

**PERFORMANCE EVALUATION OF THE MAIN TERMINAL CONTAINERS IN
THE IBERIAN SEAPORTS: A BENCHMARKING APPROACH**

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Abstract

The efficiency of the operations of an intermodal terminal of containerised cargo has been a focus of analysis of many researchers. The most effective method to quantify the performance key indicators is DEA (*Data Envelopment Analysis*). Nowadays, this method used together with the *Data Mining* represents a more reliable diagnosis tool when comparing the ports operational data. The present study applies this methodology to assess the ports performance of the containerised cargo terminals in the Iberian seaports hinterland during 2007. The analysed performance indicators are fundamental to a detailed operational description of the studied ports and highlight the aspects that should be improved within the port management level. Taking into account that ports are global logistical networks junctions, the evaluation concerning the performance is essential in order to able effective decision making with the goal of improving their efficiency, their productivity and, therefore, their competitiveness.

Keywords: Benchmarking, Performance Measurement; Efficiency; DEA; Seaports.

1 Introduction

Benchmarking is generally associated with quality excellence since several researches use the Deming PDCA cycle approach (NPC, 1999; Lee, 2002; Chan *et al.*, 2006; Ribeiro and Cabral, 2006). Benchmarking is a popular tool which is used universally as a tool to improve organizations' performance and competitiveness in business life (Wong and Wong, 2008). Its scope of application ranges from large firms to small businesses, public as well as semi-public sectors, and encompassed various types of industries (Ball, 2000; Davis, 1998; Jones, 1999; McAdam and Kelly, 2002).

Some authors (McNair and Leibfried, 1992; Spendolini, 1992; Bhutta and Faizul, 1999; Bogan and Callahan, 2001) denotes benchmarking as a management tool that can be defined as the systematic process of searching for best practices, innovative ideas and efficiencies that lead to continuous improvement. Benchmarking has been considered not only as a systematic process for evaluating the products, services and work processes of organizations that are recognized as representing best practices but also as a continuous improvement philosophy (Talluri and Sarkis, 2001). From a simple concept, benchmarking has undergone an evolutionary approach towards more sophisticated forms. Ahmed and Rafiq (1998) present different generations of benchmarking: i) reverse benchmarking; ii) competitive benchmarking; iii) process benchmarking; iv) strategic benchmarking; v) global benchmarking; vi) competence benchmarking or bench-learning and vii) network benchmarking which is occurring in this century.

Depending on the objectives and areas of benchmarking application a set of tools could be identified associated with it. We can find the Deming PDCA cycle tool (Chan *et al.*, 2006; Ribeiro and Cabral, 2006), the SCOR model (Theeranuphattana and Tang, 2008), and the DEA model (Wong and Wong, 2008; Doyle and Green, 1994). According to Wong and Wong (2008) DEA is justified to be used as a benchmarking tool because of its features and inherent characteristics such as: i) it is a robust, standardized and transparent methodology; ii) it is an effective tool for evaluating the relative efficiency of peer DMUs (*Decision Making Units*) when multiple performance measures present; iii) it evaluates efficiency without the need to specify the relationships or tradeoffs among the performance measures prior to the computation; iv) it utilizes the concept of efficient frontier as a measure for performance evaluation.

While there is extensive literature on benchmarking, applied to a wide variety of economic areas, the scarcity with regard to sea ports bears testimony to the fact that this is a relatively under-researched area (Barros, 2005). In this context, and according to Barros and Athanassiou (2004) the benchmarking of European Sea ports should be a priority on the research agenda since, despite the clearly non-homogeneous nature of European Sea ports, they perform the same task and thus, may be compared benchmarking purposes (Tongzon, 2001; Barros and Athanassiou, 2004)

The complexity scenery that has been created by the present global logistic networks associated to the phenomena of financial uncertainty, as well as the economic growth of geographic zones far from Europe puts emphasis on the importance of the Iberian logistic management in operational terms. According to the global networks inclusive logic, the container terminals individual performance will affect directly the functioning of the chains that make them (Marlow and Casaca, 2003). The terminals impedance (Hesse and Rodrigue, 2004) must be small in order to maximize the added value generated within them and as a consequence to improve their attractiveness in business terms.

Within a management enlarged context, evaluation is the last process of a back-fed system of continuous improvement and supplies the decision makers with the information related to the unity performance. In the past, evaluation was mostly endogenous, while the new trends point out to a comparison between the competitors results. The benchmarking concept includes not only the internal analysis as well as the external comparison, in which the performance indicators are established and valued and supply precious information. This relative comparison creates the necessity to change the internal processes. Some managers even adapt “competitive” processes to their businesses having as goal the cost reduction of their products and, as a consequence to increase their competitiveness within the markets they work with in

phenomena describes as co-opetition (Song, 2003; Dias, 2006). Besides this direct saving, we have to take into account the improvement in the company's image, being difficult to quantify with a low level error, but the existing studies are conclusive concerning the effects caused by the leadership's image in the investors, suppliers, collaborators, consumers and customers preferences.

Historically, the port operations are closed business activities, with scarce, vague and imprecise information. In the last years, there has been a growth in the TEU's handled and so, the terminal operations management should take into account their performance in a systematic and objective way. This scenario has been changing, and Soppé *et al.* (2009) presented the changes in the relations between Shipping Lines (SL) and Terminal Operators (TO), which where rivalry and are changing to cooperation. The world biggest terminals have been investing in the information technologies and systems directed to the customer and it is expected an increase in the number of services and available information. This open strategy, not only reinforces the terminals position within the market, but also within a global logistic view, giving them a critical capacity and importance in maintaining wealth in the geographic areas where they are located.

The performance measurement of the main Iberian container terminals presented in this study has as main goal to establish performance key indicators of the operational management of the above mentioned terminals and to value them during 2007 and at the same time to verify the availability of this information in the international network sites.

The research is structured as follows: next to this introduction, comes the review of literature centred in the importance, indicators and the performance evaluation methodology of the selected terminals. In the third part, the research methodology is presented by proposing the

objectives, research hypotheses, characterisation of the study sample, the data collecting and the measurement of the variables. In the fourth section, the results of the research work will be presented as well as the results recursive analysis with the appliance of DEA method. Finally, the results, the conclusions and a future research proposal.

2 Sea ports Logistics Performance

Globalisation is mostly set in the improvements made on transportation means, which have played a significant role in enlarging the number of consumers of company's products. If we consider that the technological improvements weren't fundamental to a real reduction of the time used to the goods' transportation, we will understand that the efficiency in transshipment is mostly achieved in the intermodal terminals (Rodrigue, 1999).

Though the studies concerning the supply network management did not analyse them with a special care and nor the researchers have made any efforts to come up with models that would allow a better knowledge of the used processes (Janelle, 1991) we can say that a change is occurring and the last few years have been fruitful within this context. The movement of goods is mainly made by maritime transport not only because it is cheaper but also by geographic reasons. Nowadays, sea sea ports have many specialised areas related to the commodities movement, according to their features and they tend to a normalisation because of economies of scale. The big economic growth of countries outside Europe justifies the growing demand of container cargo, taking its own advantages out of the concept of "package" modularization, by a space-time compression and of the scale effect. As it is referred by Dowd and Leschine (1990), the container terminals are the physical connection between the ocean and the several modes of land transportation and the biggest component in the containerization systems.

As previously mentioned, the terminals play an important role in the efficiency of the supply networks, and according to Hesse and Rodrigue (2004) the impedance concept, or the sum of the frictional costs (Dias *et al.*, 2008) caused by logistics processes and physical circulation, must be observed through four different points of view: the traditional transportation costs, the supply chain organization and the physical and transitional environments in which the distribution is made. In table 1 we can see the relation between these four impedance factors and the assessment measures being minimised in each one of them.

Table 1- Logistics Friction

Impedance factor	Assessment measures
Transport/Logistics costs	Distance, time, composition, transshipment, decomposition
Supply Chain	Number of suppliers, number of distribution centres, number of parts/variety of components
Transactional Environment	Competition, (sub-)contracting, inter-firm relationships, power issues, (de-)regulation
Physical Environment	Infrastructure supply, road bottlenecks and congestion, urban density, urban adjustments

Source: Hesse and Rodrigue (2004)

Summing up, the sea ports operations should be considered as impedance factors directly connected to the physical environment. The systemic nature of logistics does not allow management to overlook the other three aspects as they will affect the terminal performances. The optimization should be supported by economic analysis and *trade-offs* (Dias, 2006) aiming to achieve a good value between traffic and investment as it happens with the untying

point of the value chains. Figure 1 shows this balance and establishes a relation with the dimension of the network that we aim to optimize.

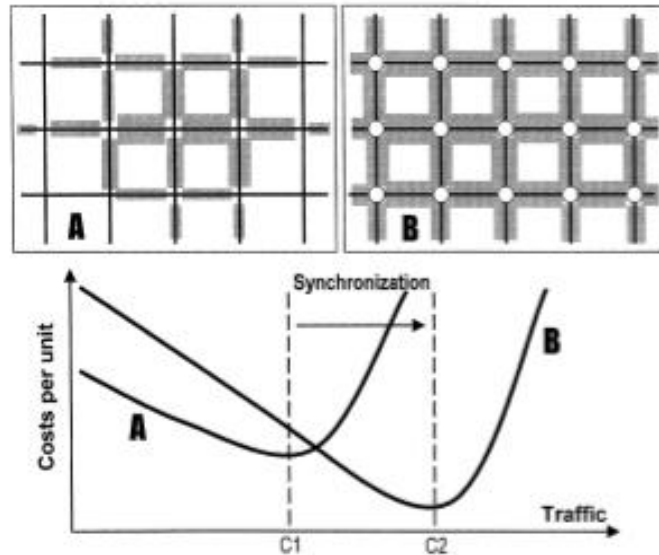


Figure 1 – Transportation costs per unit; networks A and B

Source: Rodrigue (1999)

2.1 Sea port performance indicators

In the 1976's United Nations Conference on Trade and Development (UNCTAD) published a document about the port performance indicators was written and since then it is seen by the researchers in this area as a reference (UNCTAD, 1976). In this document there are several types of indicators to evaluate the operational and financial performance. The evolution of the concept of logistics, in which the operators are classified according to its level of intervention in the supply chains and designated as Transport Service Providers (TSP) allows us to understand that the measurement of the efficiency level of this entities is not confined to quantitative aspects and proves that qualitative indicators are necessary (Antão *et al.*, 2005). However, the scope of this study is more reduced and it focuses itself exclusively in the movement of containers within a terminal, in what is known as *handling*. Hence, and according to a set of studies in this area (Roll and Hayuth, 1993; Tongzon, 2001; Turner *et*

al., 2004; Cullinane *et al.*, 2004), the measurement objects are the indicators presented in table 2.

Table 2 – Performance indicators used

Performance Indicator	Type	
Number of cranes [Un.]	Input	<i>E1</i>
Number of employees [Un.]	Input	<i>E2</i>
Terminal area [ha]	Input	<i>E3</i>
Number of trailers [Un.]	Input	<i>E4</i>
Yard equipments [Un.]	Input	<i>E5</i>
Terminal length [m]	Input	<i>E6</i>
TEU handled [Un.]	Output	<i>S1</i>
Containers movement by ship by hour [Un.]	Output	<i>S2</i>

2.2 Sea ports Data Analysis

The performance measurement studies in containers' terminals are made according to two types of approaches: *Stochastic Frontier Analysis* (SFA) e *Data Envelopment Analysis* (DEA). Both present advantages and weaknesses, however the DEA applied under certain conditions shows more strength, as Cullinane *et al.* (2006) have shown. The comparative studies developed by Barr (2004) present several solutions to the data processing. The DEA-SAED application, besides being free, assures low simulation times and uses the Dynamic Link Library (DLL) technology. To perform a SOM analysis of the DMUs inputs it was used the SOM toolbox which is an implementation of SOM in the MatLab 5 computer environment (Vesanto *et al.*, 2000).

3 Iberian main containers terminals

The organizational model of the Iberian sea ports is similar, that is, the State owns the management rights of these areas and gives the power to the sea ports authorities to organize and develop them. Having in mind the surrounding environment, the port authority assigns the exploitation of certain zones to the private sector. The circulation of goods depends on the Global Economy and the sea ports gain or lose their importance within the logistics global networks mainly due to their geographic location and corresponding hinterlands (Dias, 2005). Usually, their relevance is measure by the cargo throughput, either in weight or in TEU's, which means that the area included by the port's activity has an economical-financial critical mass able to generate goods flows enough to make the sea ports business to look attractive. These differences lead to the classification of the sea ports as hub's or feeder's (Dias, 2005) that are destined for Short Sea Shipping (SSS) and/or Long Sea Shipping (LSS), with the capacity to make transshipment, and their intermodal infrastructures. The scenery studied by Gaspar (2001) presents the distribution of the gravity influence of seven Iberian sea ports, and the statistics referring to 2007 allow us to conclude that the scenery has not been altered, with the exception of the growth in the demand of containers movement. Figure 2 presents the movements of containers in 2007, expressed in thousands of TEU's, and to sea ports that show a handled above 100.000 TEU's.

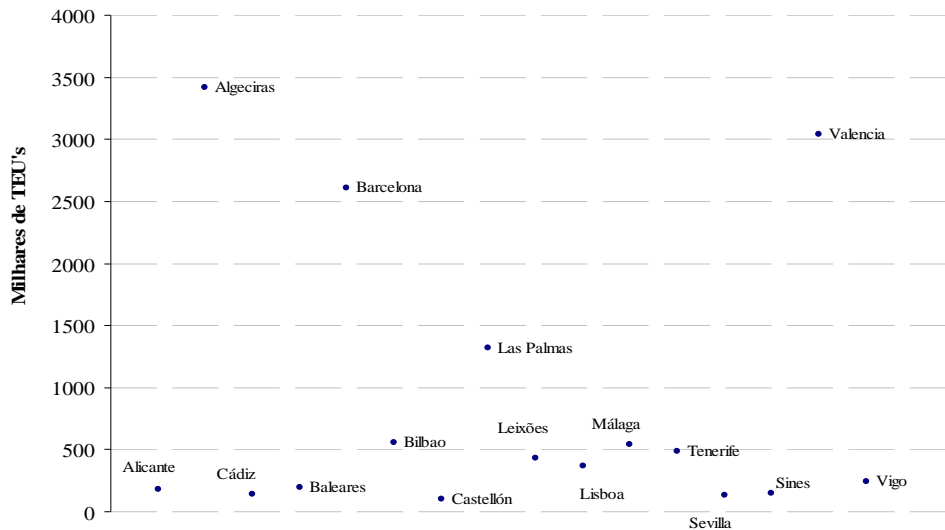


Figure 2 – Moved Cargo in the Main Iberian Sea ports during 2007

In this study, were not considered the sea ports of Las Palmas, Málaga, Cádiz, Baleares, Castellón, Tenerife, Sevilha because we had not access to the data. Also, there is one port that has more than one container' terminal (Leixões). In this sense, the Iberian terminals focused on this study are the ones presented in Table 3.

Table 3 –Performance evaluation of used terminals

Seaport	Terminal	
Bahia de Algeciras	Terminal 2000; Isla Verde	<i>DMU 1</i>
Barcelona	TCBCN; Catalonia	<i>DMU 2</i>
Valência	Principe Felipe; Levante	<i>DMU 3</i>
Bilbao	Santurtzi-Zierbena A1	<i>DMU 4</i>
	Santurtzi-Zierbena A2	
Vigo	Terminal Guixar	<i>DMU 5</i>
Alicante	Terminal de Alicante	<i>DMU 6</i>
Lisboa	TC Alcantara	<i>DMU 7</i>
Leixões	TC Leixões – Sul;	<i>DMU 8</i>
Leixões	TC Leixões – Norte	<i>DMU 9</i>
Sines	Terminal XXI	<i>DMU 10</i>

3.1 Data Collection

In the data collection, the web sites of several entities were consulted, namely: sea ports, terminals, assigned companies (dealers), stowage companies, *European Sea ports Organization* (ESPO), INE (Portuguese National Institute of Statistics) and Eurostat. The data gathering was made between the 18th and the 21st of November 2008.

The data collection is shown in Table 4.

Table 4 – Data collected in the research

	<i>E1</i>	<i>E3</i>	<i>E5</i>	<i>E6</i>	<i>S1</i>
<i>DMU 1</i>	17	86,6	39	2970	3420533
<i>DMU 2</i>	21	93,29	107	2484	2610100
<i>DMU 3</i>	27	158	157	3600	3042665
<i>DMU 4</i>	15	46,7	18	1527	554558
<i>DMU 5</i>	3	18	7	769	244065
<i>DMU 6</i>	2	6,8	15	354	172729
<i>DMU 7</i>	3	12	16	630	329000
<i>DMU 8</i>	3	16	15	540	272045
<i>DMU 9</i>	2	6	5	360	160316
<i>DMU 10</i>	3	36,4	3	380	150038

3.2 The recursive analysis to the DEA method

The DEA method proposed by Charnes *et al.* (1978) is developed from an application of the linear programming that transforms multiple inputs and outputs into a relative efficiency index between the compared DMU's. The most used models are: the CCR model (Charnes *et al.*, 1978) that takes into account continuous scale returns. Banker *et al.* (1984) introduced the

BCC model, that allowing the production technology to exhibit increasing returns-to-scale (IRS) and decreasing returns-to-scale (DRS) as well as the constant returns to scale CRS. In analysing sea ports' efficiency the BCC model is the more appropriated (Sharma and Yu, 2008).

In this sense this model will be applied to solve the dual problem shown below.

$$\Theta^* = \min \quad \Theta,$$

$$\text{Subject to} \quad \sum_{j=1}^n x_{ij} \lambda_j \leq \Theta x_{io}, \quad i = 1, 2, \dots, m;$$

$$\sum_{j=1}^n y_{rj} \lambda_j \geq y_{ro}, \quad r = 1, 2, \dots, s;$$

$$\lambda_j \geq 0, \quad j = 1, 2, \dots, n., \text{ where:}$$

Θ is the efficiency score

λ_j are the dual variables.

Based on the dual problem, a test DMU is inefficient if a composite DMU (linear combination of units in the set) can be identified which utilizes less input than the test DMU while maintaining at least the same output levels.

According to Sharma and You (2008) DEA models are also classified as radial input oriented, radial output oriented or additive (both inputs and outputs are optimized) based on the direction of projection of the inefficient unit into the frontier. The application of DEA models may be orientated by input or by output or by both. The orientation by input minimizes the entrances to the necessary level that allows a desired low level of exits. The orientation by output aims to maximize the exits to a fixed level of entrances. The orientation for both aims

the biggest efficiency, minimizing the entrances and maximizing the exits. In this study the radial output oriented models is used.

The classic DEA method has some obstacles as told by Doyle and Green (1994), and to overcome them Sharma and Yu (2008), use a recursive method applied to the first set of results as described by Zhu (2003), and the algorithm is as follows:

Define $J^l = \{DMU_j, j=1,2,K,n\}$ to be the original, complete set of all n DMUs and interactively define $J^{l+1} = J^l - E^l$ where $E^l = \{DMU_k \in J^l \mid DMU_k \text{ has a DEA efficiency score of } 1\}$. The steps of the algorithm for identifying multiple efficient frontiers are as follows, where l is the number of samples sets.

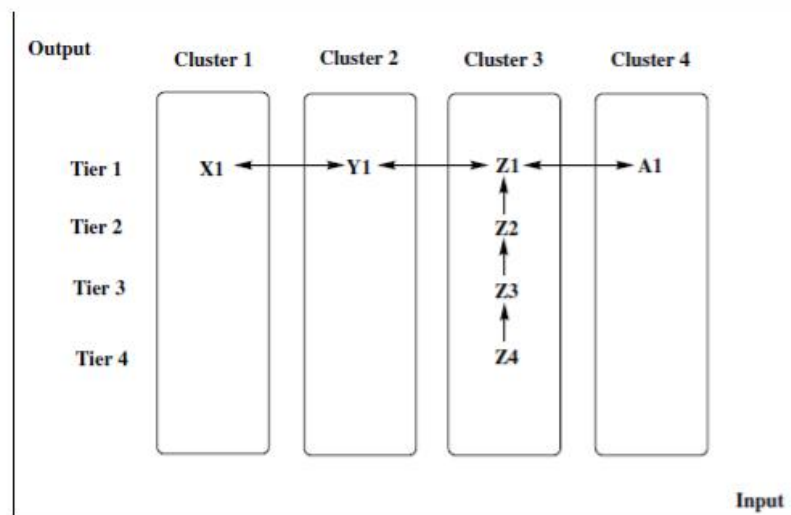
Step 1: Set $l = 1$. Evaluate the entire set of DMUs, J^1 , to obtain the set, E^1 , of the first-level frontier DMUs (i.e. when $l = 1$, the procedure runs a complete envelopment model on all n DMUs and E^1 consists of all DMUs on the resulting overall efficient frontier).

Step 2: Exclude the frontier DMUs from future DEA runs and set $J^{l+1} = J^l - E^l$.

Step 3: If $J^{l+1} = \emptyset$, then stop. Otherwise, evaluate the remaining subset of 'inefficient' DMUs, J^{l+1} to obtain the new best-practice frontier E^{l+1} .

Step 4: Let $l = l+1$ and go to step 2.

After this, the original dataset is segmented into l levels of relative efficiency, which will be the tiers on Figure 3. At last, it will be applied the *Kohonen's Self-Organizing Map* (KSOM) (Kohonen, 1982) to the original dataset, and will return clusters based upon their input characteristics. The research framework used is based in the one presented by Sharma and You (2008). The result will be an improvement path to the 'inefficient' terminals which leads them to the best practices of 'efficient' terminals.



X1, Y1, Z1, A1 --- Container terminals of different clusters but same efficiency score.
 Z1, Z2, Z3, Z4 --- Container terminals of same cluster but different efficiency score.

Figure 3 – Terminals stratification after Ksom application

Source: Sharma and Yu (2008)

In Figure 3 the improvement projection from the lowest tier to the upper most tiers of each cluster is illustrated. The application of the model reveals some interesting insight for improving poorly performing terminals. This approach is used in this study.

3.3 Data Analysis

In the results after the first efficiency measurement by the DEA method, and before applying the KSOM algorithm, we can observe that four terminals present index 1 (Terminal XXI, Alicante, TC Leixões – N and Algeciras), that is, they are efficient. The other six terminals present lower efficient levels and should be deeper evaluated using other methods in order to allow some more conclusions. Figure 4 shows the results of the analysis oriented towards the exit, with variable return, under a graphic form.

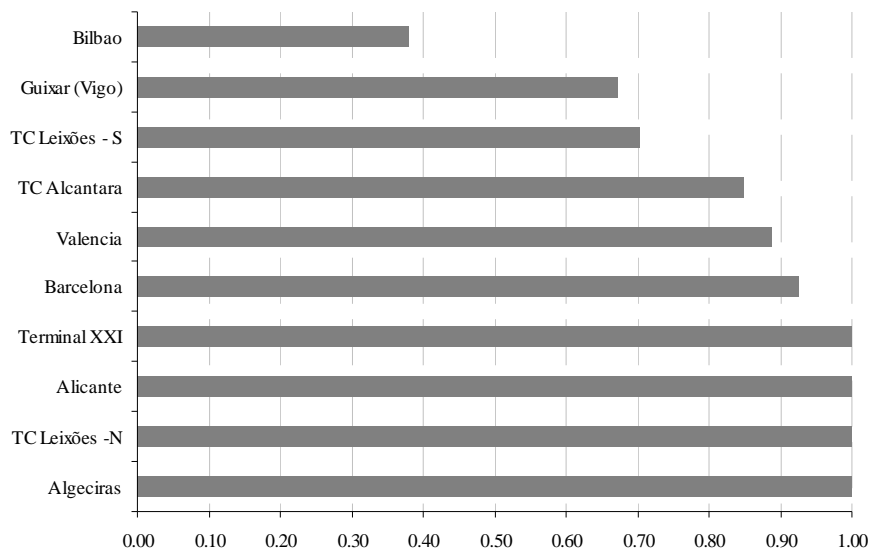


Figure 4 – Performance evaluation of the container terminals

The regressive analysis of the DEA method using the algorithm presented in 3.2 returns the following levels:

- Tier 1: Algeciras, Leixões Norte, Alicante and Terminal XXI (Sines).
- Tier 2: Barcelona, Valência, Alcântara, Leixões Sul, Guixar (Vigo) and Bilbao.

The SOM application to the original dataset has provided the following cluster scenarios:

- Cluster 1: Valência.
- Cluster 2: Algeciras, Leixões Norte, Barcelona.
- Cluster 3: Alicante, Alcântara, Guixar (Vigo), Bilbao
- Cluster 4: Terminal XXI, Leixões Sul.

So, we propose the following improvement path to the analysed terminals (figure 5).



Figure 5: New rearrangement of Container Terminals

4 Conclusions

This study used the DEA model to analyse the performance of the main Iberian container terminals in terms of their efficiency. To attain this, a set of inputs and outputs related with these terminals was collected and a benchmarking analysis was developed since a comparative approach was made. Variables considered in this research include number of cranes, number of employees, terminal area, number of trailers, number of yard equipments, terminal length, Teus's handled and containers movement by ship and by hour.

The general conclusion is that the majority of the container terminals studied are efficient however with different levels of performance. The Iberian container terminals with higher levels of efficiency are the Terminal XXI, Alicante, TC Leixões – N and Algeciras. The Bilbao container terminal shows the lower level of efficiency. These conclusions are relevant for policy-makers, for the ports authorities and for researchers. We urge the intervenient organizations, especially the sea ports and logistics authorities, the assigned companies, the navigation agents, the forwarders and others to include in their recommendations, as an option to the second generation sea ports and as an obligation to the third generation sea ports, the inclusion of a set of performance indicators to each terminal, to be defined, so that they can

inform the intervenient partners about the value networks of their performance levels, and this acts on their behalf. Those who own high levels of service quality want to be recognized by the market and those who have not yet achieved that goal should make an effort to improve in order to gain competitiveness.

The results presented themselves biased fundamentally due to the small size of the sample, low number of entrances and exits (they do not represent the port operations), data validity and extrapolation of entrance values. In spite of the sea ports investment in information technologies improvements, the data available in organisations web sites is not enough, it is not trustworthy and it is not presented in a standard way.

So, in the future and as further research we suggest that this study may be extended with an inquiry to the people in charge of each terminal operations, aiming to validate the collected data and the ones that are missing.

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