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Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

# A Hierarchical Approach to the Prioritization of Intermodal Logistics Platforms

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**Abstract**

In this article, the Intermodal Logistics Platform - ILP is presented as an element to foster intermodality and reduce logistics and transportation costs in the Brazilian road transportation system. However, when there is a considerable number of implemented ILPs, it becomes difficult to prioritize them, mainly due to the lack of methodologies developed to that specific end. This gap justifies the scientific contribution and innovation proposed in this study, which presents a methodological approach applied to the prioritization of investments in Intermodal Logistics Platforms. A case study was carried out considering as a simulated scenario the Brazilian multimodal network and the production and consumption matrices projected for the year 2031 regarding the main products of the Brazilian commercial balance. This simulated scenario identified 137 viable locations in the Brazilian territory to operate Intermodal Logistics Platforms. Considering the economic and social diversity existing in Brazil, it was clear that the methodological approach could not be treated in a restricted and isolated manner, but rather had to be correlated with aspects such as geography, transportation infrastructure and regional social developments. For that, three distinct ranking strategies were developed. Their methodological approach is presented herein.



*Keywords:* prioritization; hierarchization; logistic platform; intermodal logistic platform; transportation planning; transportation policy.

## 1. Introduction

Prioritization of transportation projects has been a topic widely discussed by several authors (Kulkarni et al., 2004; Berechman and Paaswell, 2005; Ahern and Anandarajah, 2006; Tsamboulas, 2007; Gokey et al., 2009; Gühnemann et al., 2012; Novak et al., 2015 and Rabello Quadros and Nassi, 2015). However, there is a noticeable gap in the consideration of this topic applied to the implementation of logistics platforms, which is the goal of this article.

Therefore, this study proposes to contribute and innovate by presenting a methodological approach to the hierarchization of investments in Intermodal Logistics Platforms - ILPs.

The development of the referred methodological approach is motivated by three factors: (1) identifying the viability of implementing 137 ILPs in the whole national territory; (2) the need to conceive a prioritization strategy to plan the implementation of such facilities; and (3) the lack of acknowledged studies on the hierarchization of logistics platforms. In the face of this challenge, some conception principles were outlined. The method conceived needs to meet three principles: (1) to have structured and objective technical criteria; (2) to be viable in its execution (provided with possible data); (3) to consider decision variables that are measurable and integrated with the results of simulated scenarios of a multimodal network.

The need for its applicability was taken into account, and thus, the complexity of the model was reduced as much as possible in order to avoid ambiguities and subjectivities, which are frequent in governmental investment decisions in Brazil. Despite the relevance of such theme for the private sector, this article will focus on the transportation economy under the perspective of the public sector, considering strategic issues and matters of interest for national development.

The methodological approach addressed herein was employed to rank the 137 ILPs identified as viable in a case study based on simulated scenarios of the Brazilian multimodal network, with the use of consumption and production matrices projected for 2031, considering the main products traded in Brazil.

The other parts of the article are structured as follows. Section 2 presents a review of the literature related to the hierarchization of transportation infrastructure projects and explores the differences and similarities of eight articles in this theme. Section 3 briefly describes the ILP location study, which was one of the motivators to develop the hierarchization method that is the purpose of this article. This section also evidences the geographic and quantitative dimensions of the involved cargo, and the measured economic impact. Such parameters properly measure the dimension of the proposed challenge. Section 4 presents the composition of methodological approach criteria structured in three levels. Based on the identification of the criteria, an analysis procedure was established, as seen in Section 5. After this step, the methodological approach is applied, as presented in Section 6. Section 7 presents the results and analyses on the conception and implementation of hierarchization. Finally, Section 8 presents the main conclusions.

## 2. Literature review

Transportation planning is a relevant theme that has been discussed by several authors (Tabucanon and Lee, 1995; Bristow and Nellthorp, 2000; Hayashi and Morisugi, 2000; Lee, 2000; Nakamura, 2000; Vickerman, 2000; Kölbl et al., 2008 and Lee and Sener, 2016). Among the several trends exploring this research area, the prioritization of investments in transportation projects stands out.

The hierarchization or ranking of transportation infrastructure projects is not a new topic (Kulkarni et al., 2004; Berechman and Paaswell, 2005; Ahern and Anandarajah, 2006; Tsamboulas, 2007; Gokey et al., 2009; Gühnemann et al., 2012; Novak et al., 2015 and Rabello Quadros and Nassi, 2015) and includes a diversity of studies concerning the types of analyzed infrastructures, the scope of its territoriality, the universe of facilities that are the object of hierarchization, among other aspects. Therefore, due to the extensive scientific production on the theme, eight related articles were identified that allowed us to explore relevant aspects and to identify similarities and differences among them.

It was clear that studies were employed not only to implement new projects, but also to maintain and improve the existing infrastructure. The territorial scope of the studies had 4 levels: a small scope, applicable to an American city, such as New York (Berechman and Paaswell, 2005); a state scope (Kulkarni et al., 2004; Gokey et al., 2009; Novak et al., 2015): Kansas, Virginia and Vermont (USA); a national scope (Ahern and Anandarajah, 2006; Gühnemann et al., 2012), considering Ireland, and Rabello Quadros and Nassi, 2015, considering Brazil; and finally, a continental scope (Tsamboulas, 2007), comprising 21 European countries.

The kinds of transportation infrastructure depicted in the articles were quite diversified: roads (Kulkarni et al., 2004; Ahern and Anandarajah, 2006; and Gühnemann et al., 2012); transportation assets (Novak et al., 2015); bridges (Gokey et al., 2009); roads and railways (Tsamboulas, 2007); the infrastructure of a metropolitan region (Berechman and Paaswell, 2005); and multimodal (Rabello Quadros and Nassi, 2015). The studies that presented the quantification of installations subject to ranking ranged from 8 projects (Berechman and Paaswell, 2005) to 16,000 bridges (Gokey et al., 2009). All of them presented the participation of governmental agencies in the study, with the exception of Tsamboulas (2007) and Gühnemann et al. (2012). And all, without exception, evidenced the participation of stakeholders.

Among the mentioned articles, Rabello Quadros and Nassi (2015) was one of the main articles that supported the basis of this method, since it presents in a detailed manner the decisions involving investments in transportation infrastructure of Brazil, which was also the target of the application of the methodological approach of this article.

Rabello Quadros and Nassi (2015) identified seven criteria in investment decisions regarding transportation infrastructure in Brazil. Such criteria were structured into four groups: logistics and transportation, economic and financial, social, and environmental. The priority of criteria was assessed using the Analytic Hierarchy Process (AHP) with 33 collaborators in four different groups, representatives from government, academia, the production sector, and experts in the area. The chosen collaborators had experience in planning and investment problems in transportation infrastructure projects. The criterion "reduction of transportation costs" proved to be a priority for most collaborators, regardless of the group.

Due to the diversity of institutions represented by the experts that participated in this study, it can be inferred from the results that the prevalence in the decision of investments in transportation infrastructure in Brazil is directed to privileging any and all projects that foster, in comparison to others, the greatest benefits in transportation costs reduction. The authors associated this behavior with the characteristics and needs of an economy in development and of several other deficiencies of the Brazilian road system, which contribute to high costs in cargo transportation logistics. This understanding was corroborated by a competitiveness assessment of 138 countries published in the following year (WEF, 2016a and 2016b), which considers the transportation parameters in Brazil as one of the main aspects responsible for such a low competitiveness index in the international scenario. It was evidenced that, among the most problematic aspects of doing business in Brazil, the insufficient offer of transportation ranked in third place among the 16 aspects observed (WEF, 2016b). Considering such perceptions (Rabello Quadros and Nassi, 2015) and evidence (WEF, 2016a and 2016b), the prioritization criteria were developed with two goals: maximizing intermodality and minimizing logistics and transportation costs in Brazilian cargo handling.

Concerning the goals for infrastructure projects, Tsamboulas (2007) discusses the possibility of having an exhaustive list of goals, but warns about the impossibility of simultaneously meeting all goals. In accordance with this approach, the method is conceived, grounded solely on two goals.

It must be emphasized that, among the references mentioned herein, none refers to the prioritization of investment in logistics platforms, except for the reference found in studies developed by the research group of the Federal University of Rio de Janeiro (UFRJ), which is responsible for the authorship of this article (MT, 2016d).

The lack of technical literature that depicts the hierarchy of logistics platforms was observed not only during the development of this article, but also in the development of the study by UFRJ, which had a two-year execution period.

## 3. Summary of the intermodal logistics platform location study

The Ministry of Transportation in Brazil requested of the Federal University of Rio de Janeiro (UFRJ) a study with the purpose of identifying in the Brazilian transportation network the appropriate locations to deploy logistics platforms, thus contemplating modal connection points according to the expected cargo demands and the existing and planned transportation infrastructures in the country.

As a result of this study, several articles were published (Costa et al., 2012, Costa et al., 2013, Costa et al., 2014, Guimarães et al., 2014 and Guimarães et al., 2017).

The study included the application of declared and revealed preference surveys, with the participation of 55 stakeholders from 45 institutions from both the public and private sectors. In total, 5 meetings were held with different subgroups of stakeholders (MT, 2016b).

A logistics platform location methodology was developed based on the application of a mathematical model seeking to optimize network systems to find priority locations to install logistics platforms (Guimarães et al., 2017).

The process analyzed 56 production and consumption matrices from 89 products divided into five cargo groups (categories): vegetable solid bulk, neo-bulk, liquid bulk, mineral solid bulk and general cargo. Then, the products that can only be transported by road were identified and excluded from the experiment. The experiment did not include petroleum and natural gas, since, in Brazil, such products have their own specific distribution network, with a specific sectorial planning headed by the Ministry of Transportation (MT, 2016c).

For these computational experiments to be carried out, six scenarios were needed. Five scenarios contemplating segregated analysis, as follows: (1) vegetable bulk; (2) neo-bulk; (3) liquid bulk; (4) solid bulk; and (5) general cargo. And one scenario made of the aggregation of the results obtained in the five previous scenarios (MT, 2016c).

The results of the application of the methodology showed a significant reduction in transportation costs, reaching the order of US$ 13 billion. These savings were essentially obtained thanks to the promotion of intermodality in cargo transportation by the simulated operation of ILPs, which resulted in facility for the intermodal transportation of 640 million tons of a total of 2.1 billion tons present in the production and consumption matrix, effectively used in the simulations. It must be emphasized that the simulation was made only for a fraction of the 5.5 billion tons expected for 2031, considering the criteria set in the model (MT, 2016d).

After identifying the 137 locations appropriate for the implementation of ILPs (MT, 2016d), the need to establish technical criteria to support strategic decision in the prioritization of the investments in such structures was also identified. The prioritization criteria were based on the need to maximize intermodality in the country and, at the same time, minimize logistics and transportation costs in the Brazilian cargo handling.

## 4. Composition of criteria for the hierarchization of intermodal logistics platforms

The indication of a portfolio of logistics platforms promoting intermodality to be implemented in a country depends on factors that go beyond the results of the location viability methodology. It involves, among other factors, those related to synergy with ongoing projects, especially those under the responsibility of the federal public sector, which may even be an essential condition for the viability of the installation of this kind of logistics facility (MT, 2016d).

Meidutė (2007) claims that the assessment of a logistics platform project has two main and complementary axes: the financial and socioeconomic assessment, and the assessment of the factors relevant to the establishment of formal agreements between the private and public sectors. Tsamboulas and Kapros (2003) suggest a wider approach, involving the following: choice of location and traffic forecast; definition of the offered services and their respective dimensioning; estimates of investments and main fixed costs and assessment of the project's attractiveness. Additionally, they suggest the use of mathematic models that incorporate uncertainties related to variables such as income, costs and investments made in logistics platforms (MT, 2016a).

Thus, factors such as those described have a certain degree of subjectivity. In this context, a set of criteria were established seeking to support a proposal of hierarchization of investments in logistics platforms. The criteria were conceived in three different levels of analyses. Each level is made of a set of criteria (MT, 2016a).

### *4.1. Level 1 – Primary parameters*

Logistics platforms with a higher quantitative of handled cargo are considered more relevant as they foster greater transportation cost reductions, thus, they must be considered a priority.

The association of the amount of attracted cargo and the reductions in transportation costs may be assessed directly and, in a sense, as a linear function. For that, the same type of cargo or group of cargo must be considered, its handling costs must be from the same type of logistics platform, and the distances of multimodal transportation must be similar. However, that is not what happens, due to the territorial distributions of the production and consumption zones, even for the same product type or group. It is worth highlighting that (MT, 2016a):

- Firstly, the transportation costs reduction criterion is adopted, i.e., the logistics platforms that promote the highest percentages of transportation cost reductions must be considered as priorities;
- Next, the logistics platforms with the highest quantity of handled cargo are considered;
- Finally, the highest number of different products or groups of handled products is considered.

Based on the analyses described above, the criteria established in a first decision parameter are proposed.

### *4.2. Level 2 – Infrastructure parameters*

The second parameter considers the dependence of the logistics platform with the existing ways according to the main type of intermodality promoted. The locations in which there are existing ways must be considered as priorities, as they do not depend exclusively on road infrastructure investments. In such cases, the risks to its implementation due to exogenous factors are lower than for logistics platforms associated with roads in the planning or project phase.

Therefore, as a second criteria, it is necessary to identify logistics platforms with projects in execution and then, with projects that are already planned. The planned projects must be categorized as those included in the government investment programs and those that do not belong to these programs.

This way, projects that do not depend on road investments are considered a priority. Next are those associated with roads under implementation. The ones that depend on road investments not yet programmed are categorized as those related to projects included in governmental programs, and those not included in these programs, which have no guarantee of the necessary means for their operation.

The conjugation of both established parameters is fundamental to allow the installation of logistics platforms in more appropriate locations in the national territory, which provide high reduction in transportation costs, increase in intermodality and diversity of response for different cargo and, at the same time, have lower risks related with externalities of road investments required for their operations. The subset of logistics platforms that fall within such context are the ones most capable of forming a group of priority investments, regardless of internal hierarchy. They must be considered as the first ones to receive investments and, thus, treated with more relevance in the context of strategic guidelines.

### *4.3. Level 3 – Parameters of integration with logistics assets*

The third parameter corresponds to the synergy of each logistics platform with existing logistics assets, especially ports and airports. It considers the following criteria:

- Capacity of logistics platform to fully or partially collaborate by means of operations dedicated to a port or airport;
- Potential cargo not predicted in the simulation that can be incorporated into the operation of a logistics platform, considering the handling of products in the port or airport within its area of location.

Once the priority locations for implementation of logistics platforms are identified, it is then necessary to identify those that are near ports and airports, which are considered relevant logistics assets in the simulated scenario. Next, those that present a higher quantity of product types which are potentially favorable for use by the logistics platform must be organized in descending order. In the case of airports, the relevant ones are those that have air cargo terminals. Thus, based on the descriptions above, criteria sets are proposed to provide, in three levels of assessment, ways to establish a parity between certain logistics platforms, weighing some similar conditions between them and based on the principle of contribution to intermodal transportation:

- By reducing costs;
- By increasing the amount of cargo;
- Including different types of cargo;
- With less exogenous vulnerabilities related to the need of investing in road construction;
- And with greater potential of serving the already existing logistics assets (ports/airports).

Once the criteria were established per approach level, an analysis procedure was created, as presented below.

## 5. Analysis procedure

The use of the proposed criteria produces an analysis procedure. However, seeking a more detailed understanding, logical flows and steps are described in order to qualify each logistics platform according to the established criteria. To do so, the way and rule of attribution of the criteria to the logistics platforms were defined.

Each platform must be identified in the context of attribution of each criteria at each level. For that, the procedures that were applied and generated the final hierarchization results are presented per analysis level.

### *5.1. First level – Hierarchy of priorities*

In the first level, the logistics platforms that promote the highest percentage of reduction in transportation costs are ranked in descending order. Next, this hierarchy is generated according to the amount of cargo handled by them, also in descending order.

After that, the principle of Pareto is applied to each of these hierarchies. This identifies which logistics platforms result in 80% of transportation cost reductions and which result in an increase of 80% in intermodal cargo transportation considering the volume of cargo attracted by all logistics platforms.

Then, values were normalized for each criterion. For that, the one with highest value is considered the reference value of 100%, which is represented by "1". The others, as a result, have a normalized weight with a value lower than "1".

After that, for each logistics platform, it is done as described in Tables 1, 2 and 3, which define the tabulation and the rule to establish the general hierarchy based on the criteria of the first level of analysis.

The hierarchy obtained as conceived in Table 2 includes consideration of the three variables of the first level of analysis of logistics platforms priorities.

Thus, the basic concept that privileges the use of results from the location model attributed to each logistics platform to generate the hierarchy is effectively and jointly applied, considering concepts of normalization and the principle of Pareto.

This first general hierarchy of priorities for logistics platforms is a reference for the application of new criteria in the other levels of analysis.

Once this step is finished, the next one is the appropriation of second level attributes, which identifies the types of groups for logistics platforms, according to their relationship with their connections with the Brazilian roadway system. This identification is fundamental to designate, in time, how first-level priorities must be organized.

Table 1. Tabulation to identify variables from the first level of analysis, MT, 2016d.

| Code | Microregion | Code of the Microregion | LP Name | < % R$ | > % t | > Amount of Product | Amount of Product | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Group | Product |
| 1 | Microregion Name | Code Microregion | LP Name | $A_1$ | $B_1$ | $C_1$ | $\gamma_1$ | |
| | | | | | | | I | 1 |
| | | | | | | | ⋮ | ⋮ |
| | | | | | | | $g$ | $p_g$ |
| ⋮ | | | | | | | | |
| $n$ | | | | $A_n$ | $B_n$ | $C_n$ | $\gamma_n$ | |
| | | | | | | | I | 1 |
| | | | | | | | ⋮ | ⋮ |
| | | | | | | | $g$ | $p_g$ |

n = amount of Logistics Platforms - LP; g = amount of cargo groups; $p_g$ = amount of products in each cargo group g; $A_n$ = value of percentage contribution of the nth LP in the total reduction of transportation costs; $B_n$ = value of percentage contribution of the nth LP in the attraction of total volume of handled cargo by the operation of all LPs; $C_n$ = amount of products handled by the nth LP. Zoning of transports used in the LP location studies was based on city groups officially defined by the Brazilian Government as microregions. There were 559 microregions that were analyzed in simulated scenarios to identify the viability of LP locations.

Table 2. Normalized values of the variables α, β and γ and the weight of each LP in the final hierarchy, MT, 2016d.

| Code | Microregion | Code Microregion | LP Name | < % R$ | > % t | > Amt. Prod. | Normalized (α) | Normalized (β) | Normalized (γ) | Weighing Vol. x Amt. Prod. $\sigma = (\beta \times \gamma)$ | Norm.Weight $P = (\alpha + \sigma)$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Microregion Name | Code Microregion | LP Name | $A_1$ | $B_1$ | $C_1$ | $\alpha_1$ | $\beta_1$ | $\gamma_1$ | $\sigma_1$ | $P_1$ |
| ⋮ | | | | | | | | | | | |
| $n$ | | | | $A_n$ | $B_n$ | $C_n$ | $\alpha_n$ | $\beta_n$ | $\gamma_n$ | $\sigma_n$ | $P_n$ |

$\alpha_n$ = nth normalized value of $A$;$\beta_n$ = nth normalized value $B$; $\gamma_n$ = nth normalized value of $C$; $\sigma_n$ = nth weighed value of normalized weights of $B$ and $C$; $P_n$ = normalized weight of the nth LP.

$$\alpha_n = \left(\frac{A_n}{A_{máx}}\right) \tag{1}$$

$$\beta_n = \left(\frac{B_n}{B_{máx}}\right) \tag{2}$$

$$\gamma_n = \left(\frac{C_n}{C_{máx}}\right) \tag{3}$$

$$\sigma_n = (\beta_n \times \gamma_n) \tag{4}$$

$$P_n = (\alpha_n + \sigma_n) \tag{5}$$

Table 3. Total normalized weights in descending order, hierarchy of LPs in the first level, MT, 2016d.

| Hierarchy | Code | Microregion | Code Microregion | LP Name | Descending Order (P) |
|---|---|---|---|---|---|
| 1st | - | Microregion Name | Code Microregion | LP Name | $P_{max}$ |
| ⋮ | | | | | |
| n | | | | | $P_{min}$ |

## *5.2. Second level – Types of integration*

The identified logistics platforms can be associated, in terms of intermodal connectivity, with an existing and operational infrastructure and with road projects in construction phase or conceived only as a plan, connected or not to public investment programs.

This type of information produces a first relevant indicator, that is, it identifies the logistics platforms that can be implemented in the short term, since they do not lack road investments for their intermodal connectivity; in the mid-term, the ones depending on projects under execution; and in the long term, those in which connectivity roads for their intermodal operation are in the planning or project creation phases, which are yet to be executed.

The time organization to start investments in logistics platforms generates relevant groups, especially when defining short, mid and long-term portfolios. However, the hierarchies defined at the first level are not excluded; they are a separate analysis. These hierarchies must be adapted and reorganized for each set of logistics platforms resulting from groups established at this second level.

The tabulation of data associated with the connectivity segments of each logistics platform is represented in Table 4.

Table 4. Tabulation of road infrastructure information of the second level of analysis, MT, 2016d.

| Code | Microregion | Code Microregion | LP Name | Road Infrastructures Intermodal Connectivity | |
|---|---|---|---|---|---|
| | | | | Group | Segment |
| 1 | Microregion Name | Code Microregion | LP Name | $E_1$ | |
| | | | | I | 1 |
| | | | | | ⋮ |
| | | | | | $(\in_i^{I})_m$ |
| | | | | II | 1 |
| | | | | | ⋮ |
| | | | | | $(\in_i^{II})_m$ |
| | | | | III | 1 |
| | | | | | ⋮ |
| | | | | | $(\in_i^{III})_m$ |
| ⋮ | | | | | |
| n | | | | $E_n$ | |
| | | | | I | 1 |
| | | | | | ⋮ |
| | | | | | $(\in_i^{I})_m$ |
| | | | | II | 1 |
| | | | | | ⋮ |
| | | | | | $(\in_i^{II})_m$ |
| | | | | III | 1 |
| | | | | | ⋮ |
| | | | | | $(\in_i^{III})_m$ |

*$(\in_i^{I})_m$ = amount of road segments related to mode m, belonging to group I, used by a given Logistics Platform (LP) for its intermodal connectivity. Group I: LPs with viable short-term implementation; Group II: LPs with viable mid-term implementation; Group III: LPs with viable long-term implementation.*

### *5.3. Third level – Connection with logistics assets*

Ports and airports are essentially logistics structures of modal integration, and many of them developed to the point of, either totally or partially, working as some type of logistics platforms.

In particular, maritime ports have operational and infrastructure conditions that tend to establish operations that are similar to those of a logistics platform, mainly due to the capacity of promoting an intense integration and use of intermodal cargo transportation, especially by road, railway and pipelines.

When the location of a certain logistics platform is physically close to port or airport areas with relevant movement of cargo volumes, the indicated logistics platform should receive an additional appropriation in its characterization, regardless of its typology, with the purpose of previously establishing a bond with these types of logistics assets (ports and airports).

If there is such a connection, it is recommended, in addition to the cargo that allowed the indication of the logistics platform location, to include as potentially related cargo those that are handled in the port or airport with which a relation was established, following the described criteria.

Thus, in addition to the cargo attracted by the logistics platform as a result of the location methodology, the potential volumes of other cargo that were not included in the simulation, but are part of those handled in the associated port or airport, should be included.

Therefore, it is recommended that the assessment of the logistics platform's typology be revised every time this type of connection occurs.

Therefore, the appropriation of cargo not generated in the simulation process, but which resulted from the potential relation of port or airport cargo handling, generates a new added value to the logistics platforms involved in this simulation. As a result, the amount of cargo volumes attracted, and the quantity of different products, tend to change. As seen before, this is accounted for in the first hierarchy level. On the other hand, as this new aggregated cargo was not originated in the simulation, it is not possible to establish a transportation cost reduction value in such a direct way as in the application of the location model.

## 6. Case study

The geographic universe of the research comprises the whole Brazilian territory, divided into five regions: North, Northeast, South, Southeast and Central-West. Each region includes microregions, therefore forming a total of 559 microregions (MT, 2016c).

The number of logistics platforms qualified by the mathematical model for installation is 137 facilities. Such facilities answer for 638 million annual tons according to an estimate based on real data (MT, 2016d).

According to the established restrictions and criteria, the ILPs qualified by the model had estimates of annual movements ranging from 1.0 to 18.3 million tons each. For each logistics platform, the number of handled product types were also identified, ranging from one to 14 different products (MT, 2016d).

According to the propositions established at the first level, the platforms were separated into three priority blocks: "A", "B" and "C", following the conception below (MT, 2016d):

- Priority A: The set of ILPs, starting from the first in the hierarchy until the one that first contributes to reach 50% of the amount of cargo in relation to the total or 50% of the financial savings in relation to the total;
- Priority B: The set of ILPs, from the first one that does not contribute to the previous hierarchy, until the one that, by the accumulated sum, contributes to reach 80% of the amount of cargo in relation to the total or 80% of the financial savings in relation to the total; and
- Priority C: All other ILPs that do not fit in the previous hierarchies.

This aggregated proposition of the priorities presupposes that:

- ILPs rated as Priority A, if implemented, ensure that at least 50% of the service to the whole demand of cargo or the savings contemplated in the simulations are reached, and this level of implementation is considered satisfactory;
- ILPs rated as Priority B, if implemented, ensure that 80% of the goal is reached, which is considered a good level of implementation; and
- The other ILPs rated as Priority C, if inserted, ensure that the goal of 100% is reached, which would be considered an optimal level of implementation.

In the study, the Brazilian territory was divided into 559 microregions (MT, 2016c), and by means of the mathematic model of logistics platform location, it was found that only 137 microregions had the potential to receive logistics platforms (MT, 2016d). These microregions were designated as microregions qualified for the implementation of logistics platforms. The regional distribution of the qualified microregions is represented in Table 5 according to the prioritization criteria.

Table 5. Number of logistics platforms distributed across the regions according to the implementation priority.

| Priorities | Regions | | | | | Total |
|---|---|---|---|---|---|---|
| | North | Northeast | South | Southeast | Central-West | |
| A | 02 | 02 | 05 | 14 | 07 | 30 |
| B | 02 | 10 | 08 | 17 | 05 | 42 |
| C | 02 | 09 | 22 | 24 | 08 | 65 |
| Total | 06 | 21 | 35 | 55 | 20 | 137 |

Table 5 presents two aspects: one in the national scope and another in the regional scope. In the national scope, a select group of 30 microregions was identified as having a higher potential of return for the country and its investors, and thus classified as Priority A. The remaining 107 were divided according to a posterior order of priority. In the regional scope, no Brazilian region was ignored, neither in the planning of implementation of logistics platforms, nor during the prioritization steps. It is worth highlighting that the modeling of the mathematical model proposed had no restriction in the minimum or maximum number of microregions to be qualified per region. All identified microregions are the ones that vocationally meet the requirements to be qualified for the implementation of logistics platforms, free of regional quantitative restrictions. This weighing is important considering the concern with fostering regional development in the country.

Figure 1 shows the 30 microregions qualified as priority A and the road infrastructure. The purpose of carrying out this thematic superposition is assessing areas with intermodal vocation, considering not only the existing roads, but also the planned ones. The most relevant fact shown in Figure 1 is the analysis of the intermodality of the planned railways. For certain logistics platforms, there are considerable cargo volumes, which only generate concentrations if certain access infrastructures are effectively built. This information obtained through thematic superposition enables the assessment and application of the second level of hierarchy addressed herein, i.e., to rank logistics platforms that depend on future projects. This second level supports governmental agencies in temporal assessments and in synergy correlations between planned roads and logistics platforms.

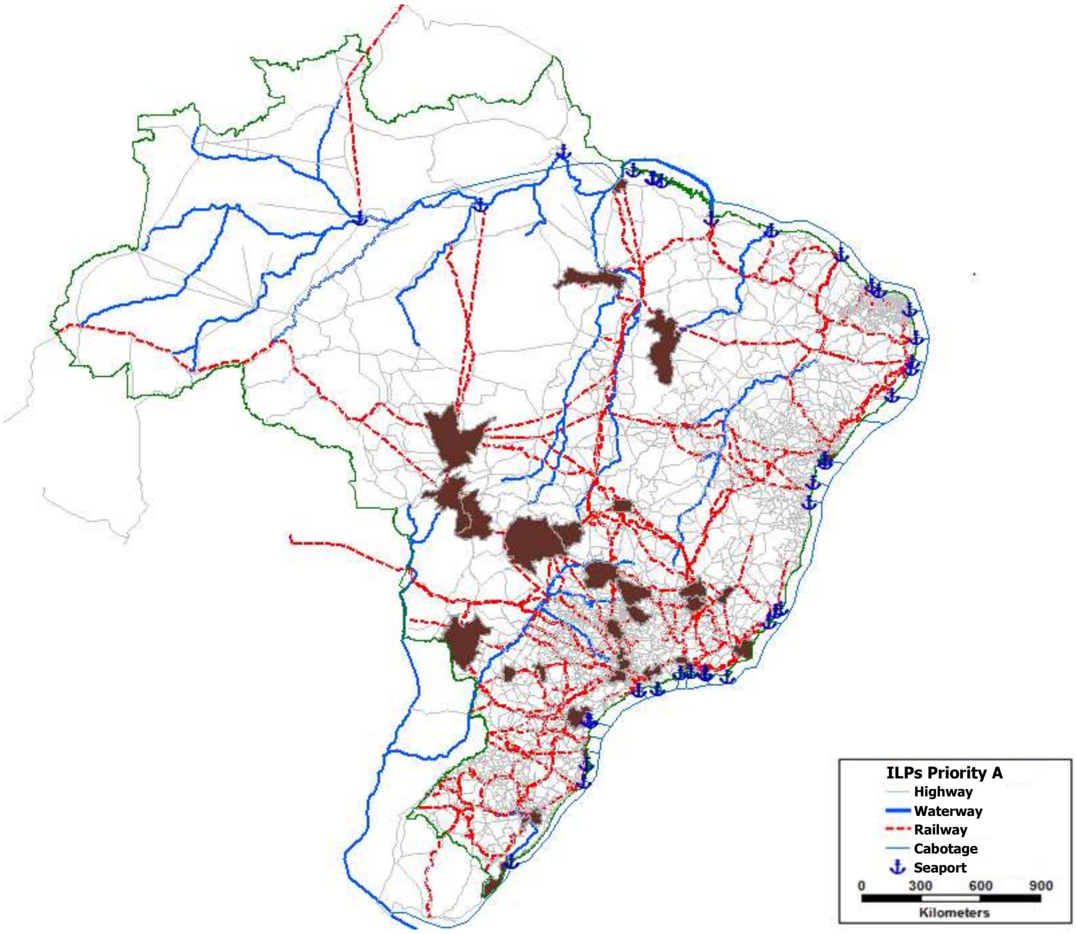


Fig. 1. Superposition of priority A microregions and the road system, MT, 2016d.

The hierarchy of the logistics platforms was created according to the order of priority (A, B and C) and according to the criteria presented in the first level. Such criteria weigh cargo volumes and their product diversities and combine a normalized weight of this consideration with another one, obtained by the cost reduction that each LP promotes, concerning the total reduction with the operation of all other LPs.

The results presented in Table 5 are restricted only to the first Level of Analysis based on Tables 1, 2 and 3.

Table 6 of the Appendix lists priority A logistics platforms and their respective cargo handling and cost reduction estimated after implementation.

Table 7 presents the amount of cargo and cost reduction estimated per priority category.

## 7. Results and discussion

The annual estimate of transportation costs reduction is US$ 13 billion with the implementation of the 137 logistics platforms. These savings are a result of the promotion of intermodality in the transportation of 638 million tons of cargo per year, from a universe of 5.5 billion tons studied (MT, 2016d).

Through the hierarchization of the 137 microregions qualified for the implementation of ILPs, a set of 30 microregions was identified that represent a share of cargo handling above 50% of the cargo demand studied and above 50% of the savings considered in this research. The other priority categories "B" and "C" respectively identified 42 and 60 microregions (MT, 2016d).

The ranking of the ILPs based on technical parameters is a supporting tool for making decisions regarding implementation, while also considering political, tributary, financial, and economic parameters, among others. In this context, the ILPs should have quite different time expectations for implementation. This time aspect can be identified according to the definition adopted by Tsamboulas (2007), who establishes four phases: a) immediate implementation; b) short-term execution; c) mid-term execution and d) long-term execution.

Considering the implementation of such logistics platforms in a country of continental size, such as Brazil, it is imperative to consider relevant geographic, road and social aspects. For that, three different strategies for ranking the implementation of ILPs were identified, considering the geographical division of Brazil, which includes five regions comprising 26 states and a Federal District and having as main governmental decision makers those of the federal and state scope. These strategies are:

- National Ranking: This ranking enables the identification in the national scope of the transportation assets of higher impact in the country. The identification and quantification of cargo movement for each ILP provides public authorities with the following potential advantages: a) prioritizing investments that have the highest social and economic impacts; b) planning in a more detailed manner the tax benefits to stimulate the implementation of each LP; c) predicting the additional cargo demand trend to the Road National System in the short, mid and long term in order to provide a more appropriate transportation infrastructure adequation plan;
- Regional Ranking: Decision making in transportation projects considering the economic and social inequality parameter is a major challenge. Novak et al. (2015) proposed a transportation project prioritization process having as one of its three goals the reduction of the inequality in the distribution of resources from transportation projects. However, the authors stated that they were not successful in achieving this goal. In order to measure inequality in the allocation of transportation resources, the authors used the Gini Coefficient. Karner (2016) presented two relevant aspects on the topic of equality in the context of transportation planning, namely: (a) it was observed that the performance of agencies when planning regional transportation in the areas of environmental justice and social equality was inferior to their performance in the legal, normative and safety areas; and (b) among the analyzed cases, none of them considered environmental justice and the analysis of equality to decide between the alternative scenarios; rather, they were mostly used to assess decisions of investments that had already been made;
- State Ranking: The hierarchization of ILPs per state according to the priority order enables state decision makers to analyze the development vectors in their state of interest to federal decision makers, the implementation time trend, and the quantification of cargo demand of each vector, represented by the ILP. From this mosaic, each state decision maker will adjust their infrastructure and land usage planning in alignment with the respective vectors. Additionally, this ranking will allow the contemplation of those ILPs that, although the conception of the national

ranking is of the C category, may be contemplated by the local manager as being from the B category, since the improvement in infrastructure necessary to make the respective ILP viable will contribute to developing the potential of other local development vectors.

It is clear, then, the importance of the three strategies, and that, despite being different, they still have synergistic interactions. The indication of prioritization of investments in ILP should be started with the national ranking. This ranking will lead to the other two. The regional ranking, fulfilling its role of safeguarding a national development with higher equality and seeking to reduce excessive contrasts; and the state ranking, indicating to local mangers two aspects: (a) the need to adjust infrastructure to the national plan; and (b) the possibility of weighing the redefinition of priorities for ILPs to be implemented in their state, considering other local parameters.

Ranking in those three levels allows decision makers in the three governmental areas (federal, state and local) to consider in a clear manner the investments that present higher potential for implementation and others that will require a greater effort to become attractive. The identification of the areas with potential for the installation of these facilities also enables the identification of impacts caused by these implementations in the short, mid and long terms.

Since the adopted criterion allows for the consideration of the ILPs' ranking in each category of the national, regional and state scopes, it is possible to plan actions which are distinct, but which follow a similar goal: developing the country and attracting investors.

## 8. Conclusions

The method developed includes three decision parameters in the ranking of ILPs to be implemented. They are: (a) the hierarchization of ILPs in order to promote the binomial maximization of intermodality and minimization of logistics and transportation costs; (b) the consideration of the time viability of the ILP investment due to its connectivity in order to operate intermodally; and (c) the weighing of the connection of possible logistics assets in the influence area of the ILP.

When developing the method, it was noticed that the definition of criteria composing the hierarchy to implement logistics platforms would be an innovation, considering that there was no evidence of published studies addressing this. However, there would still be a gap in the moment of implementing this methodological approach if the parameters of infrastructure and integration with logistic assets were not considered; thus they were included. Therefore, the method becomes more aligned with the needs of planning and operation for investments in logistics platforms.

Even though the method contributes to and impacts both the public and private sectors, its main contribution is in the governmental scope, since it provides well-defined technical criteria that allow governmental decision makers to make strategic decisions grounded on the main relevant parameters.

It is known that the choice of implementing a given logistics platform instead of others is the result of the conjugation of technical, financial, tributary, economic, social, and political aspects, among others. Therefore, the developed method is not a single decisive parameter, but an initial technical parameter, necessary to promote the referred conjugation with the other aspects.

The use of the method proved viable, as it resulted from a simulation process based on quantitative data of actual cargo projected for the year 2031.

The method does not present any restriction in its employment concerning the size of the geographical area or any restriction regarding the number of analyzed platforms. Nevertheless, since the case study was carried out in a country of continental proportions, there was a clear need to consider geographical, road and social aspects. This fact was made evident due to the existence of three needs: the prioritization of investments in national scope; the equality of regional development; and the opportunity for state decision makers to indicate the adequacy of priority for investments over other local parameters.

Among the mentioned strategies, it is worth highlighting the regional ranking, which enables the application of the method with the purpose of fostering national development under a perspective of regional equality. The authors Novak et al. (2015) and Karner (2016) addressed the difficulty of applying the topic of equality in the context of transportation planning. However, the regional ranking provides not only a treatment of inter-regional equality, but also intra-regional equality. Karner (2016) observed in a set of cases that the analysis of equality was not used to decide between alternative scenarios. Actually, it was mostly used in assessments after the decision was made. In this article, the analysis of equality is presented as a decisive parameter in the hierarchization, rather than as a parameter of assessment only after the decision is made.

Another applicability of the method was also noticed, and it goes beyond its purpose. The hierarchization of microregions that presented higher potential to promote intermodality and higher potential to reduce cargo transportation costs indicates areas that induce development. Once the areas with better ratings are identified, it is possible to consider an indicator for the prioritization of the improvement of the road system integrated with these platforms.

In the case study, of the 559 microregions in the Brazilian territory, 137 showed the potential for the implementation of ILPs. The estimated cargo handling is 638 million tons per year and the annual estimate of cost reduction is US$ 13 billion. With the application of the method, it was possible to identify that 30 of the 137 microregions answer for half of the cargo handling and for half of the savings estimated with the implementation of intermodal logistics platforms.

## Appendix A

Table 6. Intermodal Logistics Platforms of priority A obtained with the application of Tables 1, 2 and 3.

| Microregion | State | Hierarchy | Priority | Savings (US$) | Cargo (t) | No. of Products | % Savings (accrued) | % Cargo (accrued) |
|---|---|---|---|---|---|---|---|---|
| 43035 | RS | 1 | A | 314,553,876 | 18,253,990 | 14 | 2.4% | 2.9% |
| 51006 | MT | 2 | A | 338,384,339 | 17,099,570 | 13 | 5.0% | 5.5% |
| 31030 | MG | 3 | A | 550,297,869 | 11,609,580 | 10 | 9.2% | 7.4% |
| 35050 | SP | 4 | A | 387,004,292 | 19,104,570 | 10 | 12.1% | 10.3% |
| 41037 | PR | 5 | A | 337,668,138 | 18,742,590 | 7 | 14.7% | 13.3% |
| 53001 | DF | 6 | A | 243,348,118 | 13,180,690 | 11 | 16.6% | 15.3% |
| 33003 | RJ | 7 | A | 451,892,649 | 17,327,830 | 2 | 20.1% | 18.1% |
| 29021 | BA | 8 | A | 233,786,557 | 13,786,700 | 8 | 21.9% | 20.2% |
| 21020 | MA | 9 | A | 224,036,517 | 11,298,810 | 10 | 23.6% | 22.0% |
| 31027 | MG | 10 | A | 252,091,149 | 11,321,300 | 7 | 25.5% | 23.8% |
| 35032 | SP | 11 | A | 203,377,488 | 10,834,990 | 9 | 27.1% | 25.5% |
| 41003 | PR | 12 | A | 185,836,781 | 9,568,720 | 11 | 28.5% | 27.0% |
| 43026 | RS | 13 | A | 147,878,337 | 7,906,840 | 14 | 29.7% | 28.2% |
| 50010 | MS | 14 | A | 172,351,838 | 8,681,650 | 11 | 31.0% | 29.6% |
| 51021 | MT | 15 | A | 165,260,834 | 9,474,090 | 10 | 32.3% | 31.0% |
| 31039 | MG | 16 | A | 218,791,614 | 8,658,220 | 7 | 34.0% | 32.4% |
| 15020 | PA | 17 | A | 199,763,002 | 7,843,060 | 8 | 35.5% | 33.6% |
| 35046 | SP | 18 | A | 209,302,635 | 11,252,550 | 5 | 37.1% | 35.4% |
| 33011 | RJ | 19 | A | 194,230,300 | 9,062,020 | 7 | 38.6% | 36.8% |
| 52013 | GO | 20 | A | 172,917,856 | 8,623,670 | 8 | 39.9% | 38.2% |
| 31023 | MG | 21 | A | 144,789,560 | 8,191,520 | 10 | 41.0% | 39.4% |
| 35027 | SP | 22 | A | 166,263,088 | 8,708,900 | 8 | 42.3% | 40.8% |
| 41011 | PR | 23 | A | 124,212,775 | 6,439,040 | 14 | 43.3% | 41.8% |
| 15007 | PA | 24 | A | 167,094,426 | 8,925,540 | 7 | 44.6% | 43.2% |
| 42013 | SC | 25 | A | 162,791,678 | 9,226,300 | 7 | 45.8% | 44.7% |

| Microregion | State | Hierarchy | Priority | Savings (US$) | Cargo (t) | No. of Products | % Savings (accrued) | % Cargo (accrued) |
|---|---|---|---|---|---|---|---|---|
| 35014 | SP | 26 | A | 190,141,399 | 9,980,900 | 5 | 47.3% | 46.2% |
| 52014 | GO | 27 | A | 178,421,117 | 9,418,950 | 5 | 48.7% | 47.7% |
| 31018 | MG | 28 | A | 114,526,178 | 5,886,180 | 13 | 49.5% | 48.6% |
| 31047 | MG | 29 | A | 128,785,076 | 6,823,030 | 10 | 50.5% | 49.7% |
| 51017 | MT | 30 | A | 127,640,749 | 6,486,730 | 9 | 51.5% | 50.7% |
| Total | | | | 6,707,440,238 | 323,718,530 | | | |

Table 7. Cargo handling and annual cost reduction per priority category.

| Priority | No. of ILP | Savings (US$) | Cargo (t) |
|---|---|---|---|
| A | 30 | 6,707,440,238 | 323,718,530 |
| B | 42 | 3,900,667,383 | 189,337,840 |
| C | 65 | 2,387,336,760 | 125,439,690 |
| Total | 137 | 12,995,444,381 | 638,496,060 |

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