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Regional development and Organization of space: An Approach to the Dry Port location using the Hybrid Method Fuzzy-AHP

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***Abstract* —** *The choice of an ideal location for a dry port is a complex decision, in which the impacts generated lead to the need to consider multiple criterion, subcriterion and points of view, creating group decision problems. In such complex problems and decisions uncertainty is often present. Therefore, this study employs the Fuzzy-AHP hybrid method in order to minimize the uncertainties arising from the judgments and operation of the multicriterion method. The study involved in its approach companies and municipalities of the region of Greater Vitória in the State of Espírito Santo (ES) and its potential hinterlands. The results indicate that the planning of actions and policies aimed at regional development and organization of space can benefit from this study, because the approach proposed is adaptable to different contexts and particularities.*

Keywords— Dry port; Location of facilities; Multicriterion method.

I. INTRODUCTION

The logistics of cargo handling and distribution has represented a growing challenge for organizations in recent years due to difficulties in the operationalization of deliveries in urban centers (BONTEMPO et al., 2014). For Nguyen and Notteboom (2016), accessibility constraints influence the performance of the cargo flow, as well as restrict meeting the needs of stakeholders.

In this sense, Bask et al. (2014) emphasize that the evolution of the means of commercialization of products, has demanded solutions of movement that consider multiple objectives in the distribution of loads. According to Chen and Notteboom (2014), cargo handling activities have become an important part of the transportation system. According to Feng et al. (2013), these activities contribute directly to regional development because they are related to space occupation. These authors point out that due to this occupation, cargo movement activities to and from the port are being increasingly directed to the interior (secondary zone), using dry ports and transportation corridors to attend these activities.

The dry ports are inserted in this context as a link between the port and its hinterlands (areas of commercial influence of a port), assisting the operationalization, movement and distribution of cargoes, being an extension of port activities in the interior, acting in the legalization and nationalization of loads with the consenting and intervening agencies (RODRIGUE et al., 2013).

In this sense, the location of facilities is an important decision for the companies, because they have high costs, and once implemented, poorly performed investments are difficult to reverse (CHEN; NOTTEBOOM, 2014). The location of dry ports may be associated with the need to form clusters with load-carrying activities, which must meet and be close to the hinterlands (VAN DEN BERG; LANGEN, 2011).

The decision process on the location of facilities covers the identification, analysis, evaluation and selection among the alternatives (BENTALEB et al., 2016). Because of the complexity involved in analyzing stakeholder judgments, based on the definition of criterion and subcriterion, it is necessary to use multi-criterion methods that collect and measure these judgments (SAATY, 1977).

Conventional approaches to facility location problems, such as the Varignon mechanical model, Hakimi method, p-median problem, multi-product enabled plant problem, and the center of gravity method, tend to be less effective in dealing with the imprecise or vague nature of the linguistic estimate (BENTALEB et al., 2016, NGUYEN, NOTTEBOOM, 2016, KOLAR,

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RODRIGUE, 2018). In everyday business, the criterion and subcriterion used to evaluate alternatives for locating facilities are usually expressed in linguistic terms. However, due to the duality observed in phenomena of nature, and which is most often present ambiguously in the judgment and establishment of preferences by the human being, Fuzzy logic, developed by Lotfi Zadeh in 1965, has been used to establish patterns in the context of imprecisely defined criterion and subcriterion (ZADEH, 1965, CHOU, YU, 2013).

Velasquez and Hester (2013), affirm that multicriterion methods do not have in their formulation mechanisms that can attenuate distortions of opinion, and minimize the impacts generated by the lack of effective verticalization of opinions, that is, in everyday, subjective concepts to classify or consider situations of uncertainty need to be addressed.

In this context, this study presents an approach to dry port location using the hybrid multi-criterion Fuzzy-AHP (Analytic Hierarchy Process) method, because with the use of the same it will be possible to perform a hierarchical structure with parity comparisons, allowing a general ordering of importance by criterion, subcriterion and alternative, and, a treatment of the uncertainties present in the decision process, which contributes as a planning tool for actions and policies geared to the regional development and organization of the space. Therefore, this approach was tested in a field study involving the Greater Vitória region in the State of Espírito Santo (ES) and its potential hinterlands.

II. REGIONALIZATION AS A MEANS OF EXPANDING PORT ACTIVITIES

The movement and land distribution of cargo through ports is becoming an important dimension of the globalization of commercial activities (RODRIGUE; NOTTEBOOM, 2010). As a result, structural changes in logistics have generated new patterns of cargo distribution, which require innovative approaches to the hierarchy of port activities and service to the hinterlands (RODRIGUE et al., 2013).

In this context, Henttu and Hilmola (2011) point out that the implementation of dry ports in secondary zone provides a decongestion of activities in the immediate vicinity of the primary zones, due to their ability to perform an integration between the moving system and transport corridors.

For Ducruet et al. (2014), the development of global supply chains has increased pressure on the performance of shipping and port operations, as well as the distribution of cargo to inland regions (port regionalization).

Martínez-Pardo and Garcia-Alonso (2014) argue that in order to have efficient regionalization strategies, the ports need to know which transport corridors are and can be available. For these authors, the behavior of the hinterlands must be monitored and analyzed constantly, for requiring activities and actions that they use to the structures of the dry ports. In this way, this behavior can serve as a subsidy for the planning of expansions of scope in the cargo handling operations to and from the port.

The regionalization of port activities can be seen as an element that helps to improve the operational efficiency of the port (DUCRUET; NOTTEBOOM, 2012). This improvement, according to Ducruet and Notteboom (2012), occurs through the possibilities of integration of logistic operations, which use dry ports, and which, in most cases, generate cost reduction in distribution activities.

Thus, according to Rodrigue et al. (2013), port regionalization can also be understood as the expansion of the operational activities of the port, going beyond the primary perimeter, aiming to meet the hinterlands foreland (global trade) and hinterlands inland (internal or regional demand), expanding the area performance of the port.

For Ducruet and Itoh (2016), the movement of cargo between ports can be understood as a strategic action that benefits the regional development, due to the internalization of port activities. In this context, dry ports, because they are bonded warehouses, tend to assist port terminals both in catchment and cargo distribution (NGUYEN; NOTTEBOOM, 2016).

Dry ports serve as transhipment points and logistic integration with the hinterlands (MONIOS; WILMSMEIER, 2012). Corroborating, Rodrigue and Notteboom (2010) emphasize that this integration allows regional development, because the dry ports interconnect cargo distribution networks, serving as a link to the ports.

III. LOGISTIC INTEGRATION THROUGH DRY PORTS INDENTATIONS AND EQUATIONS

According to Rodrigue et al. (2013), around the world, dry ports became an intrinsic part of the transportation system, being an important element for expansion of port activities and logistic integration, as it performs both cargo consolidation activities and deconsolidation. For these authors, the massification and concentration of cargo flows in a limited set of ports, created conditions necessary for the existence and use of dry ports.

However, due to the uncertainties provided by commercial relations, according to Falguera (2012), it is important to design a distribution chain that best adapts to market changes, and for that, the levels of service expected by users should be taken in the definition of the location of the dry port.

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Monios and Wilmsmeier (2012) point out that the functions of the dry port and the transport connections that connect the distribution networks to the port, are changing. In the past, transport corridors were more static, mainly due to the geographical entrance barrier represented by the location of the port terminal, thus becoming more and more dynamic today. Therefore, these same authors emphasized that the criterion and subcriterion that meet the level of service desired by users should be taken into account when locating the dry port.

In this context, for Bazaras et al. (2015), the transport corridors play an important role in the movement of cargoes, making feasible the continuity of cargo flows, and consequent service to the hinterlands. These authors state that transport costs are considered a dominant factor in the use of these corridors, since they directly influence the needs of the hinterlands.

Because of the accessibility levels that must exist along the transport corridors, the location of dry ports should not only consider the needs of hinterlands as a parameter, but also use stakeholders 'and ports' views and plans (BASK et al., 2014).

In this sense, Ka (2011) points out that the performance of the dry port can be verified by its capacity to integrate the needs of the demand to the transport corridors. According to this author, this condition is necessary because of the influence of the hinterlands on the configuration of these corridors, which therefore requires an evolution of the available infrastructure.

According to Kolar and Rodrigue (2018), dry ports can also be understood as intermodal terminals, having logistical links that may serve different interests. This author emphasizes that these connections allow not only an expansion of port activities, but also the condition of allowing the port to interact with other commercial partners, and even, to meet hinterlands that have overlapping interests.

Considering an environment within the distribution chain, Nguyen and Notteboom (2016) emphasize that dry ports can function as extensions of port terminals, being transhipment points in secondary zones, because they promote a logistical integration in cargo movement. For these authors, in advanced economies, such as North America and Europe, the port authority and operators are primarily responsible for the development of the dry port, with the purpose of solving problems related to the limitation of capacity.

According to Bentaleb et al. (2016), the idea of locating and creating a dry port is to mitigate port congestion by promoting regionalization of activities. These authors point out that a dry port is an important component of the distribution chain, given the efficiency in operations for both importers and exporters.

The use of a dry port includes benefits that go beyond the expansion of port activities, and this use can be incorporated as a management tool by companies, such as the maintenance of strategic inventory of imported goods, raw materials and finished products (NGUYEN, NOTTEBOOM, 2016).

In this way, the location of dry ports around the world, according to Rodrigue et al. (2013), has a functional relationship with the port terminals and the hinterlands, because it is a transhipment point, and with that, fostering logistic integration. For these authors, this location should consider the regional economic, geographic and political scenario, which not only define the logistics functions to be performed, but also the forms of port regionalization, taking into account the relative uniqueness of each configuration required.

IV. MULTICRITERION METHODS TO AID DECISION MAKING

Multicriterion analysis are methods and techniques aimed at supporting decision making, based on the use of several criterion (Velasquez and Hester, 2013). Because it is versatile and applicable in varied everyday cases, this analysis has also been used in localization problems because of its ability to integrate opinions (SAATY, 1977; CHOU; YU, 2013).

According to the literature (KAT et al., 2012, WANG et al., 2016), because there are problems that have different amounts of uncertainty, there are multicriterion methods that help to elaborate specific solutions for some approaches, being able to be cited , because the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), AHP (Analytic Hierarch Process) and ELECTRE (ELimination and Choice Expressing the REality) I, II and III are present in several studies.

In this context, Saaty (1977) emphasizes that the AHP method has the principle of creating a hierarchical structure of criterion, subcriterion and alternatives, a fact that is not observed in other multicriterion methods. Another advantage of this method, pointed out by Saaty (1977), is the consistency check of judgments, resulting in general ordering of criterion, subcriterion and alternatives.

Chakraborty et al. (2013), verified when selecting a facility selection problem, involving multiple criterion and a finite set of alternatives, that the use of the AHP allowed to select a site that meets the needs of the stakeholders, besides promoting an increase in productivity in the network distribution.

Sousa and Boente (2016) use Fuzzy sets theory as a data analysis tool in a decision-making process to evaluate the performance of an institution, in order to reduce the degree of uncertainty in the judgments,

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considering the responses related to used, with ambiguity, it was possible to allow the interpretation of linguistic variables.

In this context, Chatterjee (2016) emphasizes that the Fuzzy sets have as principle to treat subjective character problems, which have inaccurate information, quantifying and approaching them by means of a numerical scale. For this author, the main ability of Fuzzy sets is to express a gradual transition between pertinence and non-pertinence, allowing the representation of imprecise concepts expressed in natural language.

Singh (2016) used a hybrid approach between the Fuzzy and AHP sets in a strategic decision-making problem for facility location, which allowed for the selection of a location that brought economic benefits to the supply chain, as well as supply of a better level of services for consumers.

Thus, according to the literature (KA, 2011, CHOU, YU, 2013, CHATTERJEE, 2016), the inaccuracies of the present judgments in the operationalization of AHP can be minimized with the integration of the Fuzzy set theory. According to Singh (2016), this integration is called Fuzzy-AHP (FAHP), which is operationalized through the following steps:

i. The criterion, subcriterion and alternatives are initially defined. Decomposed by two vectors, the first $C_n = (C_1, C_2, ..., C_n)$ representing the criterion, and the second $A_n = (A_1, A_2, ..., A_n)$ is the representation of alternatives;

ii. Subsequently, all the criterion are matched, allowing the observation of more relevant criterion, as well as assigning weights for each criterion, subcriterion and alternatives. According to Saaty (1977), weights are attributed to the alternatives through parity judgments regarding each subcriterion and alternatives (Table 1).

Tab. 1: Relative importance scale in the peer comparison. Source: [Saaty, 1977].

Saaty scale	Definition
1	Equally important
3	Weakly important
5	Fairly important
7	Strongly important
9	Absolutely important
2, 4, 6 e 8	Intermediate Amounts

The evaluations with the attributions of weights must be made by each of the respective respondents, from this will be generated matrices of evaluations with the answers obtained. In order to maintain the characteristics of the weights, by means of the modal value of the matrices, the consolidated matrices are obtained.

For Saaty (1977), the consolidated matrices verify the logical consistencies of the judgments by the Consistency Ratio (CR) which is obtained by: $CR = CI/RI$. The consistency ratio indicates the reliability of the respondents, in that it has to meet the following condition: $CR \leq 0{,}10$. The Consistency Index (CI), obtained by the following expression: $CI = (\lambda_{máx.} - n)/(n-1)$, being $\lambda_{máx.}$ auto matrix value and, n the array order. The Random Index (RI) is a tabulated value calculated in a laboratory and changes according to the sample size.

iii. After all the assignments of the weights the transformation of the judgments into a triangular matrix is performed, considering the pertinence function $\mu_A(x)$, which takes a given value in a range [0,1] (fuzzification). This function is obtained from the consideration of the vector represented by (l, m, u) on what l represents the lower limit of the judgment, m the modal value, that is, the value of the judgment, and u describes the upper limit. Thus, considering that $A = (a_{ij})_{mxn}$ is the comparison matrix, where: $a_{ij} = (l_{ij}, m_{ij}, u_{ij})$, it is possible to obtain the following clashes: $l_{ij} = 1/l_{ji}$, $m_{ij} = 1/m_{ji}$, $u_{ij} = 1/u_{ji}$. Therefore, these comparisons will be transformed into triangular Fuzzy numbers in a certain degree of imprecision δ. Following, the opinion of the interviewee, that is, the median analogue (m), along with l and u, are used as imprecise range delimiters, which assists the calculation of numerical approximation. With this, the association of the comparison with the triangular Fuzzy number is obtained the vector: $(m-\delta, m, m+\delta)$ and from it is calculated an inverse vector in which the positioning of the ends is changed, both being used to elaborate the triangular matrix. However, it is important to note that in the case of m be equal to 1, the triangular Fuzzy number will be reached by means of the vector: $[1/(9+\delta); 1, 1+\delta]$. Similarly, another particular case applies when m is equal to 9, and, in this situation, the triangular Fuzzy number is obtained by: $[1/(9+\delta); 9, 9]$. After the construction of the triangular matrix, the sum of the lines that make up this matrix is realized, being in the sequence a parity comparison of the triangular Fuzzy numbers, as for example, being the lines of this matrix

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represented by $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$, the comparison of two triangular Fuzzy numbers is obtained by: $V(M_2 \geq M_1) = {l_1 - u_2} \big/ {(m_2 - u_2) - (m_1 - l_1)}$. Thus, the sum of the sum of the columns is reached by: $SSC = (L, M, U)$.Then, after all the summations of the matrix lines are made, a data condensation is done, obtaining the Fuzzy value of synthetic extension (S), which is calculated for each criterion: $S_i = S_{Lines_i} \times \left(\frac{1}{U}, \frac{1}{M}, \frac{1}{L}\right)$, on what S_{Lines_i} is the sum of the line i. In the continuity, for all the lines are made comparisons of the Fuzzy values of synthetic extension, however, for situations in which these values assume negative values, it is assigned value equal to zero in the comparisons.

iv. Continuing the fuzzification, the calculation of the global comparison (d') for each criterion is made after performing the comparisons of the Fuzzy values of synthetic extension, however, the condition for this to happen is that: $d'(M_i) = min.\{V(S_i \geq S_k) \forall (k = 1, 2, 3, ..., n) \leftrightarrow k \neq i\}$. To consolidate these calculations, the vector of weights (W'), which is given by: $W' = [d'(M_i), ..., d'(M_n)] \forall i = 1, ..., n$.

v. Finally, the vector of weights is normalized (W'), being obtained a preference ordering, duly adjusted to the Fuzzy numbers.

V. LOCALIZATION METHODS AND TECHNIQUES

The global economic recession has led the port and transportation sectors to excessive use of their operational capacities, and this has led to actions to reduce costs and redesign the use of cargo distribution sites (RODRIGUE et al., 2013). For Feng et al. (2013), an important solution is the location of dry ports as a way of balancing the supply to the needs of the demand, and may even help improve the performance of cargo distribution.

Problems of location of facilities are complex, and, according to Bask et al. (2014), studies of these problems should involve several criterion and subcriterion for decision making, and it is necessary to address the needs of stakeholders. These authors point out that this involvement through multicriterion methods contributes to the spatial development of dry ports, this being attributed to an increased understanding of the services that influence the development of the hinterlands.

By proposing a hybrid method with multicriterion and monocriterion methods to locate a dry port, Bentaleb et al. (2016) verified that the results of the analysis are not necessarily the optimal sites. For these authors, it is necessary to employ a monocriter method to obtain an exact location and closer to the needs of the stakeholders, and with that, to allow the extension of the hinterlands.

For Ka (2011), regional political issues interact and influence the market share of dry ports, defining the modal characteristics to be used, as well as what should be considered in their location. For this reason, this author employed an approach that involved multicriterion methods and Fuzzy sets, obtaining with this a local solution that considers, congregates and minimizes uncertainties of opinions.

Núñez (2016) states that the structure of the global economy, with decentralized production and consumption centers, promotes increased freight traffic around the world, creating significant problems and challenges for the transportation and handling of cargoes. In this context, the author emphasizes that the location of a dry port requires a thorough analysis of the supply chain, using multicriterion methods and techniques that deal with uncertainties in the judgments, as it involves the needs of meeting the demands and the use of more efficient modes of transportation from the energy point of view.

Nguyen and Notteboom (2016) presented a framework for the use of multiple criterion in the assessment of the location of dry ports in developing countries, involving a perspective with several stakeholders, being evidenced the criterion reduction of transport costs as the most relevant, and that the hinterlands and supply chain are directly influenced by the market.

Thus, from the arguments and studies presented in this section, the criterion and subcriterion pointed out in the literature were considered (KA, 2011, FENG et al., 2013, BASKET et al., 2014, BENTALEB et al., 2016, NGUYEN, NOTTEBOOM, 2016 and NÚÑEZ, 2016), which compose the proposed approach of this study for dry port location - Geographic (GEO), Accessibility (GEO 1) and Geographical limitations (GEO 2); Political (POL) - Government support (POL 1) and Regional support and exemptions (POL 2); Industrial (IND) - Local productive arrangement (IND 1) and Perspective for industrial development (IND 2); Operational (OPE) - Time to and from the port (OPE 1), Available infrastructure (OPE 2), Cost of planning routes to and from the port (OPE 3), Available support services (OPE 4) and Rail and highway connection availability (OPE 5); Environmental (AMB) - Environmental restrictions (AMB 1) and Future direction of environmental policy (AMB 2); Social (SOC) - Availability of labor (SOC 1)

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and Social level of the population of the region (SOC 2); Economic (ECO) - Land acquisition cost (ECO 1); Investment needed (ECO 2) and Long-term financial return (ECO 3).

VI. METHODOLOGICAL APPROACH

This section presents the methodological approach and the research development. This study was constructed in three stages (Figure 1), in which the survey survey method was used. The data collected served to understand and analyze the studied phenomenon, besides helping to operationalize the AHP and Fuzzy sets. The data collection instrument was a structured questionnaire, in which the criterion and subcriterion of Table 2 were used, was applied to a population composed of 3264 companies present in the municipalities of Cariacica, Serra, Vila Velha and Vitória, all of the State of Espírito Santo (ES), which were selected because they involve cargo movement directly to and from the Port of Vitória (ES), where their hinterlands are located in the northeast and northwest regions of the ES (Aracruz, Colatina, Linhares and São Mateus).

The structuring step was started with a pre-test, in which a structured questionnaire was applied to 5 specialists, in order to verify the theoretical consistency of the instrument, and its context-related language, which was based on criterion and subcriterion pointed out in the literature. After assessing and analyzing this questionnaire, the experts indicated adaptations in their original format to better adapt to the context of the study. Then, as a form of test, the questionnaire adjusted with the suggested adaptations was applied to 15 randomly selected elements of the population (11 companies and 4 municipalities), in order to verify the existence of possible improvements to be performed in the data collection instrument, and textual adjustments are indicated.

Subsequently, the questionnaire was applied to the entire population (3264 companies), and a sample was obtained with 323 answers (319 companies and 4 municipalities). From this result, the second step of the proposed approach performed the reliability and data consistency analysis. The treatment was started with the interval check $|z| < 3$ ($p < 0,001$), for a value of Z_{score}, which was attended, however, 15 elements with values above this range were identified, being characterized as outliers, which along with 3 missing values were removed from the sample. From this treatment, the sample now has 305 valid elements, being considered representative a sample error of 5%, with a confidence level of 95% and a maximum percentage of obtaining of 80%. In addition, a data reliability check was performed, using the internal consistency statistic, using Cronbach's alpha (C_α) which was higher than 0.7, considered acceptable according to Cronbach (1951). To support these analyzes were used spreadsheets and statistical software SPSS (Statistical Package for the Social Science) Statistics Desktop 23.0 trial version.

Then, the third step of the proposed approach, performs the application of the FAHP hybrid method in two phases. The first involved the operationalization of the AHP method, which used the Expert Choice Demo software, which aided the process of analyzing the matrices of judgments. In the second phase, the fuzzification was performed considering the matrices of judgments obtained through the AHP, performing the conversion to Fuzzy sets, and later obtaining a triangular matrix, which allowed to treat inaccuracies originated in the formulation of the matrices of judgments.

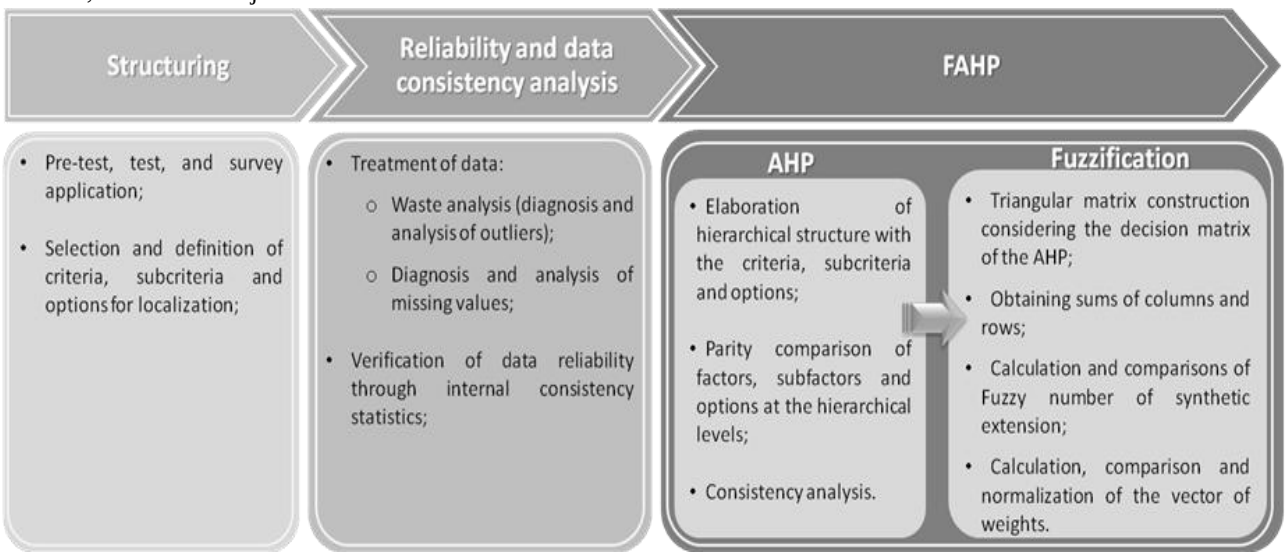

Fig. 1: Methodological steps of the study

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VII. RESULTS

From the results obtained by means of the survey type survey, in which pre-test and test were carried out, there was the selection and definition of criterion, subcriterion and alternatives for the location of the dry port (Step structuring approach). Subsequently, 4 potential municipalities (São Mateus, Linhares, Aracruz and Colatina) were selected, which were considered representative from the perspective of companies (Figure 2).

Then, in the second stage of the proposed approach, the data treatment detected abnormalities in the sample, which could compromise the analyzes to be performed. For this reason, when outliers and missing values were detected, these elements were removed from the sample, therefore, when tested again, the sampling had an acceptable internal consistency (all elements within the range $|z| < 3$ and C_α higher than 0.7).

The third step of the proposed approach considering the reliability and consistency of the data obtained through the survey survey, started with the application of the AHP method. To this end, the hierarchical structure elaborated, followed the precepts of Saaty (1977), containing the criterion, subcriterion and alternatives raised, serving as support for the operationalization of AHP. Thus, at the top of the hierarchy is the ultimate goal, which is to choose the most favorable location to locate the dry port, according to the companies' vision. Then, in the second level of the structure are arranged the criterion that indicate the characteristics for site selection, which serve to establish an order of priority. The third level contains the subcriterion, and the fourth the alternatives.

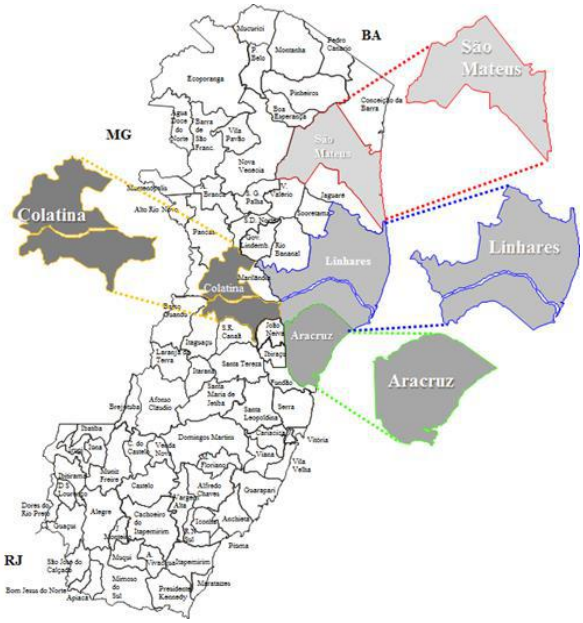

Fig. 2: Study coverage area

The weights of these relationships were obtained in the Expert Choice Demo software, the hierarchical structure and the joint judgments of the criterion, subcriterion and alternatives, as a product of the AHP operation. From this operation, it can be observed that the economic criterion exerts greater influence on the location of the dry port, which can be explained due to the expected financial disbursements and returns. Rodrigue and Notteboom (2012) emphasize that studies on the location of dry ports in secondary zones should focus mainly on financial approaches, due to the needs of cargo movements prioritize the optimization of transport costs.

The results suggest that the respondents consider that all the criterion derived from the literature review are adequate to the localization study (Figure 3). In the absence of redundant data in the hierarchical structure used, however, in case of existence it would lead to new trials (SAATY, 1977). A Consistency Ratio (CR) of 0.8, for Saaty (1977) the acceptable value for judgments to be considered consistent is $CR \leq 0.10$, it can soon be said that the judgments are consistent, corroborating with the relevance indicated in the assigned weights (CHOU; YU, 2013).

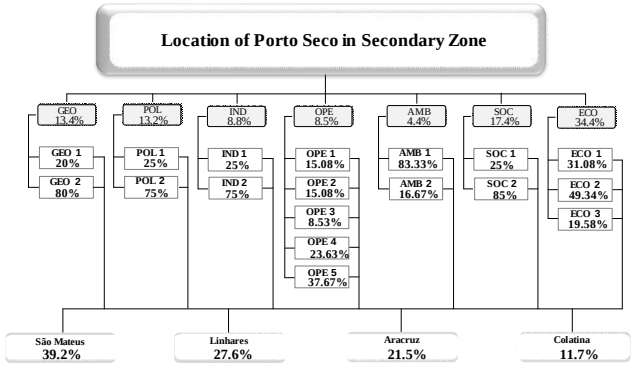

Fig. 3: Result by AHP method

The weights obtained from the criterion and subcriterion provide important information for decision makers, which can be used during the planning and management of cargo handling. Thus, depending on the characteristics and behavior of the hinterlands, the projects and the limits of financing and use of resources, decision-makers can prioritize the items with the highest returns.

Then, the fuzzification process is performed, the second phase of the third stage, the procedure considered the results obtained by the AHP, performing the conversion of the numerical values into a Fuzzy set. This procedure was carried out from the matrix of judgments of the subcriterion and the criterion, as for example Table 2, in which the relative importance of the subcriterion GEO 1 on the subcriterion GEO 2 is demonstrated.

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Tab. 2: Matrix of judgments in relation to subcriterion of the Geographic criterion

	Weights	
Subcriterion	**GEO 1**	**GEO 2**
GEO 1	1	0.25
GEO 2	4	1

Thus, considering the results of Table 2, it was possible to obtain the pertinence function $\mu_A(x)$, which presented a value of 0.51, and served as a subsidy for the calculation of the transformation process in Fuzzy numbers in a triangular matrix (Table 3).

Tab. 3: Matrix triangular in relation to subcriterion of the Geographical criterion.

Subcriterion	**GEO 1**			**GEO 2**		
	l	***m***	***u***	***l***	***m***	***u***
GEO 1	1	1	1	-0.26	0.25	0.76
GEO 2	1.32	4	-3.85	1	1	1

Then, considering the results of Table 3, the sum of the rows and columns of this matrix was calculated, and the synthetic extension Fuzzy values were calculated and compared (Table 4). And, from these comparisons, it was possible to obtain the normalized weight vector of the geographic criterion (Table 5). In this way, after finalizing the fuzzification process, it is possible to observe that the respondents consider the subcriterion accessibility (GEO 1) more relevant compared to the subcriterion geographical limitations (GEO 2).

Tab. 4: Sum of the rows and columns of the sub criterion of the Geographic criterion (GEO)

Sum lines		
l	***m***	***u***
0.74	1.25	1.76
2.32	5	-2.85
Sum of column sums		
2.32	5	-2.85

Tab. 5: Vector of results by normalized subcriterion

Normalized W'	
GEO 1	**GEO 2**
0.7685	0.6397

In this way, all the elements obtained by the AHP (Figure 3), presented a value between 0 and 1, these values indicate an acceptable degree of pertinence. However, it was possible to verify and verify that the respondents evaluated the social criterion (SOC) as the most important, in contrast to the result presented by the AHP, in which the Economic criterion was elected. Núñez (2016) attests to these results, affirming in his study that the social criterion directly influences the productivity of the dry port, and that the labor, therefore, determines the performance in the whole operational process, interfering in the location and profitability of business.

Although the final result of the FAHP indicates the best option being São Mateus, with respect to the criterion and subcriterion there were considerable changes after the fuzzification. In this sense, it is possible to see the difference of the results of the AHP method for the FAHP method, as observed (Figure 4). In the first case, the results suggest an importance of 34.4% of the economic criterion, followed by the social criterion with an importance of 17.4%, in the second case, the most relevant criterion was the social criterion with 20.48%, followed by the economic criterion with 19.99%, that is, if it were to choose the location of a dry port giving greater importance for the economic criterion, as suggested by the AHP method, the choice would be considered deficient, since the social criterion is of greater importance than the economic one, as indicated by the FAHP method.

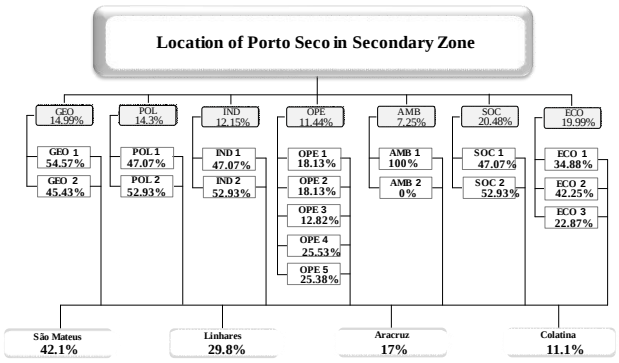

Fig. 4: Result by FAHP method

These changes indicate how important and important it is to adjust inaccuracies, such as changing the priority between economic and social criterion, suggests that planning and action should occur initially to people, not investment. This type of information is necessary to not only guide what should be done when planning a dry port deployment, but what should be done in the short, medium and long term in order to keep the business viable, and can serve needs of the hinterlands.

VIII. FINAL CONSIDERATIONS

The evolution of cargo distribution into hinterlands can be seen as a cycle in the ongoing developments in intermodal transport, since dry ports are necessarily an extension of some port activities. For this reason, the geographical characteristics linked to the modal availability and the capacity of service of the transport corridors have an important role to play in defining this development.

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As transport corridors and port terminal activities become integrated, in particular, through the relationship between maritime transport and port operations, the focus of the distribution problem has turned into the hinterlands. Therefore, determining a possible location of a dry port is a complex topic in the literature.

The dry port location approach presented in this study, using the Fuzzy-AHP multicriterion hybrid method, allows selecting sites with desirable performance, both in the present and in the changing conditions, and for this reason, it contributes as a planning tool for actions and policies focused on regional development and space organization.

However, the results suggest that it is necessary to adjust the uncertainties arising from the operation of multicriterion methods. The need for this adjustment can be observed from the comparison of the results obtained by the AHP and the FAHP, in which the judgments could be better understood, as well as verify with more rigor the opinions of the respondents. This verification allowed us to verify that in the analyzed conditions the Social (SOC) and Economic (ECO) criterion are closer, suggesting equal importance, a fact that is not observed in the result presented by the AHP. The approach also allowed to verify the pertinence of criterion and subcriterion for the location of a dry port present in the literature, and to be selected to those that meet the needs of the stakeholders, with this, the municipality of São Mateus was the chosen one. In addition, this approach can be adapted to different realities, which seek to identify the best option for locating facilities.

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