# *Efficiency analysis and Ranking of Mediterranean container Ports and terminals*

## *-Using DEA-*

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# *Abstract*

The Mediterranean Sea is the 'crossroads' of European, Asian and African continents whose trade is growing with globalisation. And as a 'maritime route' nearly a third of world trade 'passes', from the mouth of the Suez Canal to the Straits of Gibraltar or the Bosporus, from the Atlantic to the Black Sea making the region as one of the world's major trade routes in addition of the trade developed by the coastal countries situated around this landlocked sea.

For long time transport in the region has been dominated by the North-West European ports but during the last decade there is a consistent progress in ports situated on the south and east shores of the Mediterranean basin, notably Morocco, with the Tangier Med container transshipment terminals project, and also in Egypt, which has recently started the expertise of the private sector in delivering new capacity and new efficiencies. This changing environment has consistently scrambled up ports hierarchy in the region.

In this paper the efficiency and performance is evaluated for 32 seaports in the Mediterranean region using a non-parametric linear programming method, DEA (Data Envelopment Analysis) which evaluates relative efficiencies of a homogenous set of decision making units (DMUs) in the presence of multiple input and output factors.

Studies on the region using DEA never included the new emerging ports and terminal thus the ultimate goal of the study is to re-estimate the competitive environment of port industry in the region including ports from all Mediterranean sub-regions to fully assess ports' activity in the region. By analyzing the operational efficiency, revealing the causes of inefficient operations, and suggesting how to overcome the drawbacks. An

additional analysis for ranking the container ports was conducted using the super-efficiency model.

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# CHAPTER Ⅰ Introduction

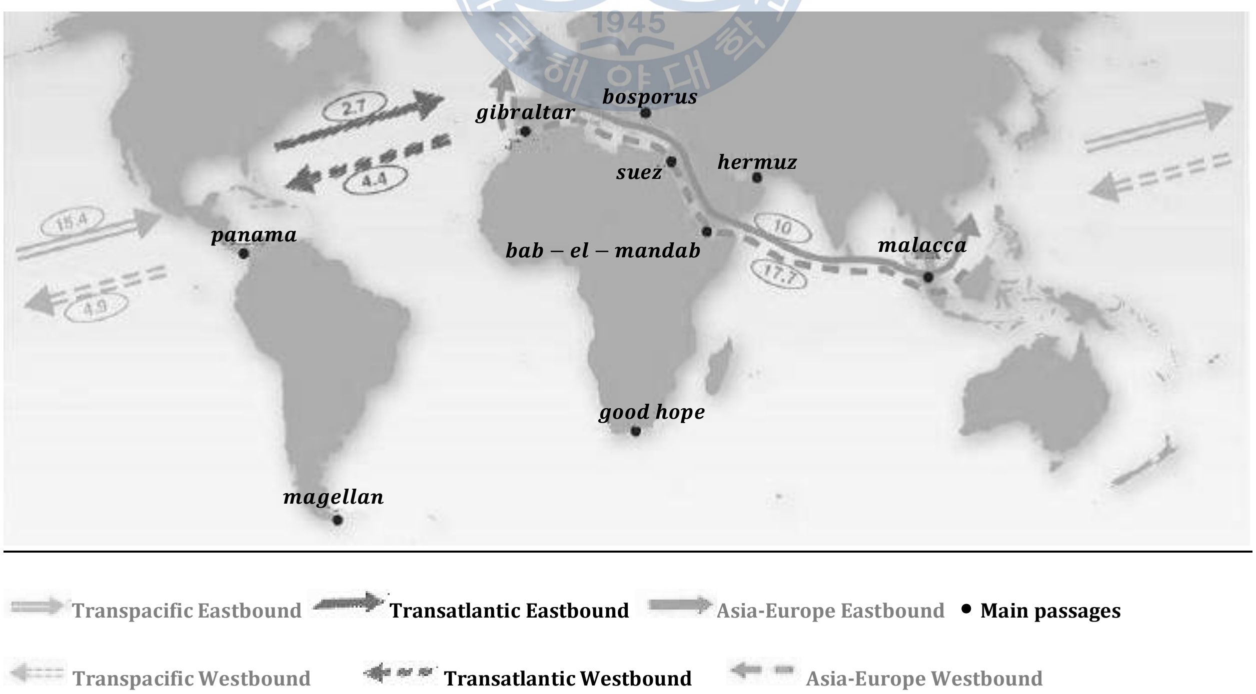
## 1. Research Background

In the last decades the considerable development emerging in the international trade, characterized by the globalization of production and consumption patterns increased the importance of the container transport, which is mainly due to the various advantages it has on both technical and economical sides compared to the previously used methods of maritime transportation, consequently steady and fast progress in technology and economy of scale in the container transportation operations appears, giving a critical importance to the port's role in the overall efficiency of the global logistics network, as it is the only link standing at the interface sea-inland transportations, This fast changing landscape brought the ports into the most intense competitive environment ever the industry knew, numbers of container ports in most of regions have increased and still increasing, and ports that enjoyed a previously existing concentration of cargo traffic and monopoly over the handling of cargoes from within their hinterland are now obliged to compete in order to share cargo handling with their neighbors within the same region.

Such fluid environment brings additional difficulties into making policies, and taking decisions in order to gauge and monitor efficiency of ports services. Therefore, the proper and precise evaluation of container port performance will not only help a port to understand and improve its marketing and competitive position, but also provides a clear and solid base for the local government policy maker for long term development. (Jie wu, et al. 2010). In this changing environment, monitoring efficiency based on historical performance might be misleading while comparing port performance with pears from around the world may be more informative. (Santiago Herrera & Gobo Pang. 2007) further more comparing ports performance with pears from the same geographical region will give more accuracy to the performance measurement. One of the important Constant aspects of seaport performance measurement is the efficiency and for evaluation of efficiency the popular method of Data Envelopment Analysis (*DEA*) is used.

Being the crossing point of the three continents, Asia, Europe, and Africa; and linked to the east coasts of the American continent through Gibraltar Detroit and the Atlantic Ocean. The Mediterranean Basin is the gateway of a major international trade route, One third of the world container traffic is based on the Mediterranean Sea ( Die Welt, July 2008), distributing manufactured goods from China and South-East Asia to Europe, and Africa (and, to some extent, to the eastern coast of America) plus the intra-Mediterranean trade volume (Figure 1.1).

**Figure 1.1: container traffic of major maritime trade routes 2007 (M TEU)**




Source: UNCTAD 2008

Traffic from Asia to Europe, which flows through the Mediterranean basin, has been estimated at 18.3 million TEU in 2006, with the breakdown of 12.5 million TEU on the leg from Asia to Europe, and 5.8 million TEU in the opposite direction (UNCTAD, 2007)

Such a situation makes the port a key factor in the Mediterranean land and sea transport system. In any case, in order to analyze ports and their performance, the efficiency of their infrastructure and equipment must be considered. Studies dealing with Mediterranean seaports efficiency using DEA have been carried out; however, all of these compare only the efficiency of seaports of the European countries bordering the northern shore of the Mediterranean Sea (Semra Birgun & Necmettin Akten, 2005; Qianwen liu & Francesca Medda, 2009;Joao C.Qaresma Dias, et al. 2009; Carvalho Pedro, 2010; Qianwen liu, 2010; … ) this study will include African, and Asian seaports bordering the Southern and Eastern sides of the sea.

In Mediterranean area Ports in the South are catching up to European ports in terms of capacity and logistic performance thanks to megaprojects. The Tanger-Med port (near Tangiers/Morocco), the most visible of all, inaugurated in 2007, should attain a capacity of 3 million containers by 2013 (and 8M eventually).Built from scratch, this port was supposed to reach a level of container traffic equivalent to the port of Marseille in france by the end of 2009, despite the crisis (Les Echos, 22 July 2009), testifying to the power of attraction of these new projects in the South. Other, likewise important projects are being completed (extension of Port Said and the new port of Sokhna in Egypt) or developed (Enfidha in Tunisia). Generally speaking, nearly all other ports from the Maghreb to the Balkans have undertaken work to upgrade their infrastructures as well. Therefore, though the ports on the North shore have a geographical advantage as points of direct entry to the EU, the south-shore ports have the advantages of being located on the mega-containership route, offering less costly services and above all, offering high-tech logistics services at recently-built port (Med 2011 Panorama) which gives a more homogenous competitive environment totally different from the previous one which has been existing.

On the academic side, after checking the existing literature about port efficiency evaluation I found that all researches about the Mediterranean Sea include only the northern countries' ports from the basin especially those situated in countries from the European Union (EU) community, (Qianwen Liu 2010 an analysis of 32 north Mediterranean seaports, Semra Birgun and Necmettin Aktens 2005 an analysis of 10 seaport terminals lying on the coast of the Sea of Marmara and the Mediterranean rim) while the present position of southern ones give them the status of an actual actor in developing the maritime transport in the Mediterranean region, and any further research about the Mediterranean seaports must include them in order to get more credibility.

The above mentioned reasons are a real motivation to re-evaluate the new competitive environment in the Mediterranean region among its ports and terminals which can give an overall idea about the potential competitiveness strength of the whole region comparing to other regions all over the world.

## 2. Research Objective

The main objective of this research is to evaluate the efficiency of 32 container ports and terminals, in the Mediterranean basin using DEA (Data Envelopment Analysis); It uses output-oriented CCR and BCC models to analyze the possibility and the way to produce the maximum possible container throughput from a given fixed quantity of resources.

Then processing to more comprehensive ranking beyond the simple dichotomous classification which can be obtained by using a DEA model by applying a super efficiency DEA method which allows to rank efficient DMUs from the most efficient to the less efficient, in order to overcome the problem of distinguishing between the efficient DMUs.

## 3. Method

The method consists of five steps, which are briefly explained below.

a) *Data Collection*: All information comes from Containerization International Yearbooks 2010 for the year of 2008; missed data on containerization International Yearbook 2010 were completed by e-mail requests to the concerned port authorities, or from Ports official sites. The quality of the collected data will in part determine the quality of the eventual decision.

b) *Identify Model Indices (Variables):* The main question to answer at this stage is "What are the main indices that could directly affect the port's efficiency?" One word of caution is that the set of indices should be limited in size, and accordingly, only the main factors which significantly affect the port's performance should be included in the set. Too many indices will cause the result of losing discriminatory power (Paradi et al., 2002). The recommended maximum number of input and output indices for DEA is equal to one-half the number of DMUs (Dyson et al., 2001).

c) *Model Selection:* According to the property of the indices and the decision purpose, we can select the most appropriate DEA model as our approach. Model types might change based on the calculation of the projection (CCR, ADD), or problem/ variable characteristics (such as input-oriented or output oriented models) may dictate the selection of the model. Steps 2, and 3 of the method should be treated very carefully as the property of the indices would have strong influence on the model to be used.

d) *Run the DEA Model:* There are several software packages for DEA calculations such as Frontier Analyst, DEA Frontier, etc. For example, in this study, we used Excel DEA Solver.

e) *Result Analysis:* the results abstained after running the software are analysed to determine the efficient and inefficient DMUs and to determine the improvement path of each inefficient DMU according to its appropriate benchmarks, then to get a full ranking of the DMUs set we run a super-efficiency analysis.

## 4. Research Scope

Due to the multiple activities involved in the port industry, Port takes the form of a complex organization with a large variety of agents (port authorities, tug boats, consignees, etc.). with various and different activities and tasks for each one (provision of infrastructure, docking, handling of merchandise, administration, assistants, and passenger services, etc.), for these reasons the study of ports as a whole homogenous entity is not recommended it is preferable to Centre the analysis on a concrete activity (Nombela & Trujillo, 1999), on a specific type of a cargo and limited number of ports (Tongzong, 2001).

This research concerns only the containers industry the sample for analysis comprises a total size of 32 Unites; either container ports or individual terminals within container ports, for ports comprising more than one container terminal each terminal will be analysed and ranked separately; Countries which have ports on different sea fronts only those situated on the Mediterranean side will be included in this research.

The ports sample includes 2 ports from Asia (2 terminal operators), 16 ports from Europe (20 terminal operators), 8 ports from Africa (10 terminal operators), all unites are situated in 14 countries bordering the Mediterranean Sea (Table 6.2, Figure 6.1)

## 5. Reasons to Use DEA

Unlike a typical statistical approach that is characterized as a central tendency approach which evaluates producers relative to an average producer, DEA compares each producer (Decision Making Unite) with only the "best" producers. DEA is not always the right tool for a problem but is appropriate in certain cases and if it is used wisely DEA can be a powerful tool.

A few of the characteristics that make it powerful are:

a) DEA can handle multiple input and multiple output models.

b) It doesn't require an assumption of a functional form relating inputs to outputs.

c) DMUs are directly compared against a peer or combination of peers.

d) Inputs and outputs can have very different units. For example, X1 could be in units of Number and X2 could be in units of tonnes or dollars without requiring a priori tradeoff between the two.

## 6. Organization of the Chapters

This work is structured as following: in Chapter II there is a review of efficiency measurement in port sector and previous related researches,

Chapter III aims to conduct a brief introduction to the Mediterranean maritime and port industries as an important link in the world maritime transport then to present the influence and changes brought by globalization and containerization to the region.

The Chapter IV presents first the theoretical aspect of DEA and explains the Principe of the methods of DEA Output Oriented and Super-efficiency that will be applied to this study

In the second part of the chapter Units from the Mediterranean region and their variables are selected and data are analyzed to get empirical results.

Finally Chapter VI discusses the conclusion and future researches suggestions.

# CHAPTER Ⅱ Literature review

## 1. Theoretical Framework

### 1.1. Efficiency Measurement

The origin of the modern discussion of efficiency measurement dates back to Farell (1957), who identified two different ways in which productive agents could be inefficient:

1) They could use more inputs than technically required to obtain a given level of output.

2) They could use a sub-optimal input combination given the input prices and their marginal productivities.

The first type of inefficiency is termed technical inefficiency while the second one is known as allocative inefficiency. Both theoretical and empirical measures of efficiency are based on ratios of observed output levels to the maximum that could have been obtained, given the inputs utilized. This maximum constitutes the efficient frontier which will be the benchmark for measuring the relative efficiency of the observations. Numerous techniques have been developed over the past decades to tackle the empirical problem of estimating the unknown and unobservable efficient frontier; these may be classified using several taxonomies. The two most widely used catalog methods into parametric or non-parametric, and into stochastic or deterministic. The parametric approach assumes a specific functional form for the relationship between the inputs and the outputs as well as for the inefficiency term incorporated in the deviation of the observed values from the frontier. The non-parametric approach calculates the frontier directly from the data without imposing specific functional restrictions (*Santiago Herrera & Gaobo Pan, 2006.)* The first approach is based on econometric methods, while the second one uses mathematical programming techniques. The deterministic approach considers all deviations from the frontier explained by inefficiency, while the stochastic focus considers those deviations a combination of inefficiency and random shocks outside the control of the decision maker.

## 1.2. Alternative Technics

We can summarize the methods reviewed as following:

### 1.2.1. Original *Least Squares* (*OLS)*

Estimation and regression method that fits an 'average line' through the data; Its strength is first It is consistent with the underlying economic theory that offers a potential explanation for cost or production structures, and distinguishes between different variables' roles which affects output; second there is an ample range of standard statistical tests available to assist the analysis;

*Its weakness is that* all firms are considered as rational (there is no inefficiency), and thus all deviations from the frontier are attributed to random noise, This assumption is not always true in reality. Therefore, the estimation bears this built-in inaccuracy.

### 1.2.2. Corrected Original Least Squares (COLS)

Is a parametric approach to evaluate productive efficiency. It belongs to the regime of regression methods but differs from the OLS estimation method.

Its strength is that, first it reveals information about the production technique, and it distinguishes between different variables' roles in affecting output as all parametric methods do; second the adjustment from the average line to the 'frontier' allows for the measurement of relative efficiency.

Its weakness is that first as all parametric methods it requires a priori specification of the production or cost function, second it is not possible to measure error and other statistical noise (Greene, 1993); and third it is sensitive to outliers, since the 'best' performer along any dimension serves as the anchor for how much the 'average' line needs to be corrected in order to become the frontier (Qianwen Liu, 2010).

## 1.2.3. Stochastic Frontier Analysis (SFA)

Is a parametric and stochastic approach to estimate productive efficiency, its advantages are first it reveals information about the production technique and distinguishes between different variables' roles affecting output; second it considers statistical noise and hence it is possible to test the validity of certain assumptions and hypotheses; third it is possible to model the effects of environmental/exogenous variables.

On the other hand we need to impose an a priori structure when constructing the frontier functional form; also the assumptions concerning the distribution of the inefficiency term have to be imposed in order to decompose the error (Qianwen Liu, 2010).

## 1.2.4. Data Envelopment Analysis (DEA)

Is a mathematical programming approach to estimate productive efficiency, The strength of this method is that no a priori structural assumption is placed on the production process; the drawback is that it does not take into account the measurement error and other statistical noise, and it is therefore not possible to test the statistical significance of the efficiency index for a specific observation.

The choice of approach must be based on the objective of the research and the available data.

## 2. Review of Previous Researches about Seaports

The Researches can be classified according to the methods or by the sample they use. Researches are based on samples coming from a single country, or they can include ports of different countries (Santiago Herrera & Gaobo Pang).

In this survey we will classify researches according to the sample. Samples can be selected within a single country, and we can mention, *Coto-Millan, et al. (2000) analysis of* 27 Spanish Ports, *,* Estache, *et al.* (2002) study of 13 Mexican seaports, Barros (2003b) analysis of 10 Portuguese seaport, *Park and De (2004) a study of 11 Korean seaports*, and Barros (2005) analysis of 10 Portuguese port authorities. With the exception of Barros (2003b), Park and De (2004) which use Data Envelopment Analysis all other studies use *Stochastic Frontier method.*

Alternatively, the sample can cover ports from different country within the same geographical region or ports from around the world, *Ahmed Salem Al-Eraqi, et al. (2008) the sample covers*22 Middle East and East African ports, Cullinane, *et al*.(2006) that covers 57 container ports/terminals within top 30 container ports, *Barros and Athanassiou (2004) analysis of* 2 Greek and 4 Portuguese seaports, also *Valentine (2001) analysis* Cross-sectional data of 15 African ports, and *Notteboom, et.al (2000) a study of 36* European terminals plus 4 Far East container terminals, all analysis used Data Envelopment Analysis (DEA) with the exclusion of Notteboom, et.al (2000) which uses Stochastic Frontier Analysis (SFA), and Cullinane, *et al*.(2006) that use a comparative study of DEA and SFA.

The variables used in the literature cited are listed in Table 2.1.

## Table 2.1: Literature Review

| reference | Sample covered | method | Data description | inputs | outputs |
|---|---|---|---|---|---|
| *Coto-Millan, et al. (2000)* | Ports/terminals from a single country | Translog Cost model | Cross-sectional data of 36 European terminals plus 4 Far East container terminals in 1994 | number of cranes, the terminal area, and the container berth length, labor | total goods moved in the port in thousand ton, no of passenger embarked/disembarked, vehicles with passengers |
| *Notteboom, et.al (2000)* | Ports/terminals from different regions | (SFA) Cobb-Douglas Production function | Cross-sectional data of 36 European terminals plus 4 Far East container terminals in 1994 | Terminal quay length, Surface, and gantry cranes | Terminal traffic (TEU) |
| *Valentine (2001)* | Ports/terminals from different countries within the same region | DEA-CCR and BCC | Cross-sectional data of 2 Greek and 4 Portuguese | Labour and capital | ships, movement of freight , cargo handled, container handled |
| *Estache, et al. (2002)* | Ports/terminals from a single country | Cobb-Douglas production function | panel data of 27 Spanish ports from 1985-1989 | Price of labor, Price of capital, Price of intermediate consumption | Volume of Merchandise handled |
| *Barros (2003b)* | Ports/terminals from a single country | DEA-Malmquist index and a Tobit model | Panel data of 10 Portuguese seaports, 1990-2000 | Number of employees and book value of assets | Ships, movement of freight, break-bulk cargo, containerized freight, solid bulk, liquid bulk |
| *Park and De (2004)* | Ports/terminals from a single country | DEA-CCR and BCC | 11 Korean seaports for the year 1999 | Berth Length, Handling ,Equipment, Storage Area | Cargo throughputs, number of ship calls, revenue and consumer satisfaction |
| *Barros (2005)* | Ports/terminals from a single country | Stochastic Translog cost frontier | Panel data of 10 Portuguese port authorities, 1990-2000 | number of ships, total cargo | Price of labor Price of capital |
| *Cullinane, et al. (2006)* | Ports/terminals from different regions | SFA) Cobb-Douglas Production function | Cross-sectional data of 57 container ports / terminals within top 30 container ports, 2001 | Terminal/port quay length Terminal/port yard area handling equipment | Throughput in TEUs |
| *SoonHoo So, et al. (2007)* | Ports/terminals from different countries within the same region | DEA with CCR, BCC, and super-Efficiency models | Cross-sectional data of 19 container ports in the Northeast Asia for the year 2004 | berth length, terminal area, no of quay cranes, no of yard equipments | container throughput |
| *Ahmed Salem Al-Eraqi, et al.(2008)* | Ports/terminals from different countries within the same region | DEA Using Window Analysis | Panel data of 22 Middle East and East African ports from 2000 to 2005 | Berth length, storage area, handling equipment | Ship's calls and Cargo throughput in tons |

# CHAPTER Ⅲ Container Ports and Terminals

## 1. Container Ports and Terminals in the Overall Shipping Market

The ocean shipping industry is heterogeneous; it is characterized by a wide range of cargo, various functions of vessels, different operation methods and distinct regulatory arrangements and contracts. The container represents only one type of cargo that is moved in ports and terminals. Container transport is one method of moving goods which requires specialized ports and terminals.

The main two components of the ocean shipping market are ocean carriers and sea ports. The functions and operation features of the two main participants are driven by the requirements of transporting various commodities, the nature and physical varieties of the carried cargo determine the different design of ships that carry it and terminals that handle it. Consequently, the type, value, and quantity of the commodity that needs to be transported and handled, together with the capital requirement of the ship and infrastructure, determines the shipping and handling operation mode (Qianwen Liu, 2010).

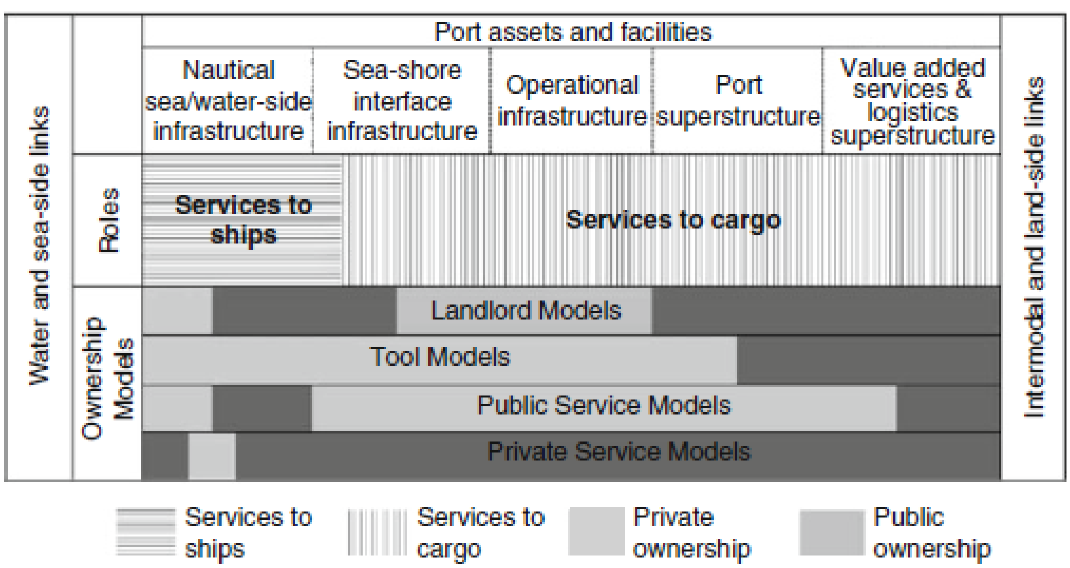
## 2. The Operation and Cost Structure of Sea Ports

In the past ports were dominantly managed in their entirety by port authorities that were selling transshipment and other port services. On some occasions, terminals were leased to private companies. Privatization marks a reversal in the trend of having ports as public entities since many became inefficient, unable to cope with market pressures (performance, reliability and quality of service) and provide adequate financing for infrastructure and equipment becoming increasingly capital intensive. As public agencies, many port authorities were seen by governments as a source of revenue and were mandated to perform various non-revenue generating community projects, or at least provide employment.

The emergence of specialized and capital intensive container terminals servicing global trade has created a new environment for the management of port terminals, both for the port authorities and the terminal operators. Port authorities are gradually incited to look at a new array of issues related to the governance of their area and are increasingly acting as cluster managers. For port operations that have conventionally be assumed by port authorities, a significant trend has been an increase in the role of private operators where major port holdings have emerged with the purpose to manage a wide array of terminals, the great majority of which are containerized.

The World Bank (2007) has outlined four administration/operation models: Public Service Port, Tool Port, Landlord Port, and Private Service Port (Figure 3.1).

**Figure 3.1: Variations of Functional Roles and Institutional Models across Different Port Services and Facilities**




Source: Bichou et al. 200

In a *Public Service Port*, the Port Authority owns the land, infrastructure and equipment, all assets of the port, and performs all regulatory and port functions.

The cargo handling operations are performed by labour that is directly employed by the Port Authority. All costs are covered by the Port Authority.

In a *Tool Port*, the Port Authority owns the land, infrastructure and most equipment including quay cranes, forklift trucks, etc., and the cargo handling operations are performed by labor that is employed both by the Port Authority and private operators. Port Authority staff usually operates all equipment it owns. Other cargo handling is usually carried out by private cargo handling firms contracted by the shipping agents or other principals licensed by the Port Authority. Therefore, the costs of infrastructure and superstructure are covered by the Port Authority. The equipment and labor costs are shared between Port Authority and stevedore.

In a *Landlord Port*, the Port Authority owns the land and infrastructure and the infrastructure is leased to private operating companies. The private operating company provides and maintains the equipment and employs labor to handle cargo. For this kind of port, only the cost of infrastructure falls under the account of the Port Authority; all other costs are covered by the stevedore.

In a *Private Service Port,* port land, infrastructure and equipment are all owned by the Privet sector. All regulatory functions and operational activities and labor are performed by private companies.

## 3. Structure of Global Container Shipping

The global container shipping system is characterized by a hub and spoke structure. In a hub and spoke system of containerized seaborne trade, cargo to a region is delivered first to a primary hub port and then transported to its final destination (whether by sea, rail, road or inland waterways). Similarly, exports from the region are collected in the primary hub, and then transported to final destination. While these primary ports are often equipped to allow for a quick turnaround time of vessels, there are usually two primary characteristics that set them apart from other ports:

a) The primary hubs tend to be geographically central to the region (sometimes with a substantial hinterland – that is, it attracts a considerable amount of cargo that would in any case flow through that port)
b) Can accommodate larger vessels than other ports in the region. The appearance of this system in global shipping is depicted in Figure. 3.2 and distinguishes three types of nodes (hubs, relay centers, and feeders), and, similar to air transport, between two primary cargo markets: origin / destination (O/D transport) and Transshipment. (European Commission, Technical Note N° 19-Maritime container trends)

In addition, per primary market a further split into several sub-markets, can be made as shown in Table 3.1.

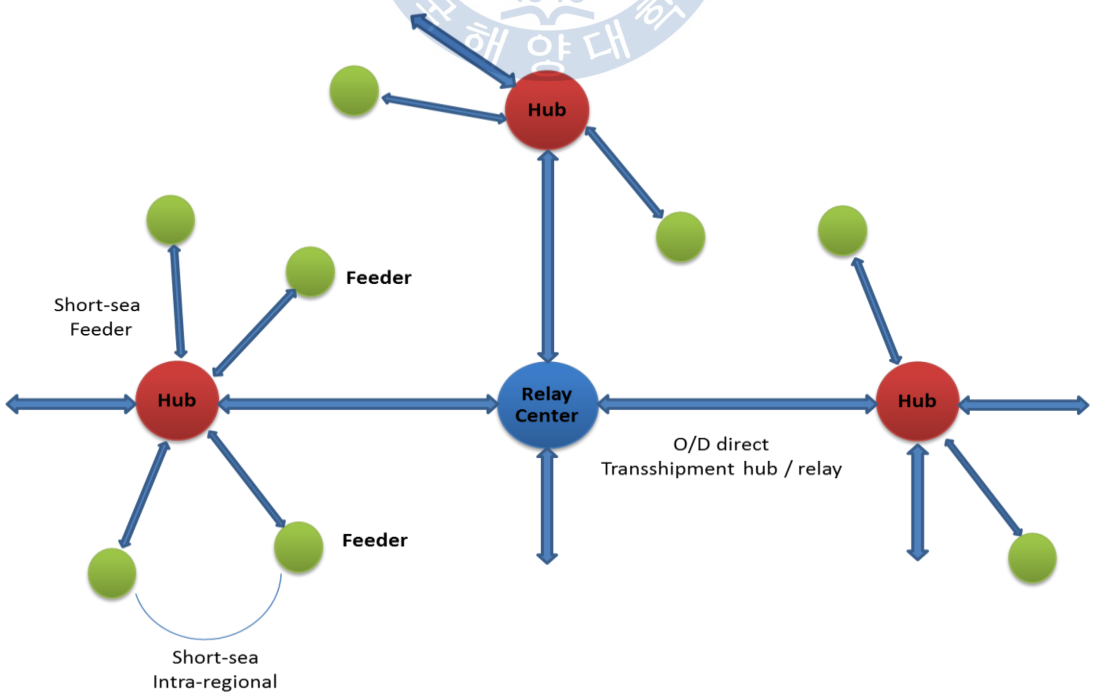
**Table 3.1: cargo markets in container shipping**

| **Cargo markets in container shipping** |
|---|
| ***Origin/destination (hinterland) traffic*** |
| ⇒ *Cargo for immediate port hinterlands and for other inland points* |
| 1. Intercontinental services on deep-sea vessels which call directly (deep-sea direct) |

| |
|---|
| 2. Intra-regional cargo carried on smaller vessels (short/near-sea intraregional) |
| 3. Cargo carried on feeder services having been transshipped at other ports (short-sea feeder). |
| ***Transshipment traffic*** |
| ⇒ *Transfer of containers from one vessel to another. Containers are held in the terminal waiting reshipping on another vessel.* |
| 1. Cargo originating in or destined for the region in which it is handled at hub ports by connecting sea feeder services (hub and spoke transshipment). |
| 2. International relay traffic originating in and destined for areas beyond the immediate regional market (relay transshipment), this being transshipment of cargo between connecting deep-sea vessels and having no involvement with the regional cargo market. |

*Source: Drewry 2000, Mediterranean Container Ports and Shipping*

**Figure 3.2: Structure of International Container Shipping**




Source: European Commission, Technical Note N° 19-Maritime container trends

# 4. Functions and Configuration of the Container Port/Terminal

Container terminal management is a very complex system, and then it may be that the only way it can reasonably be addressed is to develop a number of modular components that are specialized for solving a particular aspect of it.

The set of operations to be conducted in the terminal is very extensive, but the alternative approaches share some common systems (figure 3.3):

## 4.1. Marine Side Interface

Load planning is usually carried out as follows. Before the berthing of a vessel, a shipping company provides the work instruction, called *load profile,* where the slot in which each container must be placed is indicated. A load profile shows several clusters of cells, each one of which is assigned to a group of containers with the same length and that have the same destination port. A color code is used to recognize the different groups of containers. The process of formulation of a load profile is detailed in.

The *work scheduling* takes into account the load profile and the availability of GCs (Gantry Cranes). It sets the sequence used to load the bays of the cargo ship, solving the possible interference among the GCs.

## 4.2. Transfer System

After the work schedule is determined, the load sequencing process begins. The actual assignment of containers to specific locations in a ship bay is performed and the load sequence is determined. The sequencing problem is a very complex one, thus it is broken down into two hierarchical problems: the routing problem for Transtainers and the pickup sequencing problem.

In the **routing problem** for transtainers, the visiting sequence of each transtainer and the numbers of containers to be picked up at each visited yard bay is determined.

In the process, the planner considers the work schedule for the GCs and the yard map, which shows the storage locations of the containers in the yard.

In the **pickup sequencing problem**, the loading for individual containers is determined for the convenience of the handling activities of transtainers and GCs, the stability of the vessel, the maximum staking weight and so on.

## 4.3. Container Storage System

Represents a temporary buffer zone where containers are left while the assigned containership is available to be loaded or while picked up for inland distribution. The larger the containerships handled by a port, the larger the required container storage area.

Commonly, a terminal has also a storage area where reefers (refrigerated containers) can be plugged. About 5% of a terminal's stacking area is commonly devoted to the storage of reefers. Specific storage areas are also attributed to empties.

The allocation of containers on the yard is a problem that directly affects the previous two systems. A bad container distribution forces the transtainer to make more movements and the GCs to be inactive more time, which increases the loading time.

The way to reduce the useless transtainer movements is to increase the stacking density. Then, all the containers are allocated in close areas and the time dedicated to the movements is reduced.

Typically, the applications for the management of container terminals divide the work into two tasks: the yard configuration and the automatic container allocation.

The **yard configuration** problem deals with the assignment of the stacks to one shipping company making a specified route. This is called a *Service* in the container terminal. All the containers which have to be unloaded to one of the ports of this route must be allocated to the same area in order to improve the load/unload time.

The containers are also organized by taking into account the vessel, onto which they

## 4.4. Land Side Interface

The goal of this system is to control the access to the terminal of the trucks, which carry or take away the containers.

The information is introduced into the system using EDI messages. The shipbroker can send the container data through Internet to the terminal. When the container arrives, their data and the EDI message are compared to check their accuracy.

Another task is the control of the terminal access gates, identifying both the truck and the container using artificial vision techniques. In this way, an unattended gateway system, which speeds up the truck admission, is achieved and global productivity of the terminal is increased, thus the main components of the landside interface are the gate and the administration can be presented as following

*a) Gate.* It is the terminal's entry and exit point able to handle in many cases up to 25 trucks at once for a large terminal facility. The gate is where the truck driver presents proper documentation (bill of lading) for pick up or delivery. Most of the inspection is done remotely with cameras and intercom systems where an operator can remotely see for instance the container identification number and verify if it corresponds to the bill of lading. Modern management systems no longer require paperwork since all the documentation is kept in an electronic format interchangeable through secure connections. The priority is to verify the identity of the truck driver, the truck, the container and the chassis. For a delivery, the truck is assigned to a specific slot at the truck loading or unloading area where the chassis holding the container will be left to be picked up by a holster or a straddler. For a pickup, the truck will be assigned to a slot in a waiting area while the container is been picked up from a storage area, put on a chassis (if the truck does not bring its own chassis) and brought to the proper slot. The truck will then head out of the terminal, be inspected to insure that the right container has been picked up and head inland. If well managed (such as using an appointment system), the container will already be available for pick up (on a chassis in the truck loading / unloading area). However, delays for pick up can sometimes be considerable (hours) when a large containership has just delivered a significant batch of containers and there is a "rush" to be the first to pick them up. Therefore, substantial efforts have been made in recent years by terminal operators to improve the throughput of terminal gates through better design and with the application of information technologies.

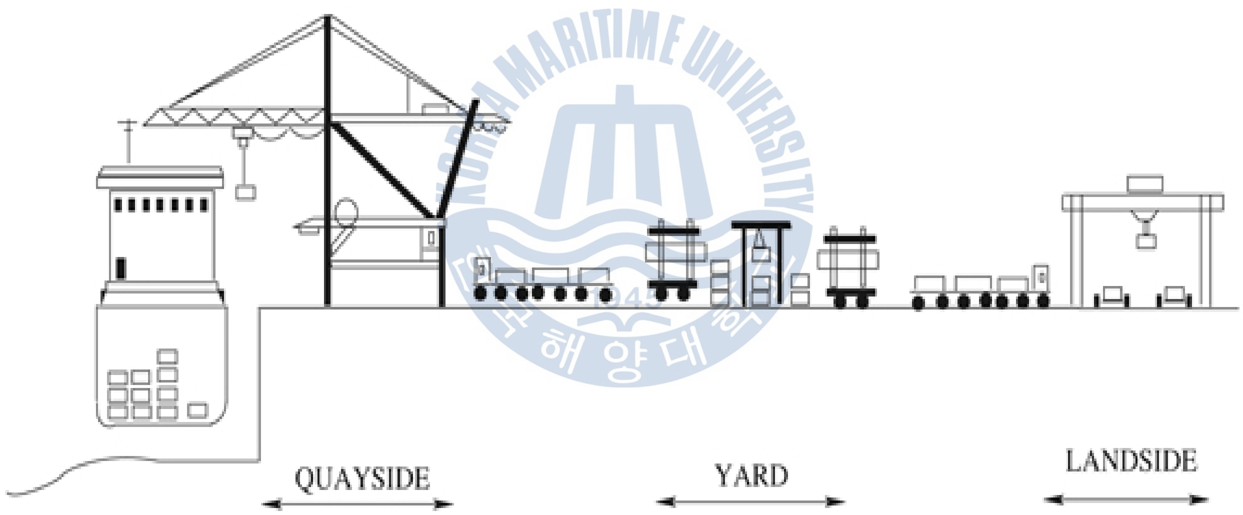
*b) Chassis Storage.* Area where empty chassis are stored while waiting to be allocated to a truck or a holster. In inland freight distribution, there are on average three chassis available per container. While in the past freight haulers such as maritime shipping companies maintained their own chassis fleets, the tendency has been the setting of chassis pools, enabling better asset utilization levels.

*c) On-Dock Rail Terminal.* Many large container terminals have an adjacent rail terminal to which they are directly connected to. This enable the composition of large containerized unit trains to reach long distance inland markets through inland ports. An important advantage of on-dock rail facilities compared with near-dock rail facilities is that the container does not require to clear the gate of the marine terminal.

*d) Repair / Maintenance*. Area where the regular maintenance of the terminal's heavy equipment is performed.

Areas nearby container terminals tend to have a high concentration of activities linked to freight distribution such as distribution centers, empty container storage depots, trucking companies and large retailers.

**Figure 3.3: a Typical Container Terminal System**




Source: Monaco, Moccia and Sammarra (2009)

## 5. Technical Changes in Container Port / Terminals

With the growth of traffic and economies of scale applied to maritime shipping, port terminals are facing pressures to improve their productivity and efficiency. A standard container port accommodating panamax and post-panamax containerships has a set of technical characteristics related to berthing depth, stacking density, crane productivity, dwell time, truck turnaround time and accessibility to rail services. A new generation of container port terminals is gradually coming online with significant improvements. This involves new infrastructures, equipment and procedures (Table 3.2). It is also a matter of competitiveness, both on the maritime and inland sides since port terminals are competing with other port terminals to service continental hinterlands.

**Table 3.2: Technical Changes in Container Port / Terminals**

| | Standard Container Port | Emerging Paradigm |
|---|---|---|
| Berthing depth | 12 to 15 meters (40 to 50 feet) | More than 15 meters (50 feet) |
| Stacking density | 1,000 to 1,200 TEUs per hectare | 2,000 to 4,000 TEUs per hectare |
| Ship-to-shore gantry crane (portainer) productivity | About 20-30 movements per hour | About 40-50 movements per hour |
| Daily throughput per ship | 3,000 to 4,000 TEUs | 5,000 to 6,000 TEUs |
| Dwell time at container yard | About 6 days | About 3 days |
| Truck turnaround time | About 60 minutes | About 30 minutes |
| Rail access | In port area | On dock |

Source: http://people.hofstra.edu/geotrans/eng/ch4en/conc4en/tbl_technicalchangesports.html

# CHAPTER Ⅳ Port Industry in the Mediterranean Region

## 1. Introduction to the Mediterranean Ports Environment

The Mediterranean region “also called Mediterranean basin, or the Mediterranean”, is all the islands and continental lands around the Mediterranean Sea (figure 4.1), it is a crossing point of the three continents, Africa, Europe, and Asia, the sea is bordered by 24 countries with a total of about 56 commercial ports and terminals. Thus the Mediterranean port system presents lot of heterogeneities starting by hinterland markets served, to its various set of ports including large ports as well as a whole series of medium sized to smaller ports, with a certain variety of commodities handled and location qualities, (Notteboom, 2010), these elements of diversity determine the ports hierarchy and competition in the region; with a predominance of ports situated on the northern part of the Sea especially ports situated in the EU countries

Another element that sustains the dominance of northern ports is that port system in south Mediterranean countries has been generally suffering from a proven lack of efficiency. This weak point is due to both significant shortcomings at ports (lack of storage space, dearth of gantry cranes, etc.) and the fact that hinterlands are often geographically remote and poorly connected to their ports (Med 2010 Panorama).

**Figure 4.1: Ports in the Mediterranean Basin**


Source: Razouls C., de Bovée F., Kouwenberg J. et Desreumaux N., 2005-2011



However more precocious in the North than in the South, Mediterranean ports have marked the onset of a regional specialisation in containerized traffic, leading to significant adaptation of existing ports and construction of new ones capable of handling larger ships (terminal extensions, new gantry cranes, etc.), and lately Ports in the South are even catching up to European ports in terms of capacity and logistic performance thanks to “megaprojects” made possible by both public and private investments motivated by the globalisation and container and logistics revolution occurring over the past two decades, which creates a real scrambling of port hierarchy in the region.

## 2. Maritime Traffic in the Mediterranean Sea

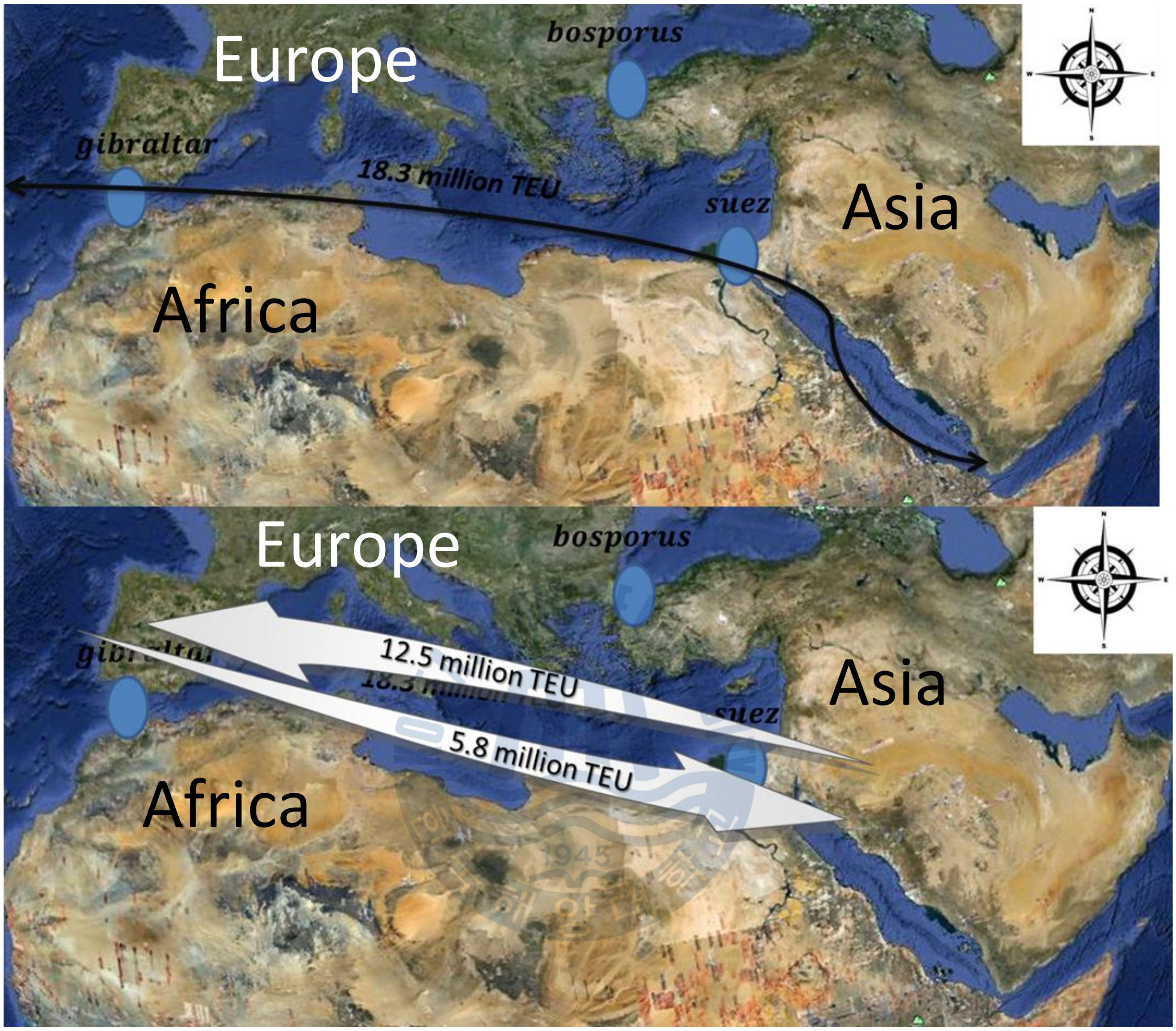
The vocation of the Mediterranean serving as a crossroads of continents has grown stronger over the past few years giving two predominant trends that can currently be observed about the maritime traffic in the Mediterranean Basin. First As a ‘maritime route’ that, as such, is one of the world’s major trade routes, Second as a ‘landlocked sea’ through which coastal countries develop their trade it prioritizes proximity and a regional definition of the area. Table 4.1 shows Volumes of Ex/Intra-Med Sea Traffic for Non-Bulk Cargo

### 2.1. Extra-MED Traffic

Nearly a third of world trade ‘passes’ through the Mediterranean basin, from the mouth of the Suez Canal to the Straits of Gibraltar and the Bosporus, from the Atlantic to the Black Sea, And as a ‘crossroads’ of continents (European, Asian and African) whose trade is growing with globalisation, EU-Asia trade is amounted to approximately 210 million tonnes in 2006, and the containerization rate for non-bulk traffic is often greater than 80 and even 90%. Container traffic represents over 150 million tonnes (Med 2009, Panorama), i.e. container traffic from Asia to Europe, has been estimated at 18.3 million TEU in 2006, with the breakdown of 12.5 million TEU on the leg from Asia to Europe, and 5.8 million TEU in the opposite direction (UNCTAD 2007, see Figure 4.2).

Trade by South Mediterranean Countries with the rest of the world apart from Europe consists of approximately 280 million tonnes. Yet this traffic is essentially comprised of bulk cargo, amounting to nearly 200 million tonnes, including oil. The transport of ‘nonbulk’ products, which are also most often containerised, is estimated at 80 million tonne (Med2010, Panorama).

**Figure 4.2: Extra-MED Containers Traffic in 2006**




Source: Author, Adapted from Google Earth

## 2.2. Intra-MED Traffic

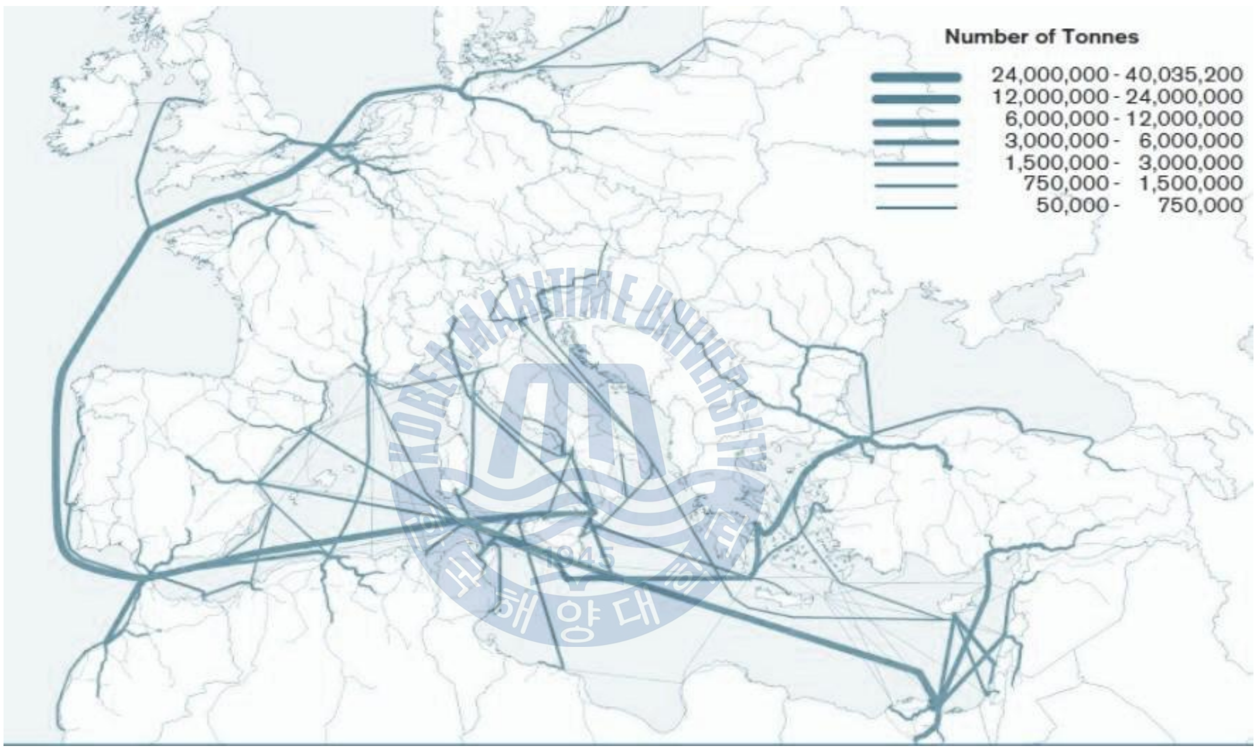
At this level three types of flows can be identified as following:

- Trade between the EU and SMCs (South Mediterranean Countries).
- Trade among the SMCs themselves.
- Trade among EU Member States bordering on the Mediterranean.

Even with significant port investment intra-Mediterranean exchanges remain quite low with respect to exchanges with Asia and do not alter the status of the Mediterranean as a “transit sea” (Bleu Plan Notes N°14 Marsh 2010).

Figure 4.3 shows the intra-Mediterranean trade volume for the year 2006

**Figure4.3: Intra-Mediterranean Trade 2006**




Source: NESTEAR, 2008; Eurostat COMEXT, 2006.

Nevertheless efforts are spent by the Mediterranean Community to consolidate and promote the maritime transport among Mediterranean countries. We can mention as example the European Neighbourhood Policy’s Regional Transport Action Plan (RTAP) 2007-2013, initiated by the EU in cooperation with non-EU Mediterranean shoreline countries, which aims to consolidate and intensify cooperation and exchange in the Mediterranean Region regarding maritime transport.

The SMCs display a high degree of dependence, trade with the EU representing 30-70% of their foreign commerce. This dependence is more marked for Maghreb countries (West North African) than for eastern Mediterranean countries, even if all of these countries have experienced a diversification of foreign trade, associated with globalisation. On the other hand the situation is not reciprocal. Mediterranean countries represent 5-20% of the EU's foreign commerce for the southern EU Member States of Spain, France, Italy and Greece. It represents a considerable volume, standing at 425 million tonnes in 2006, a large part of which consists of bulk products and, in particular, petroleum products imported by Europe. In 2006, Europe imported 285 million tonnes of liquid and solid bulk products, as compared to only 33 million tonnes of bulk products exported.

**Table 4.1: Volumes of Ex/Intra-Med Sea Traffic For Non-Bulk Cargo**

| **Extra-MED Traffic (in billions of tonne-km)** | **598 billion tonne** |
|---|---|
| EU | 400 |
| South/East MED (Europe excluded) | 198<br>(113: Asia; 85: Atlantic) |
| **Intra-MED Traffic (in billions of tonne-km)** | **176 billion tonne** |
| Med-EU | 165 in MED<br>65 Atlantic North Sea |
| South-South | 11 |
| **Total** | **774 billion tonne** |

Source: Med.2009 Panorama

# 3. Structure of Container Trade in the Mediterranean

## 3.1 In Global Perspective

The maritime container transport structure in the Mediterranean mirrors the structure of the liner shipping industry on a worldwide level with hubs, relay centers, gateways and spoke ports. A recent phenomenon within global maritime shipping is the establishment of East-West pendulum routes and North-South feeder routes. The oceanic "pendulum" routes travel mainly between the Far East, Northern Europe and North America and are the main lines that feed the hub and spoke system in this zone. On these routes, the top twenty liner shipping companies play a major role and the entrance barriers, at least in terms of ports controlled by 'incumbents', are stronger given the particular geographical configuration. There are mainly local, less specialized and more competitive companies involved on regional, international, short to medium range, North to South, specialized and feeder etc. routes (over 50 companies offer Intra Mediterranean services). As can be seen from Figure 4.4 these main routes cross the Mediterranean and create opportunities for hub ports and, more specifically, for relay centers.

**Figure 4.4: 'Pendulum' Routes Linking the Far East, Northern Europe and North America**


*Source: Euro-Mediterranean Network of Investment Promotion Agencies (ANIMA), 2005*

## 3.2. Mediterranean Container Shipping Structure

Over the past decades, the changing container shipping structure has changed the face of Mediterranean container shipping. The hub and spokes model, adopted by the big companies, led to an important structural transformation in the Mediterranean. The establishment of transshipment (hub and relay) ports has benefited some ports in the area over others, changing the competitive landscape. Traditional gateway ports such as Livorno and Marseilles-Fos were outgrown by transshipment ports such as Gioia Tauro, Algeciras, and Marsaxlokk. Currently, this new organization coexists with the previous one, obviously resulting in a different distribution in traffic quotas between the more traditional direct services systems and the new network systems (Foschi, 2003). The primary function of the majority of Mediterranean ports remains as gates to the national hinterland, due to political and geographical reasons. Some ports are also serving as hub centers, more specifically, the Spanish ports of Algeciras, Valencia and Barcelona, the Italian ports of Gioia Tauro, La Spezia and Genoa, Malta, and the ports close to the Suez Canal, Damietta and Port Said. The forecast for the future is that the balance will be tipped in favor of hub and spoke organization.

# 4. Changing Landscape

An energy transport and containerization hub, a zone of transit between Europe and Asia, the Mediterranean has seen, over the past 10 years, an intensified flow of goods, driven by the combined effect of demographic pressure, economic growth and trade liberation. In response to the growth of long-distance exchanges, ship size has significantly increased, driving countries to seek to equip themselves with appropriate port infrastructures; Numerous port creation or expansion projects have seen the light throughout the Mediterranean coastline (figure 4.5), as result the balance of power between North and South Mediterranean ports has been overturned and Ports in the South are catching up to European ports in terms of capacity and logistic performance thanks to "megaprojects. "The Tanger-Med port (near Tangiers), the most visible of all, inaugurated in 2007, should attain a capacity of 3 million containers by 2013 (and 8M eventually). Built from scratch, this port was supposed to reach a level of container traffic equivalent to the port of Marseille by the end of 2009, despite the crisis (*Les Echos*, 22 July 2009), testifying to the power of attraction of these new projects in the South. Other, likewise important projects are being completed (extension of Port Said and the new port of Sokhna in Egypt) or developed (Enfidha in Tunisia). and Generally speaking, nearly all other ports from the Maghreb to the Balkans have undertaken work to upgrade their infrastructures as well. Therefore, though the ports on the North shore have a geographical advantage as points of direct entry to the EU, the south-shore ports have the advantages of being located on the mega-containership route, offering less costly services and above all, offering high-tech logistics services at recently-built port.

**Figure 4.5: Mediterranean Ports Situation In 2010**


Source: F.Laroche. 2010, Med 2010 Panorama

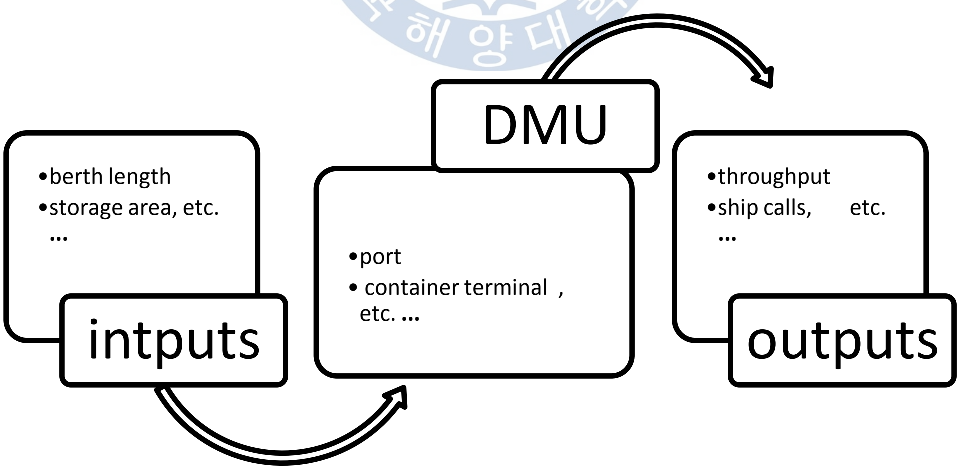
# CHAPTER Ⅴ DEA Methodology and Analysis Results

## 1. The Concept of Data Envelopment Analysis (DEA)

DEA (Data Envelopment Analysis) is an efficiency evaluation model based on mathematical programming theory. DEA offers an alternative to classical statistics in extracting information from sample observations

The concept of DEA is developed around the basic idea that the efficiency of a DMU (Decision Making Unite) is determined by its ability to transform inputs into desired outputs. (Geoffrey Poitras, et al. 1995); (Figure 5.1), thus any entity that receives a set of inputs and produces a set of outputs could be designated as a DMU able to be analyzed by DEA.

**Figure 5.1: the Basic Concept of DEA**




Source: Author

The efficiency score is the ratio of the presence of multiple input and output factors, it is defined by:

$$Efficiency = \frac{\sum weighted\ outputs}{\sum weighted\ inputs}$$

Adjusted to be a number between 0 and 1, e.g. the less inputs consumed and the more outputs produced, result for more efficient in a DMU, The ratio assumes that there are n *DMUs*; each

with m inputs and s outputs, the relative efficiency score of $DMU_p$ is obtained by solving the following model proposed by Charnes et al. (1978):

$$Max \frac{\sum_{k=1}^{s} U_k \ y_{kp}}{\sum_{j=1}^{m} V_j x_{ip}} \qquad (1)$$

*S.t.*

$$\frac{\sum_{k=1}^{s} U_k \, y_{ki}}{\sum_{j=1}^{m} V_j x_{ji}} \leq 1 \text{.....all in i, and } U_k \ V_j \ \geq 0 \text{...all in k, j,} \qquad (2)$$

Where:

k=1 to s,
j=1 to m,
i=1 to n,

$Y_{ki}$ =amount of output k produced by $DMU_i$,
$x_{ji}$ =amount of input j utilized by $DMU_i$,
$u_k$=weight given for output k,
$v_j$=weight given for input j.

The constraints mean that the ratio should not exceed 1 for every $DMU$, the objective is to obtain weight $U_k$ and $V_j$ that maximize the ratio of $DMU_i$, the $DMU$ being evaluated.

The computation of the above equations can be easily converted to a linear programming form as in LP (3)-(5) following:

$$Max \sum_{k=1}^{s} U_k \ y_{kp} = \theta_p \qquad (3)$$

*S.t.:*

$$\sum_{j=1}^{m} V_j \, x_{ji} = 1 \qquad (4)$$

$$\sum_{k=1}^{s} U_k \ y_{ki} - \sum_{j=1}^{m} V_j \, x_{ji} \leq 0 \text{.....all in i, } U_k \ V_j \ \geq 0 \text{.......all in } k, j \qquad (5)$$

The above iteration is run n times; the weight of $u_k$ and $v_j$ under the constraint of $DMU_p$can identifying the relative efficiency scores of all $DMU_s$ greater than one. The values of $\theta_p$ in (3) are the performance score of $DMU_p$ relative to all $DMU_s$ between zero and one. The optimal objective value is for equation (4), the values of input and output must be nonzero and positive (5) unless the result are not significant. In general, a DMU is considered to be efficient if it obtains a score of 1 and a score of less than 1 implies that it is inefficient.

The $\varphi_k$, and $\lambda_j$ are dual variables and $\varphi_k$ is an optimal value for the performance score of $DMU_k$ and $\lambda_j$ is the weight concern the $DMU_j$ use to produce the value of $DMU_k$.

The combination of the two models results as fellow:

a) CCR Model (Charnes, Cooper & Rhodes) (Figure 5.2)

$$Max \ ^{\emptyset_k}$$

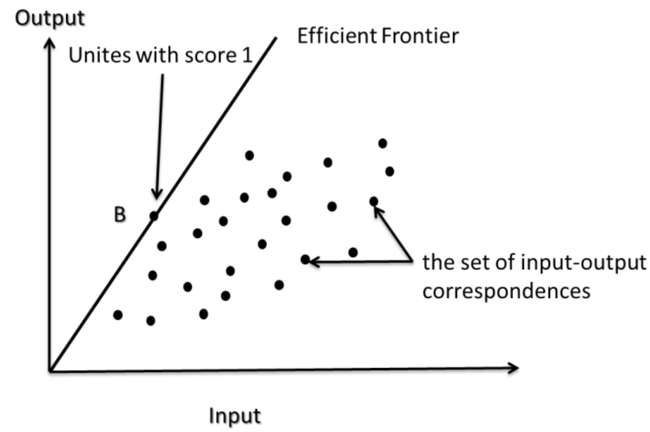
S.t.

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \emptyset_k x_{ik} \qquad \text{i= 1, 2..., m;} \qquad (6)$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \ \geq y_{rk} \qquad \text{r= 1, 2..., s} \qquad (7)$$

$$\lambda_j \geq 0 \qquad \text{all in j.}$$

**Figure 5.2: Graphical Depiction of DEA-CCR Model**

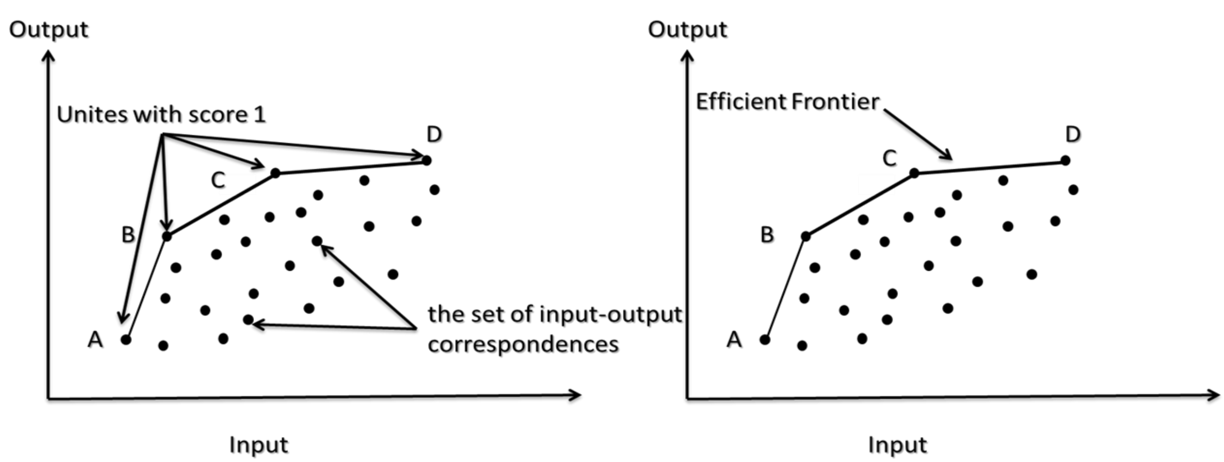



Source: Author

b) BCC Model (Banker, Charnes and Cooper) (Figure 5.3)

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad (8)$$

**Figure 5.3: Graphical Depiction of DEA-BCC Model**




Source: Author

Through the equations of BCC model we see that all $\lambda_j$ are now restricted to summing to one, given by convexity constraint. The output- oriented measure of technical efficiency of k-p DMU is:

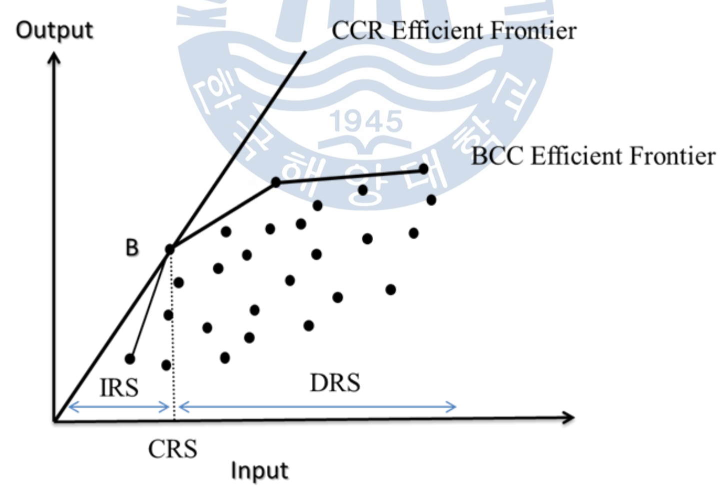
$$TE_k = 1/\sum_{k=1}^{s} u_k y_{ki} \qquad (9)$$

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

$$\text{SE} = u_{ccr}/u_{bbc} \qquad (10)$$

Equation *(10)* used to measure the score efficiency of $DMU_k$, if $SE_k$=*1* then the score is efficiency if $SE_k$<*1* the score is inefficiency.

**Figure 5.4: Graphical Depiction of DEA Return to Scale**




Source: Author

## 1.1. DEA Super Efficiency Ranking

DEA divides the MDUs into two groups the first one contains efficient DMUs having the same score 1, the second one contains inefficient DMUs with scores less than 1, In the second group (inefficient) the DMUs are ranked according to their scores from the less inefficient to the most inefficient, on the other hand the efficient DMUs have all the score 1; to rank the efficient units Super-efficiency method (Andersen and Petersen, 1993) is applied.

To allow the efficient units to receive a score greater than 1 by dropping the constraint that bounds the score of the evaluated unit k; namely the primal problem of Anderson and Peterson (A&P) of unit k will be formulated as follows:

$$h'_{kk} = \text{Max} \sum_{r=1}^{s} u_{rk}\, y_{rk}$$

s.t.

$$\sum_{r=1}^{s} u_{rk} y_{rj} - \sum_{i=1}^{m} v_{ik}\, x_{ij} \leq 0 \quad \text{for j=1,...,n } j \neq k$$

$$\sum_{i=1}^{m} v_{ik}\, x_{ik} = 1$$

$$u_r \geq \varepsilon \qquad \text{for r = 1,...,s}$$

$$\boldsymbol{v_i \geq \varepsilon} \qquad \text{for I = 1,...,m}$$

where $x_{ij}$ is input i of unit j, there are m inputs and n units; $y_{rj}$ is output r of unit j, there are s outputs; $u_{rk}$ is the ideal weight assigned to output r of unit k; $vi_k$ is the ideal weight assigned to input i of unit k; $\varepsilon > 0$ is a non-Archimedean infinitesimal; and $h'_{kk}$ is the A&P score of unit k. The dual problem, as stated by A&P is given below:

Min E – ε $(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+)$

s.t.

$$E_k x_k = \sum_{\substack{j=1 \\ j \neq k}}^{n} \lambda_j \; x_{ij} + \; s_r^+ \quad \text{i=1,..., m;}$$
$$y_k = \sum_{\substack{j=1 \\ j \neq k}}^{n} \lambda_j \, y_{rj} - s_r^+ \qquad \text{r= 1,..., s;}$$
$$\lambda_j, s^+, s^- \geq 0$$

The basic idea is to compare the unit under evaluation (k) with a linear combination of all other units in the sample, i.e. the unit itself is excluded. Intuitively, this means that unit k is removed from the frontier and $h'_{kk}$measures its distance from the new frontier.

## 1.2. Output Oriented DEA

Output oriented efficiency is a measure of the potential output of a DMU given that inputs are held constant, "at the opposite of the input oriented efficiency which aims to assess the minimum amount of inputs required for a given DMU to produce a fixed amount of outputs". Färe *et al.* (1994) modeled the output technical efficiency measure for any DMU using linear programming:

$$\underset{\theta, z}{\text{Max}} \; \theta$$

s.t.

$$\theta u_{jm} \leq \sum_{j=1}^{J} z_{ij} u_{jm}, \text{ m=1, 2,..., M,}$$
$$\sum_{j=1}^{J} z_j x_{jn} \leq x_{jn}, \text{ n=1, 2,..., N, and}$$
$$z_j \geq 0, \text{ j = 1, 2,..., J.}$$

Where:

$\boldsymbol{\theta}$: output technical efficiency measure,

$u_{jm}$: Quantity of output m produced by $DMU_j$
$x_{jn}$: Quantity of input n produced by $DMU_j$,
And, $z_j$: Intensity variable for$DMU_j$.

# 2. Measuring Efficiency of Mediterranean Container Ports and Terminals Using DEA

## 2.1. Data and Statistical Analysis

### 2.1.1. Sample's Selection

Due to the large number of ports and substantive differences in the types of cargoes handled, only the performance in handling containerised cargoes across selected ports is examined, 32 container ports and terminals were selected based on geographical location (Mediterranean region), and data availability (Figure 5.5)

**Figure 5.5: Selected Sample of Mediterranean Ports and Terminals**


Source Author (adapted from google earth)

The 32 DMUs comprise Unites including both container ports and individual terminals from 14 Mediterranean countries, number and origins of Units is listed in table 3.

## 2.1.2. Inputs and Outputs

### a) The Various Variables in Port Industry

In port industry there is a range of factors which can be considered and that vary according to the purpose, the target audience that the author has in mind, or the phenomenon in analysis.

In general factors may be related to the port operational performance such as crane productivity, ship turn-round times, berth occupancy, ship waiting times, container dwell times, or financial performance such as the level of revenue per tonne or employee of the Port Authority in the public perspective, since it reflects the output value of the range of services offered and what customers are willing to pay in terms of rates to call the port, given its condition or location.

In any case factors are related to the ability of the port to do more with less. A port may only do more in absolute terms, the performance level of costs, guaranteeing a minimum service, or the possibility to earn more for each ton moved, providing more services (Caldeirinha, V. 2010).

For the port efficiency measurement the variables are divided into inputs and outputs, the definition of the port output depends on the service considered, for example if the towing activity is considered the output will be the towed ships, that can be measured in physical unites, unites of tonnage, in some cases the income that the merchandise generates for the port firms is considered as output, or the prices of labor and capital, Barros (2005), but in most cases the output is measured in physical quantity of merchandise by employing the total quantity of cargo,  Estache et al (2002), or Number of containers in TEU for those analyzing container terminals, Soonhoo So, et al (2007), Notteboom, et al (2000)

In the second case distinction between outputs can be considered, such as container liquid bulk, remaining cargo and passenger which can be used in the same study as multiple outputs if the available data allows it, Coto-Millan, et al (2000), Valentine (2001). In addition to the physical quantity of the cargo handled the factors related to the ships such as ship's calls can be considered. In the reviewed studies the paper that distinguishes the greatest quantity of outputs is Barros (2003b) by including number of ships, movement of freight, break-balk cargo, containerized freight, liquid bulk, and solid bulk.

For the inputs nearly all empirical applications consider the labor and capital inputs, with a divergent ways to approach labor input by using number of employees, or by using hours worked, or a monetary approach such as the value of salary payment and estimating capital input,

Some authors considers that there is a fixed relation between number of port workers and number of equipment (ex, number of cranes), so they don't incorporate the labor input Notteboom, et al (2000)

Cullinane, et al (2003) defines input capital as the net value of fixed capital. The first is calculated including lands, buildings, dock structure, roads, plant and equipment and the second distinguishes between buildings and land, and mobile and cargo handling equipment, the approach is used by Barros (2003b), without specifying the asset he incorporates. Coto-Millan et al (2000) identify two types of capital, variable (percentage of net value), and quasi-fixed (linear meters of dock), studies also incorporate the surface of area of the port, Notteboom et al (2000) incorporated three variables to measure the capital used by the container terminal, docks, surface and cranes. Sea side input can be represented by number of tugboats.

Park and De (2004) employ the following variables to represent the inputs; docking capacity, cargio handling capacity (productivity and overall efficiency), cargo throughput and number of ship calls (profitability), revenue and consumer satisfaction (marketability).

## b) Selection of Inputs and Outputs for the DEA Model

The basic function of a container terminal is the transfer and storage of containers. Terminal operators are accordingly concerned with maximizing operational productivity as containers are handled at the berth and in the marshaling yards, and with efficiently utilizing available ground space. Container handling productivity is directly related to the transfer functions of a container terminal, including the number and movement rate of quayside container cranes, the use of yard equipment, and the productivity of workers employed in waterside, landside, and gate operations. The efficient use of available ground space relates to the number of containers stored in a given area of the terminal. Improving the utilization of ground space typically reduces the operational accessibility to containers. The challenge is therefore to define container accessibility in relation to ground space utilization based on a terminal's operational targets and unique physical characteristics (table 5.1).

**Table 5.1: Common Productivity Measures of Container Terminals**

| **Element of Terminal** | **Measure of Productivity** | **Measure** |
|---|---|---|
| **Crane** | Crane Utilization<br>Crane Productivity | TEUs/Year per Crane<br>Moves per Crane/Hour |
| **Birth** | Berth Utilization<br>Service Time | Vessel/Year Per Berth<br>Vessel Service Time(Hour) |
| **Yard** | Land Utilization<br>Storage Productivity | TEUs/Year Per Acre<br>TEUs/Storage Acre |
| **Gate** | Gate Throughput<br>Truck Turnaround Time | Container/Hour/Lane<br>Truck Time in Terminal |
| **Gang** | Labor Productivity | Number of Moves/Man-Hour |

Source: Lee-Griffin, H.D and Murphy, M 2006

For the analysis of efficiency Labor and capital are two generic used inputs; and as it is said above container terminal depends crucially on the efficient use of labor, land, and equipment. We use quay and yard equipment as proxies of labor and the total berth length, terminal's area and storage capacity as those of capital, the most generic outputs used in port efficiency analysis literature are port throughput and ship calls due to limitation of data resources only the annual throughput of each terminal is considered in this study,

Although there is no optimal way to decide the number of inputs and outputs, it is appropriate that the relationship among the numbers of DMUs, inputs and outputs should fulfill this condition $\mathbf{n \geq max\ [m \times s, 3\ (m + s)]}$ where $n$ is the number of DMUs, $m$ is the number of inputs and $s$ is the number of outputs (Raab and Lichty, 2002; Cooper et al., 1999; Boussofiane et al., 1991; Banker et al., 1984), The combination of indicators measured in this study fulfill both conditions; the minimum number of DMU observations is greater than three times the number of inputs plus outputs [(32≥3 (5+1)]. and also observes the convention that the minimum number of units is equal to or larger than the product of the number of outputs and inputs, therefore the constructed DEA model for this study has a high structure validity.

To estimate the efficiency of ports under study a Cross-sectional Data for the year 2008 has been used; as inputs indicators we considered the terminal area ($m^2$), Storage capacity (TEU), Total quay length (m), and yard and quay equipment separately (Unites). Containers annual throughput is considered as output indicator. (Table 5.2) All the information comes from Containerization International Yearbooks 2010 for the year of 2008; missed data on containerization International Yearbook 2010 were completed by e-mail requests to the concerned port authorities, or from Ports official sites.

## Table 5.2: Characteristics of Selected Terminals for the Year 2008

| country | port | container terminal | outputs | inputs | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Annual Throughput (TEU) | total area (m²) | total quay length (m) | quay cranes (number) | yard equipment (number) | storage capacity (TEU) |
| Algeria | Bejaia | mediteranean terminal | 117,372.00 | 90,000.00 | 500.00 | 2.00 | 34.00 | 9,000.00 |
| Egypt | Port Said | Port said | 811,222.00 | 467,130.00 | 970.00 | 9.00 | 82.00 | 24,000.00 |
| | | suez canal | 2,390,778.00 | 600,000.00 | 1,200.00 | 12.00 | 131.00 | 24,000.00 |
| | Damietta | Damietta | 1,195,630.00 | 600,000.00 | 1,050.00 | 10.00 | 143.00 | 30,000.00 |
| | El Dekhila | El dekhila | 446,748.00 | 380,000.00 | 1,040.00 | 6.00 | 79.00 | 20,000.00 |
| France | Marseille | fos | 568,203.00 | 560,000.00 | 1,180.00 | 8.00 | 30.00 | 10,500.00 |
| | | Mourepiane | 279,349.00 | 105,000.00 | 920.00 | 6.00 | 102.00 | 2,500.00 |
| Greece | Piraeus | venizelos | 433,582.00 | 900,000.00 | 3,100.00 | 15.00 | 107.00 | 30,500.00 |
| | Thessaloniki | Thessaloniki | 238,940.00 | 200,000.00 | 600.00 | 4.00 | 48.00 | 4,196.00 |
| Italy | Cagliary | Cagliari International | 256,564.00 | 400,000.00 | 1,520.00 | 8.00 | 93.00 | 24,000.00 |
| | Genoa | Volti | 1,010,000.00 | 202,995.00 | 1,400.00 | 10.00 | 117.00 | 15,000.00 |
| | La spezia | la spezia | 1,051,805.00 | 332,000.00 | 1,138.00 | 11.00 | 77.00 | 13,000.00 |
| | Livorno | Darsena Toscana | 588,778.00 | 412,000.00 | 1,430.00 | 10.00 | 42.00 | 27,000.00 |
| | | Sintermar | 190,086.00 | 131,000.00 | 563.00 | 5.00 | 24.00 | 7,000.00 |
| Lebanon | Beiruth | Beyrouth | 945,105.00 | 244,600.00 | 600.00 | 5.00 | 74.00 | 12,000.00 |
| Libya | Benghazi | Benghazi | 80,088.00 | 4,400,000.00 | 1,228.00 | 3.00 | 44.00 | 24,420.00 |
| | Tripoli | Tripoli | 94,739.00 | 210,100.00 | 1,500.00 | 3.00 | 25.00 | 10,000.00 |
| Morocco | Tangiers | APM | 64,178.00 | 400,000.00 | 2,800.00 | 8.00 | 157.00 | 40,000.00 |
| | | TangerMed TC2 | 50,100.00 | 390,000.00 | 1,600.00 | 8.00 | 47.00 | 35,000.00 |
| Malta | Marsaxlokk | Terminal 1 | 1,456,121.00 | 457,500.00 | 1,000.00 | 11.00 | 203.00 | 10,238.00 |
| | | Terminal 2 | 878,061.00 | 222,500.00 | 1,140.00 | 12.00 | 180.00 | 4,849.00 |
| | Valletta | grand harbour | 73,150.00 | 84,960.00 | 607.00 | 2.00 | 18.00 | 2,000.00 |
| Slovenia | Koper | Koper | 353,880.00 | 200,000.00 | 596.00 | 4.00 | 82.00 | 12,400.00 |
| Spain | Algeciras | APM | 3,208,580.00 | 605,184.00 | 1,491.00 | 21.00 | 177.00 | 12,902.00 |
| | | isla verde TCA | 115,730.00 | 180,000.00 | 680.00 | 2.00 | 13.00 | 5,400.00 |
| | Barcelona | Muelle sur | 1,210,660.00 | 576,100.00 | 1,380.00 | 13.00 | 53.00 | 10,370.00 |
| | Valencia | Valencia public | 1,918,797.00 | 350,000.00 | 1,440.00 | 8.00 | 108.00 | 80,484.00 |
| | castellon de la plana | castellon | 88,208.00 | 100,000.00 | 750.00 | 2.00 | 22.00 | 2,530.00 |
| Syria | Lattakia | Lattakia | 570,000.00 | 120,000.00 | 1,480.00 | 18.00 | 19.00 | 16,000.00 |
| Tunisia | Rades | Rades | 420,000.00 | 325,000.00 | 150.00 | 1.00 | 24.00 | 14,000.00 |
| Turkey | Haydarpasa | Hydarpasa | 360,000.00 | 320,000.00 | 945.00 | 9.00 | 94.00 | 6,000.00 |
| | Mersin | Mersin | 854,500.00 | 994,000.00 | 1,528.00 | 13.00 | 126.00 | 3,000.00 |

**Table 5.3** shows Descriptive statistics for variables in DEA estimation, for the year 2008;

**Table 5.3: Summary Statistics for the Year 2008**

| | total area | total quay length | quay cranes | storage capacity | yard equipment | Throughput |
|---|---|---|---|---|---|---|
| Max | 4,400,000.000 | 200,000.000 | 596.000 | 80,484.000 | 203.000 | 3,208,580.000 |
| Min | 84,960.000 | 150.000 | 1.000 | 4.000 | 13.000 | 12,400.000 |
| Average | 491,060.906 | 7,404.063 | 26.594 | 16,559.156 | 80.469 | 686,858.563 |
| SD | 735,016.968 | 34,596.134 | 102.378 | 15,464.349 | 52.394 | 724,088.317 |

### 2.1.3. Correlation Coefficient among Inputs and Output Factors

The degree of correlation between inputs and outputs is an important issue that has great impact on the robustness of the DEA model. Thus, a correlation analysis is imperative to establish appropriate inputs and outputs. On the one hand, if very high correlations are found between an input variable and any other input variable, this input variable may be thought of as a proxy of the other variables. Therefore, this input could be excluded from the model. On the other hand, if the output variable has very low correlation with all the input variables [i.e.; an increase in any input should not result in a decrease in any output, Chen-Fu Chien et al. (2003)], it may indicate that this variable does not fit the model. Correlation analyses were done for each pair of variables and the Table 5.4 shows the correlation matrix.

**Table 5.4: Correlation Coefficients in Inputs and Output**

| | total area | total quay length | quay cranes | storage capacity | yard equipment | Throughput |
|---|---|---|---|---|---|---|
| total area | 1.000 | -0.031 | -0.034 | 0.159 | 0.015 | -0.020 |
| total quay length | -0.031 | 1.000 | 0.999 | -0.185 | 0.012 | -0.166 |
| quay cranes | -0.034 | 0.999 | 1.000 | -0.185 | 0.032 | -0.137 |
| storage capacity | 0.159 | -0.185 | -0.185 | 1.000 | 0.206 | 0.275 |
| yard equipment | 0.015 | 0.012 | 0.032 | 0.206 | 1.000 | 0.598 |
| Throughput | -0.020 | -0.166 | -0.137 | 0.275 | 0.598 | 1.000 |

No DMUs with inappropriate Data with respect to the chosen Model have been detected which is a validation of the DEA model.

## 2.2. Analysis Results

DEA has been applied to analyze efficiency score of the designated ports and terminals; to compute efficiency two models have been used, DEA-CCR and DEA-BCC, DEA is carried on the 32 Mediterranean ports shown in Table 3.

### *2.2.1. CCR Model*

#### *a) Overall Efficiency Analysis and Improvement Projection*

In the first step output oriented CCR model with constant return to scale has been applied to 32 ports and terminals. DEA Excel Solver software is used for the analysis. The overall efficiency scores are presented in Table 5.5,

## Table 5.5: Relative Efficiency and Reference Sets of Terminals Using CCR Model

| No | DMU | Score | Rank | Reference set (lambda) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | bejaia med terminal | 0.284 | 23 | suez canal | 0.088 | APM Algesiras | 0.013 | Valencia public | 0.083 | | |
| 2 | Port said | 0.526 | 17 | suez canal | 0.454 | Muelle sur | 0.219 | Valencia public | 0.072 | Rades | 0.134 |
| 3 | suez canal | 1.000 | 1 | suez canal | 1.000 | | | | | | |
| 4 | Damietta | 0.572 | 16 | suez canal | 0.770 | Valencia public | 0.049 | Rades | 0.373 | | |
| 5 | El dekhila | 0.348 | 22 | suez canal | 0.430 | Valencia public | 0.068 | Rades | 0.303 | | |
| 6 | fos | 0.821 | 11 | Muelle sur | 0.549 | Lattakia | 0.048 | | | | |
| 7 | Mourepiane | 0.502 | 18 | APM Algesiras | 0.171 | Valencia public | 0.004 | | | | |
| 8 | venizelos | 0.204 | 27 | suez canal | 0.327 | Muelle sur | 0.762 | Valencia public | 0.051 | Rades | 0.759 |
| 9 | Thessaloniki | 0.357 | 21 | suez canal | 0.105 | APM Algesiras | 0.131 | | | | |
| 10 | Cagliary International | 0.157 | 29 | suez canal | 0.585 | Valencia public | 0.120 | Rades | 0.022 | | |
| 11 | Volti | 0.930 | 10 | APM Algesiras | 0.251 | Valencia public | 0.146 | | | | |
| 12 | la spezia | 0.725 | 14 | APM Algesiras | 0.333 | Muelle sur | 0.168 | Valencia public | 0.073 | Lattakia | 0.069 |
| 13 | Darsena Toscana | 0.627 | 15 | Muelle sur | 0.676 | Valencia public | 0.049 | Lattakia | 0.046 | | |
| 14 | Sintermar | 0.392 | 20 | APM Algesiras | 0.066 | Muelle sur | 0.112 | Valencia public | 0.042 | Lattakia | 0.102 |
| 15 | Beyrouth | 0.946 | 9 | suez canal | 0.379 | APM Algesiras | 0.008 | Valencia public | 0.035 | | |
| 16 | Benghazi | 0.100 | 30 | Muelle sur | 0.108 | Rades | 1.595 | | | | |
| 17 | Tripoli | 0.196 | 28 | suez canal | 0.049 | Muelle sur | 0.137 | Valencia public | 0.046 | Rades | 0.264 |
| 18 | APM Tangiers | 0.037 | 32 | suez canal | 0.421 | Valencia public | 0.360 | Rades | 0.065 | | |
| 19 | TangerMed TC2 | 0.052 | 31 | Muelle sur | 0.509 | Valencia public | 0.157 | Rades | 0.129 | | |
| 20 | Marsaxlokk Terminal 1 | 0.810 | 12 | suez canal | 0.209 | APM Algesiras | 0.404 | | | | |
| 21 | Marsaxlokk Terminal 2 | 0.744 | 13 | APM Algesiras | 0.367 | Valencia public | 0.001 | | | | |
| 22 | Valetta grand harbour | 0.223 | 26 | suez canal | 0.046 | APM Algesiras | 0.067 | Muelle sur | 0.004 | | |
| 23 | Koper | 1.000 | 1 | Koper | 1.000 | | | | | | |
| 24 | APM Algesiras | 1.000 | 1 | APM Algesiras | 1.000 | | | | | | |
| 25 | isla verde TCA | 0.435 | 19 | Muelle sur | 0.135 | Rades | 0.243 | | | | |
| 26 | Muelle sur | 1.000 | 1 | Muelle sur | 1.000 | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | Valencia public | 1.000 | 1 | Valencia public | 1.000 | | | | | | |
| 28 | castellon | 0.253 | 25 | suez canal | 0.078 | APM Algesiras | 0.051 | | | | |
| 29 | Lattakia | 1.000 | 1 | Lattakia | 1.000 | | | | | | |
| 30 | Rades | 1.000 | 1 | Rades | 1.000 | | | | | | |
| 31 | Hydarpasa | 0.259 | 24 | suez canal | 0.028 | APM Algesiras | 0.412 | | | | |
| 32 | Mersin | 1.000 | 1 | Mersin | 1.000 | | | | | | |

The average efficiency score is 0.578 and only 8 seaports and terminals (Mersin, Rades, Lattakia, Suez Canal, Valencia public, Muller Sur, AMP Algeciras, and Koper) are overall efficient among the others.

It is also seen that 6 ports are close to the efficiency frontier by ranking scores between 0.725 and 0.945 such as Volti terminal which ranks 0.930 and marks a shortage of only 0.07 to reach its potential output, there is also 5 terminals with a score around 0.5 indicating a shortage of about half of their respective potential throughputs, 6 terminals are highly inefficient with scores ranging between 0.037 and 0.204 having a significant amount of throughput shortages.

These results indicate that some container terminals have to make a substantial improvement in productivity to become efficient by reaching the highest efficiency level that is 1.

*How to identify the improvement path?*

For each inefficient DMU a set of efficient DMUs (Benchmarks) with corresponding intensity are identified and used as reference (Table 6, Reference set).

A summary of reference set and the frequency of each efficient DMU to the inefficient DMUs is presented in Table 5.6;

**Table 5.6: Frequency in Reference Set Under CCR Model**

| Peer set | Frequency to other DMUs |
|---|---|
| suez canal | 14 |
| Koper | 0 |
| APM Algesiras | 12 |
| Muelle sur | 11 |
| Valencia public | 16 |
| Lattakia | 4 |
| Rades | 10 |
| Mersin | 0 |

The output oriented measure used in the analysis of the terminals quantifies the potential output and the shortage that needs to be covered by the DMU to become efficient by using the same fixed inputs "there is to note that some inefficient DMUs can cover their shortage in output by reducing some of their inputs while keeping the rest fixed, the kind and the amount of inputs that can be reduced varies according to the inefficient Unite" (Table 5.7).

The slack variables of the corresponding models are analyzed to identify improvement directions for the inefficient ports and terminals as shown in Table 7.

Slack analysis shows the amount of the output should be increased for an inefficient Unit to become overall efficient. According to the output slack values, the 24 inefficient terminals should increase their production on an average of 2.72 times for the same inputs, to become overall efficient.

The analysis also demonstrate that some of inefficient terminals can reduce some inputs while increasing their throughput to be efficient; such as Bejaia-Med terminal which has to increase its output by 251.70% to be efficient while reducing total quay length and yard equipment respectively by 50.91% and 32.73%.

**Table 5.7: Improvement Directions for Inefficient Terminals Using CCR Model**

| No | DMU | Score | Projection | Difference | % |
|---|---|---|---|---|---|
| | I/O | Data | | | |
| 1 | bejaia med terminal | 0.284 | | | |
| | total quay length | 500.000 | 245.430 | (254.570) | -50.910% |
| | yard equipment | 34.000 | 22.873 | (11.127) | -32.730% |
| | Throughput | 117,372.000 | 412,802.706 | 295,430.706 | 251.700% |
| 2 | Port said | 0.526 | | | |
| | storage capacity | 24,000.000 | 20,796.087 | (3,203.913) | -13.350% |
| | Throughput | 811,222.000 | 1,543,700.226 | 732,478.226 | 90.290% |
| 3 | Damietta | 0.572 | | | |
| | storage capacity | 30,000.000 | 27,631.569 | (2,368.431) | -7.890% |
| | yard equipment | 143.000 | 115.054 | (27.946) | -19.540% |
| | Throughput | 1,195,630.000 | 2,090,490.765 | 894,860.765 | 74.840% |
| 4 | El dekhila | 0.348 | | | |
| | total quay length | 1,040.000 | 658.448 | (381.552) | -36.690% |
| | yard equipment | 79.000 | 70.865 | (8.135) | -10.300% |
| | Throughput | 446,748.000 | 1,284,305.881 | 837,557.881 | 187.480% |
| 5 | fos | 0.821 | | | |
| | total area | 560,000.000 | 321,933.239 | (238,066.761) | -42.510% |
| | total quay length | 1,180.000 | 828.515 | (351.485) | -29.790% |
| | storage capacity | 10,500.000 | 6,460.481 | (4,039.519) | -38.470% |
| | Throughput | 568,203.000 | 691,819.066 | 123,616.066 | 21.760% |
| 6 | Mourepiane | 0.502 | | | |
| | total quay length | 920.000 | 260.759 | (659.241) | -71.660% |
| | quay cranes | 6.000 | 3.629 | (2.371) | -39.520% |
| | yard equipment | 102.000 | 30.730 | (71.270) | -69.870% |
| | Throughput | 279,349.000 | 556,917.851 | 277,568.851 | 99.360% |
| 7 | venizelos | 0.204 | | | |
| | total quay length | 3,100.000 | 1,631.617 | (1,468.383) | -47.370% |
| | Throughput | 433,582.000 | 2,121,866.650 | 1,688,284.650 | 389.380% |
| 8 | Thessaloniki | 0.357 | | | |
| | total area | 200,000.000 | 141,848.922 | (58,151.078) | -29.080% |
| | total quay length | 600.000 | 320.385 | (279.615) | -46.600% |
| | yard equipment | 48.000 | 36.836 | (11.164) | -23.260% |
| | Throughput | 238,940.000 | 669,426.831 | 430,486.831 | 180.170% |
| 9 | Cagliary International | 0.157 | | | |
| | total quay length | 1,520.000 | 877.892 | (642.108) | -42.240% |
| | yard equipment | 93.000 | 90.099 | (2.901) | -3.120% |
| | Throughput | 256,564.000 | 1,637,662.725 | 1,381,098.725 | 538.310% |

| | | | | | |
|---|---|---|---|---|---|
| 13 | Sintermar | 0.392 | | | |
| | total quay length | 563.000 | 463.102 | (99.898) | -17.74% |
| | Throughput | 190,086.000 | 484,338.329 | 294,252.329 | 154.80% |
| 14 | Beyrouth | 0.946 | | | |
| | total quay length | 600.000 | 517.213 | (82.787) | -13.80% |
| | yard equipment | 74.000 | 54.871 | (19.129) | -25.85% |
| | Throughput | 945,105.000 | 999,411.211 | 54,306.211 | 5.75% |
| 15 | Beyrouth | 0.946 | | | |
| | total quay length | 600.000 | 517.213 | (82.787) | -13.80% |
| | yard equipment | 74.000 | 54.871 | (19.129) | -25.85% |
| | Throughput | 945,105.000 | 999,411.211 | 54,306.211 | 5.75% |
| 16 | Benghazi | 0.100 | | | |
| | total area | 4,400,000.000 | 580,524.324 | (3,819,475.676) | -86.81% |
| | total quay length | 1,228.000 | 388.378 | (839.622) | -68.37% |
| | storage capacity | 24,420.000 | 23,445.405 | (974.595) | -3.99% |
| | Throughput | 80,088.000 | 800,611.892 | 720,523.892 | 899.67% |
| 17 | Tripoli | 0.196 | | | |
| | total quay length | 1,500.000 | 353.616 | (1,146.384) | -76.43% |
| | Throughput | 94,739.000 | 482,365.743 | 387,626.743 | 409.15% |
| 18 | APM Tangiers | 0.037 | | | |
| | total quay length | 2,800.000 | 1,033.676 | (1,766.324) | -63.08% |
| | yard equipment | 157.000 | 95.630 | (61.370) | -39.09% |
| | Throughput | 64,178.000 | 1,725,284.175 | 1,661,106.175 | 999.90% |
| 19 | TangerMed TC2 | 0.052 | | | |
| | total quay length | 1,600.000 | 947.483 | (652.517) | -40.78% |
| | storage capacity | 35,000.000 | 19,698.741 | (15,301.259) | -43.72% |
| | Throughput | 50,100.000 | 971,144.898 | 921,044.898 | 999.90% |
| 10 | Volti | 0.930 | | | |
| | total quay length | 1,400.000 | 584.553 | (815.447) | -58.250% |
| | quay cranes | 10.000 | 6.438 | (3.562) | -35.620% |
| | yard equipment | 117.000 | 60.194 | (56.806) | -48.550% |
| | Throughput | 1,010,000.000 | 1,085,474.727 | 75,474.727 | 7.470% |
| 11 | la spezia | 0.725 | | | |
| | total quay length | 1,138.000 | 935.181 | (202.819) | -17.820% |
| | Throughput | 1,051,805.000 | 1,450,539.144 | 398,734.144 | 37.910% |
| 12 | Darsena Toscana | 0.627 | | | |
| | total quay length | 1,430.000 | 1,070.975 | (359.025) | -25.110% |
| | storage capacity | 27,000.000 | 11,701.730 | (15,298.270) | -56.660% |
| | Throughput | 588,778.000 | 938,596.150 | 349,818.150 | 59.410% |

| | | | | | |
|---|---|---|---|---|---|
| 20 | Marsaxlokk Terminal 1 | 0.810 | | | |
| | total area | 457,500.000 | 370,196.378 | (87,303.622) | -19.08% |
| | total quay length | 1,000.000 | 853.830 | (146.170) | -14.62% |
| | yard equipment | 203.000 | 98.963 | (104.037) | -51.25% |
| | Throughput | 1,456,121.000 | 1,797,317.996 | 341,196.996 | 23.43% |
| 21 | Marsaxlokk Terminal 2 | 0.744 | | | |
| | total quay length | 1,140.000 | 549.011 | (590.989) | -51.84% |
| | quay cranes | 12.000 | 7.715 | (4.285) | -35.71% |
| | yard equipment | 180.000 | 65.083 | (114.917) | -63.84% |
| | Throughput | 878,061.000 | 1,179,747.429 | 301,686.429 | 34.36% |
| 22 | Valetta grand harbour | 0.223 | | | |
| | total area | 84,960.000 | 70,082.739 | (14,877.261) | -17.51% |
| | total quay length | 607.000 | 159.761 | (447.239) | -73.68% |
| | Throughput | 73,150.000 | 328,026.245 | 254,876.245 | 348.43% |
| 28 | castellon | 0.253 | | | |
| | total area | 100,000.000 | 77,528.369 | (22,471.631) | -22.47% |
| | total quay length | 750.000 | 169.234 | (580.766) | -77.44% |
| | yard equipment | 22.000 | 19.194 | (2.806) | -12.76% |
| | Throughput | 88,208.000 | 349,192.816 | 260,984.816 | 295.87% |
| 31 | Hydarpasa | 0.259 | | | |
| | total area | 320,000.000 | 266,558.114 | (53,441.886) | -16.70% |
| | total quay length | 945.000 | 648.849 | (296.151) | -31.34% |
| | yard equipment | 94.000 | 76.702 | (17.298) | -18.40% |
| | Throughput | 360,000.000 | 1,390,877.919 | 1,030,877.919 | 286.35% |



### *2.2.2. BCC Model*

The Overall efficiency in CCR model, shown in Table 5.5, can be classified into technical efficiency and scale efficiency. By using this concept, we can find whether the cause of the inefficiency is from technical inefficiency or from scale inefficiency.

The technical and scale efficiencies of the Unites can be Obtained by applying DEA-BCC method (In some literature technical efficiency refers to the overall efficiency, while pure technical efficiency refers to the technical efficiency, in this study the terms of overall and technical efficiencies have been used).

### a) Technical and Scale Efficiency Analysis

I also applied the Output oriented BCC model, with variable returns to scale, to evaluate the technical efficiency of each port and terminal from the sample. The scale efficiency can be derived by the ratio of overall efficiency to technical efficiency," Table 5.8 presents the results".

The eight overall efficient terminals have the technical efficiency and scale efficiency (thus presenting constant returns to scale). In particular, six DMUs (i.e., Bejaia med terminal, Mourepiane, Volti, Beyrouth, Valetta grand harbor, isla verde TCA) have the technical efficiency scores equal to 1 while their scale efficiency scores are less than 1. They should adjust their scales of operation to improve their scale efficiencies as well as overall efficiencies.

A DMU may be scale inefficient if it exceeds the most productive scale size (thus experiencing

Decreasing returns to scale), or if it is smaller than the most productive scale size (thus having not taken the full advantage of increasing returns to scale). Indeed, most of the inefficient

terminals (including Bejaia med terminal, Mourepiane, Volti, Beyrouth, Valetta grand harbor, isla verde TCA) present increasing returns to scale that can increase the scales to effectively improve their efficiencies. In particular, eleven scale inefficient terminals (i.e., Bejaia med terminal, Fos, Mourepiane, Thessaloniki, Volti, Sintermar, Beyrouth, Marsaxlokk Terminal 2, Valetta grand harbor, isla verde TCA, and castellon) have their technical efficiency scores higher than the scale efficiency scores, respectively. This implies that the overall inefficiency is primarily due to the scale inefficiency. In the selected sample, there is no terminal that presents a decreasing return to scale that can decrease its scale to possibly improve its efficiencies.

On the other hand, thirteen overall inefficient terminals (i.e., Port Said, Damietta, El dekhila, Venizelos, Cagliary International, la spezia, Darsena Toscana, Benghazi, Tripoli, APM Tangiers, TangerMed TC2, Marsaxlokk Terminal 1, Hydarpasa) are mainly inefficient due to the technical inefficiency because their technical inefficiency scores are lower than scale efficiency scores. The technical inefficient terminals should improve their productivity and make better use of their resources (Container terminals should enhance their own efficiency by increasing their input level as these are characterized by an increasing return to scale. The container terminals of which both technical efficiency and scale efficiency are less than 1, both can be the causes of inefficiency. However, it is considered that as technical efficiency is less than scale efficiency, technical factors have given more harmful effect on their own whole efficiency rather than scale factors).

**Table 5.8: Technical/Scale Efficiencies & Return to Scales**

| No | port/terminal | efficiency | | | return to scale | |
|---|---|---|---|---|---|---|
| | | Overall efficiency | Technical efficiency | Scale efficiency | efficient DMUs | Projected DMUs |
| 1 | bejaia med terminal | 0.284 | 1.000 | 0.284 | Increasing | |
| 2 | Port said | 0.526 | 0.530 | 0.991 | | Constant |
| 3 | suez canal | 1.000 | 1.000 | 1.000 | Constant | |
| 4 | Damietta | 0.572 | 0.584 | 0.980 | | Constant |
| 5 | El dekhila | 0.348 | 0.353 | 0.984 | | Increasing |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | fos | 0.821 | 0.909 | 0.904 | | Increasing |
| 7 | Mourepiane | 0.502 | 1.000 | 0.502 | Increasing | |
| 8 | venizelos | 0.204 | 0.210 | 0.972 | | Constant |
| 9 | Thessaloniki | 0.357 | 0.789 | 0.453 | | Increasing |
| 10 | Cagliary International | 0.157 | 0.163 | 0.958 | | Increasing |
| 11 | Volti | 0.930 | 1.000 | 0.930 | Increasing | |
| 12 | la spezia | 0.725 | 0.771 | 0.941 | | Increasing |
| 13 | Darsena Toscana | 0.627 | 0.646 | 0.971 | | Constant |
| 14 | Sintermar | 0.392 | 0.912 | 0.430 | | Increasing |
| 15 | Beyrouth | 0.946 | 1.000 | 0.946 | Increasing | |
| 16 | Benghazi | 0.100 | 0.102 | 0.983 | | Constant |
| 17 | Tripoli | 0.196 | 0.272 | 0.721 | | Increasing |
| 18 | APM Tangiers | 0.037 | 0.038 | 0.991 | | Increasing |
| 19 | TangerMed TC2 | 0.052 | 0.053 | 0.975 | | Constant |
| 20 | Marsaxlokk Terminal 1 | 0.810 | 0.857 | 0.945 | | Increasing |
| 21 | Marsaxlokk Terminal 2 | 0.744 | 0.931 | 0.800 | | Increasing |
| 22 | Valetta grand harbour | 0.223 | 1.000 | 0.223 | Increasing | |
| 23 | Koper | 1.000 | 1.000 | 1.000 | Constant | |
| 24 | APM Algesiras | 1.000 | 1.000 | 1.000 | Constant | |
| 25 | isla verde TCA | 0.435 | 1.000 | 0.435 | Increasing | |
| 26 | Muelle sur | 1.000 | 1.000 | 1.000 | Constant | |
| 27 | Valencia public | 1.000 | 1.000 | 1.000 | Constant | |
| 28 | castellon | 0.253 | 0.927 | 0.273 | | Increasing |
| 29 | Lattakia | 1.000 | 1.000 | 1.000 | Constant | |
| 30 | Rades | 1.000 | 1.000 | 1.000 | Constant | |
| 31 | Hydarpasa | 0.259 | 0.294 | 0.881 | | Increasing |
| 32 | Mersin | 1.000 | 1.000 | 1.000 | Constant | |

### *b) Improvement Projection under BCC Model*

An analogous analysis to the one used for the CCR model is applied in the BCC model the data corresponding to those presented in Table 5.7 under CCR Model are presented in Table 5.9.

Reference set and the frequency of each efficient DMU to the inefficient DMUs are summarized in Table 5.10.

**Table 5.9: Ranking and Relative Efficiency of Terminals Using BCC Model**

| No | port/terminal | efficiency | | | return to scale | |
|---|---|---|---|---|---|---|
| | | Overall efficiency | Technical efficiency | Scale efficiency | efficient DMUs | Projected DMUs |
| 1 | bejaia med terminal | 0.284 | 1.000 | 0.284 | Increasing | |
| 2 | Port said | 0.526 | 0.530 | 0.991 | | Constant |
| 3 | suez canal | 1.000 | 1.000 | 1.000 | Constant | |
| 4 | Damietta | 0.572 | 0.584 | 0.980 | | Constant |
| 5 | El dekhila | 0.348 | 0.353 | 0.984 | | Increasing |
| 6 | fos | 0.821 | 0.909 | 0.904 | | Increasing |
| 7 | Mourepiane | 0.502 | 1.000 | 0.502 | Increasing | |
| 8 | venizelos | 0.204 | 0.210 | 0.972 | | Constant |
| 9 | Thessaloniki | 0.357 | 0.789 | 0.453 | | Increasing |
| 10 | Cagliary International | 0.157 | 0.163 | 0.958 | | Increasing |
| 11 | Volti | 0.930 | 1.000 | 0.930 | Increasing | |
| 12 | la spezia | 0.725 | 0.771 | 0.941 | | Increasing |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | Darsena Toscana | 0.627 | 0.646 | 0.971 | | Constant |
| 14 | Sintermar | 0.392 | 0.912 | 0.430 | | Increasing |
| 15 | Beyrouth | 0.946 | 1.000 | 0.946 | Increasing | |
| 16 | Benghazi | 0.100 | 0.102 | 0.983 | | Constant |
| 17 | Tripoli | 0.196 | 0.272 | 0.721 | | Increasing |
| 18 | APM Tangiers | 0.037 | 0.038 | 0.991 | | Increasing |
| 19 | TangerMed TC2 | 0.052 | 0.053 | 0.975 | | Constant |
| 20 | Marsaxlokk Terminal 1 | 0.810 | 0.857 | 0.945 | | Increasing |
| 21 | Marsaxlokk Terminal 2 | 0.744 | 0.931 | 0.800 | | Increasing |
| 22 | Valetta grand harbour | 0.223 | 1.000 | 0.223 | Increasing | |
| 23 | Koper | 1.000 | 1.000 | 1.000 | Constant | |
| 24 | APM Algesiras | 1.000 | 1.000 | 1.000 | Constant | |
| 25 | isla verde TCA | 0.435 | 1.000 | 0.435 | Increasing | |
| 26 | Muelle sur | 1.000 | 1.000 | 1.000 | Constant | |
| 27 | Valencia public | 1.000 | 1.000 | 1.000 | Constant | |
| 28 | castellon | 0.253 | 0.927 | 0.273 | | Increasing |
| 29 | Lattakia | 1.000 | 1.000 | 1.000 | Constant | |
| 30 | Rades | 1.000 | 1.000 | 1.000 | Constant | |
| 31 | Hydarpasa | 0.259 | 0.294 | 0.881 | | Increasing |
| 32 | Mersin | 1.000 | 1.000 | 1.000 | Constant | |

According to the output slack values, the 18 inefficient terminals should increase their production on an average of 2.65 times for the same inputs, some inefficient terminals can even reduce some inputs while increasing their throughput to be efficient; we can mention as example Damietta terminal that has to increase the throughput by 71.34% to be efficient but also can at the same time decrease the resources of total area storage capacity and total equipment respectively by 9.98%, 12.88%, 21.26%.

**Table 5.10: Frequency in Reference Set Under BCC Model**

| Peer set | Frequency to other DMUs |
|---|---|
| suez canal | 6 |
| Mourepiane | 0 |
| Beyrouth | 5 |
| Valetta grand harbour | 7 |
| Koper | 0 |
| APM Algesiras | 7 |
| isla verde TCA | 0 |
| Muelle sur | 4 |
| Valencia public | 9 |
| Lattakia | 5 |
| Rades | 13 |
| Mersin | 1 |

Table 5.11 shows technical efficiency and improvement directions based on the Output oriented BCC model.

**Table 5.11: Improvement Directions for Inefficient Terminals Using BCC Model**

| No | DMU | Score | Projection | Difference | % |
|---|---|---|---|---|---|
| | I/O | Data | | | |
| 2 | Port said | 0.530 | | | |
| | total quay length | 970.000 | 961.426 | (8.574) | -0.88% |
| | Throughput | 811,222.000 | 1,530,406.732 | 719,184.732 | 88.65% |
| 4 | Damietta | 0.584 | | | |
| | total area | 600,000.000 | 540,131.579 | (59,868.421) | -9.98% |
| | storage capacity | 30,000.000 | 26,137.105 | (3,862.895) | -12.88% |
| | yard equipment | 143.000 | 112.592 | (30.408) | -21.26% |
| | Throughput | 1,195,630.000 | 2,048,551.145 | 852,921.145 | 71.34% |
| 5 | El dekhila | 0.353 | | | |
| | total quay length | 1,040.000 | 685.484 | (354.516) | -34.09% |
| | yard equipment | 79.000 | 77.316 | (1.684) | -2.13% |
| | Throughput | 446,748.000 | 1,264,182.415 | 817,434.415 | 182.97% |

| | | | | | |
|---|---|---|---|---|---|
| 6 | fos | 0.909 | | | |
| | total area | 560,000.000 | 337,852.197 | (222,147.803) | -39.67% |
| | total quay length | 1,180.000 | 932.024 | (247.976) | -21.01% |
| | Throughput | 568,203.000 | 625,420.493 | 57,217.493 | 10.07% |
| 8 | venizelos | 0.210 | | | |
| | total area | 900,000.000 | 590,144.439 | (309,855.561) | -34.43% |
| | total quay length | 3,100.000 | 1,366.885 | (1,733.115) | -55.91% |
| | storage capacity | 30,500.000 | 14,433.690 | (16,066.310) | -52.68% |
| | Throughput | 433,582.000 | 2,061,869.775 | 1,628,287.775 | 375.54% |
| 9 | Thessaloniki | 0.789 | | | |
| | total area | 200,000.000 | 146,709.175 | (53,290.825) | -26.65% |
| | quay cranes | 4.000 | 2.991 | (1.009) | -25.22% |
| | yard equipment | 48.000 | 28.155 | (19.845) | -41.34% |
| | Throughput | 238,940.000 | 302,976.901 | 64,036.901 | 26.80% |
| 10 | Cagliary International | 0.163 | | | |
| | total quay length | 1,520.000 | 971.716 | (548.284) | -36.07% |
| | Throughput | 256,564.000 | 1,569,489.661 | 1,312,925.661 | 511.73% |
| 12 | la spezia | 0.771 | | | |
| | total quay length | 1,138.000 | 969.358 | (168.642) | -14.82% |
| | Throughput | 1,051,805.000 | 1,364,995.865 | 313,190.865 | 29.78% |
| 13 | Darsena Toscana | 0.646 | | | |
| | total quay length | 1,430.000 | 1,037.272 | (392.728) | -27.46% |
| | storage capacity | 27,000.000 | 16,550.892 | (10,449.108) | -38.70% |
| | Throughput | 588,778.000 | 911,804.390 | 323,026.390 | 54.86% |
| 14 | Sintermar | 0.912 | | | |
| | quay cranes | 5.000 | 2.317 | (2.683) | -53.66% |
| | storage capacity | 7,000.000 | 4,171.211 | (2,828.789) | -40.41% |
| | Throughput | 190,086.000 | 208,419.605 | 18,333.605 | 9.64% |
| 16 | Benghazi | 0.102 | | | |
| | total area | 4,400,000.000 | 369,857.143 | (4,030,142.857) | -91.59% |
| | total quay length | 1,228.000 | 362.229 | (865.771) | -70.50% |
| | storage capacity | 24,420.000 | 17,879.451 | (6,540.549) | -26.78% |
| | Throughput | 80,088.000 | 786,711.806 | 706,623.806 | 882.31% |
| 17 | Tripoli | 0.272 | | | |
| | total quay length | 1,500.000 | 484.452 | (1,015.548) | -67.70% |
| | Throughput | 94,739.000 | 347,979.756 | 253,240.756 | 267.30% |
| 18 | APM Tangiers | 0.038 | | | |
| | total quay length | 2,800.000 | 1,054.454 | (1,745.546) | -62.34% |
| | yard equipment | 157.000 | 100.587 | (56.413) | -35.93% |
| | Throughput | 64,178.000 | 1,709,818.890 | 1,645,640.890 | 999.90% |

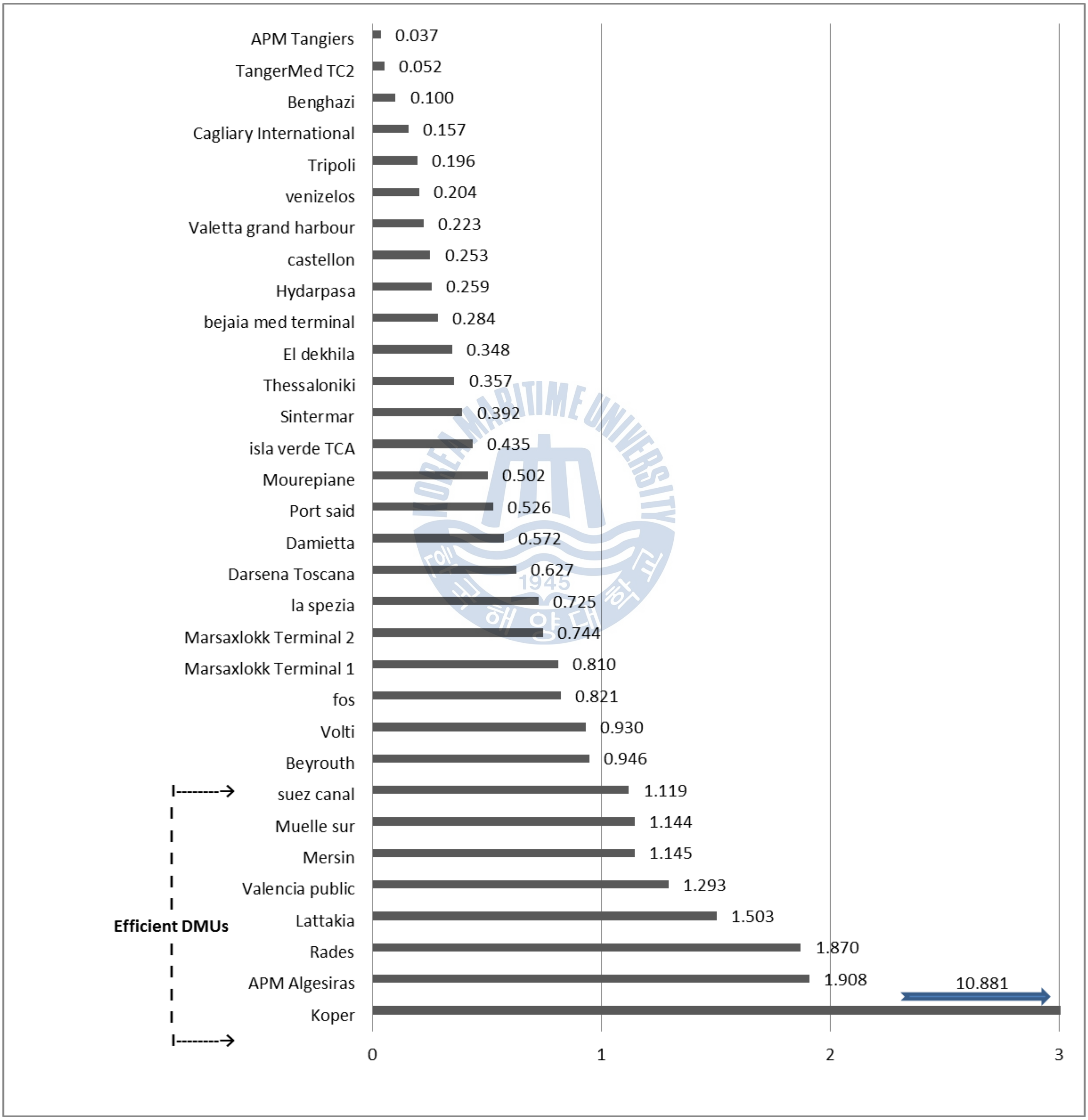
| | | | | | |
|---|---|---|---|---|---|
| 19 | TangerMed TC2 | 0.053 | | | |
| | total quay length | 1,600.000 | 917.314 | (682.686) | -42.67% |
| | storage capacity | 35,000.000 | 24,039.388 | (10,960.612) | -31.32% |
| | Throughput | 50,100.000 | 947,162.694 | 897,062.694 | 999.90% |
| 20 | Marsaxlokk Terminal 1 | 0.857 | | | |
| | total area | 457,500.000 | 360,157.774 | (97,342.226) | -21.28% |
| | total quay length | 1,000.000 | 971.311 | (28.689) | -2.87% |
| | yard equipment | 203.000 | 104.787 | (98.213) | -48.38% |
| | Throughput | 1,456,121.000 | 1,698,293.634 | 242,172.634 | 16.63% |
| 21 | Marsaxlokk Terminal 2 | 0.931 | | | |
| | quay cranes | 12.000 | 9.682 | (2.318) | -19.32% |
| | yard equipment | 180.000 | 119.039 | (60.961) | -33.87% |
| | Throughput | 878,061.000 | 943,228.126 | 65,167.126 | 7.42% |
| 28 | castellon | 0.927 | | | |
| | total area | 100,000.000 | 95,096.365 | (4,903.635) | -4.90% |
| | total quay length | 750.000 | 591.123 | (158.877) | -21.18% |
| | yard equipment | 22.000 | 18.853 | (3.147) | -14.31% |
| | Throughput | 88,208.000 | 95,185.384 | 6,977.384 | 7.91% |
| 31 | Hydarpasa | 0.294 | | | |
| | total area | 320,000.000 | 278,512.710 | (41,487.290) | -12.96% |
| | total quay length | 945.000 | 933.957 | (11.043) | -1.17% |
| | yard equipment | 94.000 | 76.629 | (17.371) | -18.48% |
| | Throughput | 360,000.000 | 1,225,091.637 | 865,091.637 | 240.30% |

### *2.2.3. Ranking analysis by super-efficiency Model*

In order to obtain a full ranking of the terminals in our sample (refers to chap V.1.1); I applied DEA super-efficiency model that allows the efficient Units under evaluation to be excluded from the reference set, and thus to be able to get a score that is bigger than 1, this method will allow us to rank the terminals in the sample under study from the relative most efficient to the relative most inefficient, which permits to fully compare the performance of the terminals in the region. Due to the infeasibilities that may arise in super-efficiency DEA models under variable return to scale for some efficient DMUs specifically those at the extremities of the frontier (Cook, Wade D, et al. 2008), to decide the rank of each container terminal the super-efficiency analysis will be restricted to output-oriented CCR model. Results of the analysis for efficient terminals are presented in Figure 5.6

The results show that the super-efficiency scores of the terminals; Koper, APM Algeciras, Rades, Lattakia, Valencia, Mesrin, Muler sur, and Suez Canal of which all efficiency indices are equal to 1 under CCR-DEA are about, 10.881, 1.907, 1.869, 1.502, 1.292, 1.145, 1.144, and 1.118, respectively. Therefore, Koper terminal is evaluated as the most efficient. On the other hand, as the super-efficiency scores of the inefficient container ports are the same as the efficiency indices in CCR model, APM Tangier terminal is the most inefficient among the whole units in our sample. While the inefficiencies on outputs for efficient container terminals are all zero, there are too much inputs or too little output for inefficient container Terminals (refers to Table 7). In the case of APM Tangier terminal, which shows the lowest scores of 0.037, it should increases 1,661,106 TEU (999.90%) of its container throughput and also can decrease 1766 m (63.08%) of quay length and about 61 Units (39.09%) of Yard equipment to reach the 100% efficiency.

**Figure 5.6: Terminals' Ranking With Using Super Efficiency**



# CHAPTER Ⅵ Conclusion

## I. Research findings

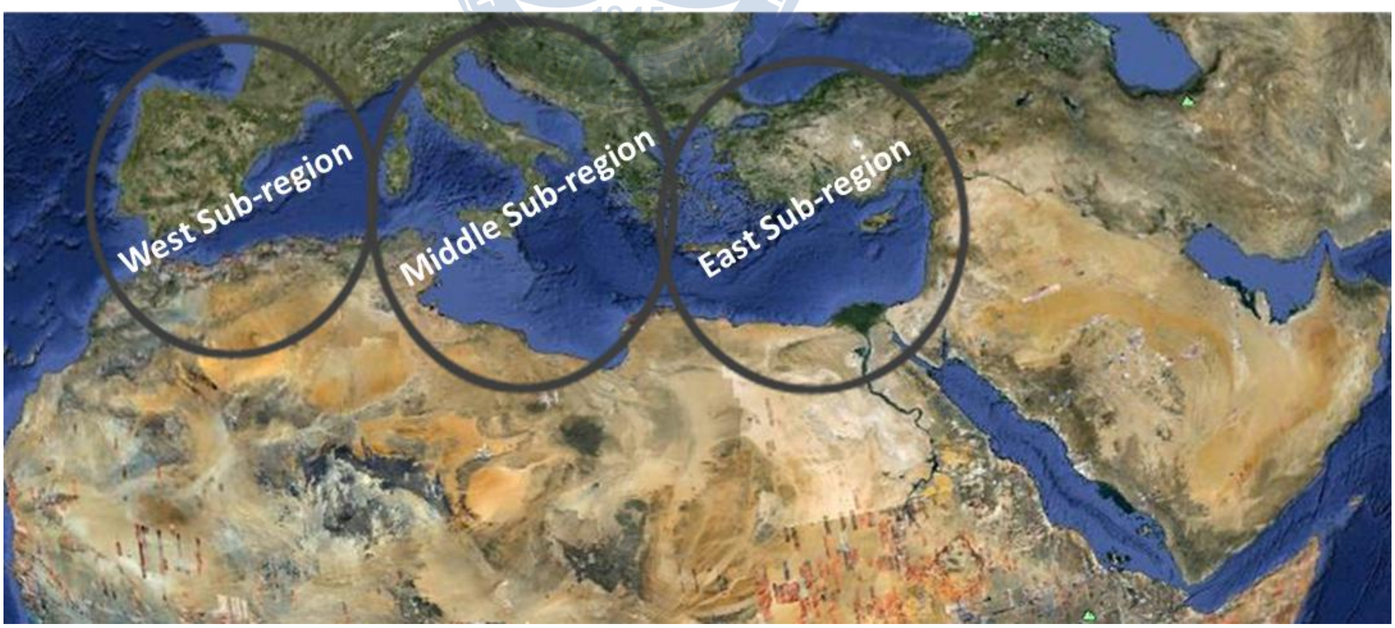
The Mediterranean is a key world maritime route with 30 % of worldwide traffic, 25 % of oil transport, and 56 ports and terminals. The largest port, Marseilles (France), is ranked fourth in Europe (http://www.bluemassmed.net, 2011). Oil and natural gas are transported from small specialised ports on the southern shores, such as Arzew (Algeria) and Sidi Kerir/Alexandria (Egypt) to Marseilles and Augusta, Trieste and Genoa (Italy). Container traffic is experiencing particular expansion, notably in Algeciras (Spain), a large hub at the entrance to the Mediterranean that now faces competition from Tanger-Med (Morocco). It is therefore necessary for Mediterranean container ports and terminals (as everywhere all over the world) to strengthen their own competitive powers through the improvement of operational efficiency for achieving competitive advantages against their rivals

Almost 56% of container terminals in the Mediterranean Sea dataset are technically inefficient:

50% of inefficient Unites are situated in the south and 50% in the north of the Mediterranean basin, 50% of the container terminals in the south have a technical efficiency lower than 0.70; while about 22% of the container terminals in the north have technical efficiency lower than 0.70. The scale efficiency of the ports and terminals shows that: 72% of all the terminals in the north have scale efficiency larger than 0.70; also in the south about 70% of all terminals have scale efficiency larger than 0.70. For the south Mediterranean terminals we can conclude by observing their low technical efficiency values and relatively high scale efficiency values that inputs level is sufficient, but that container ports and terminals are not using their resources efficiently. which can be explained by the fact that Some terminals are new emerging such as AMP Tangiers and TangerMed TC2 .which started operating in 2007 within the economic downturn, which begins at the end of 2007 and the data used for their analysis (2008) represent the product of their first operating year which is a transitive period to reach their optimal performance which explain their underperformance compared to other terminals in the sample.

On the other hand If we subdivide the basin into 3 Sub-Regions, West Sub-region including; 11 Terminals (situated in, Morocco, Spain, Algeria, Tunisia, and France), Middle Sub-region including; 13 terminals (situated in, Greece, Italy, Libya, Malta, and Slovenia), and East Sub-region which includes; 8 terminals (situated in, Egypt, Lebanon, Syria, and Turkey) (Figure 6.1).

**Figure 6.1: Clustering of Mediterranean Ports and Terminals from East to West**




Source Author (adapted from google earth)

The results of the comparison among container and terminal ports in Mediterranean nations show that

The performance of eastern Sub-region's container terminals is higher than those situated in other Sub-regions (Table 6.1), marking scores of 37% overall efficient terminals, 12% terminals which are inefficient but close to the efficiency frontier and 25% terminals with an efficiency around 0.5 and 25% highly inefficient terminals.

While the container Terminals in Middle Sub-region are the less performing; marking scores of 7% overall efficient terminals 30% terminals which are inefficient but close to the efficiency boundary and 7% terminals with an efficiency around 0.5 and 54% highly inefficient terminals.

the performance of West sub-region of the basin have scores of 36% overall efficient terminals, 9% terminals which are inefficient but close to the efficiency boundary and 18% terminals with an efficiency around 0.5 and 36% highly inefficient terminals

**Table 6.1: Efficiency Results By W, E, Mid, Sub-Regions**

| | West Sub-region | Mid Sub-region | East Sub-region |
|---|---|---|---|
| overall efficient terminals | 36% | 7% | 37% |
| close to efficiency frontier | 9% | 30% | 12% |
| Average efficiency | 18% | 7% | 25% |
| highly inefficient | 36% | 54% | 25% |
| Total DMUs | 11 | 13 | 8 |

We can notice also that the most performing terminals are situated near to the three passages "Gibraltar, Bosporus, and Suez canal". The classification of ports in the

Mediterranean is more appropriate if we group ports from the East to the West side rather than North to South, which can give a better estimation of the competitive environment in the region and may also give good indices about possible Concentration and Formation of Multi-Port Gateway Regions (Concentration and the Formation of Multi-Port Gateway Regions in the European Container Port System Notteboom, T. 2010), in the Mediterranean Container Port System, which has been wildly influenced by The hub and spokes model, adopted by the big shipping companies

## 2. Limitations of the Study

Firstly, the study is applied only to a cross-sectional data, which is mainly due to (as mentioned previously) that some new emerging container terminals have been operational only for one year before the year of selected data; which is quite restrictive to assess the trend of evolution of the terminals' performance in a permanently changing environment.

Secondly, this study included only ports and terminals from the Mediterranean basin therefor the DEA model does not give results that reflect the actual position of the Units under study in a global industry and economic environment.

Third, the study focused mainly on measuring the efficiency of ports, and why a port has a higher output for the same amount of inputs used. But it is also important to consider the operating environment of each port such as governance, ownership and management, institutional factors and public policy, market characteristics or to check what is the GDP per capita in the country where the port is inserted, and also the physical location of the port "if it is in an estuary, Nearby the city", which may restrict the expansion of port or congest the land access and distance to major roads or points of cargo handling, if there is other ports in the same country on other sides than the

Mediterranean, and to evaluate the influence of these elements on the characteristics of the port and the variables' performance.

There is also to mention that most of the studies reviewed that apply DEA reflect the multi-output nature of port activity, Ahmed Salem Al-Eraqi that considered number of ship's call and cargo throughput in tons, et al (2008), Valentine (2001) that used ships, movement of freight, cargo handled and container handled, and also Park and De (2004) used cargo throughput, number of ship's calls, revenue and consumer satisfaction.

In this study and due to data resources limitation only one output variable (container throughput) has been considered.

## 3. Future Researches on Port and Terminal Efficiency

The present study allows us to evaluate different levels of efficiency of each container port in the sample and to identify their strength and weakness, eventually to suggest an efficient way of benchmarking for each inefficient container port. Super-efficiency model also comes to evaluate the ranking of container ports in terms of their efficiency.

Despite of the above implication, we still need to conduct further studies as follows:

It is required to conduct various studies using models with DEA/Window analysis with time-series data to make a more completed analysis and get a better estimation of the ports efficiency performance.

It is also needed to include ports and terminals from other regions in the world in order to give a better evaluation of Mediterranean ports which will be useful to assess the standing of the whole Mediterranean region in the global port industry hierarchy.

And to consider the operating environment of each port under study in order to explain the different factors that determine the different levels of port efficiency, which would be very important to help improving the efficiency.

# References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