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TECHNICAL EFFICIENCY OF ARABIAN AND EAST AFRICAN CONTAINER TERMINALS

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Abstract. *In this paper the efficiency and performance is evaluated the terminal container for 22 seaports in the region of East Africa and the* Middle East. *The aim of our study is to compare container terminals situated on the maritime trade road between the East and the West. These are considered as middle-distance ports at which goods from Europe and Far East/Australia can be exchanged and transshipped to all countries in the Middle East and East Africa. All these seaports are regional coasters, and dhow trade was built on these locations, leading this part of the world to become an important trade centre. Data was collected for 6 years (2000-2005) and a non-parametric linear programming method, DEA (Data Envelopment Analysis) CCR and BCC models are applied with a cross-sectional. The ultimate goal of our study is: to estimate the performance levels of the container terminals under consideration. This will help in proposing solutions for improvement the performance and developing future plans.*

1. Introduction

The transport and communications sector experienced growth fuelled by the increase in sea and air traffic volumes of cargo and passengers. The important and competitive maritime transport services in containers benefit the economy of any region as a whole, since more than 80 percent of the world trade volume is carried by ships; maritime transport is thus an efficiency facilitator of the world trade, (Haralambides et al. 2001). This role has become more apparent and crucial in today's expanded and diversified world trade system. Maritime transport was, and currently is, the backbone of development for many countries, (Cullinane et al. 2002). The privilege of containers transport is the speed, comfort, safety and the possibility and ability to handle heavy traffic of goods and passengers at low prices. The present research analyses technical efficiency of Middle East and East African seaports with a DEA- Data envelopment analysis procedure. The contribution of the present research for seaport economics is based on the analysis of container terminals.

The motivation for the present research is the following: First, through the years, the operations in container terminals become more and more complex; the new technology imposes new requirements in the infrastructure and materials handling. The fast development in the port industry, construction of large containers vessels, which need advanced handling equipment to manipulate the containers easily from/to the ship and other equipment's which transport from the terminal to the stack, and from stack to ship. Therefore, efficiency is a main issue in seaport management, (Tonzon, et al. 2005). Second, the movement of steamboats, ship, and goods in ports with diverse and multiple tasks is subject to the concept of modelling a large set of events which occur concurrently and simultaneously in their occurrence and correlation. Through dividing the port in terms of the allocation of terminals, mechanisms, and stores, the process of determining the locations for steamboats according to their qualities has been done, taking into consideration the level of accuracy and details. In that they would be suitable for simulation, and policy plans to manage asset so that for us to obtain results identical with the real situation, therefore the identification of strategically management inputs and outputs is of paramount importance to make a meaningful efficiency analysis, (Rios and Maçada, 2006). Finally, the paper focus on Arabian and African seaports, that have attracted the attention of the researcher so far and includes distance as an input to analyse such network industry.

The present paper is organised as follow: The first section presents the introduction. Section two presents the contextual setting. In section three the literature survey is presented. The fourth section the methodology is displayed. In section five the data is presented. Section six provides the results and finally section seven which presents the conclusion and discussion.

2 Contextual Setting

Over the past few decades, port industry witnessed remarkable development in many countries, particularly in East Africa (such as Sudan, Eritrea, Djibouti, Kenya and Tanzania) and the Middle East region (especially Saudi Arabia, Yemen, Oman, the United Arab Emirates and Iran). These countries possess ports of critical geographic locations on the international maritime trade route between the East and the West Figure1. These ports are considered as middle distance ports at which goods carried from Europe and far East/Australia can be exchanged and transshipped to all countries in the Middle East, the Red Sea and East Africa. The strategic/geographic location of some of these ports encouraged modern container vessels to make short duration calls upon them for the interchange of goods (e.g. shipping lines operating along Asia/Europe route, Asia/Mediterranean route and Asia/US East Coast route). Many studies dealing with container terminals ports efficiency have been carried out but were limited to ports of the European countries, Trujillo and Tovar (2007) and Asian seaports, Cullinane, Song and Wang (2005). In this paper we try to highlight this side of the world which is: 1) considered as middle of the cord, linking the East and West sides of the world through the maritime routes, 2) Presently the region witnessing economic development in various domains, 3) Proposal Model to improve the transshipment of containers in the region Figure 3. Table 1 show the data of the terminals container of the seaports which will be analysed.

Table 1. Ports of the Region

Port	Berth Container	Quay Crane	RTGs	Container Area	Ships Containers	Container Throughput
Bander Abbas Iran	1000	10	5	220000	1817.83	778827.83
Khor Fakkan Sharjah	1330	14	14	50000	2049	1536588
Khalid Sharjah	575	2	4	20000	532.50	59770
Salalah Oman	1236	12	30	240000	1139.50	1404777
Mascut Oman	366	5	8	50000	711	203492.50
Dubai Emirates	1220	39	128	1006050	4986.50	4992503.33
Kuwait	370	2	3	170000	1663.66	301275.50
Mukalla Yemen	130	0.01	0.01	5000	41.60	8622.66
Aden Yemen	1080	7	13	10825	561.83	302958.33
Hodeida	500	2	0.001	90000	817	42310
Damman Saudi	1400	8	0.001	480000	1275	584014.83
Jubail Saudi	1500	2	0.001	15000	329	20161.16
Yanbu Saudi	750	3	0.001	17000	17	1472.33
Jeddah Saudi	2550	24	32	293800	2758.50	1897728
Sudan	278	3	4	225000	1114	145647.83
Mombasa Kenya	964	3	2	20000	1788.83	3250555.166
Dar es Salaam anzania	550	2	9	84000	746.5	166101.66
Tanga Tanzania	130	0.01	0.01	5000	41	10612.66
Mtwara Tanzania	130	0.01	0.01	5000	48	9241.16
Assab Eritrea	260	2	4	40354	35.83	4647.33
Asmara Eritrea	175	1	0.01	7200	645	24621.66
Djibouti	400	4	10	828000	696	206343.50

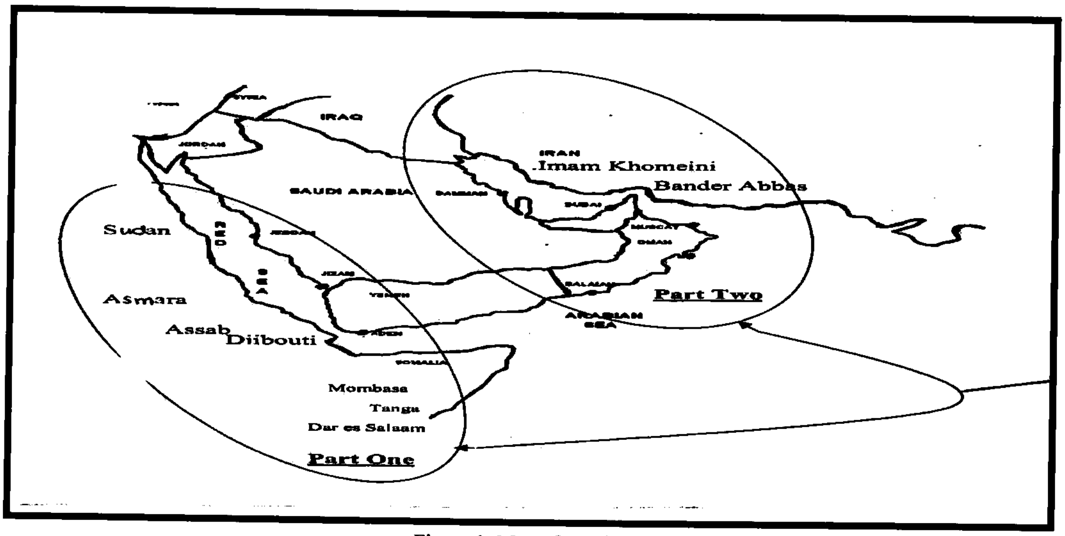

Figure 1. Map of Region

3. Literature Survey

There is extensive literature on DEA, applied to a wide diversity of economic field in particular in seaports transportation. Cullinane et al. (2005) used DEA to highlight the major objective of port privatisation wish is to improve the efficiency of this sector, with as data the container throughput as output and area and length terminal, quay crane, yard crane, straddle as input. They concluded that public and private/public ports perform better than public/private and private. Hidekazu (2002) open a window in applied DEA in increasing import cargo and growing the number of container ship size in eight major international container ports using data for the period between 1990 and 1999. Song and Cullinane (2001) apply ratio analysis to Asian container separates. Among the papers using DEA are Roll and Hayuth (1993), who present a theoretical exposition and propose the use of cross-sectional data from financial reports in order to render the DEA approach operational. The author observed that the ports which are already redeveloped can receive large-sized container vessels and increase their throughputs. Poitras et al. (1996) limited the performance and efficiency only in handling containerized cargo across selected ports in term of geographical location, and data availability. Coto-Millan et al. (2000) applied a stochastic frontier model to evaluate the efficiency of 27 Spanish ports, Using the number of twenty foot container equivalent units handled per berth hour, and total number of containers handled per year as inputs. The efficiency results obtained depend on the type of DEA model employed, which depends on assumption made about returns to scales properties of the port production function. Tongzon (2001) applied DEA model CCR to provide an efficiency measurement for four Australian and 12 other international container ports for the year 1996.The output measures used are the total number of containers loaded and unloaded, and ship working rate. To produce the previous output, he introduced a variety of inputs as land, labor and capital which detailed in port equipments. The study has demonstrated that DEA provides a viable method of evaluating relative port efficiency. Cullinane, Song and Gray (2002), analyzed the administrative and ownership structure to estimate a Cobb-Douglas production function for major Asian container terminals. The relative inefficiency of these ports estimate using cross-sectional and panel data version. Cullinane and Song (2003) whose estimate a production function increasing for Korean container terminals in case of privatization policies, have chosen the stochastic frontier model as justified methodology and applied to cross-sectional data. Valentine and Gray (2002) focusing on the selected ports of North America and Europe attempts to comparing efficiency, assuming that there are many factors for evaluating the port performance such as the location, infrastructure, and connectivity to other ports. The Data used for 1998 constitute of number of containers, total throughput, total length of berth and container berth length. Valentine and Gray (2002) concluded that DEA is useful to test the container port efficiency and highlights the characteristics of an efficient port. The main aim to emerge that the measure of efficiency concern an individuals are not particularly highly correlated the department level DEA efficiency score. Wang et al. (2003) analyzed the container terminal port efficiency using two alternative techniques DEA model CCR, BCC and FDH Model. Wang et al. (2003) applied methods on the top of 30 container ports in the world in 2001, using throughput as output and quay length, area, quay crane, yard crane and straddle carrier as inputs. Borros et al. (2004) evaluated the Greek and Portuguese seaports by using DEA-CCR and DEA-BCC models, the input are the labour, capital and the output defined by ships calls, freight and container. Lee Chee (2005) deals with treat tackles study on Malaysian container port industry with cross sectional of year 2003 as well as panel data over the years 2000 to 2003, compared to Singapore port, the Malaysian container port on average is sufficient to support the market demand. Barros (2006) evaluates the performance of Italian seaport for period 2002 to 2003 using DEA with CCR and BCC model, to analyzing 24 seaports. The outputs measured by liquid bulk, solid bulk, number of containers, number of ships and total receipts, and the inputs measured by number of personnel's, the capital invested and the value of operational costs.

4. Data Envelopment Analysis

Charnes et al (1978) were the first to introduce the DEA as a multi-factor productivity analysis module for measuring the relative efficiencies of a homogenous set of decision making units (DMUs). The principle of this non parametric method is based on two important sets of multiple variables called inputs and outputs variables (this will be discussed later). The ratio assumes that there are n DMUs, each with m inputs and s outputs, the relative efficiency score of DMUp is obtained by solving the following model proposed by Charnes et al. (1978), where n is the number of units. There are two models on the return to scale of ports production function, called CCR model (constant return to scale) is a scale efficiency and technical efficiency, BCC model (variable return to scale) is a pure technical and scale efficient [Fare et al, 1994].The combination of the two model result is as follows:

CCR Model (Charnes, Cooper and Rhodes)

$$\text{Max } \phi_k$$

$$s.t. \quad \sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{ik} \qquad i=1, 2\ldots m; \qquad (1)$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq \phi_k y_{rk} \qquad r=1,2,\ldots,s; \qquad (2)$$

$$\lambda_j \geq 0 \qquad \forall j.$$

BCC Model, Banker, (Charnes and Cooper, 1984) is defined to added equation (3) to the above.

$$\sum_{j=1}^{n}\lambda_j = 1 \qquad (3)$$

Through the equations of BCC model we see that all λj are now restricted to summing to one equation (3), given by convexity constraint.

The output- oriented measure of technical efficiency of k-th DMU is:

$$TE_k=1/\sum_{j=1}^{s}u_j\, y_{ji} \qquad (4)$$

The technical efficiency is concluded from DEA-CCR and DEA-BCC models as following [Wiliam et al.2000]:

$$SE=U_{CCR} / U_{BCC} \qquad (5)$$

Equation (5) used to measure the score efficiency of DMU_k, if $SE_k=1$ then the score is efficiency otherwise the score is inefficiency if $SE_k<1$.

5. Data and variables

DEA is a multi-criterial approach, capable of manipulating multiple inputs and outputs which are expressed in different measurement units. Any statistical method can not perform this type of analysis. In general DEA focuses on the number of observations repeated of the events through the resources surroundings. To estimate the suitable location of the ports under study, we used the average data for the years 2000-2005; the ports considered in analysis are listed below Table 2:

Table 2. Characteristics of the Variables.

	Input			Output		
	Berth length m	Quay crane	RTGs	Terminal area m2	Ships call	Container Throughput (TEU)
Mean	767.9091	6.592273	12.09127	176465	1082.504	725103.2925
Std. Error of Mean	129.2907	1.966672	5.845712	57701.82	244.7532	267785.8706
Median	562.5	3	4	50000	728.75	184797.08
Mode	130	2	0.001	5000	17	1472.33
Std. Deviation	606.4269	9.224509	27.41882	270645.5	1147.994	1256027.068
Range	2420	38.99	127.999	1001050	4969.5	4991031
Minimum	130	0.01	0.001	5000	17	1472.33
Maximum	2550	39	128	1006050	4986.5	4992503.33
Sum	16894	145.03	266.008	3882229	23815.08	15952272.44
Count	22	22	22	22	22	22

The data was obtained from the annual statistics reports of some ports authorities, by fax and Email and through internet (using Google Earth and ports web site as Maritimechain.com and Ports Harbours Marines Worldwide). The measurement of output is indicated for two elements 1) Ships and 2) movement of containers (TEU) unload and load. The measurement of the inputs is considered by the indicators: Total container berth length, container storage area, RTGs and number of quay cranes.

The number of DMUs (n) is greater than the combined number of inputs and outputs (m+s), the selection of input and output elements is crucial for successful application of DEA and ensured the convention above (22>3(2+5)) [Raab and Lichty, 2002]. The software Frontier Analyst from Banxia software was applied to solve the DEA models. In DEA-CCR model all observed production combinations can be scaled up or down proportionally, and in DEA-BCC model the variables allow return to scale and is graphically represented by a piecewise linear convex frontier [Cullinane et al. 2006]. In this paper we propose the input-oriented and output-oriented DEA models seeking maximization of output while the given current inputs remain the same. The technical efficiencies derived from the DEA-CCR and DEA-BCC models are frequently used to obtain a measure of scale for DMU, given by SE=UCCR / UBCC [William et al.2000].

The efficiency of any port depends crucially on security port system, services provided, easy entrance, labour skill, storage capacity and equipment. The objective of this paper to compare the different levels of efficiency ports in the region, on the other, increase the number of ships call, increase the average hours working of equipment handling and decrease the handling cost and attempt through the results obtained a transshipment point/s (e.g. suitable hub/s). The containers throughput and ships call variables are important indicators of any container terminal production considered as outputs. The resources of the container terminal are defined by the total berth length, terminal area, distance and equipment handling. The variables selected are correlated between them, whereas the inputs and the outputs impacted together Figure 2.

Ship Call →Distance→Berth←→Crane←→ RTGs←→Area

Figure 2. Movement of containers

The efficiency measure assume that production function of the firm is different compared to container terminal production function, whereas the variables in first one are more flexible and easy to improve in short time, on the other hand, the variables for the second are difficult to improve, costly and time consuming when changed. The efficiency measure in port terminal maybe mislead in result where some large ports (in term of infrastructure, equipment and throughput) turn out to be inefficient and some small ports efficient, such ambiguity lead to management problems and marketing.

6. Results

We applied DEA to analyse the efficiency score of the ports, using the software DEAP version 2.1 (Data Envelopment Analysis Program) Coelli Tim.J, with two models namely DEA-CCR and DEA-BCC. DEA is carried on e 22 ports show in Table 1. Table 3 represents the efficiency estimates, the scale efficiency and scale type of each port. The score reported show that twelve and eighteen ports out 22 are efficient under DEA-CCR and DEA-BCC models. Comparing the result of two models, the BCC show more efficient ports than CCR as indexed with average value of 0.81 and 0.87 for each model, because CCR model provides information in scale and technical efficiency together, while BCC model measures pure technical efficiency only Table 3.

The output oriented applied in this paper to select the ports specific in term of container throughput (TEU), equipment and sophisticated management. Theatrically, the output of technical efficiency is given by $TE_k=1/U_k$ for k term of DMU, that the ports under study must increase their product on average to 1.2 times for the same inputs. The scale properties of ports production show thirteen constant returns to scale, seven increasing returns to scale and two decreasing returns to scale.

Table 3: The relative efficiency of seaports using DEA-CCR and DEA- BCC models

Country Terminal	DEA - CCR	DEA - BCC	Scale Efficiency	Return to scale
Bander Abbas Iran	1	1	1	Constant
Khor Fakkan Sharjah	1	1	1	Constant
Khalid Sharjah	0.451	1	0.451	Decreasing
Salalah Oman	0.953	1	0.953	Decreasing
Mascut Oman	0.746	1	0.746	Decreasing
Dubai Emirates	1	1	1	Constant
Kuwait	1	1	1	Constant
Mukalla Yemen	1	1	1	Constant
Aden Yemen	1	1	1	Constant
Hodeida	1	1	1	Constant
Damman Saudi	1	1	1	Constant
Jubail Saudi	0.611	1	0.611	Decreasing
Yanbu Saudi	0.041	0.041	1	Constant
Jeddah Saudi	0.971	1	0.971	Decreasing
Sudan	0.891	1	0.891	Decreasing
Mombasa Kenya	1	1	1	Constant
Dar es Salaam Tanzania	0.634	0.635	0.998	Increasing
Tanga Tanzania	1	1	1	Constant
Mtwara Tanzania	1	1	1	Constant

Assab Eritrea	0.044	0.049	0.906	Increasing
Asmara Eritrea	1	1	1	Constant
Djibouti	0.392	0.397	0.988	Increasing
	0.806	0.869	0.933	

The inefficiency assumed for CRS and VRS is due to decline in the numbers of ships call which cause the decreasing of throughput. In general the global result is sufficient for the majority of ports using both model CCR and BCC Table 3. The result show that the large terminals having throughput more than 500,000 TEU appear scale inefficient terminals and decreasing return to scale and efficient constant return to scale. The terminals those have annual container throughput less than 500,000 TEU and greater than 50,000 TEU are scale inefficient show increasing return to scale efficient constant return to scale and decreasing return to scale. The ports with small containers throughput less 50,000 TEU, most of them are efficient constant return to scale and show increasing return to scale. The result show that the large ports to be efficient must increase the throughput between 5% - 21% and increase the ships call between 3%- 58%. To explain these results, it will be divided into two parts: first part Policy management of big ports must show no correlation with their sophisticated infrastructure and their throughput. Some of these ports are approach to each other (have a short distance between them) and establish a policy management to share the transshipment which will be considered an efficient through increasing number of ships call and throughput Figure 2. Examining the map in Figure 1 we see that most of the large container terminals are situated in the same area of the Gulf and only one in the Red Sea. Second part economic, concern the ports which need important improvement which must be take in consideration like an investment capital to develop the infrastructure and equipment in term of extend berth, area and increase the number of handling equipment for future growth in demand. On the other hand, an interpret of inefficient maybe due to the slowdown development in certain regions of some countries due to reason economic, politic and insufficient density of population.

7. Discussion and Conclusion

The aim of this paper was to evaluate the efficiency in ports situated in the Middle East and East Africa. DEA analysis allows us to determine the relative efficiency of the above ports. Firstly the nine ports must improve the level of their outputs up to 1.2 times keeping the same inputs; secondly the container sector of the region is shown in average well. Regarding to the items (quantity) of inputs and outputs, we noted that the improvement of the inefficient ports due to less number of ships call and throughput. The analysis shows that thirteen ports are currently working efficiently; five are localized in the Arabian Gulf such as, Bander Abbas, Damman, Dubai, Khor Fakkan and Kuwait, four in east Africa Asmara, Mombassa, Tanga and Mtwara and two in Arabian Sea, Aden and Mukalla and the last two Hodeida and Yanbu on the Red Sea. Regarding to inputs and output variables of the ports, the approach location, big equipment, capacity of berthing and storage are the important input factors. In general we concluded that the big length of the berth does not impact on the ships arrival i.e. the increase in ships call in these ports is possible without causing any congestion problem. So according to Table 1 there are crucial indicators to distinct the port performance emerged from the data; such modern equipment with high performance, enough berth length and good location, therefore, within the selection of the suitable container transshipment terminals (hub) from the above efficiency ports will be easy. The model proposed in Figure 3 will increase the ships entrance in to the ports and this will contribute effectively in the development of economy and enrich the meantime of the poor countries of the region. The idea summarises by allow ships come from East load/unload in the hub and back, and same for ships come from Europe (West), instead to go directly from East to West and reverse. The transshipment will be effected between the hub and other ports in the region. Finally an investment of the public and private sector will help seriously to participate to develop and expand the inefficient ports in the region (It is noted that the construction or the reconstruction in port sector is very difficult and takes time), and suggest to ships lines to create a policy to encourage their ships to load/unload in these ports. More investigation is needed to clarify unsettled questions.

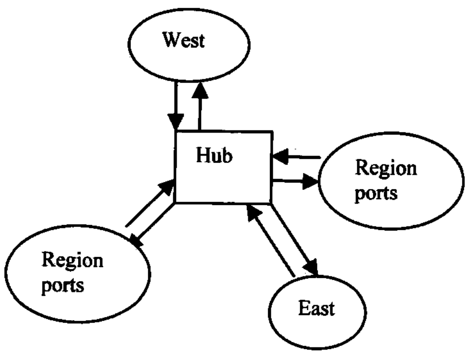

Figure 3. Hub model.

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