EFFICIENCY MEASUREMENT AT PORTS PERFORMANCE ASSESSMENT

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ABSTRACT

The importance of ports for countries' economies around the world and the expected growth of international trade make efficiency a great concern for this sector. In Brazil, in order to measure ports service quality, the Brazilian Transport Waterways Agency (ANTAQ), the federal organization that regulates and inspects ports activities, had proposed a ranking of ports and terminal that operates the main Brazilian cargoes. This ranking consider five variables: total cargoes, consignment average, number of dockage, average ship waiting time and average operation time, whose weights was determined by Analytic Hierarchy Process - AHP. With the objective of evaluate how much the mentioned performance ranking takes into account ports efficiency, this paper presents a comparison between its classification and a mathematical ranking determined using Data Envelopment Analysis (DEA) method, considering the same variables and the same data basis.

Keywords: Port performance; Port efficiency; DEA.

INTRODUCTION

In 2010, Brazilian ports have participated in about 90% of the country's trade with the rest of the world. Given the economic importance of the sector, efficiency and quality in shipping are increasingly relevant.

The Brazilian Transport Waterways Agency (ANTAQ), regulatory agency of the federal government, regulates, supervises and oversees the activities of provision of water transport and operation of waterway and port infrastructure. This institution, through its Port Performance System (SDP), maintains a database on port facilities in order to obtain information to assist in their duties.

Accordingly, the agency presented a performance ranking, for 2010, for the main cargoes handled (container, soy bean, sugar, fertilizers, corn, wheat, fuel and iron ore), based on the weights obtained through expert opinion sector and with the use of Hierarchical Analysis of Process technique, for each of the following indicators: total cargoes, consignment average, number of dockage, average ship waiting time and average operation time.

Aiming to understand how ports efficiency is considered at the performance ranking proposed by ANTAQ, it was madden a comparison with a ranking of efficiency for the same units, obtained by applying the technique of Data Envelopment Analysis. The mathematical model was applied to the same group of ports, using the same variables and the software SIAD (Integrated Decision Support) version 3.0, Meza et al. (2005).

The efficiency rankings obtained for each load beheld the same number of units of the performance rankings, with the classification of ports and terminals defined by composite normalized efficiency calculated by DEA model.

The comparison results showed that ports classification by the evaluation proposed by ANTAQ is in many ways different from the efficiency ranking.

LITERATURE REVIEW

Brazilian Port System - Structure and importance

With a navigable coastline of 8500 km, the Brazilian port system consists of 37 public ports, between sea and river, 42 private terminals and three port complexes that operate under concession to the private sector (SEP, 2012).

Different institutions act on port activities, however, specifically with regard to the activities and operation of transport infrastructure waterway it can be highlight the role of two agents: the Secretary of Ports (SEP) and the National Agency for Waterway Transportation (ANTAQ).

To the Secretary of Ports (SEP) competes policy development and implementation of measures to support the development of infrastructure of seaports to ensure safe and efficient maritime transport of cargo and passengers (SEP, 2012).

In order to regulate, supervise and monitor the activities of provision of water transport and operation of waterway and port infrastructure was created ANTAQ, a regulatory agency under the Ministry of Transport, a member of the Federal Administration (ANTAQ, 2012).

The importance of the sector to the economy can be measured by the participation of the ports in the country's trade relations with the rest of the world. In 2010, about 700 million tons were handled by the ports of Brazil, which corresponds to 90% of Brazilian foreign trade (SEP, 2012).

Considering the continuous growth of international trade flow, efficiency and quality in shipping increasingly gain relevance (TONGZON, 1995; BLONINGEN AND WILSON, 2008; MARTINS E CRUZ, 2011).

Performance evaluation of ports and terminals

The efficiency of facilities for cargo handling and port services quality have decisive influence on the competitiveness of freight. Therefore, to meet the demands of its customers, the port should measure the performance of their operations in order to improve them and direct their planning (ARRUDA, NOBRE JÚNIOR E MAGALHÃES, 2008).

Performance indicators and comparison with benchmarks can contribute to the identification of improvement opportunities and provide support for decision-making at both operational and strategic level, aiding at the knowledge of ports and terminals level of use and the trace of causes of inefficiencies (NG FUNG AND LEE, 2007; ARRUDA, NOBRE JÚNIOR E MAGALHÃES, 2008; MARTINS E CRUZ, 2011).

In this sense, ANTAQ maintains a database, the Port Performance System (SDP), and uses performance indicators to obtain data and information that help the agency at their tasks of supervision and regulation of ports (ANTAQ, 2012).

Ranking of Brazilian ports performance

Among ANTAQ's tasks, there are promoting studies for tariffs and freight rates definitions, establishment of standards and rules for port authorities and the enforcement of efficiency, safety, comfort, regularity, punctuality and reasonable rates at people and goods transportation (ANTAQ, 2012).

In order to support those purposes, the Agency developed the Port Performance System, designed to provide a database and information that serve as a baseline for measuring the quality of services (ANTAQ, 2012).

The indicators calculated using the system information are references for operational management and planning of port development, with focus on user port services, from the perspective of service to public and social interest (ANTAQ, 2003).

Whereas the level of performance achieved by a port can be determined by the degree of customer satisfaction (ARRUDA, NOBRE JÚNIOR E MAGALHÃES, 2008), ANTAQ (2011) proposed a performance ranking for main commodities along 2010, taking into account the importance given by experts for each of the following indicators:

a) average operation time (containers / hour or tons / hour): indicates the average productivity of each terminal or set of cradles against time for berthing of vessels;

b) consignment average (containers / vessel or tons / vessel): indicator of ship size that frequents the harbor, for each type of cargo at each terminal;

c) average ship waiting time (hour / vessel): measures the quality of service, in terms of time, by the hours and minutes spent waiting for berthing of vessels of each group of cargo for each terminal;

d) number of dockage (units) and

e) total cargoes (in units for containers and in tones for bulk).

The opinions were collected through questionnaires and the weight were determined through Analytic Hierarchy Process (AHP). Set the weights, it was calculated a performance grade for each terminal. The scores were normalized to vary in a scale of 5 to 10 and the terminals ordered - the higher the score the better the performance shown in 2010.

The Analytic Hierarchy Process (AHP) developed by Saaty (1980) is a method of decision support that helps identify and weigh multiple selection criteria relating to existing alternatives, incorporating measures of objective and subjective evaluation.

For bulk, the indicators consignment average and total cargo handled gained greater importance against the average waiting time, however, the average operation time was identified as the main performance indicator. For containers, the average waiting time and the average operation time were identified as indicators of greater weight, which is attributed to the higher value of the loads and the need for speed of operations.

The evaluation was made for terminals that handled more than 100 thousand tons in 2010.

Efficiency Analysis of ports using DEA model

The Data Envelopment Analysis (DEA) is a methodology for measuring efficiency, developed by Charnes, Cooper and Rhodes (1984), based on the work of Farrell (1957), which has been used in several port studies (BLONINGEN AND WILSON , 2008, BERTOLOTO, 2010).

The procedure uses data, as inputs and outputs, and function theory to estimate the production frontier efficiency on a set of decision-making units, called DMUs. (BLONINGEN AND WILSON, 2008; BERTOLOTO, 2010).

DEA functions allow at the understanding of the overall performance of a terminal and compare efficiency between terminals (WANG, SONG AND CULLINAME, 2002). The DEA model identifies the reference units (benchmarks) for organizations that do not perform efficiently, enabling comparisons identifying potential improvements in the performances (BERTOLOTO, 2010).

Knowledge of the process of transforming inputs into outputs is not necessary, as there is no need to build hypotheses on the production function or establish a functional relationship between inputs and outputs (BERTOLOTO, 2010). The focal point of DEA is on individual observations, in opposite to the individual optimization approach that focuses on statistical averages of parameters (TONGZON, 2001).

The way the projection is done determines the orientation of the model: input orientation, when you want to minimize inputs while keeping constant the values of outputs, and output orientation, when you want to maximize results without diminishing the resources (BERTOLOTO, 2010).

The DEA technique is sensitive to the number of inputs and outputs and to the observed sample size. Thus, it is recommended a sample size at least three times greater than the sum of the inputs and outputs (LETA et al., 2005; BERTOLOTO, 2010).

OBJECTIVES

The main objective of this research is to analyse how much port efficiency is taking into account at ports performance measured by Brazilian Transport Waterways Agency (ANTAQ).

Beside this, it will be presented Brazilian Port efficiency ranking for the main cargoes and a comparison with ANTAQ's classification.

DATA / METHODOLOGY

This study is based on an investigative deductive research (LAKATOS E MARCONI, 1993, GIL, 1999) and quantitative approach, which uses numerical information for analysis. With regard to methodological goals (GIL, 1999), it is an exploratory research, aiming to provide greater familiarity with the problem in order to make it explicit.

The work was developed in a literature basis and the source of information was the Port Performance System, a database maintained and made available by ANTAQ.

ANTAQ's performance ranking classifies ports and terminals based on grades obtained from the indicators average board, average consignment, average waiting time, number of berths and amount of cargo handled, whose weights were defined based on the opinions of experts, with the use of AHP technique (ANTAQ, 2011).

The mathematical model DEA was applied to the same set of ports, using the same variables: average consignment, average board and average waiting time as inputs; the indicators of quantity of cargo handled and frequency of ships were selected as outputs. Regarding that all ports have good management and also that there are no different resources used in each case, each group was considered homogeneous (BERTOLOTO, 2010).

Since there is no presumption of proportionality between inputs and outputs, the chosen model was BCC. The output orientation adopted was used to analyze the necessary improvements in the output, remaining inputs unchanged. This makes it possible to identify the amount of cargo that can be handled at a port with the existing resources (BERTOLOTO, 2010).

The classification of ports in the ranking of efficiency was defined by the normalized composite efficiency ratio, which is obtained by dividing the composite efficiency index, defined as the arithmetic mean between efficiency at conventional DEA frontier and the complement of efficiency to inverted frontier, with the highest value of this index (SOARES DE MELLO, MEZA E GOMES, 2012). As DEA model can return more than one efficient unit, estimated by standard frontier, this ratio can make a better distinction of them.

However, as normalized composite efficiency ratio is not a measure of efficiency, the groups efficiency averages was calculated using standard efficiency estimated by DEA.

Considering the sensitivity of the model to the number of analyzed units, the performance of ports in 2009 was also included at the analyzes, however, the efficiency ranking presents only the better results ports and terminals in 2010, with the same number of elements of ANTAQ's ranking. To calculate the efficiencies it was used the software SIAD (Integrated Decision Support) version 3.0, Meza et al. (2005).

RESULTS

ANTAQ's performance ranking, estimated with AHP technique, and the results of the analysis of ports and terminals efficiency, calculated with DEA model, are presented for each cargo at tables I to VIII.

From simple view analysis is possible to realize the differences at the composition of each ranking.

Table I – Comparison between Containers' rankings

ANTAQ's Performance Ranking - Containers			DEA Efficiency Ranking - Containers		
Ranking	Port	Terminal	Ranking	Port	Terminal
1	Santos-SP	TECON	1	Paranaguá-PR	TCP
2	Rio de Janeiro-RJ	Libra	2	Rio Grande-RS	TECON
3	Rio Grande-RS	TECON	3	Rio de Janeiro-RJ	Multi-Rio
4	Santos-SP	TECONDI	4	Rio de Janeiro-RJ	Libra
5	TUP Chibatão-AM	Chibatão	5	Itaguaí-RJ	Sepetiba Tecon
6	Rio de Janeiro-RJ	Multi-Rio	6	TUP Super Terminais-AM	Super Terminais
7	Santos-SP	Libra (T-37)	7	Suape-PE	TECON
8	Salvador-BA	TECON	8	Salvador-BA	TECON
9	Santos-SP	Libra (T-35)	9	TUP Portonave-SC	Portonave
10	Itajaí-SC	TECONVI	10	Santos-SP	Libra (T-35)

Table II – Comparison between Iron Ore's rankings

ANTAQ's Performance Ranking - Iron Ore			DEA Efficiency Ranking - Iron Ore		
Ranking	Port	Terminal	Ranking	Port	Terminal
1	TUP CVRD Tubarão-ES	Tubarão	1	TUP Gregório Curvo-MS	Gregório Curvo
2	TUP Ponta da Madeira-MA	Ponta da Madeira	2	TUP Porto Sobramil-MS	Porto Sobramil
3	TUP MBR-RJ	MBR	3	TUP Granel Química-MS	Granel Química
4	TUP Ponta de Ubu-ES	Ponta de Ubu	4	TUP Ponta da Madeira-MA	Ponta da Madeira
5	Itaguaí-RJ	Term. de Minério	5	TUP CVRD Tubarão-ES	Tubarão
6	Itaguaí-RJ	Terminal de Carvão	6	TUP Min. e Met. Amapá-AP	Amapá
7	TUP Min. e Met. Amapá-AP	Amapá	7	TUP Ponta de Ubu-ES	Ponta de Ubu
8	TUP Porto Sobramil-MS	Porto Sobramil	8	TUP MBR-RJ	MBR
9	TUP Gregório Curvo-MS	Gregório Curvo	9	Itaguaí-RJ	Terminal de Carvão
10	TUP Usiminas-SP	Usiminas	10	Itaguaí-RJ	Term. de Minério

Table III – Comparison between Soy Bean's rankings

ANTAQ's Performance Ranking - Soy bean			DEA Efficiency Ranking - Soy bean		
Ranking	Port	Terminal	Ranking	Port	Terminal
1	TUP CVRD Tubarão-ES	Tubarão	1	Rio Grande-RS	Tergrasa
2	Santos-SP	TGG	2	TUP Bianchini-RS	Bianchini
3	Itaqui-MA	CVRD	3	TUP Cargill Agrícola-RO	Cargill Agrícola
4	TUP Hermasa Graneleiro	Hermasa Graneleiro	4	TUP Hermasa Graneleiro	Hermasa Graneleiro
5	Paranaguá-PR	Corex	5	Paranaguá-PR	Corex
6	Santos-SP	Cargill	6	TUP Cotegipe-BA	Cotegipe
7	São Francisco do Sul-SC	Cais Público	7	Santos-SP	Corex (ADM)
8	Santos-SP	Corex (ADM)	8	Santos-SP	Cargill
9	TUP TERMASA-RS	Termasa	9	Porto Velho-RO	Cais Público
10	TUP Cotegipe-BA	Cotegipe	10	Ilhéus-BA	Cais Público

Table IV – Comparison between Sugar's rankings

ANTAQ's Performance Ranking - Sugar			DEA Efficiency Ranking - Sugar		
Ranking	Port	Terminal	Ranking	Port	Terminal
1	Santos-SP	Teaçu 3	1	Santos-SP	Cargill
2	Santos-SP	Teaçu 1	2	Recife-PE	Cais Público
3	Santos-SP	Teaçu 2	3	Maceió-AL	EMPAT
4	Santos-SP	Cargill	4	Antonina-PR	Ponta do Félix
5	Santos-SP	Corex (ADM)	5	Paranaguá-PR	Múltiplo Uso
6	Santos-SP	Moinho Santista	6	Santos-SP	Teaçu 2
7	Paranaguá-PR	Múltiplo Uso	7	Santos-SP	Teaçu 3
8	Maceió-AL	EMPAT	8	Santos-SP	Moinho Santista
9	Recife-PE	Cais Público	9	Santos-SP	Teaçu 1
10	Paranaguá-PR	Corex	10	Paranaguá-PR	Corex

Table V – Comparison between Fertilizers' rankings

ANTAQ's Performance Ranking - Fertilizer			DEA Efficiency Ranking - Fertilizer		
Ranking	Port	Terminal	Ranking	Port	Terminal
1	Paranaguá-PR	Múltiplo Uso	1	TUP Yara Fertilizantes	Yara Fertilizantes
2	TUP Inácio Barbosa-SE	Inácio Barbosa	2	Rio Grande-RS	Cais Público
3	Paranaguá-PR	Fospar	3	Aratu-BA	Cais Público
4	TUP Yara Fertilizantes	Yara Fertilizantes	4	Porto Alegre-RS	Cais Navegantes
5	TUP Ultrafertil-SP	Ultrafértil	5	Porto Alegre-RS	Serra Morena
6	TUP CVRD Tubarão-ES	Tubarão	6	Paranaguá-PR	Múltiplo Uso
7	Santos-SP	TMG	7	TUP Hermasa Graneleiro	Hermasa Graneleiro
8	Rio Grande-RS	Cais Público	8	TUP Oleoplan-RS	Oleoplan
9	Vitória-ES	Peiú	9	Paranaguá-PR	Fospar

Table VI – Comparison between Corn's rankings

ANTAQ's Performance Ranking - Corn			DEA Efficiency Ranking - Corn		
Ranking	Port	Terminal	Ranking	Port	Terminal
1	Santos-SP	TGG	1	TUP Cargill Agrícola-RO	Cargill Agrícola
2	TUP CVRD Tubarão-ES	Tubarão	2	TUP Hermasa Graneleiro-AM	Hermasa Graneleiro
3	Paranaguá-PR	Corex	3	TUP CVRD Tubarão-ES	Tubarão
4	Santos-SP	Cargill	4	Santos-SP	Corex (ADM)
5	Santos-SP	Corex (ADM)	5	Paranaguá-PR	Corex
6	TUP Hermasa Graneleiro-AM	Hermasa Graneleiro	6	Paranaguá-PR	Múltiplo Uso
7	São Francisco do Sul-SC	Cais Público	7	Porto Velho-RO	Cais Público
8	Santarém-PA	Cargill	8	Santarém-PA	Cargill
9	Porto Velho-RO	Cais Público	9	Santos-SP	Cargill
10	TUP Cargill Agrícola-RO	Cargill Agrícola	10	Santos-SP	TGG

Table VII – Comparison between Wheat's rankings

ANTAQ's Performance Ranking - Wheat			DEA Efficiency Ranking - Wheat		
Ranking	Port	Terminal	Ranking	Port	Terminal
1	TUP Bianchini-RS	Bianchini	1	Santos-SP	Cais Público
2	Fortaleza-CE	Cais Público	2	TUP TERMASA-RS	Termasa
3	Santos-SP	Corex (ADM)	3	Fortaleza-CE	Cais Público
4	TUP TERMASA-RS	Termasa	4	Rio de Janeiro-RJ	Cais Público
5	TUP Inácio Barbosa-SE	Inácio Barbosa	5	TUP Inácio Barbosa-SE	Inácio Barbosa
6	Paranaguá-PR	Corex	6	Salvador-BA	Cais Público
7	Rio Grande-RS	Tergrasa	7	Belém-PA	Cais Público
8	Rio de Janeiro-RJ	Cais Público	8	TUP Cotegipe-BA	Cotegipe
9	Suape-PE	Cais Público	9	Porto Alegre-RS	Serra Morena
10	TUP Cotegipe-BA	Cotegipe	10	Suape-PE	Cais Público

Table VIII – Comparison between Fuel's rankings

ANTAQ's Performance Ranking - Fuel			DEA Efficiency Ranking - Fuel		
Ranking	Port	Terminal	Ranking	Port	Terminal
1	TUP Alm. Max. Fonseca-RJ	Alm. Max. Fonseca	1	TUP Alm. Tamandaré-RJ	Alm. Tamandaré
2	TUP Almirante Barroso-SP	Almirante Barroso	2	Belém-PA	Miramar
3	TUP São Francisco do Sul-SC	São Franc. do Sul	3	TUP Manaus-AM	Manaus
4	TUP Madre de Deus-BA	Madre de Deus	4	TUP Almirante Barroso-SP	Almirante Barroso
5	TUP Alm. Soares Dutra-RS	Alm. Soares Dutra	5	TUP Ipiranga Base Porto Velho-RO	Ipiranga P. Velho
6	TUP Carmópolis-SE	Carmópolis	6	Santos-SP	Cais Público
7	TUP Guamaré-SE	Guamaré	7	Suape-PE	Cais Público
8	TUP Pecém-CE	Pecém	8	Vila do Conde-PA	Cais Público
9	TUP Alm. Tamandaré-RJ	Alm. Tamandaré	9	Santarém-PA	Cais Público
10	TUP de GNL da B. de Guanabara-RJ	GNL B. de Guan.	10	Fortaleza-CE	Píer Petroleiro

For Iron Ore, Sugar and Corn, 90% of the units are common in both rankings. This result was expected, given that the sets of ports and terminals evaluated for those goods were very small, consisting of 11 units each one. However, the classification of the elements is different for approximately 93.00% of the cases.

For other cargoes, whose analyzes considered major groups of elements, ranging from 19 to 36 units, the percentage of common units in both rankings was lower.

With the comparison for containers group, in which 27 units were analyzed for the year 2010, 50.00% of ports and terminals better evaluated by customers had the highest percentages of efficiency.

For the set of 19 ports and terminals of soy handling, there is also 50.00% of units common to both rankings.

In the group of fertilizer ports, composed of 19 elements, 40.00% of the better classified units at efficiency ranking were also pointed at performance ranking.

For the 22 ports and terminals that operate on wheat handling, the percentage of common units at both rankings was 60.00%, a result that most closely matches the two methods used.

For the 36 units for fuel handling, only 20.00% of those with higher performance are also among the most efficient, representing the farthest result among the observed in all comparisons.

The information above is summarized at table IX.

Table IX – Common Efficient Units

% Efficient Units (Composite Efficiency Ratio)		
Cargo	**Total units**	**ANTAQ's Ranking**
Containers	27	50,00%
Iron Ore	11	90,00%
Soy Bean	19	50,00%
Sugar	11	90,00%
Fertilizer	19	40,00%
Corn	11	90,00%
Wheat	22	60,00%
Fuel	36	20,00%

As a consequence, the standard efficiency average of each of the smallest groups presents close results for both rankings, as showed at table X.

Those information allows to conclude that, for the smallest groups of ports, ANTAQ's performance ranking efficiency average is less than 10% different from DEA's ranking average. For the biggest groups, this difference is more than 20% in all cases.

Table X – Comparison between efficiency averages of both rankings

Standard Efficiency Average				
Cargo	**Total units**	**ANTAQ's Ranking**	**DEA's Ranking**	**<>**
Containers	27	70,15%	92,47%	22,32%
Iron Ore	11	45,91%	55,74%	9,83%
Soy Bean	19	66,96%	87,10%	20,14%
Sugar	11	60,76%	69,26%	8,50%
Fertilizer	19	52,36%	92,60%	40,24%
Corn	11	88,89%	96,96%	8,07%
Wheat	22	67,99%	90,98%	22,99%
Fuel	36	45,80%	73,24%	27,44%

IMPLICATIONS

Considering the continuous growth of international trade flow, it is essential to evaluate the efficiency and quality of shipping in order to reach competitiveness in freight transport.

To assess port facilities in Brazil, ANTAQ presented a ranking for ports performance in 2010, for the main cargoes handled. The construction of the ranking was based on information from a database maintained by the regulatory institution (Port Performance System) on total cargoes, consignment average, number of dockage, average ship waiting time and average operation time, whose weights were set based on the perception of experts.

In order to know how ANTAQ's performance ranking considers port efficiency parameter, this study applied the mathematical model of Data Envelopment Analysis (DEA) on the same units. DEA technique, which allows capture and compares efficiency between terminals, has been used in several studies on ports.

From DEA's efficient ranking it could be observed that sometimes efficient units are not considered at ANTAQ's ranking, while inefficient units can be listed among those who performed better. Furthermore, it was observed that even when efficient units are pointed at performance ranking they can be classified as more underperformed than inefficient units.

The view differences between the rankings are confirmed with efficiency average of each one. ANTAQ's rankings have the lowest efficiency for all cargoes, what means that this performance assessment must be used carefully at some analysis.

The definition of policies and investments for the sector, based only on performance ranking can, for instance, direct resources and solutions to efficient ports and terminals that were poorly evaluated, leaving a lack of solutions to inefficient ports and terminals. Moreover, customers choices based on ANTAQ's ranking can be not as accurate as they need.

Therefore, the results can be useful as efficiency reference, complementary to ports well known information, and can helps at the decision of use ANTAQ's ranking.

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