**ORIGINAL ARTICLE**

# Evaluation of the efficiency of logistics activities using Data Envelopment Analysis (DEA)

*Avaliação da eficiência das atividades logísticas utilizando a Análise Envoltória de Dados (DEA)*

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**Abstract:** This study aimed to analyze the efficiency of activities related to logistics modes, transport and cargo handling in Brazil. The theoretical framework was composed of the logistics efficiency and of the discussion of the characteristics of modes of transport and of variables related to efficiency. The study was classified as descriptive and quantitative, using the technique of data envelopment analysis. As main results, the ancillary activities to air transport stand out as efficient, which reached scores of 100% in the analyzed periods, except in 2010, in which they obtained 91.58%. It is worth noting that the activities cabotage and long-haul and ancillary activities to land transport achieved three maximum efficiency scores. In addition to evaluating the benchmark for the activities of lower efficiency score, the study also included improvements needed for other activities to achieve maximum efficiency. Finally, the central contribution of the article lies in the proposition of a multimodal analysis model.

**Keywords:** Logistics efficiency; Data Envelopment Analysis (DEA); Logistics.

**Resumo:** O objetivo do estudo foi analisar a eficiência das atividades relacionadas aos modais logísticos, transporte e movimentação de cargas no Brasil. A plataforma teórica sustentou-se pela eficiência logística e pela discussão das características dos modais e das variáveis relacionadas à eficiência. O estudo classificou-se como descritivo e quantitativo utilizando a técnica de análise envoltória de dados. Como principais resultados destacam-se como eficientes as atividades auxiliares aos transportes aéreos que atingiu escores de 100% nos períodos analisados, exceto no ano de 2010 que obteve 91,58%. Cabe ressaltar ainda que obtiveram três escores máximos de eficiência as atividades de cabotagem e longo curso e atividades auxiliares ao transporte terrestre. Além de avaliar os benchmarkings para as atividades de menor escore de eficiência o estudo contemplou ainda melhorias necessárias para que outras atividades atinjam a eficiência máxima. Por fim, a contribuição central do artigo está na proposição de um modelo de análise multimodal.

**Palavras-chave:** Eficiência logística; Análise Envoltória de Dados (DEA); Logística.

## 1 Introduction

Logistics represents an organizational segment that seeks to mitigate the relations between production and demand, in order that consumers have goods and services at the time and physical condition they want (Ballou, 1993). In this context, it is stated that logistics is part of the supply chain process that efficiently plans, implements and controls the flow and storage of goods and services, from the point of origin to the point of consumption, with the purpose of meeting customer requirements (Council of Supply Chain Management Professionals, 2003).

Logistics analysis is also inserted in a perspective of contribution to value chain activities, since an efficient logistics system may create value from the sources of basic raw materials to the final product that is delivered to consumers (Shank & College, 1989). Therefore, logistics activity is essential for the creation of value and efficiency of these services.

Logistics may still be an obstacle to new enterprises because they do not have experience, knowledge and reputation to efficiently choose the least costly supply chain (Naudé & Matthee, 2011). Hence, companies need to include it in a macro perspective, supporting managers in the design of organizational strategies.

The managerial performance of organizations is also directly affected by logistics, the set of suppliers and customers and their location impact on a detailed managerial analysis. Corroborating this statement, Dimitrov (2005) declares that companies must master logistics and its implementation in order to improve their practices, tools and applied management methods.

Brazil occupies one of the worst positions of the world in terms of minimizing logistics cost, accounting for about 12% of GDP, while in the US this cost represents 8% of GDP; however, geographical aspects and economic development must be taken into account when comparing these percentages. When evaluated in monetary values, in Brazil these costs represent an annual loss of 83.2 billion dollars per year (Fundação Dom Cabral, 2012).

Numerous studies consider the logistics efficiency approach for only one logistics mode or a specific logistics situation, among them Kim (2010), Bertoloto & Mello (2011), Wanke (2012), Banaszewska et al. (2012), Silva et al. (2011). On the other hand, there are proposals that aim at the integration of logistics modes or of differentiated strategies such as outsourcing or deposit efficiency, as in the studies of Ishfaq & Sox (2010).

In Brazil, road transport is predominantly used because of the extensive road network, which causes an increase in the logistics costs of companies due to poor road conditions. For the Confederação Nacional dos Transportes (CNT, 2013), 63.8% of the Brazilian roadway in 2012 had some deficiency in pavement, signaling or road geometry, and there was also an increase in critical points, from 221 to 250 (Brasil, 2012).

The comparison of the different modes of transport that compose the logistics system is little noticed in the literature, or performed in a difficult way, since each mode of transport represents a specific production function, being the findings of Savolainen (2007) one of the studies that contemplate this multimodal analysis. Data on the cargo and capacity of the modes of transport are extremely different when analyzed on a single basis, thus, it is necessary to define variables that standardize and make such comparison possible.

Management accounting helps in this process of standardization by providing data that may be comparable by activity, company or department, as it is a common business language. As logistics systems have a direct impact on companies' results

and consequently on managerial analysis, and considering the efficiency of these systems, the following question emerges: **What is the efficiency of activities related to logistics modes, transport and cargo handling in Brazil?**

Thus, the present study is justified, for the analysis of logistics efficiency holds the deepening of opportunities in organizations through the choice of the best logistics modes. Therefore, comparing efficiency may contribute to define the logistics model to be adopted by the organization and to collaborate to the economic scenario where logistics activities are.

In agreement with the identification of mode of transport efficiency, it is intended to disseminate to organizations the knowledge about the various existing modes of transport and their efficiency variables perceived individually as well as when compared among them. Thus, organizations may stipulate new strategies, design scenarios with greater analysis subsidies, and improve their logistics relationships inherent in the time and cost of modes of transport.

## 2 Review of the literature

### 2.1 Logistics efficiency

Efficiency may be defined as synonymous with the rational use of resources in order to maximize the probability of achieving certain outcomes. Fried et al. (1993) cite that performance depends on the state of the employed technology and on the degree of efficiency of its use.

Technical efficiency is understood as the scale of use of various established resources, given the specialization of the organization, in order to maximize such use through the capacity to avoid losses and to produce as much as the inputs allow. Allocation efficiency, on the other hand, reflects the firm's capacity to use inputs in an optimal proportion, given their respective prices (Uri, 2001).

In the studies carried out by Brissimis et al. (2010), the technical efficiency (TE) reflects the capacity of a company to obtain the maximum output of a given set of inputs; while the allocation efficiency (AE) reflects a company's ability to use inputs to optimal proportions given their respective prices. The TE and AE product is generally given by economic efficiency (EE). However, the authors state that it is difficult to break the frontiers of such efficiencies given the complexity of the factors and components.

According to Kumbhakar & Lovell (2003), technical efficiency is defined in terms of the distance of a production frontier from its optimal value and economic efficiency uses an economic frontier. From this it follows that a productive process is economically efficient if there is no other alternative process, or the combination of processes, that produces the same quantity at the lowest cost or highest possible profit.

Relating the concepts of efficiency, its applications and contemporary studies with the present study, we chose to follow the line of allocation efficiency (AE), since the use of inputs in logistics efficiency influences the prices attributed by the organizations.

For companies to play a good role in the exploration of markets, it is necessary that they efficiently develop logistics activity and that they have available resources in the form of working capital, investments and fixed assets. Therefore, it is important to consider the financial issues and especially the return that these investments in logistics brings to the organization. The measurement of this system linked to factors

such as people management, environmental management, strategic cost management contributes to the achievement of organizational efficiency.

## 2.2 Logistics efficiency variables

Firstly, to compare the presented modes, five items are listed that allow an analysis of the operational characteristics of each transport, which are: speed, availability, reliability, capacity and frequency (Blowersox & Closs, 2001).

Speed refers to the time of movement in a given route, also known as transit time, being the aerial mode the fastest one (Nazário, 2007). However, for the purpose of correctly measuring the carrier performance, it is better to measure door-to-door delivery time, even though more than one mode of transport is involved (Ballou, 1993).

Availability is the ability that a mode of transport has to meet any origin-destination locations. The road carriers have the highest availability, since they manage to go directly to the points of origin and destination, characterizing a differentiated service (Nazário, 2007).

Reliability results from the possibility of changes in expected or disclosed delivery schedules. Due to its continuous service and to the low possibility of interference from weather conditions and traffic congestion, the pipelines occupy a prominent place in this respect (Blowersox & Closs, 2001).

Capacity refers to the possibility of a mode of transport to handle any transport requirement, such as size and type of cargo. The maritime/fluvial transportation is the most suitable for this task. Finally, frequency depends on the number of scheduled cargo handling, once again the pipelines lead this item due to their continuous service between two points (Blowersox & Closs, 2001).

For the Fundação Dom Cabral (2012), Brazil has a faster delivery compared to other BRIC countries, however, the negative points are in infrastructure, international shipments and traceability. The faster delivery is due to the fact that the volume of stocks close to customers is higher and the significant contribution of the road transportation in Brazil helps to improve delivery time.

When analyzing the mentioned characteristics, it is possible to observe that the efficiency variables are related to cost (items such as labor force, direct costs, capacity, among others) or inherent to the time variable such as frequency, handling, weather conditions and availability.

## 2.3 Related studies

Gillen & Lall (1997) applied the Data Envelopment Analysis (DEA) technique to study airports and their terminals. The main objective of their study was to analyze the efficiency of airport production, aiming at 21 of the top-30 airports in the US, which were different in terms of ownership and financial and operational characteristics. For this research, the number of runways, number of companies, terminal area, number of employees, number of cargo pickups and the total area of the airport were used as input variables, and the output variables were the annual result of cargo handling and the type of flight service, being regular or irregular.

Sousa et al. (2008) evaluated the efficiency of Brazilian Northeastern ports, firstly applying the DEA technique for the handling of containers, using as input variable the total area and as output variable the TEU unit, which is a measure corresponding to

20 feet (Twenty-foot Equivalent Unit). Subsequently, they measured the cargo handling by means of the variables 'berth' and 'draft' for input and 'quantity handled' for output.

Also analyzing the ports, Silva et al. (2011) conducted an exploratory analysis of productive efficiency in Brazilian ports, using the following items as inputs: width and depth of the navigation basins, of the access channels and of the existing wharves; the containers being the products of the analysis (in unit, tons and TEUs) and the general cargo handled.

To facilitate the visualization, Chart 1 follows with some efficiency studies related to logistics and to management accounting:

**Chart 1.** Contemporary studies.

| Author/Year | Objective | Variables | Result |
|---|---|---|---|
| Sarkis (2000) | To evaluate the efficiency at 44 US airports. | - expense<br>- number of employees<br>- number of companies<br>- profit<br>- frequency of service<br>- number of passengers<br>- volume | High correlations were found as a result of the verification of the correlation among efficiency, external factors and characteristics of airports. |
| Taliani & Escobar (2008) | To evaluate the technical efficiency of road transportation companies between 2004 and 2006. | - sales<br>- primary materials<br>- personnel expenses<br>- depreciation<br>- costs and expenses | The size of companies influences efficiency.<br>The cost structure may be improved in all respects. Potential for improvement in revenue generation. |
| Savolainen (2007) | To evaluate the efficiency of rail, road and water transports in the United Kingdom. | - capacity<br>- line numbers<br>- labor force<br>- volume | The results of the analysis show that efficiency differences exist in rail operations, however, specialization among the actors exists in both transport subsectors. |
| Heinen et al. (2012) | To analyze the environmental technical efficiency of Brazilian airlines. | - Flight and ground employees<br>- Fleet<br>- Fuel consumption<br>- Earth hours<br>- Revenue passenger kilometer (RPK)<br>- Revenue ton kilometer (RTK) | For passenger transportation, the most efficient companies are Azul, Tam, Webjet, Gol, and for cargo transportation are Absa and Master Top. Regarding the environmental analysis, it was verified that it is possible to reduce 286.62 GgCO2 from total emissions. |

Source: Research data (2014).

It should be noted that some studies containing efficiency analysis include accounting indicators in order to identify efficiency related to performance evaluation. An example of this use are the findings of Casa Nova (2002), who used variables such as liquidity, profitability, asset value, among others to evaluate the efficiency of companies listed in the stock market.

## 3 Methodology

This research develops a survey of the efficiency of logistics activities related to logistics modes, transport and cargo handling through data envelopment analysis (DEA). The study is delineated from a quantitative analysis in logistics activities in order to show the operational efficiency in Brazil and to contemplate the various modes of transport in a comparative analysis.

### 3.1 Data collection

Firstly, to align the research with the scope of management accounting, it is verified that an efficiency analysis is possible with the choice of indicators that are directly related to accounting.

The variable inherent in the volume of cargo transported (present in numerous studies that analyzed the individual efficiency of each mode of transport) (Sarkis, 2000; Gillen & Lall, 1997; Savolainen, 2007; Sousa et al., 2008; Silva et al., 2011) was not used because it is consistent that the rail mode will transport a greater quantity than the air mode, the latter limited by the size of the aircraft holds. As proxy for this variable, the 'net operating revenue' was used, which has direct relation with the transported volumes.

The variables of the study were then formatted. Knowing that any efficiency analysis requires a classification between input and output variables (inputs and products), Chart 2 contains a brief explanation of them and the references that were used when choosing these variables:

**Chart 2.** Explanation of variables.

| I/O | Variables | Acronym for Identification | Composition of variables | Empirical theoretical reference |
|---|---|---|---|---|
| *Input* | Modes of transport | ACQUIS_ TRANSP | Total acquisition of modes of transport. | - Martín-Cejas (2002)<br>- Uri (2001) |
| | Personnel expenses | MOD | It includes the total amounts of wages and bonuses as well as other values, among them profit sharing and social contribution taxes. | - Sarkis (2000)<br>- Taliani & Escobar (2008)<br>- Savolainen (2007)<br>- Heinen et al. (2012) |
| | Costs | COSTS | Costs of services, consumables and other expenses, except fuel. | - Sarkis (2000)<br>- Taliani & Escobar (2008) |
| | Fuel | FUEL | Total fuel costs in the analyzed period. | - Taliani & Escobar (2008) |
| *Output* | Revenue | REVENUE | Proxy used in the place of volume. | - Taliani & Escobar (2008) |

Source: adapted from IBGE (2013).

The variables were collected as follows:

a) Firstly, the IBGE website was accessed choosing the Sidra option, which is the IBGE Automatic Recovery System. In this section the Pesquisa Anual de Serviços (Annual Survey of Services) was selected;

b) Thus, it is possible to visualize the section that contemplates transport activities and ancillary services (according to the National Code of Economic Activity), in which the variables that are present in the IBGE's annual surveys are available, among them those listed in Chart 2;

c) Subsequently, we chose the variables and also the period (2008 to 2012), in order that the IBGE system generates the database according to the selected parameters, giving the option to generate the data in Excel® (a limitation is the temporal cut, since after 2012 the IBGE did not update this database);

d) The data returned from the survey in the database correspond to the total values of companies that compose the sample of the annual survey that the IBGE performs with several companies and economic sectors. They are aggregate values resulting from the sum of values surveyed in several regions, municipalities, companies, which are classified according to the activity codes table.

After the collection, the organization of the database was performed, since some data collected were not used, such as those related to the pipeline transportation and mail, and these activities are not related to the study, which includes activities in which there is modal-shift transportation.

## 3.2 Population

The research population consisted of activities related to each logistics mode in Brazil, it was selected by data accessibility and composed in order that the study contemplates at least one investigation of each logistics activity, as shown in Chart 3:

**Chart 3.** Research population.

| Mode | Activity |
|---|---|
| Railway | 1. Rail freight transport |
| Roadway | 2. Road freight transport |
| Waterway | 3. Cabotage and long-haul |
| | 4. Inland navigation |
| | 5. Support navigation |
| | 6. Other modes of water transport |
| Airway | 7. Air freight transport |
| Ancillary Activities | 8. Cargo handling and storage |
| | 9. Ancillary activities to land transport |
| | 10. Ancillary activities to water transport |
| | 11. Ancillary activities to air transport |
| | 12. Organizing activities of cargo transport |

Source: IBGE (2013).

There is no cut-off in the population, since all the activities that use a mode of transport to assist in their activities were contemplated in this study.

In relation to Chart 3, it was necessary to include in the analysis the ancillary activities of the modes of transport, because without them, the objective of the mode which is the transport, handling and storage of the cargo may not be fulfilled.

## 3.3 Data processing procedures

In order to analyze the efficiency, the statistical technique of Data Envelopment Analysis (DEA) was used, being a non-parametric method to process factors and to establish efficient logistics activities by means of scores. In this method, the activities were treated as DMUs (Decision-Making Units).

The initial DEA model created by Debreu (1951) and extended by Farrell (1957) was perfected by Charnes et al. (1978), and later by Banker et al. (1984). In order to reach the current framework, there are two models that are oriented both to products and to inputs and are named with the initials of the names of their pioneers: CCR and BCC (Souza & Wilhelm, 2009).

To define which DEA analysis model to choose, some procedures were performed. Firstly, scatter plots were generated through SPSS® in order to verify if the relation between inputs and outputs is constant or variable. Next is Figure 1, with the relation between the output variable 'Revenue' and the input variable 'Personnel expenses':
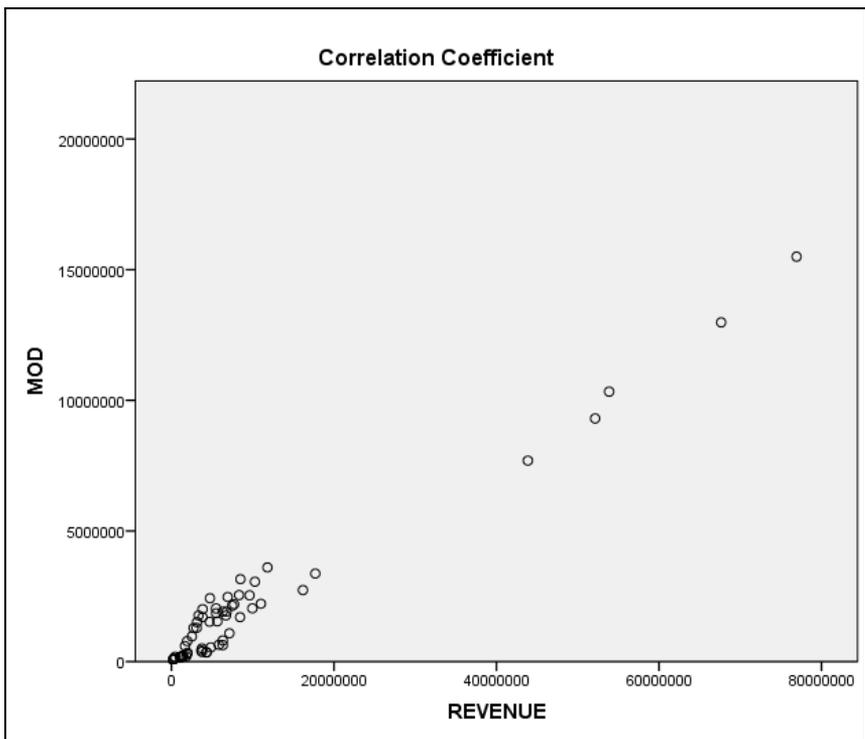


**Figure 1.** Scatter plot between Revenue and Personnel Expenses (MOD). Source: Research data (2014).

It should be noted that the production function of the activities, considering the revenue as a product and the personnel expenses as input, is a linear representation, i.e., as the revenue increases, personnel expenses increase almost proportionally,

generating a coefficient $R^2$, which means an adjustment of a linear, relatively high model in the value of 0.982. Thus, Table 1 shows the other results of the correlations:

**Table 1.** Results of the $R^2$ indicator.

|  |  | REVENUE | FUEL | MOD | COSTS | ACQUIS_ TRANSP |
|---|---|---|---|---|---|---|
| **REVENUE** | Correlation | 1 | .962** | .982** | .983** | .952** |
|  | Sig. (2-tailed) |  | .000 | .000 | .000 | .000 |
|  | Sum of Squares and Cross-products | 1.484E16 | 2.181E15 | 1.120E14 | 1.516E15 | 1.340E15 |
|  | Covariance | 2.515E14 | 3.696E13 | 1.899E12 | 2.569E13 | 2.271E13 |
|  | N | 60 | 60 | 60 | 60 | 60 |
| ** Significance index lower than 1% | | | | | | |

Source: Research data (2014).

All variables present high correlations, showing indicators above 0.9 and a significance index lower than 0.01. The highest correlation is present between the output variable Revenue and the input variable Costs, which has an indicator of 0.983, i.e., 98.3% of the variation in the costs of the studied logistics activities may be explained by the same proportion of revenue variation.

Thus, for this study the efficiency analysis model entitled CCR was used, which, according to Charnes & Cooper (1985), has as an essential characteristic the reduction of multiple inputs for a single product or 'virtual' input (100%).

For the statistical processing of the data, the database in Microsoft® Access 'MaxDEA' was used, which allowed the import of the inputs and outputs of each DMU through the database prepared in Excel®. In addition, the database provides the generation of tables for the comparison and evaluation of the DMUs and also of the input and output components individually.

After defining the variables and DMUs of the study, we have the following function for efficiency, in which the inputs are: fuel expenses, labor force costs, direct and indirect costs and acquisition of transport, being the product the value of the operating revenue: $Q = f\left(FUEL; MOD; COSTS; ACQUIS\_TRANSP; REVENUE\right).$

The present assumption is reinforced in the definition of the variables that in order to obtain a uniformity in the comparison of the productive units sought the output variable 'revenue' because the capacity of each mode of transport extinguishes the possibility of comparison in relation to the volume, with the revenue having a direct correlation with the transported volumes.

## 4 Analysis of results

The DMUs with a result equal to 100% are considered efficient and the analysis was performed in a concentrated way for the five years (2008 to 2012) to obtain only one efficiency frontier. Table 2 shows the results for the period from 2008 to 2012:

**Table 2.** Efficiency scores.

| Num | Description | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| 1 | Rail freight transport | 78.63% | 83.47% | **100.00%** | **100.00%** | 75.50% |
| 2 | Road freight transport | 57.76% | 56.97% | 54.61% | 55.60% | 54.49% |
| 3 | Cabotage and long-haul | **100.00%** | **100.00%** | **100.00%** | 91.52% | 81.07% |
| 4 | Inland navigation | 49.82% | 55.95% | 51.34% | 55.05% | 56.33% |
| 5 | Support navigation | 47.41% | 42.70% | 41.85% | 42.60% | 38.43% |
| 6 | Other modes of water transport | 36.62% | 36.16% | 38.61% | 38.76% | 37.93% |
| 7 | Air freight transport | **100.00%** | 77.75% | 72.84% | 80.07% | **100.00%** |
| 8 | Cargo handling and storage | 74.73% | 64.80% | 61.24% | 66.03% | 74.29% |
| 9 | Ancillary activ. to land transport | 96.37% | **100.00%** | **100.00%** | **100.00%** | 98.59% |
| 10 | Ancillary activ. to water transport | **100.00%** | **100.00%** | 95.60% | 95.76% | 68.91% |
| 11 | Ancillary activ. to air transport | **100.00%** | **100.00%** | 91.58% | **100.00%** | **100.00%** |
| 12 | Organizing activ. of cargo transport | 76.72% | 71.64% | 57.10% | 70.12% | 64.00% |
|  | MEAN | 76.50% | 74.12% | 72.06% | 74.63% | 70.80% |
|  | MINIMUM | 36.62% | 36.16% | 38.61% | 38.76% | 37.93% |
|  | STANDARD DEVIATION | 0.193644 | 0.194157 | 0.21273 | 0.199318 | 0.174462 |

Source: Research data (2014).

Among the activities that are at the efficiency frontier, the 'ancillary activity to air transport' is the most efficient one. This activity was efficient in four of the five analyzed periods, followed by the activity 'Cabotage and long-haul', which reached 100% efficiency in from 2008 to 2010, and also the 'ancillary activity to land transport', which reached maximum efficiency from 2009 to 2011.

The activity 'cabotage and long-haul' reached maximum efficiency due to government and business investments, listed in the 2011 ANTAQ (National Waterway Transportation Agency) annual report, which confirms the high investments in previous periods, contributing to the high scores. In addition, there was a considerable increase in cargo volume in 2010, reaching 616.4 million tons handled by ports, which are part of the long-haul navigation, coinciding with the end of the maximum efficiency period (Agência Nacional de Transportes Aquaviários - ANTAQ, 2012).

The 'ancillary activity to land transport' had maximum efficiency from 2009 to 2011 because it is an activity that complements both the rail and the road modes of transport. The absolute data show that in 2008 and 2012, an improvement of 3.63% and 1.41% in the revenue variable would be needed for it to reach maximum efficiency in the five periods. These data are in line with the increase in the fleet of trucks at an average rate of 7% per year, thus, fleet growth also demands a higher level of ancillary service to meet the goal of land modes of transport.

The activities that achieved maximum efficiency score in two years are the 'rail freight transport' (2010 and 2011), the 'air freight transport' (2008 and 2012) and the 'ancillary activity to water transport' (2008 and 2009).

It is important to highlight the efficiency of the 'rail freight transport', which is linked to the viability of alternatives by the government. Among these actions are the construction of the Nova Transnordestina Railway, made possible by the funding from regional development agencies, as well as the concession of the Norte–Sul Railway (between multimodal yards of Colinas-TO and Palmas-TO, inaugurated in 2010), intending to generate resources to complement the rail link to Palmas-TO. All these actions allowed to obtain better conditions of meeting the market demand, both from the point of view of logistics and of productivity (Brasil, 2012).

Regarding the 'air freight transport', there were high efficiency scores in the five analyzed periods (from 72.84% to 100%) due to the following reasons: a) from 2008 to 2012 the number of flights in Brazil increased year after year, with a total of 750,000 flights in 2008 and one million two hundred and sixty-one flights in 2012, resulting in a 67% increase. With a higher number of flights, an increase in the transported volume and consequently an increase in the revenue is possible; b) the evolution of transported cargo also had an increased volume of 66% (from 2008 to 2012) in the international market, and the increase in the domestic market corresponded to 49%; c) from 2008, there was an average decrease of 25% in cancellations and delays in flights, thus, fewer delays are a consequence of more take-offs and landings (ANTAQ, 2012).

Also with respect to the 'air freight transport', efficiency becomes relevant when it is observed that the performance of the activity is limited to the size of the aircraft holds, therefore, its revenue generation is also limited. It adds to the analysis the fact that civil aviation is essentially used to transport people and to optimize the space of aircraft with cargoes, which is the second goal of most airlines, except for those that are made specifically for cargo transport. These points elevate the analysis in the sense that, even though it is a secondary activity of the air mode of transport and has a limitation in relation to the volumes, the scores were relatively high, between 72% and 100%.

It is also worth noting the 'ancillary activity to water transport' (with maximum efficiency in 2008 and 2009), which includes the organization and support for water transport, as well as classification of vessels and maritime piloting services. Between 2008 and 2010 there was an increase of more than 100 million tons in the ports, and this handling represents 60% of the total waterway matrix of Brazil. Thus, the companies that help the ports and the vessels had an increase in demand mainly in these periods, a fact that contributed for the efficiency of this activity in 2008, 2009 and 2010 to reach respectively 100%, 100% and 95.6%.

The activity 'cargo handling and storage' presented medium scores, between 61% and 75%. One of the characteristics of this activity is the high expense with variable costs, among which is the fuel. Another peculiar characteristic of the companies that develop this type of activity is that they are responsible for a smaller number of transported volumes allied to several companies existing in the same region.

Lower scores are noticed in some activities related to water modes of transport; however, they are concentrated in those activities that operate on inland waterways, with a negative highlight for the activities 'inland navigation', 'support navigation' and 'other modes of water transport'. According to the Plano Nacional de Logística e Transportes - PNLT (2012), Brazil does not fully exploit all its hydrographic potential, even though it has levels of economic activity that combine the need for transportation with the possibilities of its rivers.

Inland navigation comprises cargo transport by rivers, canals, lagoons, bays and also the chartering of vessels, not including the operation and management of cargo

terminals. According to data from ANTAQ (2012), Brazil has had a considerable development in the last years and it has been growing, mainly in the North region. Transport demand statistics for inland navigation also point to an increase, resulting in the increase in operators; however, the investment reflections described by ANTAQ did not result in a high efficiency score, remaining around 50%. If compared with another activity of the same mode, the cabotage and long-haul, it is possible to state that inland navigation requires higher investments to reach higher efficiency scores.

Considering the scores presented in Table 2, it is necessary to analyze the transport matrix of Brazil. It should be noted that the modal distribution of the matrix depends on the application of correct development policies and a transformative view of the future, being affected by market reasons that decisively influence the choices and are strong determinants of the intensity of the regional handling of goods, thus, Figure 2 is presented:
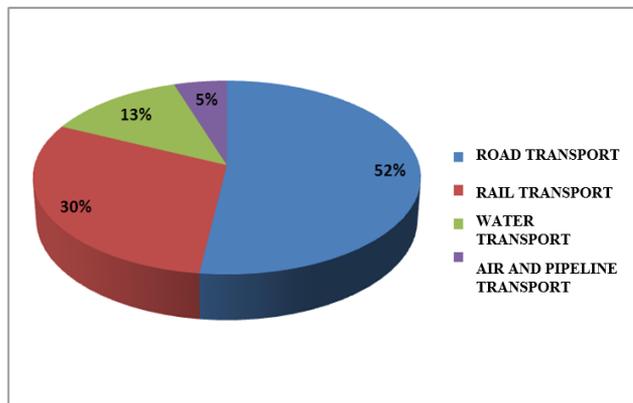


**Figure 2.** Modal distribution of the Brazilian matrix. Source: PNLT (2012).

It is possible to observe that the most used mode of transport in Brazil is the road one, which, in 2011, represented 52% of the transported volume. Thus, the efficiency analysis shows that, even with scores between 50% and 60%, the activity road freight transport is the most used in the country. Another point worth mentioning is that, according to the PNLT (2012), water and rail freights may be 62% and 37% cheaper than road freight.

The evolution of the aviation sector in the last ten years shows that the free competition environment in the sector tends to stimulate innovation, cost optimization, efficiency improvement, moderate tariffs and maintenance of supply at levels compatible with the growth of the demand (PNLT, 2012). Although it accounts for less than 5% of the total Brazilian transport matrix, the air mode of transport presents high efficiency given the calculated scores, both for air freight transport and for ancillary activity to air transport.

## 4.1 Benchmarking

In addition to the efficiency analysis by means of scores, the DEA application also provides benchmarking for units that have not reached maximum efficiency. Figure 3 shows the activities that most served as benchmarking for other DMUs:
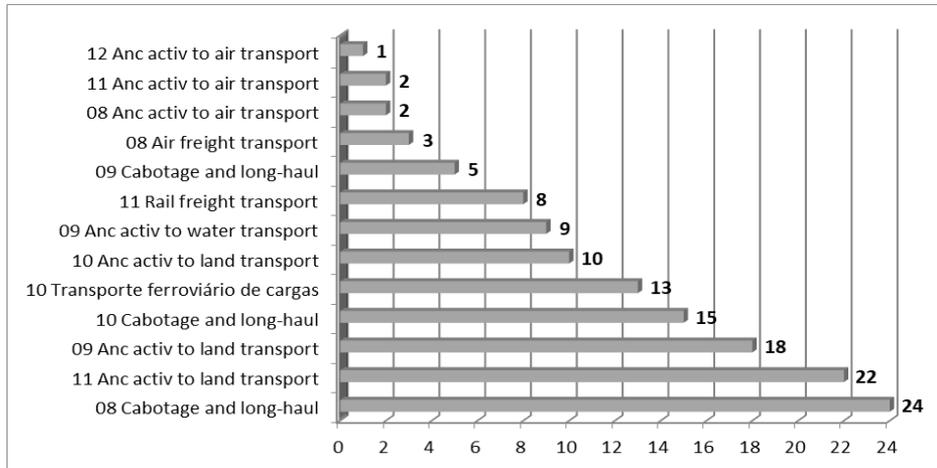
**Figure 3.** Occurrences for other DMUs. Source: Research data (2014).

The activity that most served as reference for another DMU was the 'cabotage and long-haul' in 2008 with 24 occurrences and in 2010 with 15 occurrences, followed by the 'ancillary activity to land transport' in 2011 with 22 events and in 2009 with 18 frequencies. The activity 'rail freight transport' also appears in 2010 with 13 occurrences.

It is possible to observe that the activities described are those that serve as examples for less efficient activities. Thus, the 'ancillary activity to air transport', the 'cabotage and long-haul' and the 'rail freight transport' are highlighted, which, in addition to having high scores, are a good reference for improvement in the other activities.

The DMUs that do not appear in Figure 3 are not good examples of benchmarking for the other activities, since they did not have any occurrence in the DEA modeling. These occurrences serve to design the inefficient units suggesting optimal values for the variables, minimizing inputs and maximizing the products.

After the benchmarking analysis, in which it is possible to verify the positive examples for improvement of each DMU, the analysis of improvement of the variables is performed.

## 4.2 Analysis of improvement of variables

Potential improvements indicate how much each variable needs to be minimized if it is input, or maximized if it is a product, for the DMU to achieve maximum efficiency. There is no way to change only one variable in order that the activity reaches efficiency (except if only one variable appears as a possible improvement). There must be a change in the set of all the variables, minimizing the input variables and maximizing the output variables. Thus, Table 3 is presented with an overview of the necessary improvements:

**Table 3.** Potential improvements (%) for less efficient DMUs.

| YEAR | DMU | Input | | | | Output |
|------|-----|-------|---|---|---|--------|
| | | MOD % | FUEL % | COSTS % | ACQUIS_ TRANSP % | REVENUE % |
| 2008 | Anc. activ. to land transport | 0.00 | 0.00 | 0.00 | 0.00 | 3.77 |
| 2008 | Organizing activ. of cargo transport | 0.00 | 0.00 | 0.00 | -67.44 | 30.35 |
| 2008 | Cargo handling and storage | 0.00 | 0.00 | 0.00 | 0.00 | 33.82 |
| 2008 | Support navigation | 0.00 | 0.00 | 0.00 | -89.26 | 110.92 |
| 2008 | Inland navigation | 0.00 | -0.45 | -69.22 | -43.24 | 100.73 |
| 2008 | Other modes of water transport | 0.00 | 0.00 | 0.00 | -5.01 | 173.09 |
| 2008 | Rail freight transport | 0.00 | -8.73 | 0.00 | -11.50 | 27.18 |
| 2008 | Road freight transport | 0.00 | 0.00 | 0.00 | -85.81 | 73.12 |
| 2009 | Organizing activ. of cargo transport | 0.00 | 0.00 | 0.00 | -5.08 | 39.58 |
| 2009 | Cargo handling and storage | 0.00 | 0.00 | 0.00 | -28.74 | 54.31 |
| 2009 | Support navigation | 0.00 | 0.00 | 0.00 | -88.28 | 134.18 |
| 2009 | Inland navigation | 0.00 | -19.33 | -75.95 | -67.62 | 78.74 |
| 2009 | Other modes of water transport | 0.00 | 0.00 | 0.00 | 0.00 | 176.55 |
| 2009 | Air freight transport | 0.00 | 0.00 | 0.00 | 0.00 | 28.62 |
| 2009 | Rail freight transport | 0.00 | -3.94 | 0.00 | -62.36 | 19.81 |
| 2009 | Road freight transport | 0.00 | 0.00 | 0.00 | -90.92 | 75.53 |
| 2010 | Anc. activ. to air transport | 0.00 | 0.00 | 0.00 | -11.77 | 9.20 |
| 2010 | Anc. activ. to water transport | 0.00 | 0.00 | 0.00 | 0.00 | 4.60 |
| 2010 | Organizing activ. of cargo transport | 0.00 | 0.00 | 0.00 | 0.00 | 75.12 |
| 2010 | Cargo handling and storage | 0.00 | 0.00 | 0.00 | -0.52 | 63.30 |
| 2010 | Support navigation | 0.00 | 0.00 | 0.00 | -89.95 | 138.97 |
| 2010 | Inland navigation | 0.00 | -9.78 | -75.78 | -66.23 | 94.80 |
| 2010 | Other modes of water transport | 0.00 | 0.00 | 0.00 | 0.00 | 159.00 |
| 2010 | Air freight transport | 0.00 | 0.00 | 0.00 | 0.00 | 37.28 |
| 2010 | Road freight transport | 0.00 | 0.00 | 0.00 | -84.08 | 83.12 |
| 2011 | Anc. activ. to water transport | 0.00 | 0.00 | 0.00 | 0.00 | 4.43 |
| 2011 | Organizing activ. of cargo transport | 0.00 | 0.00 | 0.00 | -8.11 | 42.60 |
| 2011 | Cabotage and long-haul | 0.00 | 0.00 | -41.28 | -96.56 | 9.27 |
| 2011 | Cargo handling and storage | 0.00 | 0.00 | 0.00 | -53.08 | 51.45 |
| 2011 | Support navigation | 0.00 | 0.00 | 0.00 | -93.31 | 134.72 |
| 2011 | Inland navigation | 0.00 | 0.00 | -78.34 | -73.31 | 81.65 |
| 2011 | Other modes of water transport | 0.00 | 0.00 | -34.41 | -15.97 | 158.01 |
| 2011 | Air freight transport | 0.00 | 0.00 | 0.00 | 0.00 | 24.89 |
| 2011 | Road freight transport | 0.00 | 0.00 | 0.00 | -87.99 | 79.87 |
| 2012 | Anc. activ. to water transport | 0.00 | 0.00 | 0.00 | 0.00 | 45.11 |
| 2012 | Anc. activ. to land transport | 0.00 | 0.00 | -27.04 | 0.00 | 1.43 |

| YEAR | DMU | Input | | | | Output |
| | | MOD % | FUEL % | COSTS % | ACQUIS_ TRANSP % | REVENUE % |
| --- | --- | --- | --- | --- | --- | --- |
| 2012 | Organizing activ. of cargo transport | 0.00 | 0.00 | 0.00 | -20.25 | 56.24 |
| 2012 | Cabotage and long-haul | 0.00 | 0.00 | -19.35 | -82.75 | 23.35 |
| 2012 | Cargo handling and storage | 0.00 | 0.00 | 0.00 | -71.30 | 34.61 |
| 2012 | Support navigation | 0.00 | 0.00 | 0.00 | -90.93 | 160.20 |
| 2012 | Inland navigation | 0.00 | 0.00 | 0.00 | -21.65 | 77.52 |
| 2012 | Other modes of water transport | 0.00 | 0.00 | 0.00 | 0.00 | 163.61 |
| 2012 | Rail freight transport | 0.00 | 0.00 | 0.00 | -5.94 | 32.44 |
| 2012 | Road freight transport | 0.00 | 0.00 | 0.00 | -89.79 | 83.52 |
| | MEAN | 0.00 | -0.96 | -9.58 | -38.84 | 70.24 |
| | MAXIMUM | 0.00 | 0.00 | 0.00 | 0.00 | 176.55 |
| | MINIMUM | 0.00 | -19.33 | -78.34 | -96.56 | 1.43 |
| | STANDARD DEVIATION | 0.00 | 1.72 | 15.67 | 36.25 | 42.63 |

Source: Elaborated by the author.

Table 3 shows that the variable labor force did not present improvement percentages for any activity and in any analyzed period. Thus, the analyses of improvement focus on the variables fuel, costs and acquisition of transport for the inputs and on the variable revenue for the outputs.

The variable with the highest standard deviation is the 'revenue'; coincidentally it is the variable that needs to be maximized in all DMUs according to Table 3. The revenue has high values, and the three activities related to the water mode of transport are highlighted, which are the support navigation, the inland navigation and other modes of water transport. The suggestion to maximize the revenue in these activities may be linked to the low use of Brazil's inland waterways, which represent less than 13% of the transport matrix.

Lower percentages arise in activities in which if only the revenue were raised they could achieve the maximum efficiency score. In this condition, the ancillary activity to land transport is an example that if the revenue were maximized in 3.77%, it would be possible to reach the maximum score in 2008.

High percentages of revenue optimization are also noticed in the road mode of transport, which shows improvement scores between 70% and 80%. This fact requires attention when we retrieve data from PNLT (2012), in which it is possible to observe that water and rail freights may be 62% and 37% cheaper than road freights. In other words, in addition to having a freight more expensive in relation to other modes of transport, this activity is not succeeding in generating high revenues, since a percentage of improvement of, e.g., 79.87% in 2011, represents a value higher than 54 billion to be obtained as additional revenue in this activity.

The main improvements indicated for the variable FUEL are related to the activities rail freight transport and inland navigation. The higher fuel consumption in the inland navigation activity is linked directly to the speed indicator of the mode of transport. According to Gainza & Brinati (2010), fuel expenses are associated with the use of power and speed of vessels and are also influenced by the local price of fuel where the

vessel is refueled. Thus, inland navigation often uses lower speed compared to the long-haul, which causes a high fuel expense. Another factor that has influence is the price of fuel, since the long-haul activity may be supplied in international ports and it may occur at a transaction cost due to its worldwide operation and displacement, thus minimizing this variable.

The activities that are most frequently used to improve the variable COSTS are related to the water mode of transport, including the activities 'inland navigation' (in four analyzed periods), 'cabotage and long-haul' (in two periods) and 'other modes of water transport'.

A characteristic of the water mode of transport are the moderate fixed costs when compared to the costs of the rail and road modes of transport (Blowersox & Closs, 2001). Thus, even with state investment in order to contribute to reducing costs in the waterway activity (ports), this DMU needs high cost reduction percentages (% improvement) to reach a desired situation (Optimum).

The number of vessels in inland navigation was 1305 in 2010 and increased to 1477 in 2011. This increase also led to a rise in freight capacity, which increased by 14.16% in 2011 (ANTAQ, 2012). Therefore, the increase of the fleet and the rise in the capacity of the vessels indicates a need to incur costs (direct and indirect), such as costs of conservation and maintenance.

In addition to the activities related to water transport, the 'ancillary activity to land transport' emerges in the possible improvements of the variable costs, in 2010. If the costs were reduced by 27.04% and the revenue increased by 1.43%, the DMU under analysis would reach maximum efficiency that year. The cost in this activity is composed of amounts inherent to maintenance, depreciation, administrative costs, selling expenses, among others.

The main improvements to the variable asset acquisition (ACQUIS_TRANSP) are perceived in the water transport (cabotage and long-haul, inland navigation and support navigation), road freight transport and also in the rail freight transport activity.

The highest frequency is in activities related to water transport and such a considerable increase in this input variable is directly linked to the acquisition of new vessels. According to data from ANTAQ (2012), from 2009 to 2011 there was a 42% rise in the number of vessels, and this increase is related to the amount of cargo handled in the same period.

In order for the water mode of transport to meet its objectives, it is necessary to acquire more 'modes of transport', which are the vessels, regardless of their size. Some improvements amounted to 96.56%, e.g., in 'cabotage and long-haul' in 2011, and for 'inland navigation' the improvement percentages vary between 21.65% in 2012 reaching up to 73.31% in 2011.

The road freight transport, due to the accelerated growth of the fleet representing the vehicles in circulation, more than doubled in the 2000s. According to PNLT (2012), it is evident that the circulating fleet has been evolving with growth rates higher than those of the GDP and of the population, and the difference has increased in recent years, making clear the importance of the dimension of the evolution.

With DNIT data, 48% of roads under federal jurisdiction were classified as presenting poor quality, while 36% were classified with regular quality and only 16% with good quality (PNLT, 2012). Thus, the quality of the highways also influences the renewal of the assets, since poorly maintained highways cause a lower service life for the vehicles that circulate through it. Finally, companies engaged in road freight transport are committed to making efforts to constantly renew their fleets.

Regarding the suggested improvements for the rail freight transport, the highest percentage is in relation to 2009, in which the activity would need to reduce transportation investment by 62.36%. One factor that could have influenced the acquisition of assets that year is the fact that the indicator 'accidents per million of trains x km' reached 16, and in 2012 this indicator decreased to 12 (ANTT, 2014). This indicator may suggest that in that year companies had a higher investment to restore damages caused by the high accident rate.

The high expenses with terminals, switching yards and locomotives are also peculiar characteristics of the rail transport (Kim, 2010; Brasil, 2012; Nazário, 2007; Ballou, 1993; Blowersox & Closs, 2001) and 2009 may be considered an atypical year in which such investments may have occurred.

## 5 Final considerations

This research developed a survey of the efficiency of the activities related to logistics modes, transport and cargo handling in Brazil through data envelopment analysis (DEA). The logistics sector was chosen because of the importance it represents for the country's economy and its development.

The choice of the variables used to calculate the efficiency was based on contemporary studies that calculated the efficiency in several forms (environmental, technical, accounting, allocative), being the allocative efficiency applied in this study.

The main variables perceived in the literature and related to logistics were fuel expenses, labor force, direct and indirect costs, investment in assets, investment in modes of transport, number of companies and generated revenue. The option for these variables consists in standardizing the efficiency equation using accounting and managerial variables which are common to all logistics activities, regardless of the mode of transport, be it air, rail, road, water or pipeline.

The returns to scale of the variables that compose the study were tested in order to determine the method of evaluation of the efficiency of the logistics activities. Given the used variables, scatter plots were generated through SPSS® and the correlations among the variables were verified in order to diagnose the returns to scale. As the returns were constant, data envelope analysis (DEA) was used with the product-oriented CCR model, thus, the study approach was quantitative.

The data envelopment analysis (DEA) allowed comparisons of the efficiency indicators of each activity, i.e., a comparison among the twelve DMUs that were part of the sample, and the period from 2008 to 2012 was analyzed. The resulting scores of this study serve as an evaluation of the performance of the modes of transport, since they may be seen as indicators of aid to companies that opt for an activity concentrated in a certain mode of transport.

As an efficient activity, we highlight the ancillary activity to air transport, which reached scores of 100% in the analyzed periods, except in 2010, which obtained 91.58%. It should also be noted that three maximum efficiency scores were obtained for the activities 'cabotage and long-haul' and 'ancillary activity to land transport'. The activities 'rail freight transport' (2010 and 2011), 'air freight transport' (2008 and 2012) and 'ancillary activity to water transport' (2008 and 2009) had two maximum efficiency scores in the years highlighted in parentheses.

There is a negative highlight for the activities inland navigation, support navigation and other modes of water transport, which presented low efficiency scores. Hence, the water mode of transport, regarding the navigable inland routes and their exploration

requires investments and expansion for an effective improvement in the efficiency of these activities.

Data envelopment analysis (DEA) also allowed comparisons in order to suggest values and percentages of improvement for the activities. Thus, it is possible to indicate which activities use more or less fuel, incur direct and indirect costs and invest in assets.

Among the benchmarking or references for improvement and reaching the efficiency frontier, there are examples such as the cabotage and long-haul (2008) and the ancillary activity to land transport (2011), with 22 and 24 benchmarking occurrences, respectively. In relation to the variable 'fuel expenses', the inland navigation and the rail freight transport are the ones with the highest improvement rate, e.g., in 2009 the rail freight transport should have improved or reduced its fuel expenses by 3.94% to reach the efficiency frontier. For the variable 'costs', activities related to water transport, such as 'inland navigation' and 'cabotage and long-haul', stand out, and from 2008 to 2011 the activity 'inland navigation' reached high scores of improvement, reaching 78.34% in 2011. Lastly, regarding the 'acquisition of assets', the highest percentages of improvements were noticed in the organizing activities of cargo transport in 2008 with 96.56%, and also the activity support navigation, with 93.31%, also in 2008.

It is possible to observe that some activities may be stimulated to become more efficient, as is the case of the rail freight transport and the air freight transport, which have a high potential of efficiency and still represent low percentages in the Brazilian transport matrix. In the scientific field, this study provided a discussion of logistics efficiency in order to understand the comparison among modes of transport, also carried out by Savolainen (2007) in Europe and that presents similarities with this study, mainly in the attempt of comparability among the modes of transport that compose the current logistics scenario of a country or continent.

The contribution in the accounting focused on the adoption of variables that have a direct relation with the volume of cargoes, an example of these variables is the fuel expenses and the revenue generated by the activities. The alignment of these variables allowed for a multimodal analysis that may be adopted for comparisons and studies on efficiency, viability, results, among others. Thus, these metrics reinforce the importance of accounting for measurement and calculation of results and performance.

## Acknowledgements

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