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Technical Efficiency Analysis of Container Terminals in the Middle Eastern Region

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ABSTRACT

Despite an increasing number of studies on the efficiency of container terminals, their focus has mostly been on advanced and emerging markets. There are limited studies on container terminals in developing countries such as those of the Middle Eastern region, which are located in a critical geographic position in the international maritime route between the East and the West. Information on their potential for development relative to other terminals worldwide is thus not readily available. This study aims to evaluate the technical efficiency of 19 container terminals in the Middle Eastern region. The DEA approach is used to measure technical efficiency, and slack variable analysis identifies potential areas of improvement for inefficient terminals. The results show that the Jebel Ali, Salalah and Beirut container terminals are the most efficient terminals in the region, and that the least efficient is the terminal in Aden. The results provide valuable information for terminal managers, helping to develop resource utilisation for steady development in operational efficiency.

1. Introduction

Ports are the backbone of international trade; over 90% of worldwide trade is moved by sea transport (UNCTAD, 2012). This is driven by the globalisation of the world economy. The current outlook and the increasing globalisation of economies call for higher efficiency from all actors in the transport sector, especially ports, where there is massive public input in their production processes (Bergantino et al., 2013). Seaport authorities have increasingly been under pressure to improve efficiency by ensuring that services are provided on an internationally competitive basis. The efficiency of ports is an indicator of a country's economic development (Liu, 2008), and thus monitoring and comparing one port with other ports in terms of their efficiency has become an essential part of microeconomic reform programmes in many countries (Jiang and Li, 2009).

Eighty percent of seaborne cargo is moved in containers (Ramani, 1996). This confirms the importance of maritime trade by containers (Cho, 2014). Improvements in the efficiency of container ports are therefore needed. An efficient operational system can help significantly in making the best use of container port resources and infrastructure (Vacca et al.,

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2010).

Efficiency plays a key role in container port competition (Yuen et al., 2013, Luo et al., 2012, Tongzon and Heng, 2005), and therefore, the analysis of container port efficiency is important for the survival and competitiveness of the industry (Cullinane and Wang, 2006). In this context, not only can such an analysis provide a powerful management tool for container port operators, it also constitutes important input for informing regional and national container port planning and operations (Verhoeven, 2010).

An extensive review of previous studies related to container port efficiency shows that the majority of studies are focused on European countries, and are limited studies that focus on Asian countries. Munisamy and Jun (2013) confirm that the majority of research concentrates on the efficiency of container ports in European countries.

Only two studies have focused so far on the efficiency of container terminals in the Middle Eastern region, those by Al-Eraqi et al. (2008) and Al-Eraqi et al. (2010). It is thus important to study the Middle Eastern region, as the container terminals in this region are located at a critical geographic position in the international maritime trade route between the East and the West. These terminals are central terminals, in which goods transferred between Europe and the far East/Australia are exchanged and transshipped to terminals in the Middle East (Al-Eraqi et al., 2010). These terminals play an important role in the region's economic development.

One of the reasons for the limited region-specific Middle East analysis to date has been a scarcity of data resulting from the political issues, security situation, and lack of transparency in government sectors. This study thus used various data sources and crosschecked the information provided by each port to make sure the data was accurate. In an effort to fill existing gap, this study aims to evaluate the technical efficiency of container terminals in the Middle Eastern region.

This study contributes to the field of transport economics by providing empirical evidence on container terminal efficiency in the Middle East region. The findings will also provide valuable guidance for terminal operators. The methodology adopted for this study was data envelopment analysis (DEA), which is frequently used to assess the efficiency of container terminals.

2. Literature Review

A study of the efficiency of the port sector first appeared in academic journals in 1993, reported by Roll and Hayuth (1993) who used DEA to assess the efficiency of 20 ports. Since then there has been a good number of studies on port efficiency, demonstrating a growing interest in methods to measure their efficiency (Pallis et al., 2011).

Based on efficiency scores for ports, previous studies had dissimilar results and conclusions; some showed high scores and others showed low efficiency scores. This raises the question of "whether there is something wrong with the techniques used or simply whether something is not captured by the existing studies" (Bichou, 2012). In fact, empirical estimations of port efficiency differ across many factors, including the method used for measuring efficiency, the type of data (inputs/outputs variables) and the region or country in which ports are located (Odeck and Bråthen, 2012).

Ports are complex organisations where multiple activities take place, with a large variety of agents, including port authorities, tugboats, consignees, and stevedores. The main port activities and services include the provision of infrastructure and machinery, docking, container handling and administration (González and Trujillo, 2009). The above considerations make the study of ports as a homogeneous entity more difficult, and therefore this study focuses on container ports/terminals. Table 1 provides an overview of port-related studies classified according to the author(s) name, method used, data type, and geographical location.

Table 1
Studies reviewing the efficiency of container ports/terminals

Author(s) (year)	Method used	Data type	Geographical location
(Al-Eraqi et al., 2008)	DEA-CCR DEA-BCC	Panel data	22 Middle East and East Africa
(Liu et al., 2008)	DEA-BCC	Panel data	45 China
(Min and Park, 2008)	DEA-BCC	Panel data	11 Korea
(González and Trujillo, 2008)	SFA	Panel data	17 Spain
(Jiang and Li, 2009)	DEA	Cross-sectional	12 (China, Korea, and Japan)
(Wu and Liang, 2009)	DEA-BCC	Cross-sectional	77 international
(Ablanedo-Rosas and Ruiz-Torres, 2009)	DEA-BCC	Cross-sectional	29 Mexico
(Al-Eraqi et al., 2010)	DEA-CCR DEA-BCC	Panel data	22East Africa and Middle East
(Cullinane and Wang, 2010)	DEA-BCC	Panel data	25 international
(Simões and Marques, 2010)	DEA-CCR	Cross-sectional	41 Europe
(Hung et al., 2010)	DEA-BCC	Cross-sectional	31Asia-Pacific region
(Wu and Goh, 2010)	DEA-CCR DEA-BCC	Cross-sectional	20 largest container ports
(Wu et al., 2010)	DEA-CCR	Cross-sectional	77 international
(Kamble et al., 2010)	DEA-BCC	Cross-sectional	12 India
(Munisamy and Singh, 2011)	DEA-CCR DEA-BCC	Cross-sectional	69 major Asian Container ports
(Bichou, 2011)	DEA-CCR	Panel data	10 international
(Niavis and Tsekeris, 2012)	DEA-CCR DEA-BCC	Cross-sectional	30 Europe
(Demirel et al., 2012)	DEA-CCR DEA-BCC	Panel data	16 Mediterranean
(Bichou, 2012)	DEA-CCR DEA-BCC	Panel data	420 International
(Yuen et al., 2013)	DEA-CCR	Panel data	21 China and Asian
(Trujillo et al., 2013)	SFA	Panel data	37 African coast
(Schøyen and Odeck, 2013)	DEA-CCR DEA-BCC	Panel data	24 (Nordic + UK)
(Polyzos and Niavis, 2013)	DEA-CCR	Cross-sectional	30 Mediterranean
(Medda and Liu, 2013)	SFA	Cross-sectional	165 international
(Mokhtar and Shah, 2013)	DEA-CCR DEA-BCC	Panel data	Malaysia
(Munisamy and Jun, 2013)	DEA-CCR DEA-BCC	Panel data	30 Latin America
(Infante and Gutiérrez, 2013)	DEA-CCR DEA-BCC	Panel data	33 Asian Pacific region
(Sarriera et al., 2013)	SFA	Panel data	67 Latin America and Caribbean
(Ding et al., 2015)	DEA-CCR DEA-BCC	Panel data	21 China

Many authors provided a literature review for the measurement of ports efficiency. The most thorough reviews of studies focusing on the efficiency of ports are found in Odeck and Bråthen (2012), Woo et al. (2012), Pallis et al. (2011), Panayides et al. (2009), and González and Trujillo (2009).

Based on the previous studies, and with regard to Table 1, several general remarks can be made. First, the basic approaches to evaluating the efficiency of ports can be divided in two categories: those using parametric methods and non-parametric methods. The most popular non-parametric methodology is data envelopment analysis (DEA), and the most common parametric method is stochastic frontier analysis (SFA). Previous studies show that the DEA approach is commonly used to evaluate the efficiency of ports (Ding et al., 2015, Wu and Goh, 2010, Hung et al., 2010, Al-Eraqi et al., 2010, Jiang and Li, 2009). The general conclusion drawn by Schøyen and Odeck (2013) is that the DEA approach is more popular than SFA, is used more recently in applications across studies, and dominates the literature. The models mostly used applying the DEA approach are the CCR model as proposed by Charnes et al. (1978), which assumes constant return to scale (CRS), and the BCC model as proposed by Banker et al. (1984), which assumes variable returns to scale (VRS). DEA is a data analysis method aiming at the comparison of technical efficiency in the decision making units (DMUs). Generally, DEA is a method of linear programming which uses the input, and output of productive processes in order to calculate the relative efficiency of each DMU (Polyzos and Niavis, 2013).

The specification of variables to be used in the model is critical. Specifying erroneous or unfit input or output could lead to biased results and thus inappropriate conclusions (Panayides et al., 2009) and therefore, based on previous studies, the most frequent input variables upon which a container terminal depends are often based on the efficient use of labour, land and equipment, such as total quay length, terminal area, number of gantry cranes, the number of yard gantry cranes, the number of straddle carriers, quayside water depth. Container throughput was widely accepted by most of the previous studies as the output variable of efficiency measurement.

Types of data also determine the specific objective of the studies. As shown in Table 1, cross-sectional data and panel data are the most commonly used in the literature. Cross-sectional data is data collected from multiple ports/terminals at a single point in time. This type of data enables researchers to evaluate and compare the efficiency of different ports/terminals and to study the structure of the industry at a single point in time. In contrast, panel data, that is, data collected from multiple ports/terminals over multiple time periods can be used to observe and study changes in efficiency, management, and the impact of regulation of container ports/terminals.

Finally, geographical location is one of the most distinctive features of a seaport and therefore the selection of ports/terminals is important. Three types of sampling can be identified in the literature: international, regional, and national ports/terminals.

International studies are those with a benchmark of efficiency in a global context. Since terminal operators nowadays work more internationally, a sample including international ports/terminals is important, particularly if the focus is to examine the effects of global terminal operators. Samples are usually selected, however, from the top container ports/terminals by throughput. The focus of these kinds of samples is large container ports/terminals. These views are found in several studies, for instance, Medda and Liu (2013), Bichou (2012), Cullinane and Wang (2010), and Wu and Liang (2009).

Region-specific studies usually consist of ports/terminals in particular continental economic regions. These studies benchmark ports/terminals serving the same mass market, but from different countries, and therefore compare the efficiency of ports/terminals under different regulations. These studies include Sarriera et al. (2013), Demirel et al. (2012), Munisamy and Singh (2011), Al-Eraqi et al. (2010), and Al-Eraqi et al. (2008).

Finally, country-specific studies involve ports/terminals from a single country; they compare efficiency under the same regulations, policies, and authority. These studies are reported by several authors, for instance, Mokhtar and Shah (2013), Kamble et al. (2010), Min and Park (2008), Liu et al. (2008), and González and Trujillo (2008).

3. Research Methodology

DEA is a non-parametric method for measuring the relative efficiency of decision making units (DMUs) that have multiple input and output (Charnes et al., 1978), which in this study are container terminals. This study will use the DEA approach to measure and evaluate the technical efficiency of container terminals in the Middle Eastern region. The use of DEA methodology highlights some significant questions that must be answered before proceeding to a DEA analysis. These questions, as suggested by Cook et al. (2014), are as follows:

1. "What is the purpose of the performance measurement and analysis?"
2. "What are the decision-making units (DMUs) and the output and input to be used to characterize the performance of those DMUs?"
3. "What is an appropriate number of DMUs, given the number of input and output chosen?"
4. "What is the appropriate model orientation (input or output)?"

The answers to the above questions will provide the guidance for DEA analysis in this study.

3.1. *Purpose of Efficiency Measurement and Analysis*

It is necessary in any study of container terminal efficiency to have a clear understanding of the process being estimated and a clear specification of the functions to be considered as they will drive the selection of input and output variables to be inspected (Cook et al., 2014). The purpose of this study is therefore to measure and evaluate technical efficiency by using the operational variables of container terminals in the Middle Eastern region in order to improve their resource utilisation.

3.2. *Data Selection (Input and Output Variables)*

The selection of variables is the primary step in any efficiency analysis, because it weighs on the accuracy of the analysis. This study examines container terminal efficiency through their basic function, that is, the transfer of the containers from sea to inland and back to the sea.

In order to transport the containers within the terminal itself, and from ship to berth, facilities require handling equipment to load and unload the containers, quays for ships to berth and an area to store containers.

The input and output variables should reflect the actual objectives and process of the container terminal production as accurately as possible (Cullinane et al., 2004). For the DEA applied in this study, the input/output variables include most of the main physical characteristics of container terminal operations, with regard to reliable and available data on technical efficiency, excluding price and cost.

Dowd and Leschine (1990) and Cullinane and Wang (2010) note that the production of container terminals depends on the efficient use of labour, land, and equipment. The measurement of terminal production, therefore, is a means of quantifying efficiency in the use of these three resources (Trujillo et al., 2013). Experts meeting about assessing port efficiency at UNCTAD AD HOC, Geneva, on the 12th December 2012, concluded that port efficiency measurements need to take into account multiple types of input (e.g. land, labour, and capital).

Given the characteristics of container port production, the terminal area, quay length, and draft are the most appropriate proxies for the 'land' factor input, and the amount of quay crane and yard equipment are the most suitable proxies for the 'equipment' input factor, and used by most previous studies (Trujillo et al., 2013, Munisamy and Jun, 2013, Wu et al., 2009, Sharma and Yu, 2010).

The labour data is very difficult to collect, because it is often restricted, not only because it is regarded as commercially confidential but also because, in some circumstances, it can be politically sensitive (Demirel et al., 2012). A number of authors, such as Cheon et al. (2010), Notteboom et al. (2000), and (Turner et al., 2004), claim that in light of the difficulties in obtaining reliable direct data and information on labour input, this variable should be excluded from the efficiency estimation. Cullinane et al. (2002), Cullinane et al. (2004), Cullinane et al. (2005a), Cullinane et al. (2005b), Cullinane and Song (2006), Cullinane et al. (2006), and Trujillo et al. (2013) do not incorporate labour input. The 'labour' factor in this study is therefore not taken into consideration due to the lack of availability of data, and also following most previous studies, which suggest excluding it.

In accordance with the above discussion, and following the extensive literature on container port efficiency, such as Cullinane et al. (2005b), Cullinane et al. (2006), Demirel et al. (2012), Niavis and Tsekeris (2012), and Cullinane and Wang (2010), the variables selected in this study are the most widely used input and output variables in applications of DEA to container ports. The selected variables in this study consist of five input variables and one output variable. The input variables are the quay length in metres, the number of quay gantry cranes, maximum draft in metres, the number of pieces of yard equipment, such as yard gantry cranes, straddle carriers, reach stackers, empty container handlers, forklifts and front-end loaders, and finally, the total terminal area in hectares, comprising the container yard side, quayside loading/unloading area, marshalling yard and container storage area.

The output variable is the container throughput, which is the total number of containers loaded and unloaded in twenty foot equivalent units (TEUs). The container throughput is unquestionably the most important and widely accepted indicator of container port output, and almost all previous studies have treated it as an output variable (Cullinane and Wang, 2010). Another consideration is that container throughput is the most appropriate and analytically tractable indicator of the effectiveness of the production of a port (Wu et al., 2009).

The data used was mostly obtained from terminal websites and the annual reports of ports authority, as well as from secondary sources such as the *International Association of Ports and Harbours*, and *Containerisation International Yearbooks* (CIYs). The dataset consists of container terminal annual observations for the year 2012. Summary statistics for the data collected as input and output variables are presented in Table 2.

Table 2
Summary statistics of variables for efficiency analysis

Variables	Minimum	Maximum	Mean	Std. Deviation
Throughput (TEU)	187,000	13,270,000	2,109,236.68	2,995,476.846
Terminal area (ha)	28	330	86.153	72.558
Quay length (m)	500	7475	1939.421	1702.279
Quay crane (no.)	4	79	16.84	17.737
Yard equipment(no.)	8	418	103	98.244
Maximum draft(m)	9.5	18	15.516	2.008

3.3. *Sampling (DMUs)*

The basic requirement for reliable port efficiency benchmarking is the appropriate selection of homogenous port DMUs. This study includes countries in Middle Eastern region, which have different political and social structures. For instance, the Jebel Ali and Salalah container terminals are located in United Arab Emirates and in the Sultanate of Oman. Beirut and Aden container terminals are located in the Lebanese Republic and in the Republic of Yemen. The two former are countries with monarchies and the latter two have republican forms of government.

Some seaports in the Middle East region continue to be affected by geopolitical conflict, turbulence, and instable environment, especially during the movement of the Arab Spring in February 2012, which impacted maritime and terminal flows, especially in Yemen, Syria and Egypt. The Arab Spring crisis prompted terminal operators to change their strategies toward greater rationalisation of services and investment, and to a more cautious assessment of their future prospects; we have therefore chosen to analyse the results from 2012 in order to provide insights into possible future trends in the efficiency of container terminals operations.

To ensure homogeneity, this study therefore follows similar criterion for selecting DMUs as most previous studies that used the DEA approach for measuring the efficiency of container terminals, such as Bichou (2012), Trujillo et al. (2013), Cullinane and Wang (2006), Liu et al. (2008), Medda and Liu (2013), and Infante and Gutiérrez (2013). As a result of homogeneity and data availability, this study selected terminal DMUs with operational features focused only on container terminals. Terminals with multipurpose facilities (handling non-container cargo), and those that lack complete or reliable data were excluded from the sample. These terminals use the same types of input to produce the same type of service. The choice of container terminals is made in relation to the value of throughput in 2012 (over 10000 TEU), as in most previous studies.

The sample size was thus purposely limited to the main container terminals, leading to an original sample of 19 container terminals from 15 countries in Middle Eastern region. Due to non-available data, this study excluded Iraq, Qatar, and Kuwait. The final sample included 19 container terminals in 12 countries of the Middle Eastern region, as shown in Table 3.

Table 3
Sampling container terminals (DMUs) in 2012

No	Country	Container Terminals	Abbreviations
1	Emirates	Jebel Ali Container Terminals	JACT
2	Saudi Arabia	Jeddah Islamic Container Terminals	JICT
3		Dammam Container Terminals	DACT
4		Jubail Container Terminals	JCT
5	Egypt	Suez Canal Container Terminals	SCCT
6		Alexandria Container Terminals	ALCT
7		Damietta Container Terminals	DCT
8	Oman	Salalah Container Terminals	SCT
9		Sohar Container Terminal	SOCT
10	Turkey	Ambarli container terminals	AMCT
11	Iran	Shahid Rajaee Container Terminals	SRCT
12	Israel	Haifa Container Terminals	HCT
13		Ashdod Container Terminals	ASCT
14	Lebanon	Beirut Container Terminal	BCT
15	Jordan	Aqaba Container Terminal	AQCT
16	Bahrain	Khalifa Bin Salman Container Terminal	KBSCT
17	Syria	Lattakiah International Container Terminal	LICT
18	Yemen	Aden Container Terminal	ACT
19		Hodeidah Container Terminal	HOCT

In DEA, to achieve a reasonable level of discrimination power, the rule of thumb proposed is that the number of DMUs should be at least double the combined of the number of input and output variables (Golany and Roll, 1989). This study follows this rule, where the ratio of DMUs (19 container terminals) to the number of input and output variables (6 variable) is 3.16, which means that more than three times the number of input and output variables are used.

3.4. *DEA Model and Orientation*

A common feature of studies on port efficiency measurement is the use of operational (technical) data, due to the difficulty of collecting cost and prices data. DEA mostly seeks to examine the technical efficiency of DMUs without using cost and price data (Bichou, 2012). The idea of DEA is to map all the technical input and output of DMUs, and to seek the margin of the lowest input or the highest output (Thanassoulis, 2000). DEA is intended as a technique for evaluating and benchmarking efficiency against best-practice (Cook et al., 2014).

DEA must undoubtedly identify what to achieve from analysis: input reduction or output augmentation. If the aim is to recognise elements that are over-using resources, then input reduction should be the central concern of the application, and the appropriate analysis tool is the input-oriented model. If the goal is output augmentation, however, then the appropriate analysis tool will be an output-oriented model (Cook et al., 2014). In this study, the goal is to produce a given output using minimum input; thus an input-oriented model is considered more suitable than an output-oriented model.

This section describes the formulation of the DEA model as implemented in this study for the measurement of the technical efficiency of container terminals. Let us assume that there are *n* DMUs to be analysed, where each uses *m* input to produce *s* output. Also assume that $x_{ij} > 0$ is the quantity of the input *i* which is used by DMU *j*, and $y_{rj} > 0$ is the quantity of output *r* which is produced by DMU *j*. The DEA-CCR model is used to evaluate the cross-sectional data where time is ignored and DMUs are compared with others in the same period.

Panel data can review dynamic changes based on yearly data in order to obtain a precise measurement, considering the transition of efficiency results, however, due to the difficulty of gathering panel data for container terminals in developing countries located in the Middle Eastern region that have difficult political issues, security situations, lack of transparency in port authorities, and weakness of concern for recording data in some countries, cross-sectional data is therefore used instead of panel data in this study. A literature review reveals that in container terminals studies, the application of dynamic analysis using panel data is scarce due to the limitations of collecting data (Cullinane and Wang, 2010).

The input orientation DEA-CCR model can be formulated by minimising the input and holding the output constant, and can be described according to Charnes et al. (1978) as below:

$$\theta^* = \min \theta$$

$$\text{s.t.} \quad \sum_{j=1}^{n} x_{ij}\,\lambda_j \le \theta x_{io} \qquad i = 1, 2, \ldots\ldots, m$$

$$\sum_{j=1}^{n} y_{rj}\,\lambda_j \ge y_{ro} \qquad r = 1, 2, \ldots\ldots, s$$

$$\lambda_j \ge 0 \quad j = 1, 2, \ldots\ldots, n \quad \text{(CCR)} \qquad (1)$$

Where

x_{io}, y_{ro} the i^{th} input and r^{th} output for a DMU o under evaluation;

λ_j the decision variables which represent the weights DMU j would place on DMU o in constructing its efficient reference set, and;

θ^* the relative technical efficiency of DMU o.

DEA determines the efficiencies of individual container terminals within a group relative to the other terminals in the group. The most efficient terminals constitute the efficient frontier of the group, relative to which the efficiencies of the remaining terminals are measured. The DEA frontier is non-parametric; no functional formulation needs to be specified, and each input/output variable can be measured in its natural measurement units, such as hectare, meters, or numbers.

The DEA-CCR model is used because this model expresses the overall technical efficiency (pure technical and scale efficiency) of each container terminal. The condition of DEA-CCR is: if $\Theta^* = 1$, the terminal is considered efficient, and if $\Theta^* < 1$, the terminal is considered inefficient (Charnes et al., 1978).

With respect to the efficiency value analysis of the terminals, when the efficiency score of the terminal is less than 1, then the terminal is technically inefficient, and the implication is that the operational input to produce the output being used is not appropriate. It may therefore be necessary to decrease input or increase output depending on the type of orientation model used. Slack variable analysis can be used for inefficient terminals, to indicate and improve the major sources of inefficiency. The analysis will also identify the use rate of variables (input and output), by assessing how to improve the operational efficiency of inefficient terminals by indicating how much output to increase, and/or how much input to decrease, thereby making the inefficient terminals efficient (Lin and Tseng, 2007).

In summary, the DEA analysis flow process for this study can be represented as shown in Fig. 1.

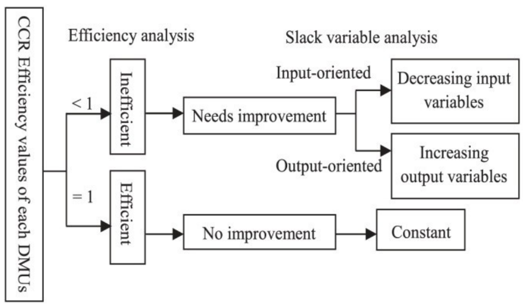

Fig. 1. Flow process of DEA-CCR analysis and slack variable analysis

The research procedure of this study can be summarised as shown in Fig. 2. The DMUs were first selected and represented by the container terminals listed in Table 3. The completeness of data for variables (input and output) was an important part in measuring the efficiency of container terminals in Middle Eastern Region. We then used a DEA-CCR input-orientation model with cross-sectional data to measure the overall technical efficiency. We ran the DEA software using MATLAB R2013a with DEA-CCRI toolkit and validated the result using DEA frontier with Excel Solver 2010 version (http://www.deafrontier.net/frontierfree.html). We then obtained the efficiency result of the container terminals (efficiency value analysis and slack variable analysis). Finally, the conclusion and recommendations were presented.

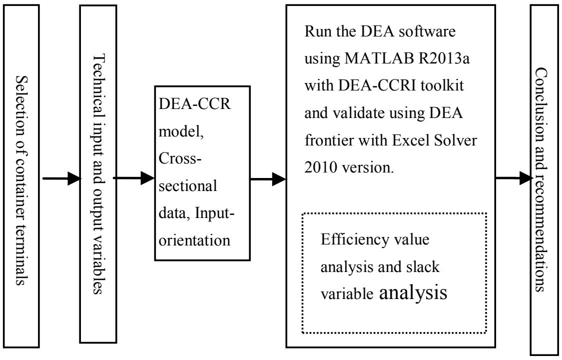

Fig. 2 Research procedure

4. Results and Discussion

This section presents and analyses the results of the overall technical efficiency of 19 container terminals in the Middle Eastern region. Cross-sectional data for 2012 was estimated by applying DEA-CCR model input-orientation and then slack variable analysis was used to provide a reference set of specific recommendations for each inefficient terminal.

4.1 *The Relative Technical Efficiency of Container Terminals*

Table 4 and Fig. 3 show the scores of efficiency estimated for the container terminals. An efficiency score of 1 signifies efficient terminals and scores less than 1 indicates inefficient terminals.

Table 4
Efficiency results of using DEA-CCRI cross-sectional 2012

No	Container Terminals	Efficiency scores		Benchmarks	Sum of lambdas	Return to scale
1	JACT	1	Efficient	5	1	Constant
2	SCT	1	Efficient	15	1	Constant
3	BCT	1	Efficient	8	1	Constant
4	SCCT	0.85795	Inefficient	1, 2	0.67	Increasing
5	KBSCT	0.757	Inefficient	2, 3	0.463	Increasing
6	JICT	0.75398	Inefficient	1, 2	0.765	Increasing
7	SRCT	0.75225	Inefficient	1, 2, 3	0.56	Increasing
8	AMCT	0.73554	Inefficient	1, 2	0.678	Increasing
9	AQCT	0.6757	Inefficient	2, 3	0.425	Increasing
10	DACT	0.6717	Inefficient	2, 3	0.54	Increasing
11	HOCT	0.66198	Inefficient	2	0.083	Increasing
12	SOCT	0.61989	Inefficient	2	0.052	Increasing
13	JCT	0.54081	Inefficient	2	0.068	Increasing
14	ALCT	0.52341	Inefficient	2	0.414	Increasing
15	HCT	0.49815	Inefficient	1, 2, 3	0.447	Increasing
16	LICT	0.49253	Inefficient	3	0.328	Increasing
17	ASCT	0.48885	Inefficient	2, 3	0.444	Increasing
18	DCT	0.48564	Inefficient	2, 3	0.313	Increasing
19	ACT	0.19465	Inefficient	2	0.055	Increasing

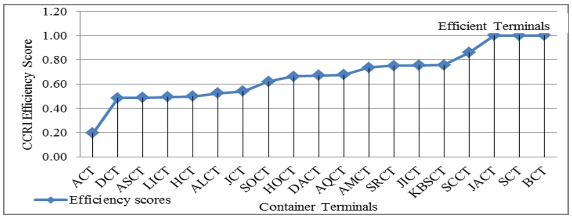

Fig. 3. Efficiency of container terminals in middle eastern region

Based on the CCRI efficiency level of each terminal, the analysis shows that only three terminals were efficient with score of 1: Jebel Ali, Salalah and Beirut. The remaining terminals are inefficient, with scores less than 1. In order to provide more insight regarding the distributional efficiency scores of container terminals, a stem and leaf and a box and whisker plot diagram were created using the efficiency results from Table 4, and are presented in Fig. 4.

It is obvious that approximately 84.21% of the terminals are inefficient; 11 terminals present efficiency scores between 0.5 and 0.8, 5 terminals between 0.1 and 0.4, and only 15.8% of the terminals in the region are efficient with a score of 1.

Efficiency stem and leaf		
Frequency	Stem	Leaf
5.00	0.	14444
11.00	0.	55666677778
3.00	1.	000
Stem width : 1.00000 Each leaf : 1 case (s)		

Box and whisker plot

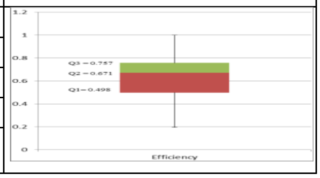

Fig. 4. Stem and leaf, and box and whisker plot figure of efficiency scores

In fact, it is not surprising that Jebel Ali and Salalah terminals are the most efficient terminals in the region. Their proximity to large shipping markets, successful collaboration with foreign investors, and a higher level of management practice are the reasons behind their relatively high efficiency scores. A government plan is also underway to make them international centre terminals.

Despite the fact that the Beirut container terminal has limited production potential compared with bigger terminals in the region, the results of efficiency analysis shows that the Beirut terminal is one of the most efficient terminals in the region. This indicates that the Beirut terminal is very busy in handling operations, but that sufficient resources for future expansion are needed.

In contrast, the Aden container terminal has the lowest efficiency score of 0.19465. This may be connected with the discord between Aden container terminal authority and Dubai Ports World (DPW). The Aden container terminal was previously operated by DPW but the operations were been shifted to a public operator in 2012. The Arab Spring revolution that started in 2012 also affected the economy of the country, which in turn affected the operations of the container terminal.

4.2 *Benchmars*

As shown in the benchmarks column of Table 4, the inefficient container terminals can use a group of efficient terminals as a reference set for benchmarking. The benchmarks (best practice or peer referents) in Table 4 provide two different explanations based on whether the terminal is efficient or inefficient. For the efficient terminal, benchmarks show how many inefficient terminals used this efficient terminal as their benchmarks, while, for the inefficient terminal, benchmarks offer information on which terminal(s) have to follow in order to be efficient.

According to the results, the terminal that is most frequently used as a benchmark by inefficient terminals is the Salalah container terminal, which is used by 15 inefficient terminals. Beirut is used as a benchmarks by 8 inefficient terminals but only 5 inefficient terminals benchmark using the Jebel Ali terminal. This is because Jebel Ali is a hub in the region and the biggest terminal (in terms of operational resources, production TEU, and numbers of shipping line) in the region. Jebel Ali is a genuinely well-performing terminal that outperforms many other terminals in the region. According to the benchmark results, the inefficient terminals can follow their efficient reference terminal(s) to improve themselves and become efficient. For instance, SCCT, JICT, SRCT, AMCT, and HCT container terminals are the five inefficient container terminals that benchmarked Jebel Ali container terminal.

4.3 *Return to Scale*

This study also explains the return to scale of the container terminals. Scale inefficiency can be either decreasing return to scale (DRS) or increasing returns to scale (IRS), which can be determined by checking the sum of weights (lambdas) as provided in Table 4, according to the specifications of the CCR model. If the sum of lambda is equal to 1, then the rule of constant returns to scale (CRS) dominates, however, if the sum is greater than or less than 1, then DRS and IRS respectively dominate, within an input-oriented model (Wanke et al., 2011).

As shown in Figure 5, all the inefficient terminals in the Middle Eastern region represent IRS, and the three efficient terminals represent CRS. For the terminals that experience IRS in their operations, an increase in input will result in more than a proportional increase in output. The terminals that operate with IRS could thus achieve significant efficiency gains by increasing their scale of operations to be as efficient as their reference terminals (Benchmark terminals). The scale can be improved through expansion and building associations in shipping organisation.

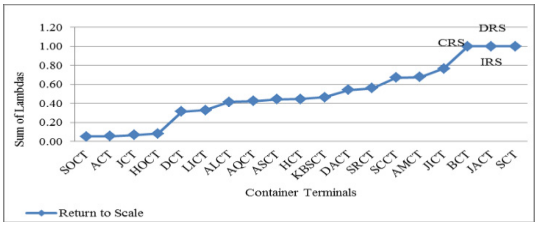

Fig. 5. Return to scale

4.4 *Efficiency and Scale of Production (TEU)*

In previous studies on container terminals, it is often noted that terminals with a large scale of production (TEU) are more efficient than terminals with a small scale of production, due to economies of scale, however, the results of this study do not offer definite proof that a larger terminal in TEU is more efficient than smaller ones.

As shown in Figure 6, some terminals with larger TEU are less efficient. Jeddah terminal, for example, is larger than Salalah terminal, but it is less efficient, and Beirut terminal is smaller than Jeddah, Suez Canal, Ambarli, Shahid Rajaee, Dammam, Alexandria, Haifa and Ashdod terminals, but it is more efficient than they are.

This finding therefore indicates that terminals with large scale production are not necessary more efficient than terminals with a small scale of production. This result is thus consistent with the findings of Munisamy and Singh (2011), Al-Eraqi et al. (2010), and Al-Eraqi et al. (2008).

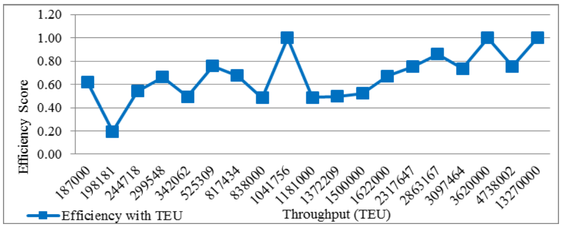

Fig. 6. Relationship between efficiency and scale of production TEU

4.5 *Efficiency and Size of Terminal*

The findings of Turner et al. (2004), Tongzon and Heng (2005), and Niavis and Tsekeris (2012), indicate that larger terminal sizes tend to operate more efficiently than smaller terminal sizes. In contrast, the results of analysis of the relationship between efficiency and terminal size, Figure 7, suggested that the large terminals are not necessarily more efficient than smaller ones. For example, Beirut terminal is smaller than Jeddah, Suez Canal, Ambarli, Shahid Rajaee, Alexandria, Haifa, Dammam, Lattkia, Dammietta, Ashdod, Aqaba and Aden terminals, but it is more efficient. Salalah terminal is smaller than Haifa, Alexandria, Shadid Rajaee, Ambarli, Suez Canal and Jeddah terminals but it is also more efficient.

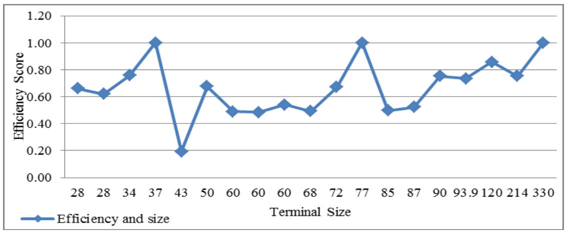

Fig. 7. Relationship between efficiency and terminal area

4.6 *Slack Variable Analysis*

In addition to providing efficiency measures, DEA also provides other information relevant for inefficient terminals. Slack variable analysis provides a references set of specific recommendations to help each inefficient terminal become efficient, by minimising the input resources to produce a given output (TEU) efficiently, as we used input-orientation model in this study. It should be noted that this information is described only for the inefficient terminals, and the efficient terminals tend not to provide any slack.

The slack variable analysis showed that Jebel Ali, Salalah, and Beirut container terminals had been relatively efficient; their ratios of input variables to output variable were appropriate, and they were capable of applying their input resources effectively to achieve efficiency. In contrast, Jeddah, Dammam, Jubail, Suez, Alexandria, Damietta, Sohar, Ambarli, Shahid Rajaee, Haifa, Ashdod, Aqaba, Khalifa Bin Salman, Lattakiah, Aden and Hodeidah container terminals were relatively inefficient as a result of the inappropriate application of input resources. For instance, as shown in Table 5, the efficiency score of Jeddah Islamic container terminal (JICT) is 0.75398, which implies that JICT should adjust all input by 24.6% in order to be technically efficient. The result indicates that JICT should adjust its terminal area, quay length, number of quay cranes, number of yard equipment and its draft to be technically efficient. In addition to adjusting and improving the input variables, each inefficient container terminal should increase the number of shipping line that will increase the number of vessels arriving at terminal and loading/unloading volumes if they want to reach a relatively efficient state.

The results for DACT, JCT, SCCT, ALCT, DCT, SOCT, AMCT, SRCT, HCT, ASCT, AQCT, KBSCT, LICT, HOCT and ACT terminals are interpreted in the same way as the result of JICT.

Indeed, the results of slacks show that each terminal with a different efficiency score reflects the real situation, where each terminal is good at different element: some terminals have a large area and more yard equipment but less throughput, etc.

Table 5
DEA-CCRI results and slack variable analysis for inefficient terminals

Terminals	Input measured					Output	Efficiency
	T.A	Q.L	Q.C	Y.E	M.D		
JICT	214	4190	37	228	18	4738002	0.75398
AMCT	93.9	3764	29	129	16.5	3097464	0.73554
SCCT	120	2400	24	92	14	2863167	0.85795
SRCT	90	1834	18	90	17	2317647	0.75225
DACT	72	2040	14	191	14	1622000	0.67170
ALCT	87	2461	17	76	15	1500000	0.52341
HCT	85	1660	16	145	15.5	1372209	0.49815
ASCT	60	1700	14	164	15.5	1181000	0.48885
DCT	60	1050	10	56	16.5	838000	0.48564
AQCT	50	740	7	50	14.5	817434	0.67570
KBSCT	34	900	4	44	15	525309	0.75700
LICT	68	810	4	48	13.3	342062	0.49253
HOCT	28	500	4	12	9.5	299548	0.66198
JCT	60	1300	5	12	18	244718	0.54081
ACT	43	700	7	27	16	198181	0.19465
SOCT	28	520	4	8	16	187000	0.61989
Terminals	Efficient input target after slacks					Output	Efficiency
	T.A	Q.L	Q.C	Y.E	M.D		
JICT	110.51411	2762.03155	27.89738	139.12370	13.57170	4738002	1.00000
AMCT	69.06752	1846.18703	18.10333	86.54822	12.13647	3097464	1.00000
SCCT	63.07040	1716.38000	16.70127	78.93178	12.01136	2863167	1.00000
SRCT	52.66005	1379.62764	13.54051	67.70256	9.84913	2317647	1.00000
DACT	36.42610	983.50477	9.40377	48.64020	9.40377	1622000	1.00000
ALCT	31.90608	913.67403	8.70166	39.77901	7.45856	1500000	1.00000
HCT	31.38237	826.93021	7.97041	42.24261	7.72134	1372209	1.00000
ASCT	27.57245	713.65836	6.84395	38.48455	7.57723	1181000	1.00000
DCT	19.52627	506.47832	4.85636	27.19560	5.34995	838000	1.00000
AQCT	21.53020	488.26768	4.72992	33.78517	6.94534	817434	1.00000
KBSCT	17.80405	304.53859	3.02801	33.30813	7.22255	525309	1.00000
LICT	12.14900	197.01082	1.97011	23.31295	5.08945	342062	1.00000
HOCT	6.37160	182.45949	1.73771	7.94381	1.48947	299548	1.00000
JCT	5.20533	149.06165	1.41963	6.48976	1.21683	244718	1.00000
ACT	4.21545	120.71522	1.14967	5.25563	0.98543	198181	1.00000
SOCT	3.97762	113.90470	1.08481	4.95912	0.92983	187000	1.00000

Note: T.A: Terminal Area; Q.L: quay length; Q.C: quay crane; Y.E: yard equipment; and M.D: maximum draft

5. Conclusion

This study is an attempt to provide a satisfactory understanding of the technical efficiency of container terminals in the Middle Eastern region and to add to the body of literature available in such study in this region. The DEA-CCR input-orientation model was used to analyse 19 container terminals from 12 countries in the region. The DEA efficiency score gives the terminal management a warning signal that the lower their DEA score, the greater likelihood a container terminal has of failure. DEA is thus very useful for identifying the least efficient terminals, which require the closest attention.

Numerous conclusions can be drawn from this study, as follows. Among the 19 terminals in the region only 3 terminals (Jebel Ali, Salalah and Beirut) are efficient; the rest of the terminals are inefficient. Aden terminal shows the lowest level of efficiency with a score of 0.194.

All the inefficient terminals in the region show increasing returns to scale. Middle Eastern terminals need to increase their operating scale in order to be as efficient as their benchmark terminals.

The results of this study reveal that the indicators of production scale and terminal size are not the main factors of efficiency or inefficiency, as some terminals with medium and lower scale of production and size are more efficient than larger terminals.

The findings recommend that any strategies and plans for ongoing extension and improvements should begin with correct demand forecast and information sharing between port authorities and carriers and shippers. The seaport authorities should adapt policies to encourage shipping lines to load/unload in their seaports, for example by ensuring seaport security, decreasing seaport fees and improving service performance.

It is also important that the container terminals authority should conduct yearly comprehensive efficiency evaluations. This will not only support the management of the terminal in responding to the stress of international competition, but also act as a basis for decision-making with respect to continuing development in operational efficiency.

Finally, the inefficiency of container terminals in the Middle Eastern region may also be the result of issues including the Arab Spring revolutions in some countries in the region such as Yemen, Syria, and Egypt, which affected the economy, investments, security, shipping lines and internal policy, and consequently the efficiency of container terminals in the region. Countries in the Middle Eastern region have different political and social structures, including monarchy and republican forms of government that might affect the efficiency of container terminals in the region. Thus, we suggest that further studies examine the effect of government type and political instable factors on the efficiency of container terminals within the context of Middle Eastern region.

On the other hand, when interpreting this study results, some caution should be taken. The findings are based on only a few observations from each country involved in the study; thus the derived efficiency scores may not express the complete detail of the terminal in each country. Bearing in mind that some container terminals were not included in the sample due to lack of data availability, these missing terminals are likely to exert either a positive or a negative influence on the efficiency estimates of those that remain in the sample. The study is also based on a single-period (cross-sectional) data; however, a panel data approach may be more appropriate for capturing the dynamics of capacity optimisation, efficiency changes over the years, expansion, and technical innovations that may eventually occur.

It is also noteworthy that several factors were not given consideration in this study due to the difficulty of obtaining data; these factors also have implications for the operational efficiency of terminals and include factors such as labour, operational time, berth occupancy, and handling speeds of cranes. Terminal management, with regard to its terminal operations, should strive for complete and detailed data. It would be appropriate to consider some exogenous factors that may influence the container terminals efficiency, such as hinterland, GDP, type of ownership and so on.

Despite these limitations, this study has contributed to the literature by revealing the efficiency of Middle Eastern container terminals, as there has previously been very limited study in this region. From this point of view, the derivation of the efficiency estimates for the Middle Eastern container terminals evaluated in this study simply constitute a beginning, rather than an end in itself.

A challenge for academics and researchers is to attempt to involve the respective authorities in obtaining comprehensive and reliable data that will lead to deeper information on the industry. Further research should address these issues within the context of Middle Eastern container terminals.

References

ABLANEDO-ROSAS, J. H. and RUIZ-TORRES, A. J. (2009), "Benchmarking of Mexican ports with data envelopment analysis", *International Journal of Shipping and Transport Logistics,* 1**,** 276-294.

AL-ERAQI, A. S., MUSTAFA, A. and KHADER, A. T. (2010), " An extended DEA windows analysis: Middle East and East African seaports", *Journal of Economic Studies,* 37**,** 208-218.

AL-ERAQI, A. S., MUSTAFA, A., KHADER, A. T. and BARROS, C. P. (2008), "Efficiency of Middle Eastern and East African seaports: application of DEA using window analysis", *European Journal of Scientific Research,* 23**,** 597-612.

BANKER, R. D., CHARNES, A. and COOPER, W. W. (1984), "Some models for estimating technical and scale inefficiencies in data envelopment analysis", *Management science,* 30**,** 1078-1092.

BERGANTINO, A. S., MUSSO, E. and PORCELLI, F. (2013), "Port management performance and contextual variables: Which relationship? Methodological and empirical issues", *Research in Transportation Business and Management*.

BICHOU, K. (2011), "A two-stage supply chain DEA model for measuring container-terminal efficiency. *International Journal of Shipping and Transport Logistics,* 3**,** 6-26.

BICHOU, K. (2012), "An empirical study of the impacts of operating and market conditions on container-port efficiency and benchmarking", *Research in Transportation Economics*.

CHARNES, A., COOPER, W. W. and RHODES, E. (1978), "Measuring the efficiency of decision making units", *European journal of operational research,* 2**,** 429-444.

CHEON, S., DOWALL, D. E. and SONG, D.-W. (2010), "Evaluating impacts of institutional reforms on port efficiency changes: Ownership, corporate structure, and total factor productivity changes of world container ports", *Transportation Research Part E: Logistics and Transportation Review,* 46**,** 546-561.

CHO, H.-S. (2014), "Determinants and Effects of Logistics Costs in Container Ports: The Transaction Cost Economics Perspective", *The Asian Journal of Shipping and Logistics,* 30**,** 193-215.

COOK, W. D., TONE, K. and ZHU, J. (2014), "Data envelopment analysis: Prior to choosing a model", *Omega,* 44**,** 1-4.

CULLINANE, K., JI, P. and WANG, T.-F. (2005a), "The relationship between privatization and DEA estimates of efficiency in the container port industry", *Journal of Economics and Business,* 57**,** 433-462.

CULLINANE, K. and SONG, D.W. (2006), "Estimating the relative efficiency of European container ports: a stochastic frontier analysis", *Research in Transportation Economics,* 16**,** 85-115.

CULLINANE, K., SONG, D.W. and GRAY, R. (2002), "A stochastic frontier model of the efficiency of major container terminals in Asia: assessing the influence of administrative and ownership structures", *Transportation Research Part A: Policy and Practice,* 36**,** 743-762.

CULLINANE, K., SONG, D.W., JI, P. and WANG, T.F. (2004), "An application of DEA windows analysis to container port production efficiency", *Review of Network Economics,* 3.

CULLINANE, K., SONG, D.W. and WANG, T. (2005b), "The application of mathematical programming approaches to estimating container port production efficiency", *Journal of Productivity Analysis,* 24**,** 73-92.

CULLINANE, K., WANG, T.F., SONG, D.-W. and JI, P. (2006), "The technical efficiency of container ports: comparing data envelopment analysis and stochastic frontier analysis", *Transportation Research Part A: Policy and Practice,* 40**,** 354-374.

CULLINANE, K. and WANG, T. (2010), "The efficiency analysis of container port production using DEA panel data approaches", *OR spectrum,* 32**,** 717-738.

CULLINANE, K. P. and WANG, T.F. (2006), "The efficiency of European container ports: a cross-sectional data envelopment analysis", *International Journal of Logistics: Research and Applications,* 9**,** 19-31.

DEMIREL, B., CULLINANE, K. and HARALAMBIDES, H. (2012), "Container Terminal Efficiency and Private Sector Participation", *The Blackwell Companion to Maritime Economics***,** 571-598.

DING, Z.Y., JO, G.S., WANG, Y. and YEO, G.T. (2015), "The Relative Efficiency of Container Terminals in Small and Medium-Sized Ports in China", *The Asian Journal of Shipping and Logistics,* 31**,** 231-251.

DOWD, T. J. and LESCHINE, T. M. (1990), "Container terminal productivity: a perspective", *Maritime Policy & Management,* 17**,** 107-112.

GOLANY, B. and ROLL, Y. (1989), "An application procedure for DEA", *Omega,* 17**,** 237-250.

GONZÁLEZ, M. and TRUJILLO, L. (2008), "Reforms and infrastructure efficiency in Spain's container ports", *Transportation Research Part A: Policy and Practice,* 42**,** 243-257.

GONZÁLEZ, M. M. and TRUJILLO, L. (2009), "Efficiency measurement in the port industry: a survey of the empirical evidence", *Journal of Transport Economics and Policy (JTEP),* 43**,** 157-192.

HUNG, S.W., LU, W.M. and WANG, T.P. (2010), "Benchmarking the operating efficiency of Asia container ports", *European journal of operational research,* 203**,** 706-713.

INFANTE, Z. and GUTIÉRREZ, A. (2013), Port Efficiency in apec1. *México y la Cuenca del Pacífico*.

JIANG, B. and LI, J. (2009), "DEA-based performance measurement of seaports in northeast Asia: Radial and non-radial approach", *Asian Journal of Shipping and Logistics,* 25**,** 219-236.

KAMBLE, S. S., RAOOT, A. D. and KHANAPURI, V. B. (2010), "Improving port efficiency: a comparative study of selected ports in India", *International Journal of Shipping and Transport Logistics,* 2, 444-470.

LIN, L. and TSENG, C. (2007), "Operational performance evaluation of major container ports in the Asia-Pacific region", *Maritime Policy & Management,* 34**,** 535-551.

LIU, B.L., LIU, W.L. and CHENG, C.P. (2008), "The efficiency of container terminals in mainland China: An application of DEA approach", Wireless Communications, Networking and Mobile Computing, 2008. WiCOM'08. 4th International Conference on, 2008. IEEE, 1-10.

LIU, C.C. (2008), "Evaluating the operational efficiency of major ports in the Asia-Pacific region using data envelopment analysis", *Applied economics,* 40**,** 1737-1743.

LUO, M., LIU, L. and GAO, F. (2012), "Post-entry container port capacity expansion. *Transportation Research Part B: Methodological,* 46**,** 120-138.

MEDDA, F. and LIU, Q. (2013), "Determinants and strategies for the development of container terminals", *Journal of Productivity Analysis,* 40**,** 83-98.

MIN, H. and PARK, B.I. (2008), "A hybrid Data Envelopment Analysis and simulation methodology for measuring capacity utilisation and throughput efficiency of container terminals", *International journal of logistics systems and management,* 4, 650-672.

MOKHTAR, K. and SHAH, M. Z. (2013), "Efficiency of Operations in Container Terminals: A Frontier Method", *European Journal of Business and Management,* 5**,** 91-106.

MUNISAMY, S. and SINGH, G. (2011), "Benchmarking the efficiency of Asian container ports", *African journal of business management,* 5**,** 1397-1407.

NIAVIS, S. and TSEKERIS, T. (2012), "Ranking and causes of inefficiency of container seaports in South-Eastern Europe", *European Transport Research Review,* 4**,** 235-244.

NOTTEBOOM, T., COECK, C. and VAN DEN BROECK, J. (2000), "Measuring and explaining the relative efficiency of container terminals by means of Bayesian stochastic frontier models", *Maritime Economics & Logistics,* 2**,** 83-106.

ODECK, J. and BRÅTHEN, S. (2012), "A meta-analysis of DEA and SFA studies of the technical efficiency of seaports: A comparison of fixed and random-effects regression models", *Transportation Research Part A: Policy and Practice,* 46**,** 1574-1585.

PALLIS, A. A., VITSOUNIS, T. K., DE LANGEN, P. W. and NOTTEBOOM, T. E. (2011), "Port economics, policy and management: content classification and survey", *Transport Reviews,* 31, 445-471.

PANAYIDES, P. M., MAXOULIS, C. N., WANG, T. F. and NG, K. Y. A. (2009), "A critical analysis of DEA applications to seaport economic efficiency measurement", *Transport Reviews,* 29**,** 183-206.

POLYZOS, S. and NIAVIS, S. (2013), "Evaluating port efficiency in the Mediterranean", *International Journal of Data Analysis Techniques and Strategies,* 5**,** 84-100.

RAMANI, K. (1996), "An interactive simulation model for the logistics planning of container operations in seaports", *Simulation,* 66**,** 291-300.

ROLL, Y. and HAYUTH, Y. (1993), "Port performance comparison applying data envelopment analysis (DEA) ", *Maritime Policy and Management,* 20**,** 153-161.

SARRIERA, J. M., ARAYA, G., SEREBRISKY, T., BRICEÑO-GARMENDÍA, C. and SCHWARTZ, J. (2013), Benchmarking Container Port Technical Efficiency in Latin America and the Caribbean, Inter-American Development Bank.

SCHØYEN, H. and ODECK, J. (2013), "The technical efficiency of Norwegian container ports: A comparison to some Nordic and UK container ports using Data Envelopment Analysis (DEA) ", *Maritime Economics & Logistics,* 15**,** 197-221.

SHARMA, M. J. and YU, S. J. (2010), "Benchmark optimization and attribute identification for improvement of container terminals", *European Journal of Operational Research,* 201**,** 568-580.

SIMÕES, P. and MARQUES, R. (2010), "Seaport performance analysis using robust non-parametric efficiency estimators", *Transportation Planning and Technology,* 33**,** 435-451.

THANASSOULIS, E. (2000), "DEA and its use in the regulation of water companies", *European Journal of Operational Research,* 127**,** 1-13.

TONGZON, J. and HENG, W. (2005), "Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals)", *Transportation Research Part A: Policy and Practice,* 39**,** 405-424.

TRUJILLO, L., GONZÁLEZ, M. M. and JIMÉNEZ, J. L. (2013), "An overview on the reform process of African ports", *Utilities Policy,* 25**,** 12-22.

TURNER, H., WINDLE, R. and DRESNER, M. (2004), "North American containerport productivity: 1984–1997", *Transportation Research Part E: Logistics and Transportation Review,* 40**,** 339-356.

UNCTAD (2012), Review of Maritime Transport. *United Nations Conference on Trade and Development http://www.unctad.org.*

VACCA, I., SALANI, M. and BIERLAIRE, M. (2010), Optimization of operations in container terminals: hierarchical vs integrated approaches, Swiss Transport Research Conference.

VERHOEVEN, P. (2010), "A review of port authority functions: towards a renaissance? *Maritime Policy & Management,* 37**,** 247-270.

WANKE, P. F., BARBASTEFANO, R. G. and HIJJAR, M. F. (2011), "Determinants of efficiency at major Brazilian port terminals", *Transport Reviews,* 31**,** 653-677.

WOO, S. H., PETTIT, S., BERESFORD, A. and KWAK, D. W. (2012), "Seaport Research: A Decadal Analysis of Trends and Themes Since the 1980s", *Transport Reviews,* 32**,** 351-377.

WU, J. and LIANG, L. (2009), "Performances and benchmarks of container ports using data envelopment analysis", *International Journal of Shipping and Transport Logistics,* 1**,** 295-310.

WU, J., YAN, H. and LIU, J. (2009), "Groups in DEA based cross-evaluation: An application to Asian container ports", *Maritime Policy & Management,* 36, 545-558.

WU, J., YAN, H. and LIU, J. (2010), "DEA models for identifying sensitive performance measures in container port evaluation", *Maritime Economics & Logistics,* 12, 215-236.

WU, Y.-C. J. and GOH, M. (2010), "Container port efficiency in emerging and more advanced markets", *Transportation Research Part E: Logistics and Transportation Review,* 46, 1030-1042.

YUEN, A. C.L., ZHANG, A. and CHEUNG, W. (2013), "Foreign participation and competition: A way to improve the container port efficiency in China? ", *Transportation Research Part A: Policy and Practice,* 49**,** 220-231.