Function Deployment – QFD method; and with a variation of the AHP itself: the Analytic Network Process – ANP.

Thus, the second part of applying the AHP methodology was about its use to define the best locational alternative among three possibilities raised, and these should be evaluated based on criteria related to locational, operational, capacity and territorial aspects, as detailed in Table 4.

Table 4. Criteria and subcriteria table - AHP for selection of locational alternative.

Level 1 - Objective	Level 2 - Criteria	Level 3 - Subcriteria
Identification of criteria and decision-making factors that characterize the implementation of a logistics solution such as the Logistics Integration Center (CILOG) in the Amazon Region	Location Aspects Operational Aspects Aspects related to Capacity Territorial Aspects	Santarém, on the banks of the Amazon River Miritituba, on the banks of the Tapajós River Santarém, on the banks of the Amazon River

Local average priorities (PM)

The first results were the local average priority values, which occurred through the arithmetic average of the lines of the normalized matrix, which represents the priority of each device, according to the AHP method.

In the first judgment carried out, the sub-criteria of the Location Aspects Criteria were compared to calculate the average local priorities (PML's). From this comparative analysis, shown in the graph illustrated in Figure 2, the choice obtained previously in the Google Forms responses was confirmed, with Waterway Access standing out among the other sub-criteria with an average weight of 0.453 (45.3%). The other criteria obtained lower values, as evidenced: Rail Access (0.159) Rail Access (0.150) and Distance from Residential Areas (0.072).

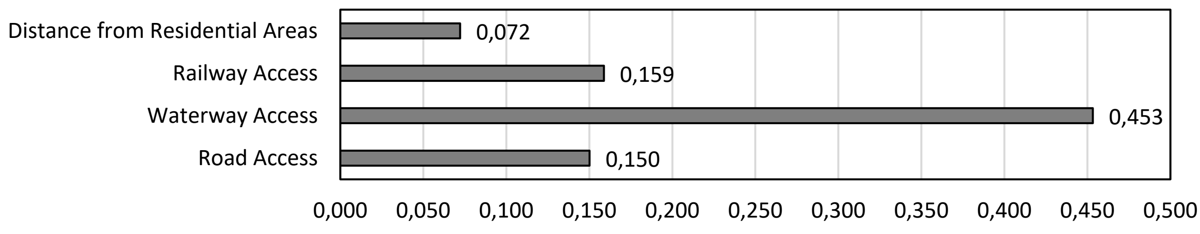

Figure 2. Ranking of criteria priority.

Regarding the second criterion analyzed in the computational tool in relation to the sub-criteria, there was the criterion Operational Aspects, which obtained majority percentages between two sub-criteria. The sub-criteria Reliability and Cost in Port Operations and Cost and Ease of Services had higher average values in relation to the others, with 0.337 and 0.36, respectively. Followed by Operations Flexibility (0.263) and Systems and Communications Level (0.04).

Regarding the penultimate criterion analyzed in relation to its sub-criteria, there was the Criterion Aspects Related to Capacity. Regarding this, there were majority values between two sub-criteria. Roads and Accesses Capacity and the Handling Capacity sub-criterion obtained the highest values evidenced for this criterion, obtaining, respectively, 0.289 and 0.259. Regarding the others, the Port Equipment Capacity sub-criterion obtained 0.233 and Storage Capacity obtained 0.22. Such values showed that with regard to the Aspects Related to Capacity Criterion, despite having sub-criteria with more significant values, the difference between them is on average 3% in the absolute percentage, a fact that reiterates the importance of the sub-criteria in question, reflected in the experts' answers and, eventually, in the proximity of the AHP ranking.

Finally, the final analysis of Local Average Priority was the verification of the weights of the sub-criteria of the Territorial Aspects criterion. In relation to this analysis, very close majority values were obtained for two sub-criteria, namely: Proximity to the Consumer Market, with a weighting of 0.275, and Government and Industry Support, with a weighting of 0.273, that is, reflecting in an almost equal percentage among these sub-criteria. The others that were Land Availability and Local Labor Availability obtained, respectively, 0.239 and 0.213.

Global priorities (PG)

Given the presentation of local average priorities, it is possible to present global priorities, which can be achieved through the product of all intermediate priorities from the lowest hierarchical level to the highest. In Figure 3, the Global Average Priorities are highlighted, which allow a better observation of the comparison from the application of the methodological tool, with the presentation of the criteria with the highest adherence considering both the number of choices and the scale assigned to each choice by the decision maker.

From the observation of the graph in Figure 3, it is possible to observe that, for the decision-making group, the Locational Aspects criterion is the most important in relation to the others, with 0.333, while the Operational Aspects criterion was evidenced second, with 0.290, and the others: Aspects related to Capacity and Territorial Aspects with, respectively, 0.224 and 0.153.

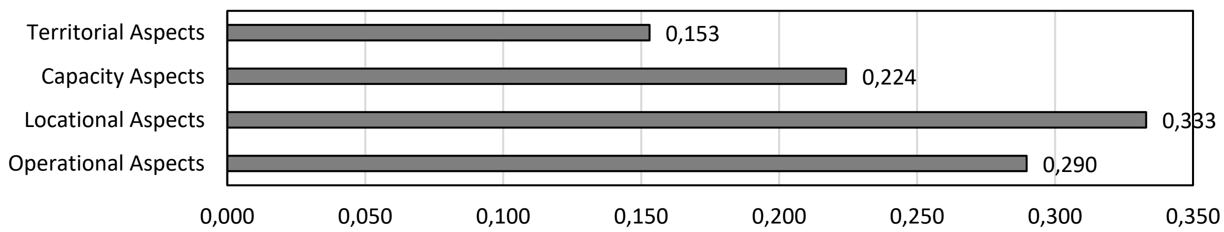

Figure 3. Global sub-criteria priorities.

Overall ranking results for criteria and sub-criteria

The facility location decision is a critical part of strategic logistics planning. Currently the location of facilities (ie warehouses, hubs/logistics centers, etc.) is the main concern of companies related to this business. The success of a logistics hub depends on four main factors such as; location, operation, territorial facilities and capacity (Sirikijpanichkul, Van dam, Ferreira, & Lukszo, 2007). Considering that the factors in question are the fundamental ones for the determination of a locational selection, as a result of the present study, an analysis flow was developed to define a locational selection. The flow in question is shown in Figure 4.

AHP result for location **alternative selection**

In addition to the aforementioned analysis, given that the Location Aspects criterion is considered by experts as the main one in defining a Logistics Platform, a detailed study was then carried out applying the AHP methodology in order to evaluate alternatives locations in relation to each criterion. In this way, three locations were considered in the analysis: Miritituba, Santarém and Alça Viária, with these alternatives being evaluated based on parity comparisons for each of the four criteria: Location Aspects, Operational Aspects, Capacity Aspects and Territorial Aspects. The analysis in question is shown below.

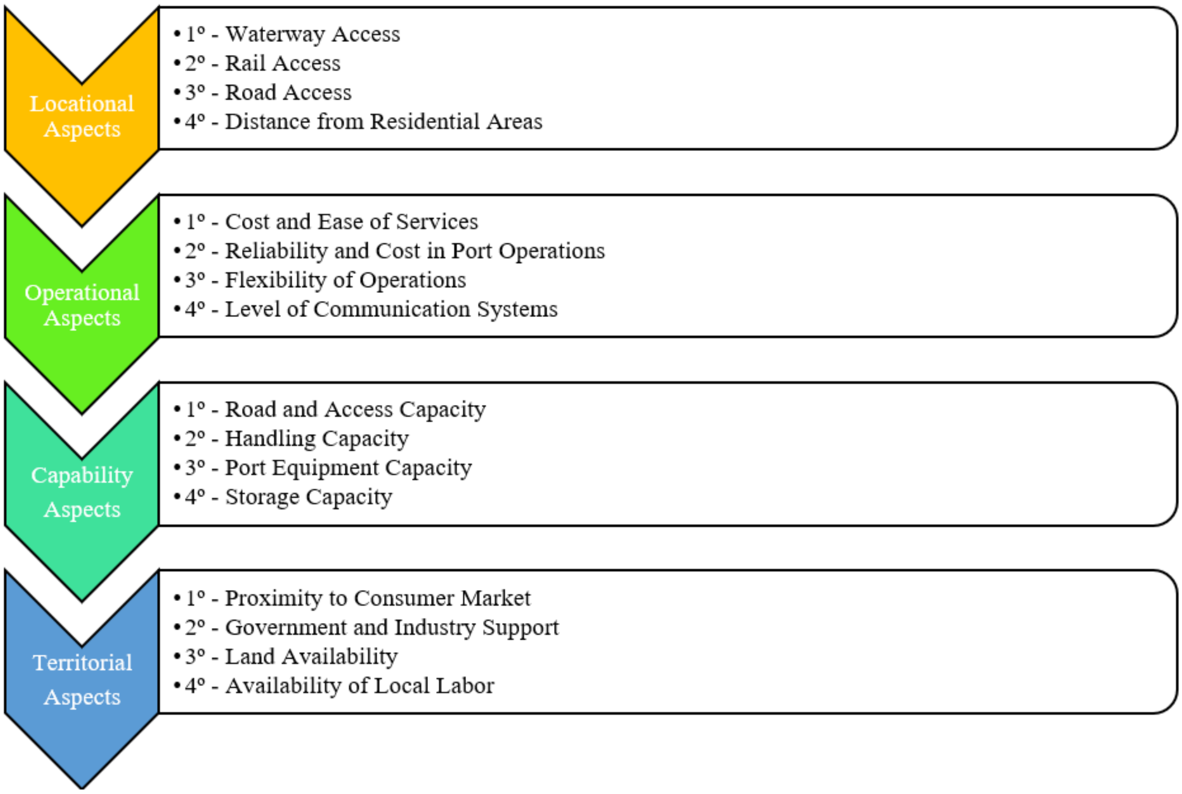

Figure 4. Analysis flow for location selection.

In this way, it became possible, therefore, to obtain the values of Average Local Priorities for the alternatives regarding the Location Aspects criterion, obtaining Miritituba-Itaituba with the best ranking (0.351), followed by Santarém (0.349) and Alça Viária (0.30), as shown in Figure 5.

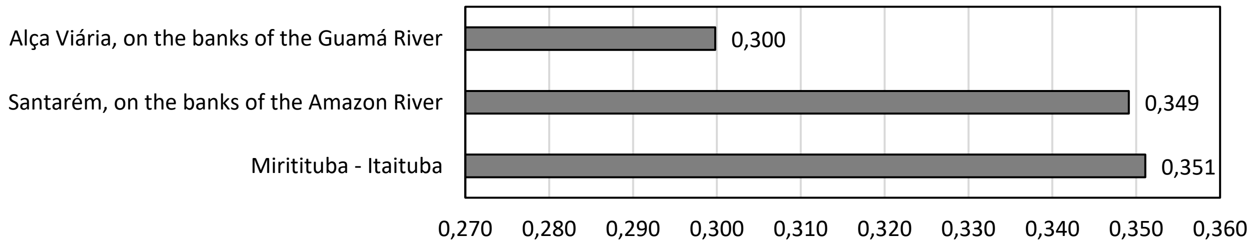

Figure 5. Paired comparison – locational aspects: PML.

In a second analysis, the values of Local Average Priorities were obtained for the alternatives regarding the criterion Operational Aspects, with Santarém having the best ranking (0.409), followed by Miritituba-Itaituba (0.327) and Alça Viária (0.264), as shown in Figure 6.

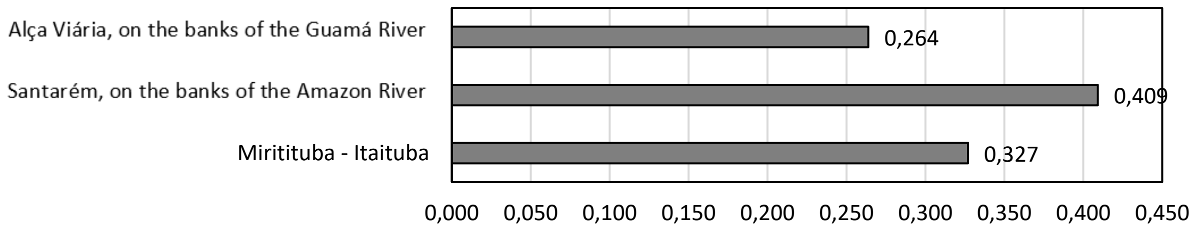

Figura 6. Paired comparison – operational aspects: PML.

In a third analysis, the values of Local Average Priorities were calculated for the alternatives regarding the criterion Operational Aspects, obtaining Santarém with the best ranking (0.419), followed by Alça Viária (0.307) and Miritituba-Itaituba (0.274), as shown in Figure 7.

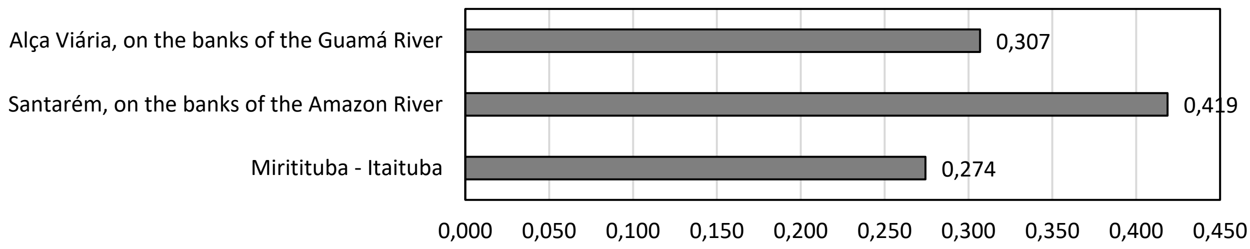

Figure 7. Paired comparison – aspects related to capacity: PML.

Finally, the PML values for the alternatives regarding the Territorial Aspects criterion were obtained, with Santarém with the best ranking (0.396), followed by Miritituba (0.348) and Alça Viária (0.256), as shown in Figure 8.

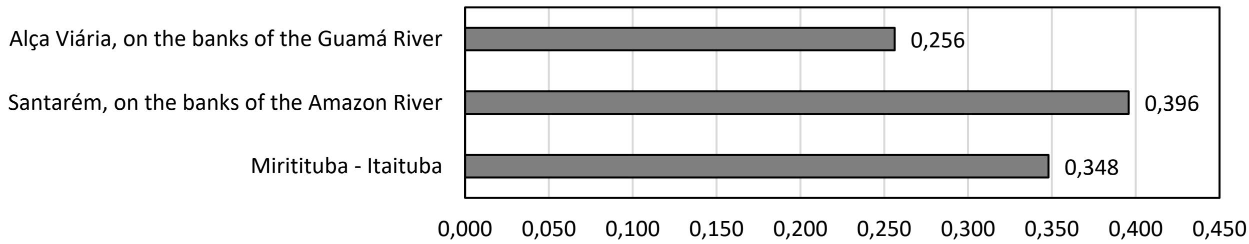

Figure 8. Paired comparison – territorial aspects: PML.

From the analysis of the rankings of the aforementioned topics, the summary shown in Table 5 is verified, and it is possible to verify that the Location Alternative "SANTARÉM" has always been the most chosen by the specialists, both in the evaluation of the raw results, as in the evaluation from of the methodological treatment developed via AHP.

Table 5. Result of the ranking of locational alternatives.

Nível 2 - Critérios	Nível 3 - Subcritérios
Aspectos Locacionais	1ª – Miritituba (0,351) 2ª – Santarém (0,349) 3ª – Alça Viária (0,30)
Aspectos Operacionais	1ª – Santarém (0,409) 2ª – Miritituba (0,327) 3ª – Alça Viária (0,264)
Aspectos relativos à Capacidade	1ª – Santarém (0,419) 2ª – Alça Viária (0,307) 3ª – Miritituba (0,274)
Aspectos Territoriais	1ª – Santarém (0,396) 2ª – Miritituba (0,348) 3ª – Alça Viária (0,256)

Thus, as the main result of this stage of the methodological evaluation, it was obtained, therefore, that the evaluation listed Santarém, on the banks of the Amazon River, as the best location for the installation of a logistics platform, from the perspective of locational, operational, relating to capacity and territories.

Conclusion

It follows, therefore, that the present dissertation was constituted of a proposal of analysis of feasibility of implantation of a center of logistic integration in the Amazon region, from the perspective of several criteria pointed out by the literature as fundamental in the locational selection of an enterprise, being these: locational, operational, capacity-related and territorial aspects.

Furthermore, the research in question presents itself as a way to implement a discussion about the aforementioned theme, with the objective of stimulating such discussions, in view of the scarcity of research, projects and academic and scientific proposals linked to the development of Integration Centers Logistics in

Brazil with a methodological approach bibliographically supported and scientifically validated, being evidenced in the literature mostly studies that associate such guidelines.

Based on this context, a decision support methodology was used for the development of two study areas: (1) to list the main criteria that must be taken into account when approaching the location selection of an enterprise and (2)) to obtain the best location among locational alternatives proposed for the study, aiming to result in the formulation of a specific strategy for the development of premises capable of systematizing these processes.

Concomitantly, with the development of criteria based on their importance within an enterprise in the port sector, it was possible, first, to carry out a pair-wise comparison without considering the importance scales implemented by Saaty, in order to assess, initially, only the raw amount of responses for each criterion and sub-criterion. Such analysis made it possible to assess, in general terms, which criteria and sub-criteria the evaluators considered most important.

As a consequence, in a second analysis, the evaluation of criteria and sub-criteria was carried out with the consideration of scales of importance, making it possible to verify, this time, the weights of each criterion within a shipbuilding enterprise. Such an analysis is of fundamental importance, given that it enables the verification of which criteria and sub-criteria should be intensified and directed towards more incisive and targeted implementation measures.

Regarding the results obtained through such analyses, one was complementary to the other. The analysis of the criteria showed that the Location Aspects criterion has relatively greater importance in relation to the others, when evaluating the general average priority index. Following this criterion, the Operational Aspects criterion was of significant importance. With the emphasis on these criteria, it became possible to evaluate their sub-criteria and verify their relative importance, in which it was evidenced that the sub-criteria Waterway Access and Cost and Ease of Services were the ones that obtained the highest relative importance among all those evaluated.

It is possible to observe that, for the decision-making group, the Locational Aspects criterion is the most important in relation to the others, with 0.333, while the Operational Aspects criterion came in second, with 0.29, and the other Aspects Related to Capacity and Territorial Aspects with, respectively, 0.224 and 0.153.

In addition, the importance factors obtained for these criteria and sub-criteria mentioned were also obtained for the other criteria and sub-criteria, a fact that made it possible to develop general guidelines about the flow that must be considered in the locational selection of a logistics platform, based on the opinion of experts in the field.

Therefore, in view of the application of the multi-criteria methodology, the computational tool and the application of the case study, the research in question proved to be satisfactory, fulfilling the objectives initially raised, which consisted of the application of problem structuring and support methods multicriteria to the decision, that is, Analytic Hierarchy Process, as a way of helping the decision-making process, from different perspectives, based on the criteria listed and ranked by specialists in the naval industry and port sector. With the results obtained, the justification for carrying out the research was supported and the hypothesis presented was able to be validated, evidencing the potential of the research in question.

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