

DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF MARITIME BUSINESS ADMINISTRATION
MARITIME BUSINESS ADMINISTRATION PROGRAM
MASTER’S THESIS

BENCHMARKING THE OPERATIONAL EFFICIENCY
OF CONTAINER TERMINALS
BY USING DATA ENVELOPMENT ANALYSIS

Demir Ali AKYAR

Supervisor
Assoc. Prof. Dr. Ismail Bilge CETIN

İZMİR – 2019

THESIS APPROVAL PAGE



DECLARATION

I hereby declare that this master's thesis titled as "Benchmarking the Operational Efficiency of Container Terminals by Using Data Envelopment Analysis" has been written by myself in accordance with the academic rules and ethical conduct. I also declare that all materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honour.

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Demir Ali AKYAR

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ABSTRACT
Master's Thesis
Benchmarking the Operational Efficiency of Container Terminals by using
Data Envelopment Analysis
Demir Ali AKYAR

Dokuz Eylül University
Graduate School of Social Sciences
Department of Maritime Business Administration
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Maritime transportation is the most cost effective transportation mode when it is examined in terms of unit transportation cost over long distances. Container transportation, first emerged in the 1950s, continues to expand day by day. It is utmost important that the operations carried out in container terminals are done in time and without any errors regarding to the cost minimization, turn-around/dwell time minimization and operational safety issues in ports. In this sense, the efficiency measurements of the ports are of great importance.

Efficiency analysis in container terminals has been frequently studied in the last thirty years, especially for foreign ports. As a non-parametric method, Data Envelopment Analysis (DEA) is widely used in the literature. When the similar studies in the literature are examined, it is seen that many input and output variables have been utilized in DEA analysis.

Seven input and one output variables are determined considering the fact of data availability for the efficiency analysis of all the container terminals operating in Turkey. Input variables are determined as; terminal area, number of berths, berth length, number of ship to shore cranes, number of handling equipments in container stacking area, port draft depth and number of port employees. The output variable is selected as the annual container throughput and efficiency analyzes were performed.

The aim of this study is measuring and comparing the efficiencies of 26 ports capable of handling containerized cargo in Turkey by Data Envelopment Analysis method. Findings of the study and potential improvement points are intended to be a conductor for future plans of the ports. According to the findings of the study, it has been concluded that Marport, Mersin MIP, Asyaport and Kumport container terminals are relatively efficient among the evaluated terminals. However, Trabzon, Derince Safiport and Akcansa Ambarli container terminals have been identified as the least efficient terminals.

Keywords: Container Terminal, Efficiency, Data Envelopment Analysis, Comparative Analysis

ÖZET

Yüksek Lisans Tezi

**Konteyner Terminallerinin Operasyonel Verimliliğinin Veri Zarflama Analizi
ile Karşılaştırmalı Değerlendirilmesi**

Demir Ali AKYAR

Dokuz Eylül Üniversitesi

Sosyal Bilimler Enstitüsü

Denizcilik İşletmeleri Yönetimi Anabilim Dalı

Denizcilik İşletmeleri Yönetimi Programı

Denizyolu taşımacılığı uzak mesafelerde taşınan yüklerin birim başına maliyeti açısından incelendiğinde günümüzün en düşük maliyetli taşıma yöntemi olarak öne çıkmaktadır. İlk olarak 1950'li yıllarda ortaya çıkan konteyner taşımacılığı gün geçtikçe yaygınlaşmaya devam etmektedir. Konteyner terminal operasyonlarının hızlı ve hatasız gerçekleştirilmesi limanlardaki maliyet minimizasyonu, geminin/yükün limanda geçirdiği sürenin azaltılması ve operasyonel güvenlik açısından çok büyük önem arz etmektedir. Bu anlamda limanların verimlilik ölçümleri ciddi bir öneme sahiptir.

Konteyner terminallerinde verimlilik analizi konusu son otuz yılda özellikle yabancı limanlar için sıkça çalışılmıştır. Bu konuda parametrik olmayan Veri Zarflama Analizi (VZA) yöntemi alanyazında yaygın bir şekilde kullanılmaktadır. Alanyazındaki benzer çalışmalar incelendiğinde VZA analizi için birçok girdi ve çıktı değişkenlerinin kullanıldığı görülmektedir.

Bu bulgu sonucunda veri ulaşılabilirliği de göz önünde bulundurularak Türkiye'de faaliyet gösteren tüm konteyner terminallerinin verimlilik analizi için yedi girdi ve bir çıktı değişkeni belirlenmiştir. Girdi değişkenleri; terminal alanı, gemi yanaşma yeri sayısı, rıhtım uzunluğu, gemi yükleme ve boşaltma vinci sayısı, konteyner istif sahasındaki elleçleme ekipmanı sayısı, liman draft derinliği ve liman çalışanı sayısı olarak belirlenmiştir. Çıktı değişkeni olarak ise yıllık elleçlenen konteyner miktarı seçilmiştir ve verimlilik analizleri yapılmıştır.

Bu çalışmanın amacı Türkiye’de konteyner yüküne hizmet verebilen 26 konteyner terminalinin 2017 yılı verimliliklerini Veri Zarflama Analizi yöntemi ile ölçmek ve kıyaslamaktır. Elde edilen bulguların ve potansiyel iyileştirme noktalarının limanların gelecekte yapacağı planlamalar açısından birer yol gösterici olması amaçlanmıştır. Değerlendirilen terminaller içerisinde Marport, Mersin MIP, Asyaport ve MIP Kumport konteyner terminallerinin analiz sonuçları neticesinde göreceli olarak verimli oldukları sonucuna varılmıştır. Fakat Trabzon, Derince Safiport, Akçansa Ambarlı konteyner terminalleri en düşük verimlilik değerine sahip limanlar olarak belirlenmiştir.

Anahtar Kelimeler: Konteyner Terminali, Verimlilik, Veri Zarflama Analizi, Karşılaştırmalı Analiz

**BENCHMARKING THE OPERATIONAL EFFICIENCY OF CONTAINER
TERMINALS BY USING DATA ENVELOPMENT ANALYSIS**

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LIST OF ABBREVIATIONS

AAPA	American Association of Port Authorities
AGV	Automated Guided Vehicle
ASEAN	Association of Southeast Asian Nations
BCC	Banker, Charnes, Cooper
BOT	Built Operate Transfer
CCR	Charnes, Cooper, Rhodes
CFS	Container Freight Station
CRS	Container Reach Stacker
CSR	Corporate Social Responsibility
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DWT	Deadweight Tonnage
e. g.	exempli gratia
ECS	Empty Container Stacker
ESPO	The European Sea Ports Organization
etc.	et cetera
FLT	Forklift Truck
GRT	Gross Tonnage
HR	Human Resources
I	Input
i. e.	id est
ILO	International Labour Organization
IMO	International Maritime Organization
ISL	Institute of Shipping Economics and Logistics
ISPS	International Ship and Port Facility Security
IT	Information Technologies
km	Kilometer
LCH	Loaded Container Handler
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas

m	Meter
M & A	Merger & Acquisition
m²	Square Meter
MARAD	Maritime Administration
MPP	Multipurpose Ship
O	Output
PPI	Port Performance Indicators
PPP	Public-Private Partnerships
R&D	Research and Development
R. T.	Republic of Turkey
RMG	Rail Mounted Gantry
Ro-Ro	Roll on, Roll off
RTG	Rubber Tired Gantry
SC	Straddle Carrier
SCM	Supply Chain Management
SFA	Stochastic Frontier Analysis
SSG	Ship to Shore Gantry Crane
TESCI	Terminal and Supply Chain Integration
TEU	Twenty-Foot Equivalent Unit
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
US	United States
USD	United States Dollar
YTT	Yard Towing Truck

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INTRODUCTION

Speaking of maritime transportation, more than half of the world general cargo trade is carried in containers (Worldbank, 2007: 80). Container shipping sits at the heart of our modern-day transportation systems. Along with it, the container ports perhaps play the most crucial role for the container shipping. Container ports are one of the key elements on defining the efficiencies of global supply chains and are known for their complex and highly capital intensive structure. These business centers are significantly hard to manage as anyone would expect. Thus, efficiency of the container terminals plays a key role for the overall success of the supply chains.

Efficiency has been an issue for the port authorities and stakeholders in the last three decades so it has become a field of interest for the academicians as well. Making most of the previous studies, this master thesis unfolds the most significant elements determining a container terminal's operational efficiency and aims to analyze the relative efficiencies of the container ports located in Turkey.

This introduction presents a general outlook for this thesis. Initially research background of the study is explained and followed by the research questions and the research framework sub-sections, respectively. In order to generate a better overall picture in mind, the last section outlines the complete structure of this thesis.

Research Background

Seaports handle more than eighty percent of the global trade by volume and more than seventy per cent of its value (Unctad, 2017: 10). Seaports certainly occupy a critical position in the global trade since they canalize the logistics activities. In the simplest way, seaports are the intersection points where the land and sea transport systems meet. Seaports might be formed by the combination of different terminals and container terminals are perhaps the most complex ones among those.

Since its invention in the nineteen-fifties, transportation of cargo in containers has always been an increasing trend among the cargo interests. Containerization has dramatically increased since 1960s and today complies %17 of the global maritime trade in terms of tons loaded (Unctad, 2017: 6). Containerization brought advantages

of such; standardizing the unit of transport, easing the handling operations, decreasing the costs of storage/handling and enabling consolidation of even the smallest amount of cargo. Astonishingly, nowadays even some bulk cargoes began to be transported in containers. Before the appearance of container in maritime logistics, transportation of goods was so expensive that only few types of products were being shipped across countries.

With the expansion of the intermodal transport systems, the traditional understanding of trade has changed and container terminal operators who want to get the most out of it have found themselves in an intensely competitive environment (Wang and Song, 2003: 698). In addition, this competition is far beyond from national level (Hoshino, 2010: 32). Ports need to take appropriate steps in order to hold onto the market and increase the market share (Acosta et al., 2007: 502).

Intense competition brings the question of being efficient to the mind. Customers would prefer ports that are relatively efficiency to another. According to Beth, “*specialists estimate port costs as 10% of the total supply chain cost on average*” (Francou, 2002: 16). Inefficiency in port operations increases the handling costs and total transportation cost. For this reason, ‘efficiency’ and port performance measurements have become critical issues in the last thirty to forty years.

In terms of port performance measurements, studies mainly focus on measuring the efficiency and productivity. Efficiency is defined as “*doing the things right*” while effectiveness as “*doing the right things*” (Gleason and Barnum, 1982: 379). Various approaches have been used for port productivity measures and efficiency comparisons for optimization and benchmarking purposes. Benchmarking means ‘taking reference from the best practitioners’ and it allows a port to monitor its position in the competitive environment, bringing a perspective on a port’s strengths and weaknesses (Brooks, 2006: 599). Most importantly, benchmarking enables an organization to take corrective actions on inefficient points.

Efficiency in port operations is a hard concept to be measured. Port efficiency is affected by the infrastructural and superstructural elements of a port. Many attempts have been made using different methods (Poitras et al., 1996; Tongzon, 2001; Cullinane and Wang, 2006; Hung et al., 2010; Bichou, 2012; Ates and Esmer, 2011) for the purpose of port efficiency measurements.

Port business is highly competitive and it is fundamental to improve port performance levels. Ports should focus on both efficiency and effectiveness on their operations. Combination of cost minimization, on time service delivery and the right marketing-promotion objectives along with effective decision making processes is more likely to bring competitive advantages.

Port efficiency is a concept that can be measured by taking different variables into consideration. Thus there is a high uncertainty or a high chance of inconsistent results when measured. Port performance and port efficiency subjects require further and deep endeavoring although many methods and many variables have been tested by practitioners.

This study will cover all previously utilized variables and will be focusing on measurable, tangible assets of all container terminals in Turkey for revealing their efficiency status to enlighten strengths and weaknesses from the operational perspective, thus bringing a new and updated way of benchmarking.

Initial Research Questions

The aim of this study is analyzing the efficiency determinants of container ports and attempting to understand the most decisive elements on port operational efficiencies. In this regard, an extensive literature examination will be carried out and port performance determinants will be selected by testing their suitability through applying objective correlation analysis method. Following on, Data Envelopment Analysis will be utilized for measuring the relative efficiency scores of Turkish container ports. The study will be classifying Turkish container ports by their relative efficiencies and revealing the reasons of inefficiencies for the inefficient ports.

The first attempt will be towards the question of “what to measure” which means that which determinants take a decisive role on a port’s operational efficiency and onwards the findings of this case will be supported by the latest academic studies. Secondly, the question will be “how to analyze the efficiency”. In the fourth chapter the methodological approach will be discussed which will be applied to the Turkish container ports. Author aims to analyze the relative efficiency levels of container ports with different specifications by benchmarking and standardizing the

method of efficiency measurement. In the end, author aims to conclude the weight distribution on these indicators that ports should focus on so that the performance improvement can be achieved. For an inefficient container port by revealing it how the resources and focus should be dispersed over the decision units is believed to be a critical issue on “achieving efficiency” for a container port/terminal.

Research Framework

Main objective of this thesis is to develop and test a tool for measuring the operational efficiency of container terminals. Through comparing and benchmarking the modern container ports’ operational assets and outputs, it is aimed to uncover the pivotal role of higher efficiency. This study aims to provide a proper performance measurement tool for measuring their relative efficiencies of container terminals. For this reason, potential port efficiency indicators are identified through broad literature review on areas of ports and container terminals, maritime transport, logistic and supply chain management (SCM).

Efficiency in its simplest definition is producing more outputs by using less inputs. Objective and subjective methods can be used for determining the input and output variables for efficiency measurement. Subjectively, the literature review is conducted and for the justification of the variables correlation analysis was applied as an objective method to prove the suitability of the potential.

Figure 1: Research Framework

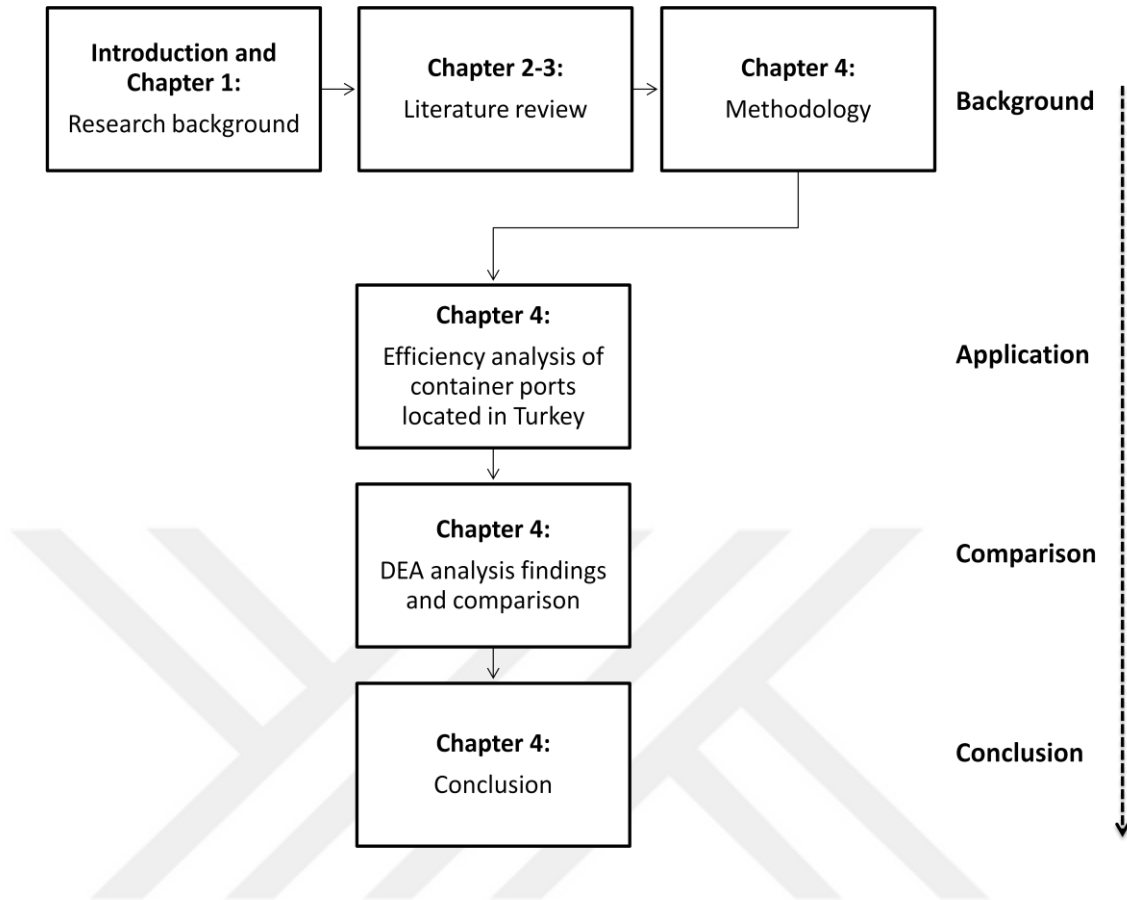


Figure 1 illustrates the research framework of this study. Firstly, research background is explained and the methodological approach has been discussed with an extensive literature examination respectively. Later on, Data Envelopment Analysis method is conducted to the selected container ports located in Turkey with the selected input and output variables. Research findings and author's conclusions on the ways to improve port efficiency levels are expressed in the last chapter.

Structure of the Thesis

This master thesis is formed by four distinctive chapters to achieve the major objectives. Chapter 1 begins with a brief introduction of maritime transport and its aspects. Later on emphasizes the importance of maritime transport for the international trade. This chapter conducts the literature review on port business environment in detail and emphasizes the position of ports in supply chains.

Developments in global maritime trade and Turkey's position in the maritime transport is examined in this chapter.

Chapter 2 is specifically focused on container terminals. It initially explains the historical development of containerization, container ships and the container terminals. Container terminal operational structure and the major facilities in container terminals as well as the handling equipments utilized in container terminals are explained and illustrated.

Chapter 3 explains the concept of benchmarking and the performance measurement systems are mentioned with reference to the studies on port efficiency measurements. Also this chapter establishes a research direction for the research framework and methodology for the port efficiency performance indicators determination. Primary (main) and supportive activities in container terminals are addressed. Afterwards, container port performance indicators related with port efficiency are explained taking reference from previous studies on broader areas such as; ports and shipping, industrial best practices and logistics and supply chain management (SCM) studies. The importance of supply chain integration for modern container ports is emphasized and potential container port efficiency indicators are investigated. Last but not least, Turkish ports that are capable of handling containerized cargo are listed and illustrated.

Chapter 4 begins with a discussion on the proper methodology for the thesis and justifies the methodological logic. The selected approach depends on the previous studies and the research objectives set by the author. Pros and cons of the selected methodology are discussed in this chapter and detailed insight information is given about the research technique. This chapter describes the ways for achieving the research goals and filling the research gap.

Chapter 4 develops a quantitative conceptual decision making tool for measuring the relative efficiency levels of container ports. This chapter validates the framework of the study through testing and demonstrating the indicators on the latest data of the container ports in Turkey. Alternative methods and Data Envelopment Analysis is explained in detail as the research model of this study. Empirical results are explained by presenting the ranking the efficiency levels of terminals with respect to their different characteristics. The relative efficiency levels of container

ports in Turkey on their physical operations are high-lightened and the most significant determinants are indicated. Later on, overall results are presented and findings of the study are revealed. The study finishes with suggesting ways for improving the inefficiencies of Turkish container terminals and discussions on research limitations and recommendations for further studies.



CHAPTER ONE

MARITIME TRANSPORT AND PORTS

1.1. IMPORTANCE OF MARITIME TRANSPORT IN GLOBAL SUPPLY CHAINS

Martin Stopford describes the oceans as “*the highways of economic development*” (Stopford, 2013: 5). Earliest evidences of maritime trade dates back to 5.000 BC where the first cargoes are transported in the Red Sea and the Mediterranean. In history, the epic voyages of Columbus, Diaz and Magellan paved the way to our modern world maritime transportation networks. The same enthusiasm brought container-ships, supertankers, and highly technological specialized ships that each year transport a ton of cargo for every person in the world (Stopford, 2013: 3). Historically thinking, economic development of modern nations would not be possible if it wasn't for maritime trade which is as old as the history of trading. Maritime transport is the result of this trade. That's why maritime transport is referred as a “derived demand”.

Maritime transport means the shipment of goods (cargo) and people by sea and other waterways so it is the actual work of carrying goods or passengers from one place to another (www.gfptt.org, 05.03.2018). More than eighty percent of the world trade is realised by maritime transport which involves long-distance (ocean) shipping, short-sea shipping and inland waterways (Unctad, 2018). In a world which is covered with water by two third, the role of maritime transport is considered to be crucial.

Maritime transport is described as a mode providing possibility to move a very large amount of cargo - especially raw material of industries- from one place to another and having qualification of such; the least energy consumption per ton and passenger, being reliable, facing minimum losses, and being 14 times cheaper than air transport, 7 times than highway, and 3.5 times than the railway hence defined as the most preferred mode of transportation in the world (Ates and Esmer, 2013: 75).

Thanks to the advantages it provides (most importantly cost advantage), maritime transport has been the driving force behind the development and growth of

world trade. Different transportation modes are compared in terms of different aspects in Table 1. When transportation modes are examined; maritime transport offers the lowest transportation unit cost and price model.

Table 1: Characteristics of Transportation Modes

	Railway	Roadway	Pipeline	Airway	Waterway
Door to door delivery	Sometimes	Yes	Sometimes	No	Sometimes
Price	Low	High	Very low	Very high	Very low
Speed	Slow	Fast	Slow	Very fast	Very slow
Reliability	Mid	Mid	Very high	Very high	Low
Need for Packaging	High	Mid	No	Low	High
Risk of loss or damage	High	Mid	Very low	Low	Mid
Flexibility	Low	High	Very low	Very low	Low
Environmental effect	Low	High	Low	Mid	Low

Source: Gourdin, 2006.

The primary duty of the transportation sector is to carry cargo around the world and the same applies to the maritime transportation. Although it is a very inadequate economic definition, it is a good starting point for studying transportation demand and the importance of maritime transport. According to customers' perspective, transportation is a service. Transportation companies carrying cargo around the world offer a variety of services to meet the specific needs of customers. The most important of these are; price, speed, reliability and safety (Stopford, 2013: 60).

In recent years, concepts of logistics and supply chain have become prominent with the expansion of businesses around the globe. Production centers are shifting away from the consumption centers with the development of technology. For this reason, businesses have to review all logistics activities to reduce costs and increase customer satisfaction.

The term of logistics has been used for about more than two decades and it is defined as *“the process of strategically managing the procurement, movement and storage of materials, parts and finished products (and the related information flow)*

through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfillment orders” (Christopher, 2016: 4).

Supply chain system is *“a one way, integrated manufacturing process wherein raw materials are converted into final products and then delivered to customers”* (Beamon, 1999: 332).

These definitions indicate that both logistics and supply chain systems cover the physical flow of materials and services from the supplier to the final customer as the end point. From this point of view, maritime transport sits at the heart of global logistics and supply chains.

1.1.1. Tramp (Bulk) Shipping

Maritime transport is categorized into three major segments according to the cargo and the ship characteristics. These segments are; bulk, liner and specialized shipping. Bulk shipping is known with its mainly raw material transportation characteristics. Liner shipping is focused on general cargoes and is referred as scheduled shipping that routes between pre-determined ports and sailing schedules. Specialized shipping may reflect both characteristics of bulk and liner but this type of shipping is carried out by ships that are specifically built for carrying certain type of cargoes such as; chemicals, liquefied gases, wheeled cargo and forest products (Stopford, 2013: 36).

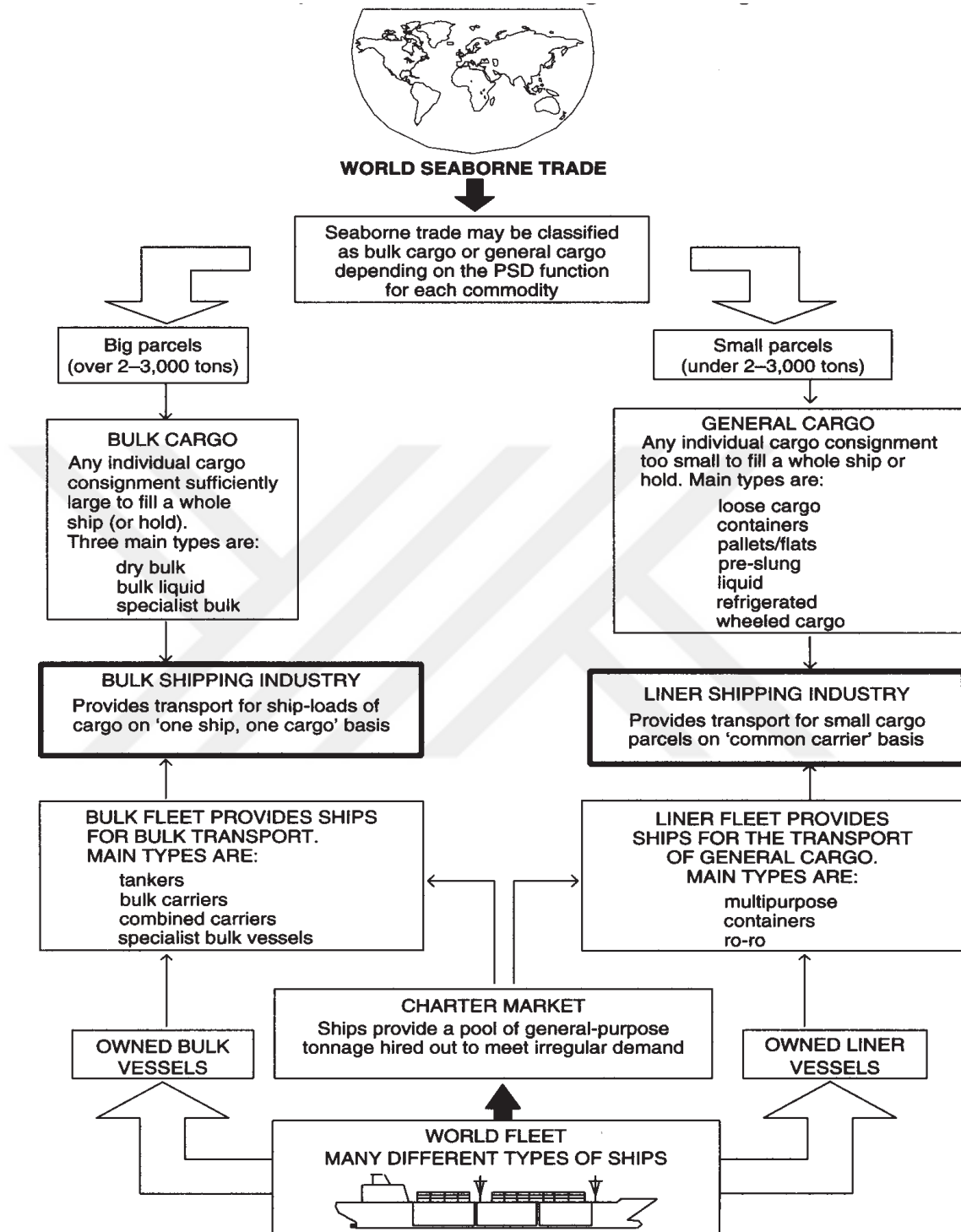
As a first step it is necessary to define ‘bulk commodity’ and ‘bulk cargo’. Bulk commodities refer to the materials such as iron ore and coal. Bulk commodities are traded in huge amounts and while being shipped, they can be handled easily and transported in bulk carrier vessels. When bulk carriers are loaded with bulk commodities, the cargo is now called a ‘bulk cargo’. In case of being shipped in containers, they are called “general cargo”. So the terminology of ‘bulk cargo’ does not describe the commodity type. It reflects the transport mode (Stopford, 2013: 64).

The term of bulk cargo is generally used for solid or liquid homogeneous raw material or product loads which are suitable for handling and transporting in bulk, such as petroleum and its products, grain, ore, coal and sulfur. Bulk loads are

transported in large quantities by vehicles such as bulk cargo ships, barges, tankers, pipelines and freight trains. This definition, based on the physical characteristics of the loads, is used by the United Nations in the classification of goods transported by sea. According to another definition based on transportation economics; any type of cargo that is carried as large as a ship load and with a lower transport cost is called as bulk cargo. Physical characteristics of the bulk cargo determine the type of ship that will carry this load, the required handling method and the structure of the maritime transport system (Baykal, 2012). Bulk cargoes are divided into two groups depending to the cargo characteristics and handling systems; dry and liquid bulk.

Sea ports as we know them today usually prefer specializing on handling specific types of cargoes in terms of achieving scale, time and operation efficiencies. Therefore the operations of ports that handle bulk cargo and general cargo differ considerably. Specialized shipping units are generally handled in liner shipping ports as their handling characteristics are alike.

Figure 2: Transportation of Bulk and General Cargo



Source: Stopford, 1997: 16.

Solid / Dry Bulk Cargo; These are homogeneous bulk solids in the form of granular and pellets and are handled by conveyor, bulk grabber crane and pneumatic systems. Main dry bulk cargoes are; iron ore, coal, grain, phosphate, bauxite,

minerals, cement and metals. Bulk cargoes such as wheat, corn are transported by ships built to carry in bulk (Baykal, 2012). The weakest aspect of general and dry bulk cargoes is that they need large, closed tanks and storage areas as volumes increase. General loads, which are often directly affected by meteorological conditions, should be stored in sheltered spaces. For this reason, there are often warehouses in general and dry bulk cargo terminals. Another advantage of closed warehouses is that they are safeguarded against lost and stolen goods. Silos and storage ponds can also be used for solid bulk cargo storage depending on the type of cargo. In some dry bulk cargo terminals, bulk material is loaded directly into the silos, whereas some terminals serve directly to the hinterland so there is no need for a closed area (Caglar, 2012). In 2017, 49% of maritime shipments in the world include major and minor bulks, 23% oil and the remaining 15% is general cargo and 13% is special cargo (Unctad, 2018¹). It should be noted that in 2017, half of the world seaborne trade (in terms of ton miles²) was generated by dry bulk shipments (Unctad, 2018: 5).

Liquid Bulk Cargo; requires tanker transportation. Liquid bulk cargoes are; Petroleum, Gasoline, LPG and LNG, Liquid chemicals, Juice and Wine. Ships that transport liquid bulk cargoes are; oil tankers, chemical product vessels, LPG and LNG vessels, wine tankers, water tankers, and acid tankers. Loading and discharging operations of liquid bulk cargoes are sustained by piping and pump systems (Long, 2003: 85).

Specialist Bulk Cargoes; include require specific handling or storage. Motor vehicles, liquefied gases, forest products, chemicals, refrigerated cargoes or a prefabricated building fall into this category (Stopford, 2003: 375).

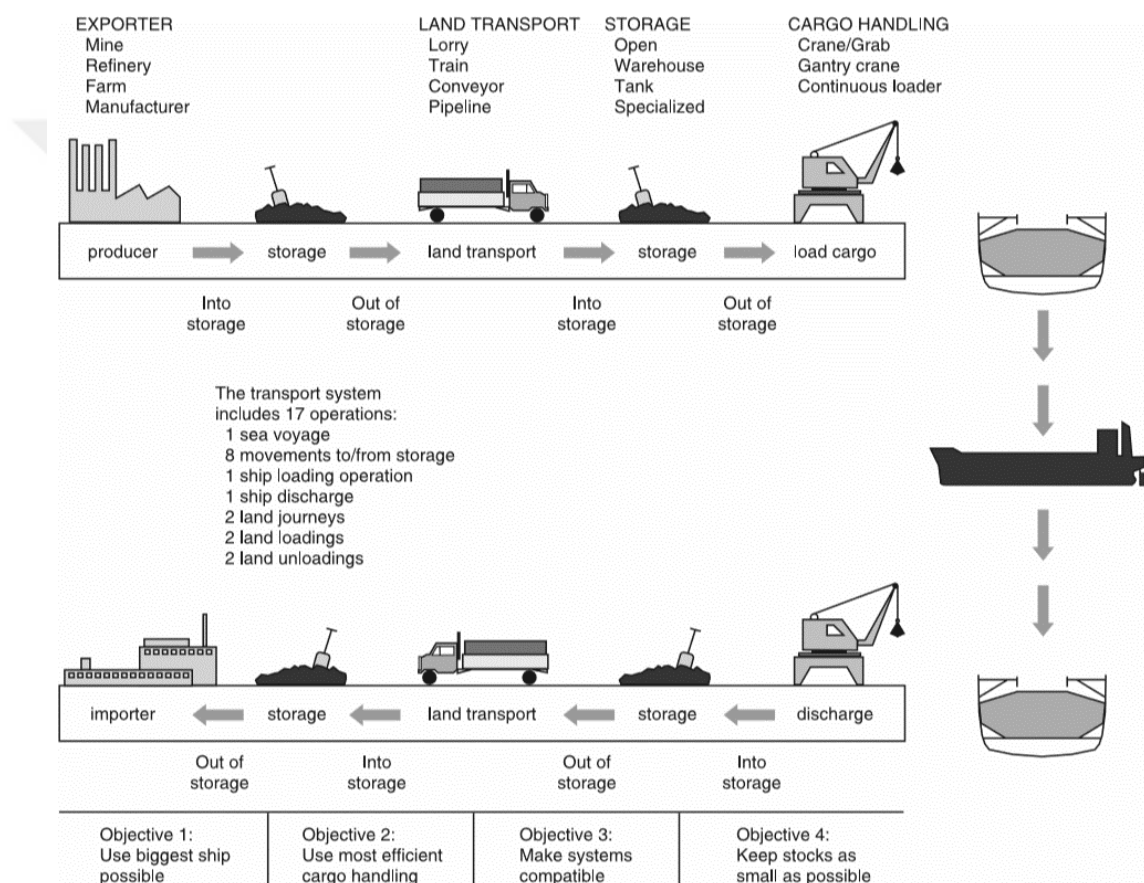
There are special terms called ‘five major bulk’ and ‘minor bulk’. Five major bulk cargoes are shipped in largest bulk carrier vessels and traded in huge amounts. These are iron ore, grain, coal, phosphates and bauxite. Bulk cargoes transported in relatively smaller amounts are referred as ‘minor bulks’ such as cement, sugar, salt, steel products, sulphur, forest products and chemicals (Stopford, 2003: 63).

¹ In this classification of Unctad, general cargo includes only container. Special cargo includes gasses, chemicals and other dry cargoes.

² A statistical unit of freight transportation equivalent to a ton of freight moved one mile.

A typical bulk transport system includes an ocean voyage and two land transportations. Land transportation can be carried out by trucks, train, conveyor, or pipeline. Figure 3 illustrates a typical bulk transport supply chain. Four storage areas are are; the origin, the loading port, the discharging port and the destination. Typically, at least 17 handling operations are needed as the cargo moves through the transportation system (Stopford, 2013: 423).

Figure 3: Elements in the Bulk Commodity Transport System



Source: Stopford, 2013: 423.

In the last fifteen years, world economy doubled its size as the global domestic production reached 80.7 trillion dollars in 2017 (World Bank, 2018). Significant increase in overseas raw material imports has led the industries to head towards port areas even more. Bulk cargo carrying fleet now forms 77% of the total world cargo carrying fleet (Unctad, 2018: 24).

1.1.2. Liner Shipping

Shipping industry is usually evaluated under two major sectors: bulk shipping and the liner shipping. Bulk shipping is involved with the transportation of homogeneous raw materials such as iron ore, oil, coal, and grain – and the liner shipping deals with final and semi-finished products such as phones, televisions, and various kinds of industrial output (Haralambides, 2007: 761). Cargo carried by liner shipping is known as ‘General Cargo’. Whether a maritime business carries out short sea shipping, cabotage transportation or offshore transportation, it provides services to customers either by tramp or liner transportation.

Liner transportation; is described as regular, continuous, and tariff based transportation whereas tramp is referred to as the service between the ports which have cargo to be transported one to another (Akten and Albayrak, 1988). Liner shipping vessels sail on scheduled dates, irrespective to that if they are full or not (Branch, 2007). Liner vessels are generally integrated into seaports with purpose-built berths and extensive port and inland infrastructures including container, Ro-Ro, passenger and other general cargo types (Branch, 2007).

Table 2: Characteristics of Tramp and Liner Transportation

Qualifications	Tramp Shipping	Liner Shipping
Operational	Homogeneous raw or semi-finished material parcels, Scale economies, Irregular schedule and port of calls	General cargo in smaller parcels, Consolidation, Regular tariffs, Fixed prices and port of calls
Operational: Cargo Type	Raw materials, Bulk Cargo	Container, Palletized, Refrigerated, Ro-Ro
Organizational	Small enterprise with a few ships and office staff	Agency network system, Sophisticated organizational structure
Contractual	Charter Party	Bill of Lading
Contractual Price	Freight rates	Cargo based tariff (Tariff = base rate + additional price – discounts)

Source: Authors own elaborations based on UNCTAD, 2004 and Stopford, 2013.

Container and Ro-Ro tonnage carry about 60 percent of the goods by value moved internationally by sea each year and generate the major growth for liner businesses (World Shipping Council, 2018). Liner shipping businesses generally deal with unitized cargoes (such as container, pallet, swap-body, even passengers can be referred as units) with efficient and reliable operations carried on highly technologic terminals. Main characteristics of liner and tramp shipping are mentioned in Table 2.

1.1.3. Specialized Shipping

‘Specialized’ shipping sits somewhere between liner and bulk shipping and has characteristics of both. Although it is treated as a separate sector of the business, the division line is not particularly well defined. The key of these specialized trades is that they use ships designed to carry a particular cargo type and provide a service targeted at a distinctive customer group. In terms of cargo transportation, some cargoes do not fit comfortably in either the container or the bulk shipping systems, and gradually specialized shipping services developed to carry these cargoes. Chemicals, gases, refrigerated cargo, forest products, vehicles, heavy lift cargoes are more open for specializing the service for the shippers. This creates transport providers an opportunity to improve their service by investing in specialized ships and services. Ships that carry these types of cargoes are highly capital intensive to build and operate so that they contribute a significant portion to the shipping industry’s capital, thus special shipping is an important business. This segment of shipping consists for about 25% of the deep sea fleet (Stopford, 2013: 470).

Five commodities have become the focus for specialized shipping operations: forest products; chemicals; refrigerated cargo; cars and wheeled vehicles; and liquefied gases. Previously all these had been carried in liners or tramps, often with the help of some special investment such as refrigerated holds and deep tanks for liquid chemicals and vegetable oil. However, the standard of service was often poor compared to modern times (Stopford, 2013: 471). World fleet and the share of specialized ships in our day are as shown in Table 3.

Table 3: World Fleet and Specialized Vessels in Numbers (2017)

Ship Type	Small ¹		Medium ²		Large ³		Total	
General Cargo Ships	4.317	12.8%	11.691	29.9%	238	1.0%	16.246	17.9%
Specialized Cargo Ships	8	0.0%	237	0.6%	73	0.4%	318	0.4%
Container Ships	19	0.1%	2.256	5.8%	2.927	16.4%	5.202	5.7%
Ro-Ro	29	0.1%	648	1.7%	816	4.5%	1.493	1.6%
Bulk Carriers	313	0.9%	3.786	9.7%	7.649	42.9%	11.748	13.0%
Oil and Chemical Tankers	1.904	5.6%	7.043	18.0%	4.484	25.1%	13.431	14.8%
Gas Tankers	36	0.1%	1.128	2.9%	815	4.5%	1.979	2.2%
Other Tankers	388	1.1%	663	1.7%	11	0.0%	1.062	1.2%
Passenger Ships	3.973	11.8%	2.734	7.0%	448	2.5%	7.155	7.9%
Offshore Vessels	2.686	8.0%	5.324	13.6%	328	1.8%	8.338	9.2%
Service Ships	2.599	7.7%	2.601	6.6%	33	0.1%	5.233	5.8%
Tugs	17.480	51.8%	1.030	2.6%	0	0.0%	18.510	20.4%
Total	33.752	100%	39.141	100%	17.822	100%	90.715	100%

Source: Equasis, 2017: 6. ⁽¹⁾ GT < 500 – ⁽²⁾ 500 ≤ GT < 25.000 – ⁽³⁾ GT ≥ 25.000

Each specialized cargo trade has its own features arising from the cargo character and the way they are carried. Chemical tankers transport liquid cargoes including chemicals, vegetable oils and oil products which must be transported separately, often subject to safety standards. The gas tankers transport LNG, LPG, and chemical gases at very low temperatures. Refrigerated ships (reefers) transport perishable commodities including frozen meat, fruit, vegetables and dairy products, and are in competition with container services. Unit load vessels carry the large general cargo units which usually cannot travel by container vessels, including forest products, wheeled vehicles and heavy lift units. Finally, passenger vessels carry people either for reason of transport or pleasure (Stopford, 2013: 471).

1.2. DEVELOPMENTS IN GLOBAL MARITIME TRADE

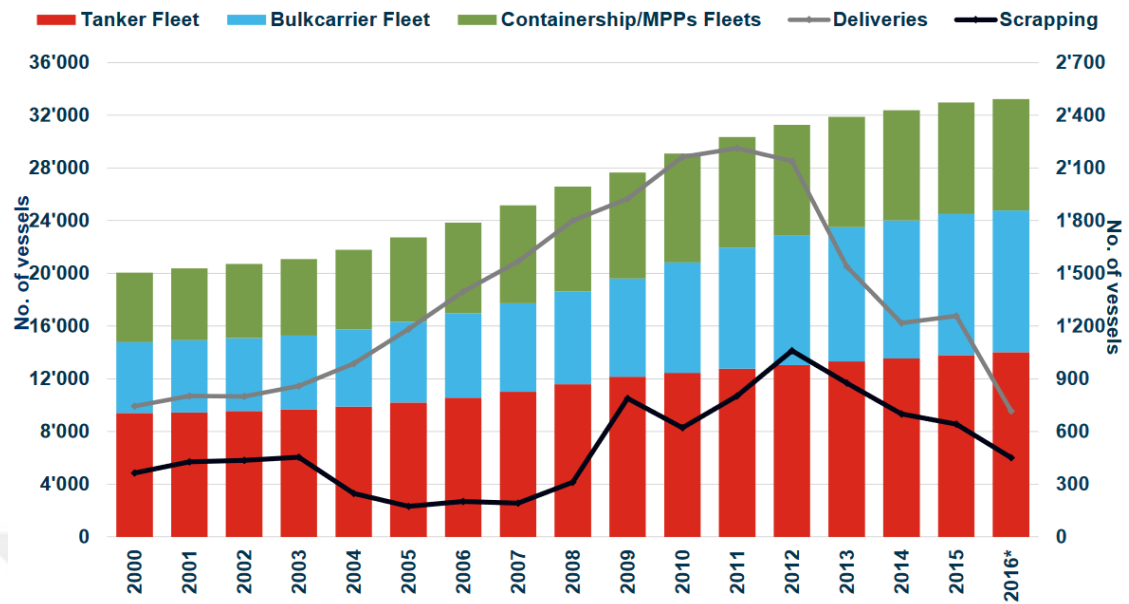
Shipping is an exciting business. Carriage of goods by the sea has emerged from the first days of trade in the world. Since the first cargoes moved by the sea about 5 thousand years ago, shipping has been at the forefront of the world trade and economic development. The discovery of new continents, building ships which are

seaworthy in trans-ocean voyages and the international transportation of raw materials have turned maritime transportation into a driving force behind the world economy and trade. Many factors have contributed to form our modern maritime transportation as we know it today. First, the transition from sails to steam engines in the 19th century is considered as a revolution in maritime transport. Steam engines freed ships from their dependence to the wind; second, iron hulls protected cargo and allowed much larger vessels to be built; third, screw propellers have made merchant ships more seaworthy, and fourth, the deep sea cable network allowed traders and shipowners to communicate across the globe (Stopford, 2013: 23).

The importance of sea transportation is increasing day by day as the world trade volume grows. Since the Second World War, as the result of the political calm and global economic growth, maritime transport continued to bloom. In addition to the industrial revolution, technological developments have had a great influence on the development of maritime transport in the world. Rapid growth in economies has led to a rapid expansion and development in transport and communication technologies worldwide. Due to the developments in technology, the amount of production and product variety increased, transportation conditions have been more convenient and more modern ships were built so the maritime trade is even more utilized in the flow of goods from one point to another.

Demand for maritime transport has led companies operating in this sector to increase their fleets, and some companies have added the maritime sector to their strategic business units. In the 1970s growth in tonnage is the outcome of the introduction of very large ships, particularly the oil tankers. In 70s and 80s the container shipping was carried out by smaller ships. In line with technological developments, economies of scale became dominant in maritime transport and the vessel capacities began to increase in 2000s (Ports, 2014: 20). Especially bulk and container shipping take the benefits of economies of scale. The development of the world merchant fleet in the 21st century so far is shown in the following Figure 4.

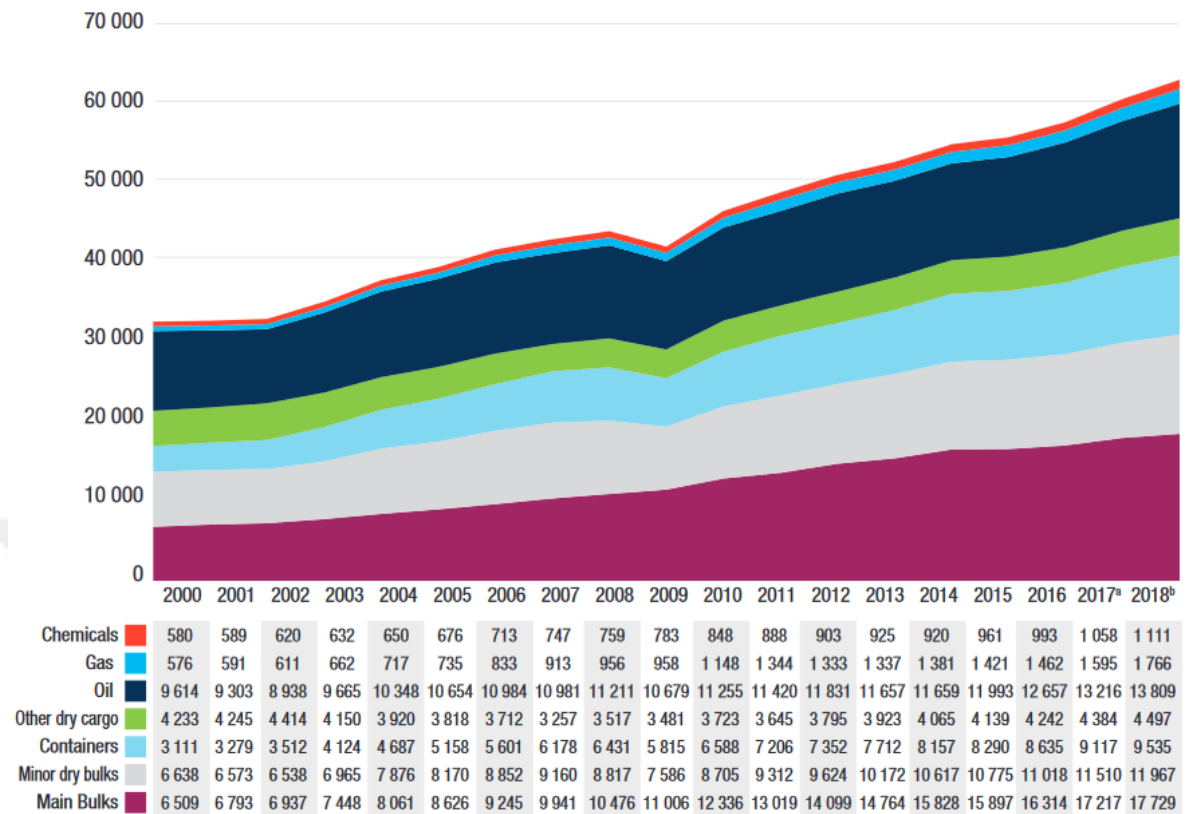
Figure 4: World Merchant Fleet Development as Number of Vessels



Source: Clarksons Research, 2016. Note: All vessels are above 100 GT. Fleet totals are on the left axis and deliveries and scrapping are on the right axis. Fleet totals are as at year end; deliveries and scrapping figures are full year totals (*August 2016).

Economic development and increasing world population has triggered maritime transport as a derived demand. Raw material needs of China and India whom achieved high economic growth figures in recent years created high demand on dry cargo ships and increased the freight rates especially between 2003 and 2009. Although the trade growth varies depending on the cargo type, almost every ship has seen some demand increase in the previous years. The upward trend in the sector has had a positive impact on shipbuilding yards as well as on raw materials suppliers to the sector (Aslan and Aymutlu, 2008: 387).

Figure 5: World Seaborne Trade in Cargo Ton-Miles, 2000–2018 (Billions)



^a Estimated.

^b Forecast.w

Source: UNCTAD, 2018: 9.

More recently, in 2017 most growth has been in gas shipping which increased by almost 10% from 1462 billion ton miles to 1595 billion ton miles. Due to the increase in gas transportation and demand on tanker vessels, freight rates of this type of ships have reached the values that even the companies would not predict. Growth rates of other types of cargoes are respectively; Chemicals %6,5 – Oil %4,4 – Other dry cargo %3,3 – Container %5,5 – Minor dry bulks %4,4 and Main Bulk cargoes %5,5. Development of seaborne trade between 1980 and 2018 is given in Figure 5.

Especially since 2008 financial crisis, traffic distribution and volumes were directly affected. Despite these cyclical changes, liner shipping was rebuilt on certain network structures (Ducruet and Notteboom, 2012: 395). International trade through maritime transport has tripled between 1980 and 2013. Dramatic increase in preference of maritime transport has been due to the fact that it is a reliable, cost efficient and environmental friendly mode of transport.

Along with the economic growth of nations, the increase in cargo amounts that is being shipped and the expansion of the world maritime fleet; another crucial key point to mention is the developments in ports and their management. This subject is going to be discussed in detail later on in this chapter. Performance of ports has crucial importance as an interchanging point of the cargo traffic from land logistics to the ocean transport and vice versa. Port business gets directly affected by the continuous growth seen in the world maritime sector. Ports require very high initial investment costs and now port business is facing fiercely competitive market conditions. For the ports that are serving in the same geography it is especially important to be competitive through using their resources effectively (Ates and Esmer, 2013).

1.2.1. Factors Affecting Maritime Trade

Nowadays, maritime transportation is not just about moving goods from one place to another by the sea, but the increase in world trade volume and parallel to the rapidly developing technologies, maritime transport in especially cargo and passenger transportation, shipbuilding industry, port services, sea tourism and yachting, covering the management of living and non-living natural resources; it has turned into a broader industry, trade and service branch. 10.7 billion tons and 58.1 billion ton-miles of world maritime transport is realized by the sea with a fleet of 94.171 ships and a total tonnage of 1.92 billion DWT (Unctad, 2018).

Maritime transport transports goods from one place to another in the most efficient and effective way and minimizes the risk of loss or damage. Maritime transport not just merely ensures that the goods are physically transported, but also helps the flow of services and information to the cargo interests. In addition, maritime transport is one of the most preferred transportation modes due to its operational efficiency (delivery time, cost) and service efficiency (flexibility and reliability) (Sanchez et al., 2003: 199). Maritime transport establishes a link between the carrier and the shipper. Maritime transport is due to international rules and regulations that are influenced by political and economic developments. Depending to the international nature of maritime trade and the increase in international trade,

factors affecting the maritime sector in the coming years are in a broad perspective; economic-political conjuncture, commodity prices (such as oil price), globalization and developments in trade, development of low cost production sites, demographic changes, global warming, energy supply and demand (Westwood, 2005: 16).

In maritime transport, the cost of the shipping changes from ship to ship or even time to time, depending on the factors such as; type of the cargo, ship carrying capacity and qualifications, experience of the ship crew and the type of voyage etc. (Saban and Gulercin, 2009: 16). Since maritime transport and trade have international characteristics, international political and economic developments determine the rules and methods of maritime transport. All political and economic events affecting the world economy and supply-demand imbalances directly affect maritime trade. Therefore, a growth or decline in international trade volume also affects maritime trade and fleets.

1.2.2. Globalization in Maritime Industry

Shipping is considered as a driving force behind the globalization and sea ports play a key role in global supply chains. Tax discounts, integration of economies, globalization and trade agreements between nations have boosted the world trade and manufacturing companies spreaded their activities around the globe searching for cheaper workforce and raw materials (Rubin and Tal, 2009: 7). This situation caused many firms to increase their geographical span of activities.

Shipping lines have adjusted themselves to the increasing competition by expanding their business networks in order to benefit from the economies of scale and began to make acquisitions and form strategic alliances. Different shipping lines began to load another line's cargo and shipping lines expanded business networks by sharing their vessels (Unctad, 2017: 49).

Among the major shipping lines there are three major alliances including Ocean Alliance, 2M, and The Alliance, which represent four fifths of the total world fleet and leaving only %20 to the remaining competition (OECD/ITF, 2018).

In the port industry, the effects of globalization took place by the appearance of so called 'global terminal operators'. Container terminal operators which were

once local are now have spreaded across countries to operate terminals in other countries. Open economies, foreign direct investments, privatization of ports have leaded the way to the birth of global terminal operators. Global terminal operators control almost eighty percent of the total port capacity in the world now (Unctad, 2017: 66).

Table 4: Global and International Terminal Operators (2015)

Rank	Terminal Operator	Throughput (million TEUs)	Share in world container ports (%)
1	PSA	53	7.7
2	Hutchison PH	47	6.9
3	DP World	37	5.4
4	APM	36	5.2
5	China Merchants	26	3.8
6	China Ocean Shipping	20	3.0
7	Terminal Investment	18	2.7
8	China Shipping Terminal Development	9	1.3
9	Evergreen	8	1.1
10	Eurogate	7	1.0

Source: Unctad, 2017: 67.

World container throughput is largely handled by global operators. In 2015, 65 percent of the total container throughput was handled by global operators as the leading five operators contributed more than 29 percent of this work. This dominance evidently has brought intense competition to port operations (Unctad, 2017: 66).

1.2.3. Developments in Turkey's Maritime Trade

Turkey is a country at the focus of transportation for the Mediterranean basin and the Arabian Peninsula, with its geographical location for Far East to Europe on the East-West route and North-South axis Mediterranean-Black Sea Route. Turkey is a production and consumption center with its 80 million population and 850 billion dollars of Gross Domestic Product, making it 17th biggest in the world (World Bank, 2019). Turkey has a geographical advantage of 4500 (8333km) nautical miles of coastline and so maritime transport is beneficial in every region within the country.

84% of the world trade and 88% of Turkey's foreign trade was transported by the sea in the year of 2017. In 2018, Turkey's exports accounted 168 billion USD and imports 223 billion USD which means a foreign trade of 391 billion USD (R. T. Ministry of Trade, 2019). Turkish ports handled 140 million tons of liquid bulk (%30), 133 million tons of dry bulk (%29), 114 million tons of container (%25), 63,9 million tons of general cargo (%14) and 8,5 million tons of cargo in vehicles (%2). In order to visualize unit information for containerized cargo, Turkish ports handled 10.010.536 TEU containers in 2017. Table 5 indicates historical changes in cargo handling amounts of Turkish ports.

Table 5: Turkey's Total Cargo Handling by Cargo Types (Million Tons)

Years	Liquid Bulk	Dry Bulk	Container	General Cargo	Cargo in vehicles	Total Handling
2005	69,0	-	36,8	-	-	213,0
2006	80,8	-	41,8	-	-	244,0
2007	108,6	-	48,6	-	-	291,5
2008	121,4	-	52,5	-	-	314,6
2009	133,3	-	46,0	-	-	309,4
2010	134,4	-	61,1	-	-	348,6
2011	129,9	107,1	70,3	46,5	9,2	363,3
2012	132,7	107,1	79,3	60,2	8,0	387,4
2013	122,5	103,6	84,6	66,0	7,9	384,9
2014	116,9	108,7	88,1	61,1	8,1	383,1
2015	146,5	110,7	87,0	63,5	8,2	416,0
2016	145,0	116,5	94,9	65,5	8,1	430,2
2017	152,8	128,8	107,9	72,1	9,3	471,1
2018	139,7	133,6	114,2	63,9	8,5	460,1

Source: www.ubak.gov.tr, 2019.

In 1999, Turkish fleet consisted 9.6 million DWT, of which 90.48% was in Turkish flag, and 9.52% was in foreign flags. As of the end of 2018, Turkish shipowners now hold 27.2 million DWT (1000 GRT and over) of fleet and 29% of them are Turkish flagged and 71% of them are foreign flagged. As of December 2018, Turkish fleet (in terms of DWT) fell by 9.1% to 15th position in the world (Unctad, 2018: 31). Turkish fleet forms 1,5% of the total world fleet in terms of

deadweight tonnage. Table 6 indicates the Turkish maritime fleet of over 100 GRT from 1999 until 2018.

Table 6: Turkish Shipowners' Fleet in National and Foreign Flags

Years	National Registry			Foreign Registry			Total		Annual change
	Number	1000 DWT	%	Number	1000 DWT	%	Number	1000 DWT	
1999	448	8.697	90	69	915	10	517	9.612	
2000	456	8.269	91	96	885	9	552	9.154	-5,10%
2001	445	7.321	82	107	1.607	18	552	8.928	-2,10%
2002	451	7.815	84	117	1.514	16	568	9.329	4,50%
2003	432	7.045	80	147	1.772	20	579	8.817	-5,50%
2004	408	6.556	75	163	2.159	25	571	8.715	-1,20%
2005	420	6.427	70	237	2.725	30	657	9.152	5,00%
2006	432	6.844	65	353	3.609	35	785	10.453	14,20%
2007	446	6.464	58	424	4.650	42	870	11.114	6,30%
2008	490	6.592	50	513	6.591	50	1003	13.183	18,60%
2009	520	6.736	44	636	8.592	56	1156	15.328	16,30%
2010	560	7.246	42	665	9.954	58	1225	17.200	12,20%
2011	547	7.797	40	672	11.863	60	1219	19.660	14,30%
2012	523	8.479	38	642	14.093	62	1165	22.572	14,80%
2013	627	9.488	31	842	20.838	69	1469	30.326	34,40%
2014	599	8.580	28	890	21.846	72	1489	30.426	0,30%
2015	564	8.297	30	834	19.209	70	1398	27.506	-9,60%
2016	551	8.272	28	984	20.879	72	1535	29.151	6,00%
2017	525	7.800	27	1022	21.465	73	1547	29.265	0,40%
2018	633	8.034	29	889	19.207	71	1522	27.241	-7,00%

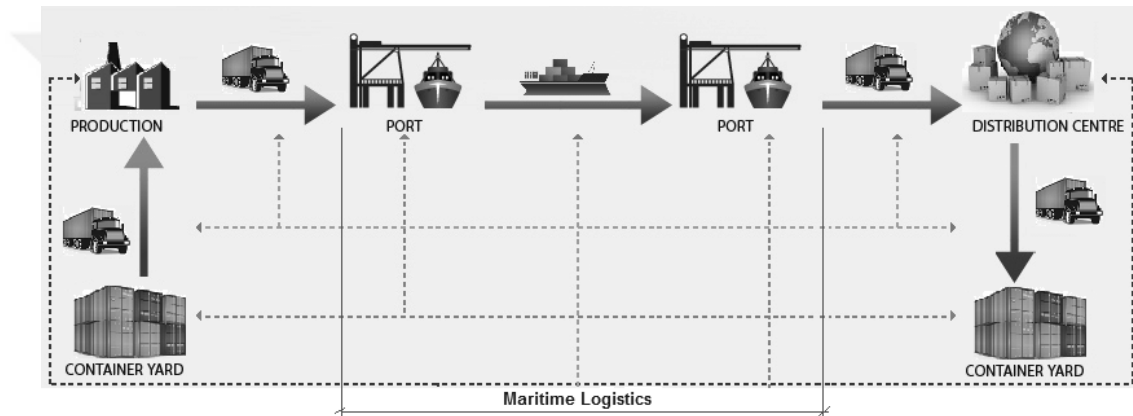
Source: www.ubak.gov.tr, 2019.

1.3. THE ROLE AND IMPORTANCE OF PORTS IN MARITIME TRADE

Throughout history, oceans and seas have become a crucial part of our social lives. With the development of technology, maritime transportation is developed and not only became an important and attractive sector for the economies, but also has led to the development of shipbuilding industry and port services, especially for cargo and passenger transportation. Port operations, shipping through the sea and freight forwarding make up the 'Maritime Logistics' activities (Song and Panayides, 2012: 16). Ports where ships take shelter in bad weather conditions increase their

importance in both world trade and maritime logistics (Esmer, 2009: 10). Ports have a crucial role in logistics as enabling modal shifting intersection point between land and sea transport systems. The ports are not only the infrastructures of transport, but also bases for industrial activities. In these aspects, ports serve not only as a logistics center for national economies, but also as a transporting point for goods into global trade. Thus, ports play an active role in the creation of maritime trade demand. As shown in Figure 6 below, ports and terminals serve as important gates and logistics centers in the international trade between the production and the consumption points.

Figure 6: Position of Ports in Typical Shipping



Source: Nicolae et al., 2016: 127.

At the beginning of world trade, sea transportation is preferred for large loads where the transportation cost is high. The essence of maritime transport is built upon port operations. For this reason, ports have to keep up with the increasing ship sizes and technological developments. In this way, it is aimed to increase the efficiency and effectiveness of the functions of the ports. Given the world maritime trade statistics, it is seen that every port in the Mediterranean and the Black Sea regions are increasing their trade volumes whereas Turkish ports show slower growth in trade (Korkmaz, 2012: 97).

Approximately 90% of international trade is realized by sea. Global port traffic volume increases by 3% on average annually (Unctad, 2018: 7). It is impossible for such a large trade to happen with inefficient ports. Efficient ports are needed to supply raw materials to production centers and distribute the final products across the globe. All these facts conclude that ports have a certain importance in the

global economy and ensure economic development and provide services for maritime logistics (Trujillo and Tovar, 2007: 148).

Correlating with the increasing international trade volume due to globalization in recent years, the competition between ports across the world continuously increase as a result of closely related factors such as the development of new technologies such as containerization, the increasing capacity of container ships, the demand for cheaper and better quality services and horizontal mergers in the business. Due to the fact that ships with high tonnage could not berth in every port, a system called “hub and spoke” was introduced. The ports that are able to become hubs in their region control the international freight transport, while the remaining ones lose their competitiveness. Many factors such as location, infrastructure, draft, quality of service, efficiency and reliability of a port can be effective in order to become a hub point (Keceli and Aydogdu, 2015: 6).

There is a two-way flow in the port activities as both towards the shipper and carrier and a service to the buyer and the seller. For this reason, a disruption in any of the in-port logistics processes leads to disruption and negative impact of international logistics operations.

1.4. ASPECTS OF PORT BUSINESS

The port business environments continuously change. Competitive ports are the ones who seek new strategies for providing better services to their customers whom usually have different perspective and expectations. This section outlines the aspects of port business broadly and takes a look into the business from different perspectives while explaining what needs to be known when it comes to port management and evolutionary developments in port business. This section creates an overview for the crucial dimensions of port business, port infrastructure and superstructures, port types and functions, management of ports, port competition and port sustainability.

1.4.1. Port and Terminal Concepts

Ports are reserved, secured, natural or artificial sites where ships can berth or take shelter in good or bad weather conditions. In ports, ships carry out loading, discharging, storing and in some cases manufacturing, packaging operations for cargo and transferring operations for passengers and vehicles. Ports provide integration and shifting options between the modes of transport for cargo, containing open and closed logistics facilities, road and railway infrastructures, different handling equipments etc. Ports contain established units and organizations required for operations such as administrative, agency, customs, sanitary, and police. Ports constitute huge economic activities and employment opportunities in a certain region of the country and also provide some socio-cultural activities within its structure and surroundings (Caglar, 2012: 7).

In maritime transport, port and terminal concepts are often used as synonyms. In fact, a specialized part of the port is called terminal. A terminal is referred to as a dedicated part of a port specializing on handling one or a few specific types of cargoes. Terminals are named according to the type of load they handle e.g. container terminal, LPG terminal and so on. For this reason, there can be different terminal areas in a port or there can be ports which only consist of one type of terminal, as seen in some container terminals. For this reason, some ports have become specialized according to specific loads and have started to be shaped according to special ships and cargoes. Historically, terminal layouts fundamentally changed since the early 1960s as the gradual shift took place from conventional break-bulk terminals to container terminals. Ports and terminals increasingly get impacted by industrial processes. In terms of containerization, it has substantially changed port dynamics to favor the emergence of specialized container ships (Notteboom and Rodrigue, 2009: 74). In the context of terminal specialization; container, Ro-Ro, liquid bulk cargo, dry bulk cargo and passenger terminals can be counted (Baykal, 2012). Detailed information regarding the container terminals subject to this thesis will be given in the second chapter.

1.4.2. Port Services and Contribution to Economic Development

Historically, ports have been named as places where the ships take shelter or approach the land in order to load and unload their cargoes. A port can be formed by natural reasons or by humans as an artificially made structure (Marine Insight, 2016: 1). Geographic factors are not considered as decisive as it was in the past in determining the locations of ports. Some ports (especially container ports) are separated from others by their handling equipments. Other ports vary according to the type of cargo handled. Cargo handling variety of some ports (such as liquid bulk ports) can be very limited.

A typical port consists of water access infrastructure, port infrastructure, terminals, land access and other facilities. Water access infrastructure; consists of approach channels and navigation aids in the water. Their maintenance is usually carried out by institutions other than the port. There are also substructures such as docks and shipyards inside the port. There are cranes and buildings at the terminals where the ships are loaded and unloaded. Highways and rail links create terrestrial access. Other facilities vary according to the commercial activities around the port (Long, 2003: 85). When all this is considered, a typical port needs to provide at least the infrastructure, superstructure and services shown in Table 7 to meet the simple needs of customers.

Table 7: Port Facilities and Services Provided by Ports

Services and Facilities for Ships	Services and Facilities for Cargo
Navigation aids and Vessel Traffic System	Cargo handling on ship and on quay
Approach channel	Transport to/from storage
Pilotage, tug and mooring	Storage/warehousing
Locks	Tallying, marking, weighing, surveying
Berths	Surveillance, protection, sanitary measures
Administrative formalities	Dangerous cargo segregation
Police, immigrations, customs, health	Customs and documentary control
Supplies and repairs	Receiving and delivery
Internet, medical, waste disposal	Additional ‘added value’ services
Port state control	Packaging, labeling, sorting, assembling

Table 7: Port Facilities and Services Provided by Ports (continued)

Cargo transfer	Cleaning
Opening/closing of hatches	Setting up a logistic network
Stuffing/stripping	Setting up a marketing package

Source: Alderton and Saieva, 2013: 5.

Ports contribute greatly to international trade and consequently to the national and regional economies. In order to assess the economic efficiency of a port, industrial dimensions need to be analyzed. In fact, the first observed characteristic of the port industry is the diversity in its activities. The opportunities created by competition in the provision of port services and all connected transactions should be considered optimally according to the size and services of the port (Trujillo and Tovar, 2007: 148). Ports have a great impact on the regional economies and therefore, ports are not only known as logistic centers, but also as industry, agency, bank, and distribution/storage centers.

Ports are very expensive and long-term investments and port industry is one of the prior sectors affected by the economic developments in the world because it serves both national and international cargo flows. Ports which are the main elements of transportation in the national and international trade of countries are one of the leading sectors due to the added value it provides, the employment it creates and the contribution to other industries it interacts with. In recent years, the port sector has been moving towards specialization according to the cargo types. Container transportation is increasing its proportion in maritime transportation every year and it is also one of the priority specialization areas (Ates and Esmer, 2013: 91).

According to Branch (2012), ports are undergoing through intense transformation and they have become technically and economically important for the maritime and international trade. The significance of ports in a country's economy is better recognized when the occupations in this area are reduced or stopped. An economic crisis of a country is immediately reflected into its ports. Port calls rapidly decrease in such circumstances (Koknel, 1978: 14). Technological developments and globalization have caused a change in the port concept; from the concept of entrance gate to the concept of organized port (Barros and Barros, 2013: 23).

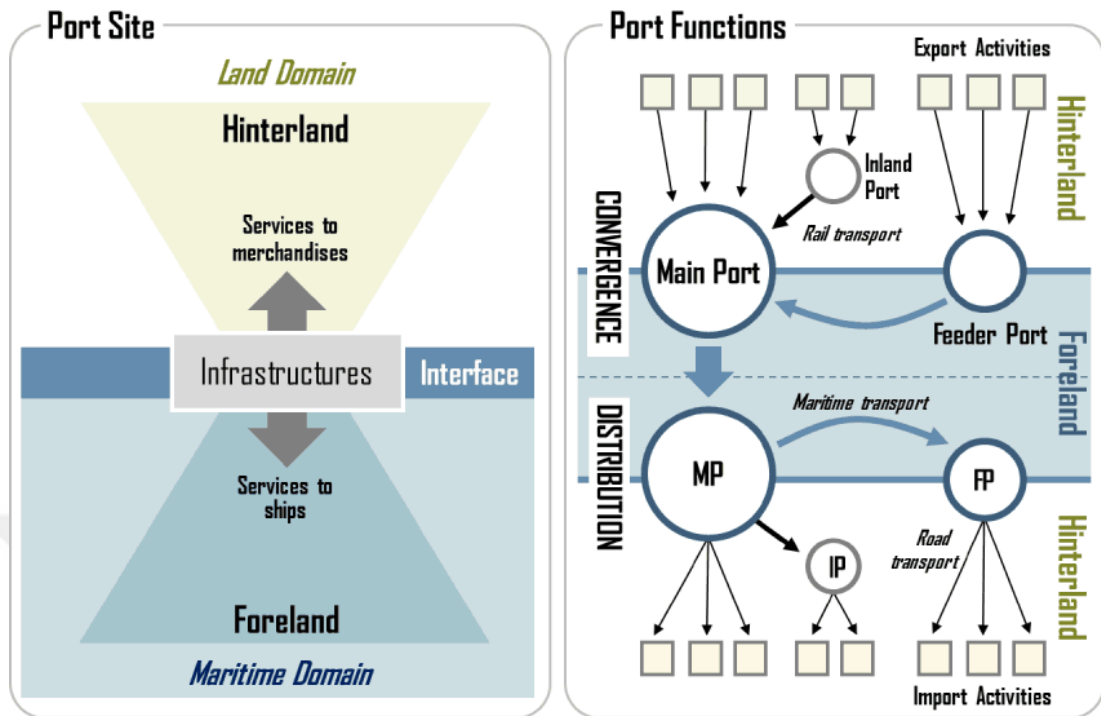
Ports constitute the most important infrastructure to maritime transportation and they are referred as gates through which the goods subject to trade enter and exit the economy. Turkey is located at the crossroads of three continents as a natural bridge between Europe, Central Asia and the Middle East, with a great potential in terms of international transportation. More than eighty per cent of the international trade of Turkey is realized by maritime transport through seaports (www.ubak.gov.tr, 12.02.2019). Hereby, ports are one of the main building blocks of maritime transport and immensely contribute to national and regional economies with domestic, foreign and transit transportation services.

Most economies rely on ports to promote international trade. Port services continue from the ship's berthing until its departure. Ports have to keep up with the developing technology, and need to use systems with high efficiency in order to provide the best practices to the cargo and vessels and keep the costs at the minimum.

1.4.3. Port Sites and Functions of Ports

Port location is constrained by the land and maritime access of the port site. Land and maritime accesses are crucial for port operations and must be jointly satisfied as maritime/land interface. This interface acts as a buffer zone along the coastline (or a river) that experiences the accumulation of port infrastructures. Activities such as the construction of port facilities are very expensive, pointing out the enduring importance of a well-conditioned port site (Rodrigue et al., 2016: 24).

Figure 7: Port Site and Functions



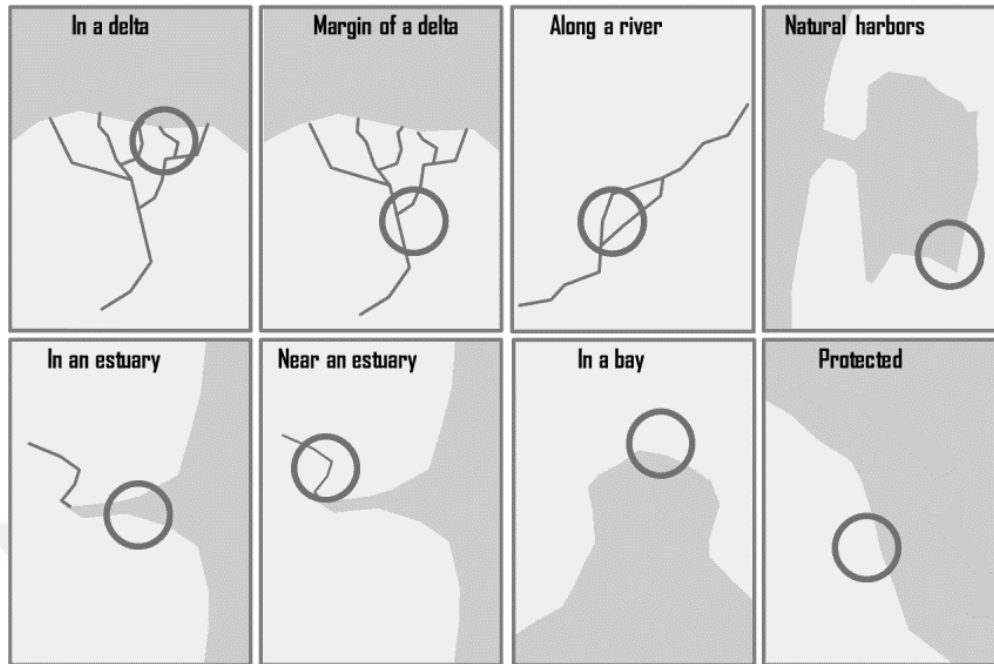
Source: www.transportgeography.org, 18.03.2019.

Ports are the components of freight distributions as they support export and import activities. Ports are convergence points of sea and land transportation systems and collection points from the surrounding land areas, defining the port hinterland and foreland. Freight can reach a port directly through road or rail transportation, or indirectly through an inland port or traffic consolidation center at a feeder port and shipped by short-sea shipping or coastal transportation. At the local level, all ports provide services to ships and cargo interests with docks, berths, cranes, warehouses and access to inland distribution systems (Rodrigue et al., 2016: 25).

As illustrated in Figure 8, there can be many different port sites depending to different nautical profiles. Port sites can be classified under two main headings as; Mainland ports and Seaports.

Mainland ports are linked to a major river, which is usually serving a giant hinterland and seaports have direct access to the sea and built to benefit from a local geographical feature. This type of ports can involve bays, natural harbors and protected locations (Rodrigue et al., 2016: 27).

Figure 8: Port Sites



Source: www.transportgeography.org, 18.03.2019.

Maritime logistics operations have three basic departments; transportation, port/terminal operations and freight forwarding. The value of maritime logistics services can be increased by better coordinating the activities of maritime operators and providing a more productive and efficient service to their customers (Lee and Song, 2015: 477). According to MARAD (1999), the roles and functions of ports are classified in political, geographical, economic and social perspectives. Ports have four basic functions as property owner, regulator, operator and community manager (Verhoeven, 2010: 247).

Ports provide many roles, functions and services for maritime transport. Port operations are generally explained by two traditional port systems as “services for ships and services for cargoes”. Services provided to the ships cover the services at sea and on the shore. Cargo services cover coastal services and carried out entirely on land areas. The institutional structures, operational and management styles of port roles and functions vary depending on port generations (Bichou and Gray, 2004: 50). Within the port system, one or more organizations can undertake the following roles (World Bank, 2007: 81):

- Providing a variety of services for private organizations

- Regulating duties in economic activities, transactions and operations
- Regulating task on environmental control, maritime safety and security
- Planning future operations and capital investments
- Nautical services and facilities
- Marketing and promoting actions of port services
- Cargo handling and storing
- Ancillary activities.

In order to carry out operations in container ports; basic needs are as berth crane, storage area, transport vehicles to be used in handling and field equipment, administrative personnel, gateway control, support services, rail and/or road connections (Altincubuk, 2000). Hassan (1993: 17) explains port operations under four headings and these are; ship operations, cargo handling operations, inland transport operations and warehousing operations.

Ship operations function is mandated by the port authorities or port managements and often related with harbormaster's function. The harbormaster's office appoints berths and coordinates all legal and operational tasks from berthing until the unberthing time of a vessel. These services may include vessel traffic services, pilotage, towage, mooring and unmooring (World Bank, 2007: 81).

Cargo handling and warehousing function covers all activities related to loading and discharging a vessel, including warehousing and inland transport. Cargo loading and unloading operations can be outsourced to a 3rd party stevedoring company (World Bank, 2007: 81).

Ports have become capital intensive industries since 1980s as the labor force is being taken over by modern handling equipments and port automations. Containerization has significantly changed port operations. The handling of containers and cargoes allows cost reductions and on the other hand it brings the need for new handling equipments. The speed and efficiency of the port operation depends directly on the equipment used in the port and their operation in a coordinated manner. Operation planning in ports is made for the effective use of important resources during critical operations (Kim and Lee, 2015: 47). Appropriate equipments should be selected according to the size, lay-out and design of the port,

the number of full/empty containers and the operation should be supported (Tumis, 2008: 89).

1.4.4. Evolutionary Changes of Ports

Ports have gone through drastical changes and developments over time. The study of UNCTAD (1992) “Port Marketing and the Challenge of the Third Generation Port” divides the historical development of ports into three different time periods. In the following Table 8, general characteristics of port generations are explained as described by Unctad.

Table 8: Evolutionary Changes in Ports: Port Generations

	1st Generation	2nd Generation	3rd Generation	4th Generation
Period of development	Less than 60 years	60 years	80 years	80 years
Key Cargo	General Cargo and Bulk	General Cargo and Bulk	Container, unitized and bulk	Container, unitized and bulk
Attitude and the Port Development Strategy	Conservative points of interface modes of transport	Expansionist Transportation Center, Commercial and Industrial	Oriented Trade Center for Integrated Transport and Logistics Platform for International Trade	Facing the international market
Activities	Loading, Unloading, Storage, Navigation Services	Transformation of Cargo, Commercial and Industrial linked to the ship	Information Distribution and Freight, Logistics Activities	Industrial Processing Zones, Clusters or Port Charges – Industrial Business Networks
Characteristics of the Organization	Independent activities within the Port Information Relationship between the Port and its users	Close relationship between Port and User, Integrated Activities in Port	Integration with the Port Community and Transportation Network	Integration with Port Community and Transportation Network
Characteristics of Production of Service	Low Value, Concentrated loads	Load Flow, Integrated Services, Average Value	Flow and Load Distribution and Information, Multiple services	Value-Added Services
Decisive factors	Labour and Capital	Capital	Technology and Know-How	Technology and Know-How

Source: Unctad, 1992; Paixao and Marlow, 2003.

In this distinction, the scope of the port services traditionally starts with the function of loading and unloading the cargo and is extended to the definition of ports

as large-scale logistics centers and areas where value-added services are provided after the 80s.

The first and second generation port era can be described as with low value-added services provided and the basic functions of a port are fulfilled. In the development of third generation ports; the rise of global trade, technological developments in the maritime industry, the increasing importance of globalization in global trade and intermodal transport, and therefore containerization has been decisive (Beresford et al., 2004; 94).

These technological developments can be summarized as the growth of ship sizes, modernization of cargo handling equipments and the development of information technologies (Chlomodis and Pallis, 2002; 17). These technological developments have strengthened the links between ports and hinterlands. Ports have evolved their services and infrastructures for national and international transportation purposes (Teilet, 1996: 13).

Third generation ports are inadequate to adapt to today's changing market conditions, uncertainties and external environmental conditions. In order to cope with these uncertainties, as in other industries, ports had become more flexible and more 'agile' (Paixao and Marlow, 2003: 355). This new approach has been described as 'fourth generation ports'. Fourth generation ports are referred as global terminals that merge port operations with the global supply chains. The terminal concept has been used in fourth generation ports (Martin and Thomas, 2001: 279). Yet still it is argued that the fourth generation ports are not responsive to the needs of the rapidly developing global port users and the needs of the stakeholders (Lee and Lam, 2015: 106).

More recently, Flynn et al. (2011) referred the fifth-generation ports as customer and community-oriented port systems. 5th generation ports are also described as customer centric, community-focused ports. The role of port stakeholders to the social and environmental area is an important indicator as a responsibility of 5th generation ports. 5th generation ports not only function as a global maritime transport centers but also have positive impacts on social environment and nature protection (Kaliszewski, 2018). If only in cooperation with

the stakeholders and their support, ports can be competitive and succeed in the long term.

1.4.5. Harbor Types, Port Types and Classifications

Harbor implies a place along the coast that provides shelter and mooring for ships, boats and barges. Ports are located on the coast and can be used to load and unload cargo or transfer passengers (Van Rijn, 2005: 39).

Harbors can be natural, semi-natural or artificial. Natural formations on sea coasts are called natural harbors. Sydney and Pearl Harbor are examples of natural harbors. Semi-natural harbors are protected on sides by headlands and require artificially made port entrance. Port of Venice is a semi-natural harbor. Rotterdam, Barcelona and Long Beach are examples of artificial harbors (Puri and Anand, 1990: 12).

Ports can be classified under 7 categories according to their function and purpose of use, geographical location, size, cargo flow and customs, activity area, management types and types of cargoes handled (Acer, 2018: 31). Table 9 lists different types of harbors and ports.

Table 9: Harbor and Port Types

Harbor types by the formation of coast:	Natural, Semi-Natural, Artificial
Ports by functions and purpose of use:	Shelter port, Fishing port, Marina, Ship building and repairing port, Fuel port, Commercial Port, Industrial port, Military port, Free zone port, Transit port, Specialized port, Local port
Ports by geographical location:	Coastal port, Estuary port, River port, Gulf Port, Island-Lake-Canal Ports, Tidal Port
Ports by their size:	Classification depends on; Cargo handling amount per year, Value of cargo, Number of berth, Ships berthed, Ship sizes
Ports by cargo flow and customs:	Import-export ports, Transit ports, Regional ports, Local ports, Customs port, Free economic zone ports
Ports by traffic area:	International, National, Regional, Local

Table 9: Port Infrastructure and Superstructure Elements (continued)

Ports by management types:	Public port, Local government port, Private port
Ports by cargo types:	General cargo, Bulk cargo, Inland waterway, Cargo-passenger, Marina

Source: Derived from Acer, 2018; Baykal, 2012; Koknel, 1978; Altincubuk 2000.

According to another source, port types are classified as; inland port, fishing port, dry port, warm-water port and seaports (cruise port, port of call, cargo port) (Singh, 2018).

Ports may focus on handling one particular type of cargo or various types of cargoes; such as container, iron ore, cement, chemicals, wheeled cargo etc. (Ha, 2017). Additionally, all ports can be divided into different terminals which can be operated by different parties which are known as terminal operators or stevedores.

1.4.6. Port Infrastructure and Superstructure

Port structure is formed by port infrastructure, port superstructure and port equipments (Cetin et al., 2017: 9). A port obviously needs a good sea access (access channels, breakwaters and so on) and land access (roads, railways etc.). A port needs infrastructures such as a deep access channel, berths, roads, railways, and internal superstructures such as; aprons, cranes, handling equipments, warehouses, office buildings, parking areas and so on (Trujillo and Nombela, 2000: 74).

Another publication distinguishes port structures as; port access infrastructure, basic infrastructure, equipment infrastructure and superstructure. Basic infrastructure comprises locks, breakwaters, pontoons, primary roads to and inside port, docks etc. Port-internal basic infrastructure includes docks, dredging and port area levelling. Equipment infrastructure includes mooring infrastructure, pontoons, landing bridges, ramps etc. Finally, superstructure includes warehouses and storage areas of all kinds, as well as the other port structures not being port access, basic and equipment infrastructures (Meersman et al., 2014: 11). In Table 10 port infrastructure and superstructure elements are pointed out in a broader view.

Table 10: Port Infrastructure and Superstructure Elements

Port Infrastructure Elements		Port Superstructure Elements	
Access Channel	Docks	Aprons	Office Buildings
Buoys	Ramps	Warehouses, Sheds	Weighing Station
Anchorage Area	Terminals (Ro-Ro, Container etc.)	Silos	Fire Fighting Station
Lighthouses	Inland Water Channels	Waste Reception Facilities	Car & Lorry Parks
Breakwaters	Roads	Reefer	CFS
Mooring facilities (Fenders, Pontoons)	Railways	Dangerous Goods Stores	Networks (Communication, Power, Fresh water)
Berths (Piers, Quays)	Pipelines	Stacking & Marshalling Areas	Gates, Fences

Port infrastructure, superstructure and handling equipments may differ depending on the cargo types handled at the port. Different terminals within a port can use the same infrastructure elements and yet superstructure and handling equipments differ depending on the cargo types handled at the terminal. As bulk cargo terminals require protected shelters for storage and conveyor systems to handle cargo, container terminals require large storage yards and Container Freight Stations for storage and gantry cranes for cargo handling. In the next chapter of this thesis, port layout (port configuration) and port equipments will be explained in detail, specifically for container terminals subject to this thesis.

Increasingly, there have been trends of automated handling equipment infrastructure in transportation. From an economic and efficiency point of view, when there is enough container traffic, it is more productive to have more specialized and modern handling equipments instead of conventional or multi-purpose ones (PSA Corporation Limited, 1999: 1).

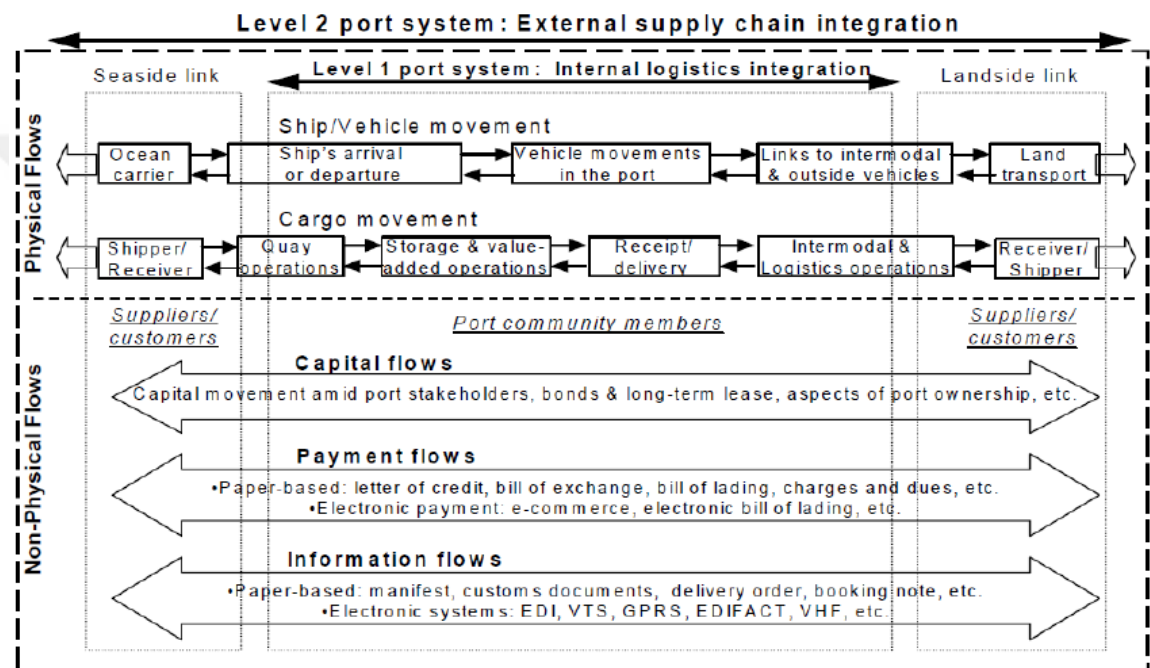
1.4.7. Ports in Global Supply Chains and the Backbone Role of Ports

The role of ports in the supply chains is crucial as it forms an intersection place where the land and sea transportation modes connect to each other. As a

logistics node in supply chains, ports provide value added services (Charler and Ridolfi, 1994: 237).

Figure 9 represents the integration concept between the port and the supply chain for the physical and non-physical movements. Ports have to fulfill all their roles in coordination with the land and seaside to achieve an efficient movement of the physical and non-physical flow of goods (Ha, 2017: 20).

Figure 9: Integration of Port Internal and External Systems



Source: Unctad, 2004.

The backbone role of seaports refers to the vessel and cargo operations as well as the operations related with the cargo transfer from ports to the railway or roadway transportation modes. The performance of the backbone role is related with productivity, output and lead-time. Companies achieving a combination of speed and productivity improvements in their operations are more likely to gain greater performances levels (Schmenner, 2015: 341).

1.4.8. Port Authority and Port Administration Models

The governing body of ports usually referred as “Port Authority, Port Management or Port Administration” (World Bank, 2007: 11). Commission of the European Communities defines the port authority as “a body which, has as its objective under national law or regulation the administration and management of the port infrastructures, and the coordination and control of the activities of the different operators present in the port” (Panayides and Song, 2015: 350). In this regard, port authorities traditionally have regulator, landlord and operator functions.

There are four main port administration models classified as; public service, tool, landlord and private service (World Bank, 2007: 82).

Table 11: Port Administrative Models

Port administrative model	Definition
Public service ports	<i>“the port authority owns the infrastructure and performs the complete range of services required for the functioning of the port system. Some ancillary services can be allocated to private companies. Service ports are generally a branch of a government ministry. The number of public service ports is declining”</i>
Tool ports	<i>“tool ports are similar to public service ports but differ in that cargo operations are handled by the private sector. However, terminal equipment, such as quay cranes and forklift trucks, is owned by the port authority”</i>
Landlord ports	<i>“this is the most common port management model, where the port authority acts as a regulatory body, while port operations – especially cargo handling – are carried out by private companies. Infrastructure, particularly terminals, are leased to private operating companies or to industries such as refineries, grain terminals, tank terminals, and chemical plant”</i>
Private service ports	<i>“the port facilities are fully privatized, but retain their maritime role. Likewise, the port authority is entirely privatized. Most of the port functions are under private control, although the public sector enjoys standard regulatory oversight powers and can own port shares”</i>

Source: www.ppiaf.org, (10.05.2018).

Each model has its own characteristics concerning the ownership of infrastructure, cargo handling equipment, terminal operation and provision of port services to ships such as cargo handling and pilotage and towage. A general overview on distribution of functions between public and private authorities for different port administration models are shown in Table 11.

Characteristics of management models vary for public and private sector responsibilities. Criterias to be considered for distinguishing the port administration models can be summarized as;

- Public, private or mixed service provision
- Local, regional or global orientation
- Ownership of infrastructure
- Ownership of superstructure and equipment
- Dock labor and management (Mundial, 2007: 14).

Involvement of private sector in port management business has brought major changes to the ownership and the operating structures ports. The institutional structures and the role of the traditional owners and operators of ports have turned into a more comprehensive management models (Unctad, 2017: 74). Mainly increasing port competition has triggered port administrations to become ‘agile’ in adapting to the changing competitive market environments. Private ports are undoubtedly more quick responsive to the market developments compared to public service ports (Paixao and Marlow, 2003: 335).

1.4.9. Port Competition and Co-Opetition

The rivalry in the port business makes it inevitable to avoid competition. Port competition is classified into three categories by World Bank: (a) inter-port competition is the type in which ports or terminals compete for the same trade, (b) intra-port competition is where the terminals of a port compete with each other for the same markets and (c) intra-terminal competition is related with the stevedoring companies competing with each other for providing the same services in a terminal.

The categories of port competition suggested are very similar but the difference between them is still identified in Table 12.

Table 12: Types of Port Competition

Author(s)	Definitions of Port Competition Types
World Bank (2017)	<i>“Inter-port competition: competition between ports or their terminals for the same trade”</i>
	<i>“Intra-port competition: competition between terminal operators within the same port for the same markets”</i>
	<i>“Intra-terminal competition: competition between companies to provide the same services within the same terminal”</i>
Van de Voorde and Winkelmanns (2012)	<i>“Intra-port competition at operator level: competition between operators within a given port with regard to a specific traffic category”</i>
	<i>“Inter-port competition at operator level: competition between operators from different ports mainly within the same range and serving more or less the same hinterland”</i>
	<i>“Inter-port competition at port authority level: competition between port authorities – utility mission of seaports with local/national port range”</i>

Source: Ha, 2017: 19.

With regard to intra-port competition, for instance Aliaga region ports in Turkey has seen intense intra-port competition since many new container terminals started up operations in that region. This extreme competitive situation brings the issue of efficiency on table.

The term ‘port co-opetition’ is a new mixture of term which is used when ports compete and cooperate at the same time. Port co-opetition can be a strategic option for terminal operators for increasing their market power in the long run by co-operating arrangements (Song and Panayides, 2012: 20). Where there is a competition, it is normal to expect that there would be a race for customer and this would bring improvements on the diversity and the quality of the value added services provided in the ports.

1.4.10. Customer-Oriented Practices

Ports are the facilities that provide value added services to the ship, cargo and passengers. Customer orientation in port operations requires the fulfillment of the desired service or added value in the desired time and manner. Different stakeholders

may have different requests and the flexibility of the port is important for customer satisfaction. There may also be disagreements on economic, social or environmental issues that may arise in the relations of different parties with the port. (Notteboom and Winkelmanns, 2001: 76).

Ports should take initiatives to ensure customer and stakeholder satisfaction and to establish good and sustainable relations with key stakeholders. The ports which are in good relationship with the customer are more likely achieve competitive advantage (Dooms and Verbeke, 2007).

For this reason, port operators and authorities tend to provide more customer-focused services and they take service quality as an important measure. Service quality measurement from the perspective of customers is a good way of investigating the customer satisfaction level for timing, quality and quantity (Brooks and Pallis, 2008: 415).

1.4.11. Port Sustainability

Port sustainability can be defined as *“business strategies and activities that meet the current and future needs of the port and its stakeholders, while protecting and sustaining human and natural resources”* (Denktas and Cetin, 2012: 309).

Port sustainability concept has three main dimensions: economic, social and environmental. Economic sustainability involves returns on investment, efficiency on operations and provision of facilities; 2) social sustainability involves such as the direct contribution to employment in port companies; 3) environmental dimension stands for prevention of natural resources, noise and air pollution, garbage management etc. (Sislian et al, 2016: 20).

Therefore, the concept of port sustainability is referred as the responsibility of the port for the social and economic welfare of all port stakeholders, including the port itself. Ports should be in close relationship with other institutions and organizations in their region and should work to benefit themselves and their environment. Ports should carry out activities in order to reduce the negative impacts they cause to their environment. Ports have environmental, security, social and

economic responsibilities. In the long term, ports that fulfill these responsibilities gain competitive advantages



CHAPTER TWO

CONTAINER TERMINALS

2.1. CONTAINERIZATION AND THE EMERGENCE OF MEGA-VESSELS

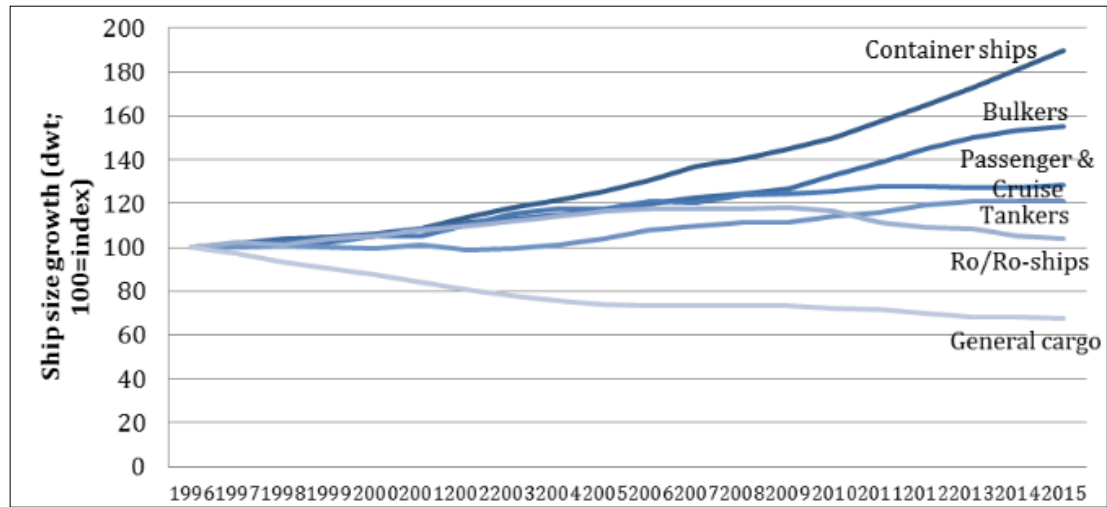
The first appearance of container in transportation goes back to 1956 when the tanker Ideal X made the first shipment with 58 trailers on deck. That was the beginning of a new era in the maritime shipping industry. This journey was followed by the conversion of six dry cargo ships into container carrying vessels with cranes on board. Since then, container volumes increased tremendously and the box has become a standard transportation unit with specialized ships carrying more than twenty thousand of it sails across the globe (World Bank, 2016: 38).

Nowadays container transport account for more than two third of the world general cargo trade (World Bank, 2007: 5). The box has been one of the most remarkable innovations in the transportation industry history, bringing a significant lower handling cost and higher quality than ever before. Productivity and effectiveness of cargo handling has increased by the introduction of container terminals.

Port industry has changed and adapted to the rapidly increasing trend of containerization. Terminals began to specialize their equipments and infrastructures for the effectively handling of the box. Huge investments have been made on port infra and superstructures, cranes and handling equipments, customer relations and process optimizations.

Efficiency in handling operations brought by containers reduced the ship turnaround times at ports and raised the terminal operational efficiencies. Modern day shipbuilding technology enabled ship sizes to get bigger and bigger to accommodate more than 20 thousand TEU of containers in order to benefit from the economies of scale in transport. Figure 11 shows the growth of container ship size has been at a tremendous pace. Today, there are more than 20,000 TEU capacity containerships serving mostly between Atlantic and Pacific trade routes (i.e. OOCL Hong Kong: 21,413 TEU, Madrid Maersk: 20,568 TEU) (www.gcaptain.com, 03.11.2018).

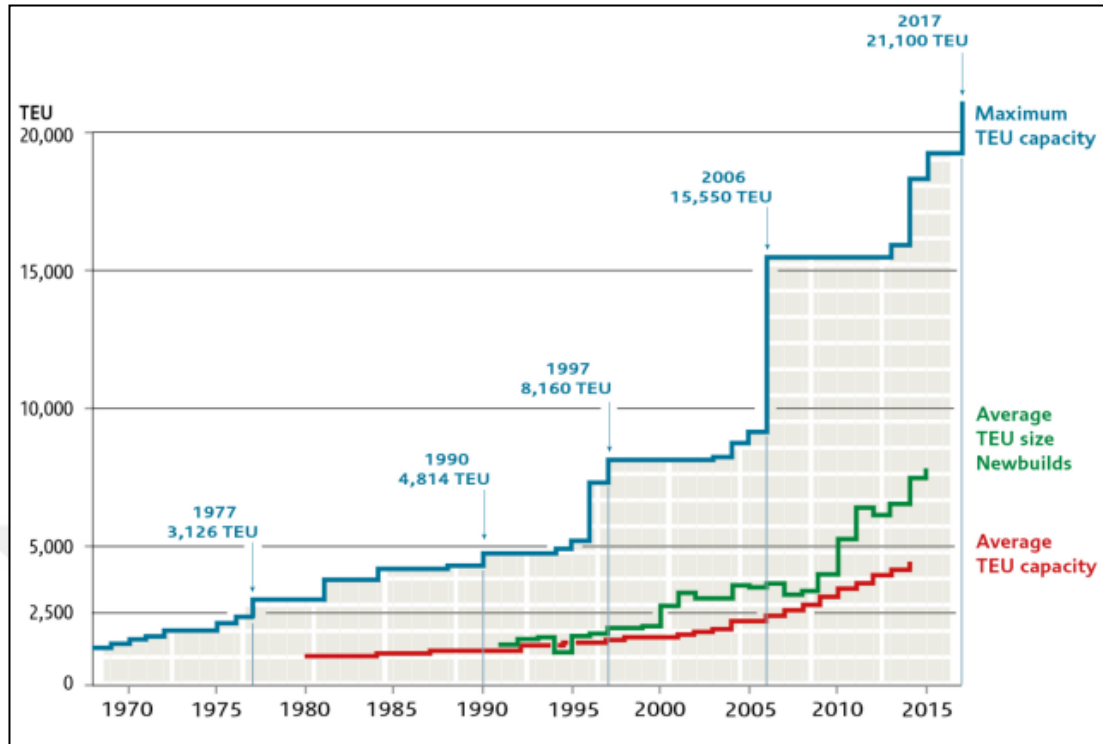
Figure 10: Ship Size Developments (1996-2015)



Source: www.itf-oecd.org, (10.06.2018).

The pace of growth in container ship sizes has been faster than all the other ship types. The average size of container ships almost doubled in DWT capacity between 1996-2015. The growth in size has been 55% for bulk carriers and 21% for tankers as in Figure 10. Ro-Ro, passenger and cruise ships also grew at slower paces unlike the average size of general cargo ships which actually declined (www.itf-oecd.org, 10.06.2018).

Figure 11: Development of Container Ship Size



Source: www.itf-oecd.org, (10.06.2018).

As the ships keep growing in size, ports will have to adapt themselves to overcome the issues of handling bigger ships and higher amounts of cargo in shorter amount of time through technological and physical improvements.

2.2. CONTAINER TERMINALS

Worldwide 873 container ports received regularly scheduled over 560,000 individual port calls from fully cellular container ships across 141 countries which accounted handling 752.2 million TEU containers in 2018 (Unctad, 2018: 71).

Container port or container terminal is a facility where containerized cargoes are transhipped between different transport vehicles, stuffed/stripped, repaired and handled for onward transportation. Ports began to specialize on handling particular types of cargoes in order to achieve cargo handling efficiencies and reducing the handling costs, favoring the shippers and the port owners. In this order, ports around the world began to adapt their existing cargo handling equipments or accommodating

container handling equipments on both sea side and the land side operations (Steenken et al., 2004: 26).

In general terms, container terminals interact with two interfaces (quayside and landside). On the quayside; loading and unloading operations are carried out and on the landside; containers are stored, loaded or unloaded on/off trucks and trains.

When a vessel arrives at a port, pilotage and tugging activities are performed for the berthing of the vessel. Berths are equipped with quay cranes for the loading and unloading operations of the vessel. Import containers are unloaded and loaded to trucks for being taken to the storage yard area and waiting to be picked for the inland transportation. Export containers are picked up by yard handling equipments such as reach stackers and RTG or RMG cranes and loaded onto the terminal trailers for approaching to the apron area and taken by the quay cranes and loaded onto the vessels. Incoming or outgoing containers can be transferred to/from the port by railway, roadway and also by inland waterway connections. Additional moves within the port area performed such as the damaged containers are repaired, empty containers are shifted to empty stock area, CFS stuffing and stripping operations are carried out for value added services etc. (Steenken et al., 2004: 26).

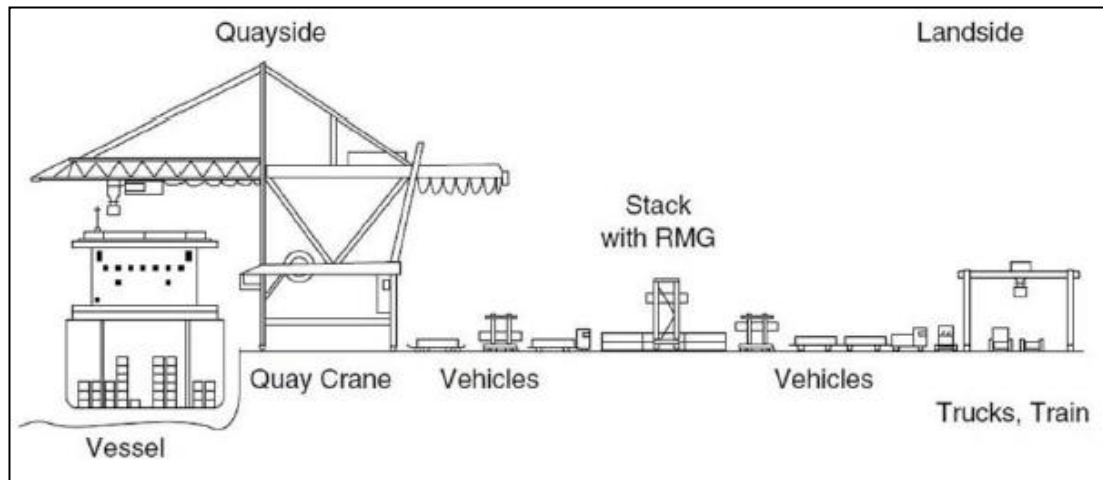
2.3. OPERATIONAL STRUCTURE OF CONTAINER TERMINALS

The main activities shown in Figure 12 that make up the whole container port operation system can be broken up into the following operation segments:

Gate operations: The gate operations deal with external freight forwarders. Two activities are involved; export delivery and import receiving. For the first one freight forwarders bring in export containers to the yard or quay to be loaded onto the vessels, and for the import receiving freight forwarders receive containers from the yard or quay for bringing into the country.

Berth operations: Berth operations are concerned with the vessel schedules and the allocation of berth space and quay cranes for handling the cargo operations to/from the vessels. Major ports can be fully equipped to handle almost all types of vessels and cargoes. The key concern of berth operations in terms of performance is the turn-around time of vessels.

Figure 12: Schematic Representation of a Container Terminal



Source: Steenken et al., 2004: 13.

Ship operations: Ship operations involve the loading and discharging of containers onboard the vessel. This is handled by quay cranes (MHC or SSG) working in synchronization with the yard equipments so as to maintain safe cargo handling operations. To achieve high crane productivity (number of containers moved per hour), the planner has to achieve optimum crane working sequence (a detailed list of crane moves), and synchronize the crane – apron operations so that there would not be any clash involving neighboring cranes or yard equipments.

Yard operations: Perhaps yard operations are the busiest of all the activities in container terminals. Yard operations involve loading and discharging operations to/from the vessels, shifting of containers in the yard block, redistribution of containers to other blocks for more efficient loading onto the next vessels and inter-terminal transport where containers are moved to other yards in another terminal.

Scheduling activities: This is the function that ensures various resource pools, such as the yard crane pool and other container handling equipment pools required to be utilized efficiently considering the constraints and demands for them (Esmer, 2008: 245).

2.3.1. Functions and Configuration of Container Port/Terminal

Container was designed for easing the cargo handling. The objective here was to improve the cargo handling operations in ports and also all the handling between different transport modes. Appearance of such a unique box brought the need for specialized container terminals with special facilities and handling equipments.

Every port has to have different kinds of facilities, service centers and technical assets in order to fulfill its purpose of handling cargo or transferring passengers. Liu adopted the classification of port assets as in Table 13.

Table 13: Categories of Port Assets

Main Infrastructure	Access Channel, breakwater, locks, berths, railway connection, road connection
Operational Structure	Turning channel, quay walls, jetties, navigation aids, buoys, moorings, docks
Superstructure	Paving, surfacing, lights, buildings, CFS
Equipment	Tug boats, ship and shore handling equipment, cargo handling equipment

Source: Liu, 2010: 29.

Container ports carry out multiple activities which are connected with each other e.g. pilotage, cargo handling, container shifting for inland transport, water and power supply, repairs and so on. Yet the primary and the most crucial function of a container terminal is the cargo handling function. Cargo handling costs account for over 80% of the total costs faced by a container vessel calling a port (Tovar et al., 2004: 6).

Container handling operations can be carried out by the port owner, terminal operator or a 3rd party stevedoring company. The objectives of different parties in port may differ and for this reason there must be coordination for instance between the port manager and the stevedoring company for the improvement of the overall efficiency (Liu, 2010: 29).

Figure 13: Configuration of a Container Terminal



Source: www.transportgeography.org, (10.10.2018).

There can be more than one container terminals within a port. In order to carry out the handling operations of containers on land and between the ship and shore, the required elements include; berths, quay cranes, yard handling equipments, storage area, gates, office buildings etc. Figure 13 provides an illustration of a typical container terminal.

Horizontal movement of containers and their stacking operations are carried out in the container yard area. Stacking equipments are RTG, RMG, empty and container stackers and reach stackers. Terminal trailers and guided vehicles contribute to the horizontal movement of the box (Liu, 2010: 30).

2.3.2. Main Facilities in Container Terminals

Container terminals have facilities such as berths, aprons, warehouses, transit storage areas as illustrated in Figure 13:

Dock

Docks are the structures that enable container ships to load/unload safely at the port with the help of container handling equipments and connect the land vehicles with the sea vehicles (Uygur, 2002).

Apron

Since a ship needs to be loaded or unloaded quickly and safely without any delay, there is an apron located just behind the quay side with a sufficiently wide space (Uygur, 2002).

Warehouse

Warehouses are structures that meet the need for long term inland storage. Cargo transportation is carried out by road and railway to the warehouses which must be built at least as far as the quay width so that it does not interfere with the access of the docks (Uygur, 2002).

Transit Storage Areas

Transit storage areas within the container terminal are the buffer storage areas that are created next to the apron in order to increase the cargo flow speed between the ship-dock-warehouse as well as the aprons that the container cannot make any waiting (Uygur, 2002).

2.3.3. Handling Equipments Utilized in Container Terminals

Container handling equipments may differ from one container port to another. There is a vast variety of container handling equipments but they can be classified into four main groups according to their main task: Ship operation equipments, yard operation equipments, CFS operation equipments and transfer equipments within the port.

Ship Operation Equipments

Ship operation equipments or shore cranes are used for loading or unloading containers to/from ships. Since shore crane investments are costly, they may not be present in ports which are usually below a certain amount of TEU capacity. In these cases, the ship cranes are used for handling containers. Since the speed of the ship cranes is relatively slow and difficult to use, special container cranes are used in the ports with medium and large capacity.

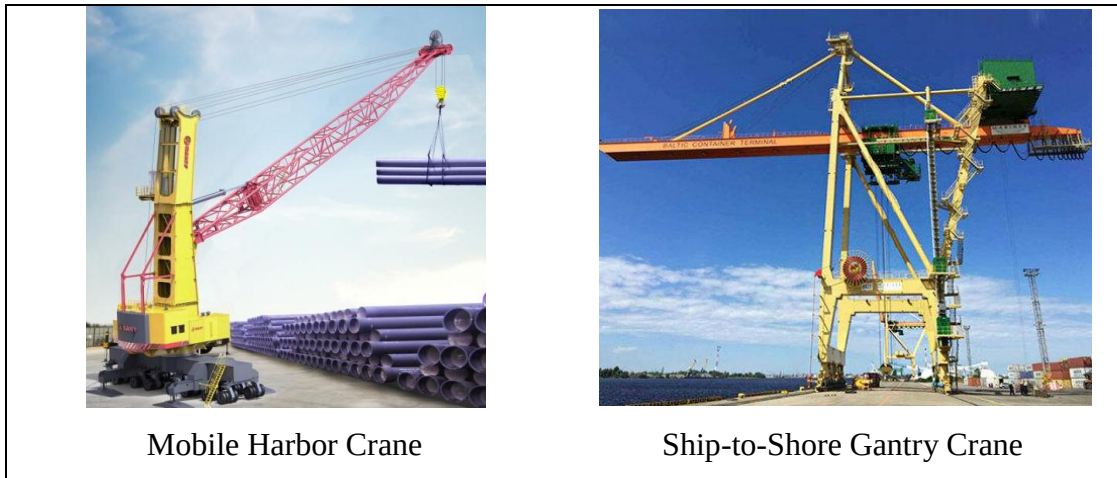
MHC (Mobile Harbor Crane)

These equipments are generally diesel or electric powered and usually preferred because of its ability to shift between different berths. Productivity of MHCs decrease as the ship size increases. Diesel MHC cranes have higher operational costs compared to SSG cranes. Handling speed of MHCs is 15-20 movements per hour according to the size of the ship, the type of operation, the loading plan and the operator's experience.

SSG (Ship-to-Shore Gantry)

Despite their high initial investment costs, they are used in modern and performance-oriented container ports which require speed, safety and low operating costs. SSG is an electric powered crane that runs on a fixed rail and works with high performance on ships of different sizes. The expectation from an SSG is that it makes 20-25 movements per hour. With the developing technology, the number of movements has increased and in some ports SSGs have doubled this movement rate. In addition, there are now SSGs that can handle four 20' or two 40' containers at the same movement depending on the spreader.

Figure 14: Mobile Harbor Crane and Ship-to-Shore Gantry Crane



Source: Sany Global, 2019.

Yard operation equipments

Yard equipments handle the containers that arrived from ships or from the gates (road or rail) to the container stacking area. Depending on the stacking design and the size of the stacking area, equipments with different operating systems can be used.

RTG (Rubber Tired Gantry)

RTGs increase the stacking capacity of ports and usually used in large capacity container ports. RTGs allow more containers to be stacked, particularly in confined spaces or in ports with small stacking area, compared with other yard handling equipments. RTGs can be diesel or electric powered and capable of stacking vertically 4-6 containers.

RMG (Rail Mounted Gantry)

RMGs are designed for the same purpose as RTGs. Unlike RTGs, RMGs move on fixed rail lines instead of rubber wheels. A fixed number of RMGs are required for each container stacking block as it moves on fixed rail lines. Usually RMGs are used in port operations linked to railway transportation.

LCH (Loaded Container Handler)

LCHs - also called as “top lifters” - are the equipments which lock and handle the container from its wider side. It is preferred in small terminals where the number of container handling is less or speed is slower. LCHs are not efficient as the throughput capacity increases. It is not preferred in modern container terminals

CRS (Container Reach Stacker)

Reach stackers are capable of reaching 2 or 3 forward row containers thanks to its telescopic boom. Ports generally prefer reach stackers with a capacity of stacking 4-5 containers vertically. Although it is advantageous compared to LCH, it is not used in modern terminals due to its high operating cost and low stacking capacities.

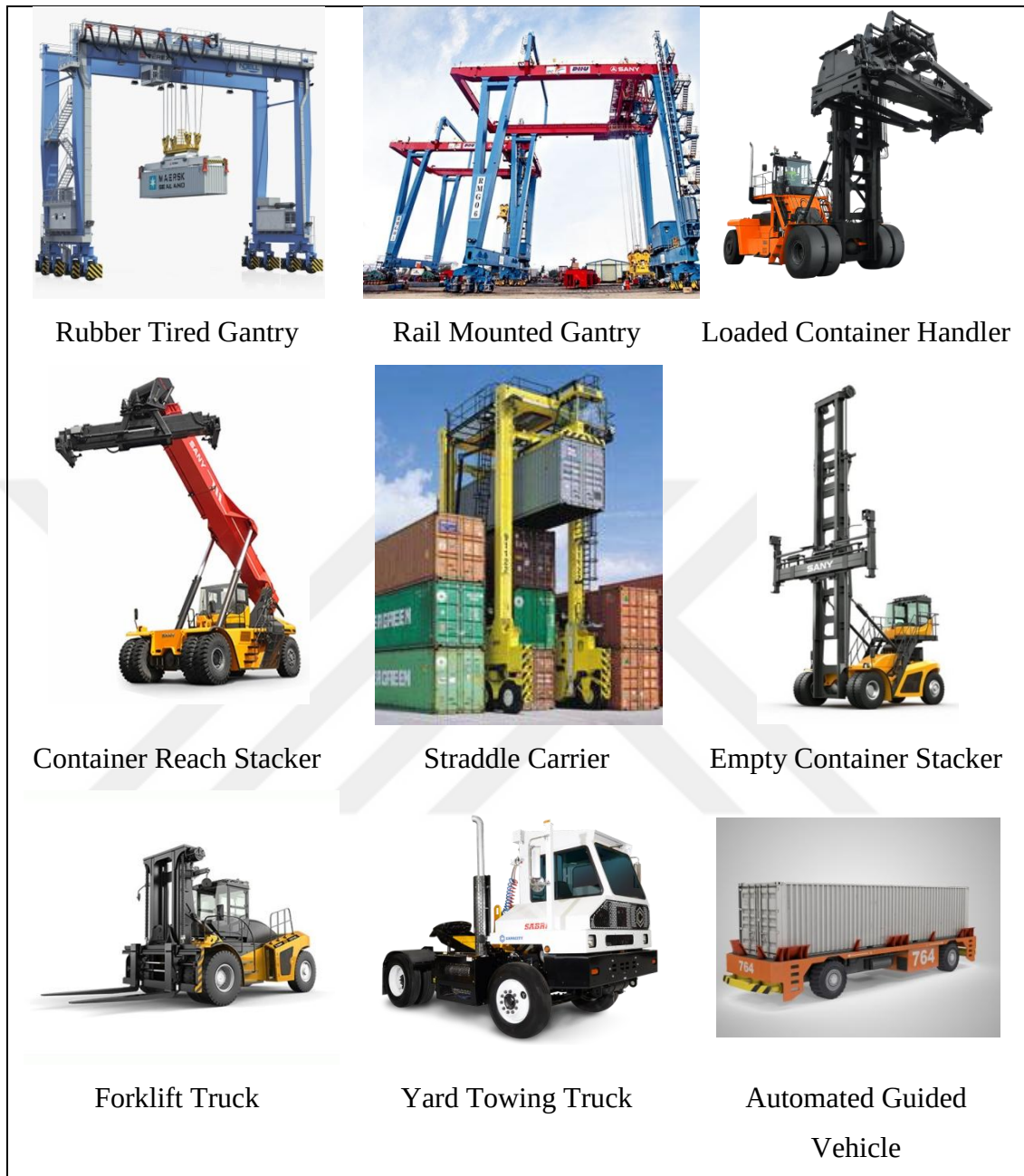
SC (Straddle Carrier)

Straddle carriers are both field handling equipments and transfer equipments within the port. It is preferred in the busiest ports with a large cargo handling capacity to achieve higher field performance and therefore requires detailed planning, software and system-guidance.

ECS (Empty Container Stacker)

ECS is used for handling empty containers. They are also called as “side lifter”. Lifting capacities and operating costs are low because they are designed for handling empty containers.

Figure 15: Yard, CFS and Transfer Equipments



Source: Sany Global, 2019.

CFS operation equipments

CFS is the facility where the containers are stuffed or stripped. Because of the variety of cargoes, the methods and equipments to be utilized for each load may vary. Mostly preferred equipment in CFS facilities is the Forklifts.

FLT (Forklift Truck)

Forklifts, with a lifting capacity of 3-9 tons, are used for container stuffing or stripping operations. They are designed to handle almost all types of cargoes due to its forked structure on the front and various equipments that can be specially attached.

Transfer equipments

Terminals without straddle carriers use transfer equipments when transporting the containers discharged from the ship to the stacking area, or vice versa. Transfer equipments are also required when containers are moved to/from CFS facility or when the containers must be moved to a distance between the stacks.

YTT (Yard Towing Truck)

Yard towing trucks can be connected to a high capacity semi-trailers. When the container needs to stay on the trailer, it is advantageous to drop it to the ground and use another trailer.

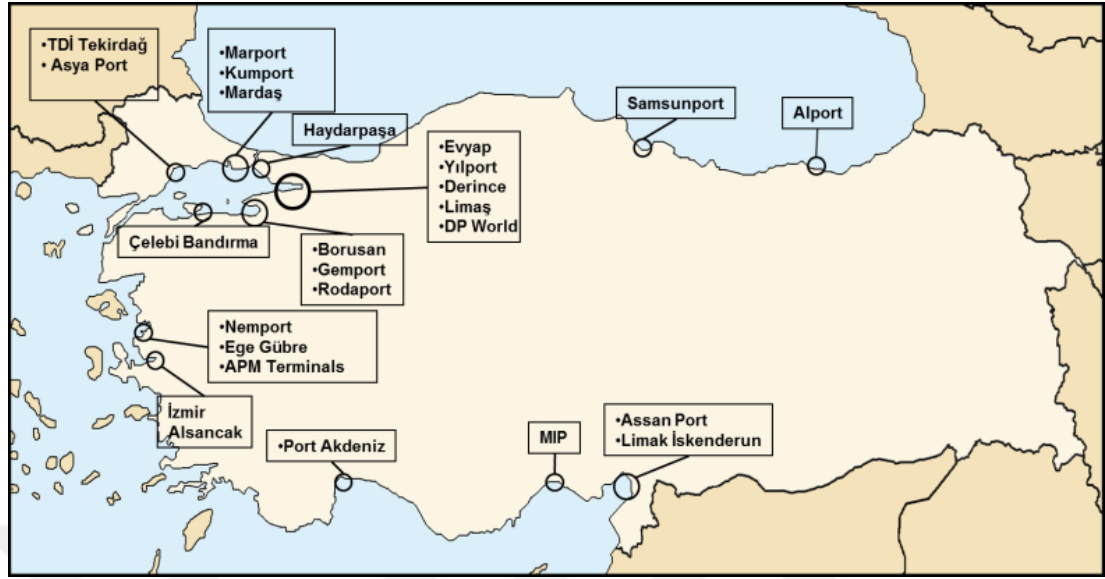
AGV (Automated Guided Vehicle)

AGVs can move with instructions from an automated system without the need for a trailer or a driver. AGVs get power from their batteries. The starting points and movements of the vehicles, the movement for battery changing, the destination, the route to be used must be defined in the system beforehand and every position of the vehicle should be followed. The tracking methods include transponder and satellite connections. Their operating costs are low, but because the initial investment costs are very high, they are used only in few ports.

2.4. CONTAINER PORTS/TERMINALS IN TURKEY

In Turkey, there are 26 ports that are capable of handling containers (Table 14). In the Black Sea Region 2 ports handle containers, 15 in the Marmara Region, 5 in the Aegean Region and 4 in the Mediterranean Region (Figure 16). The total berth length allocated to container ships is 20,757 meters (the berth length is 14,246 meters on the container terminal basis).

Figure 16: Ports/Terminals Capable of Handling Container in Turkey



Source: Turklim, 2018: 64.

Total container throughput at Turkish ports has reached 10.1 million TEUs. Foreign trade and cabotage container throughput is at 7,5 million TEUs and transit container throughput is 2,6 million TEUs. Growth of container throughput is 14,1% in total, 11,1% in foreign trade and cabotage, 26,1% in transit at Turkish ports (Turklim, 2018: 63).

Marmara Region which includes Ambarli ports, handles the highest container amount in Turkey with a rate of 62,7%. Mediterranean ports follow Marmara with 22,1% followed by Aegean Region ports with 14,4%. Black Sea Region ports handled only 0,8% of the total throughput (Turklim, 2018: 63).

While the North West Marmara Region ranks first in terms of the total berth length allocated to container ships, the Eastern Mediterranean Region ranks first in terms of the total storage yard allocated to container operations in ports (Oral, 2017: 74). Berth lengths and storage yard sizes are directly proportional to the volume of containers handled.

Table 14: Turkish Ports Capable of Handling Containers

Marport	MIP	Asya Port
Evyap	Izmir	Kumport
Yilport	Ege Gubre	Gemport
Mardas	Nemport	Borusan
Limak Iskenderun	Port Akdeniz	Assan
Haydarpasa	Roda Port	Samsunport
DP World	Trabzon	Limas
C. Bandirma	Derince Safiport	Akcansa
TDI Ceyport Tekirdag	SOCAR Terminal Aliaga	

Source: Turklim, 2018: 64.

CHAPTER THREE

BENCHMARKING AND PORT PERFORMANCE MEASUREMENT

3.1. BENCHMARKING

Benchmarking is described as *“the continuous process of measuring products, services and practices against the company’s toughest competitors or those companies renowned as industry leaders”* (Camp, 1992: 3).

The core concept of benchmarking is essentially hidden in the term of ‘best practices’ for achieving sustainable performance improvement. The logic of benchmarking is monitoring own performances and learning from the best practitioner competitors (Cassell et al., 2001: 218). However, successful organizations are the ones who adapt the best practices to their own ways of doing business. Benchmarking has been an important approach on performance measurement methods and performance comparisons in port business (Ha, 2017: 45).

3.2. PERFORMANCE MEASUREMENT SYSTEMS AND PORT PERFORMANCE MEASUREMENT

The number of publications on port and terminal performance measurement expresses that it is a well-established field of study in maritime-related academic literature. Port performance measurement studies, mainly focusing on port operational efficiency will be rigorously reviewed and examined in this sub-section. This section will be beneficial towards designing a proper research framework for this study.

3.2.1. Performance Measurement Terminology

There is turmoil in the literature about the definition of efficiency, effectiveness and productivity. Many scientists use the concepts of efficiency and effectiveness synonymously. Some researchers emphasize that two concepts have different meanings. Effectiveness can be defined as the ability to achieve more plans,

productivity as to produce a target output with minimum cost, and efficiency as to be able to do things right through an input-output mechanism. An efficient company may not be effective in its operations. Manufacturing organizations use the concept of efficiency to indicate the productivity of the organization. Productivity is provided in the literature in order to obtain the optimum output from the sources in hand, and effectiveness is the best possible result by evaluating the resources in the best way (Yukcu and Atagan, 2009: 9).

Efficiency: Organizational efficiency is expressed as the ratio of the total output of an organization's producing goods or services to the total inputs (Aldemir, 1985: 14).

From business point of view; efficiency is an evaluation criterion that shows how sufficient or efficient the business uses its workmanship, materials, raw materials, and other inputs while producing outputs. Efficiency shows the degree to which a pre-determined program is realized by the production factors of an enterprise. In other words, it measures how close the actual (actual) performance is compared to the pre-determined standard (performance).

Efficiency measurement provides an indication of how well the current capacity can be used, as well as how well the output is generated from the existing inputs (Ekodialog, 2018: 1). The degree of efficiency can be determined by the following equation:

$$\text{Efficiency} = \text{standard performance (value)} / \text{realized (actual) performance.} \quad (1)$$

For example, if a standard job takes 10 hours to complete but in practice it takes 15 hours: Efficiency would be $10 / 15 = 0.66$. Accordingly, it can be concluded that the work is not efficiently done. If the efficiency rate is below 1, this means that the activity does not take place as desired. If the ratio is greater than 1, it shows a level of efficiency greater than the standard.

It is known that even in the most successful enterprises, the available resources cannot be fully utilized and many factors within and outside the enterprise affect the use of resources. Losses occur in the existing resources due to reasons that

cannot be controlled by the business itself. Real standard performance levels are determined by taking these losses into account (Yukcu and Atagan, 2009).

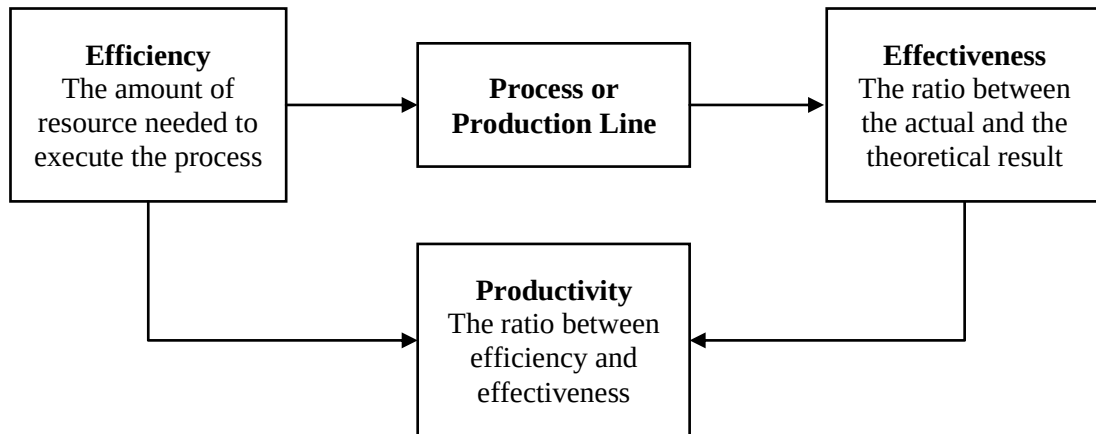
Effectiveness: The use of the effectiveness concept in management sciences began after the Second World War and this term has spread to other disciplines of economics. Effectiveness determines the extent to which an organization achieves its goals as a result of the activities carried out (Horngren, et al., 2000).

Preffer and Salancik (1978) consider organizational effectiveness as an 'external standard' as the extent to which an organization meets the demands of various groups. The concept of effectiveness refers to the level and the degree of reaching the desired result of the organization. This result is different from the output expressed by the physical values. For example; the number of new products developed is referred as the output, but the number of those who has a demand or a market share is the result (Akal, 2005: 18).

Productivity: In the most general way, the productivity that expresses the relationship between the various factors (inputs) introduced into the production process and the products (outputs) obtained at the end of this process means a production which is far from extravagance and evaluating the resources in the best way.

Therefore, productivity is defined in a technical sense as "the ratio between the quantity of goods and services produced and the inputs used to produce this quantity of goods and services", and this measure is usually formulated as output/input (Prokopenko, 1998: 7). The relationship between efficiency, effectiveness and productivity is visualized in the following Figure 17.

Figure 17: Efficiency, Effectiveness and Productivity Relationship



Source: Buyukkilic, 2004: 22.

To put in a different way, effectiveness is the extent of achieving an objective while the efficiency is the degree of which resources have been used economically (Gleason and Barnum, 1982: 379). Simply put, efficiency is ‘doing things right’ and effectiveness is ‘doing the right things’ (Drucker, 2012).

3.2.2. Performance Measurement Systems

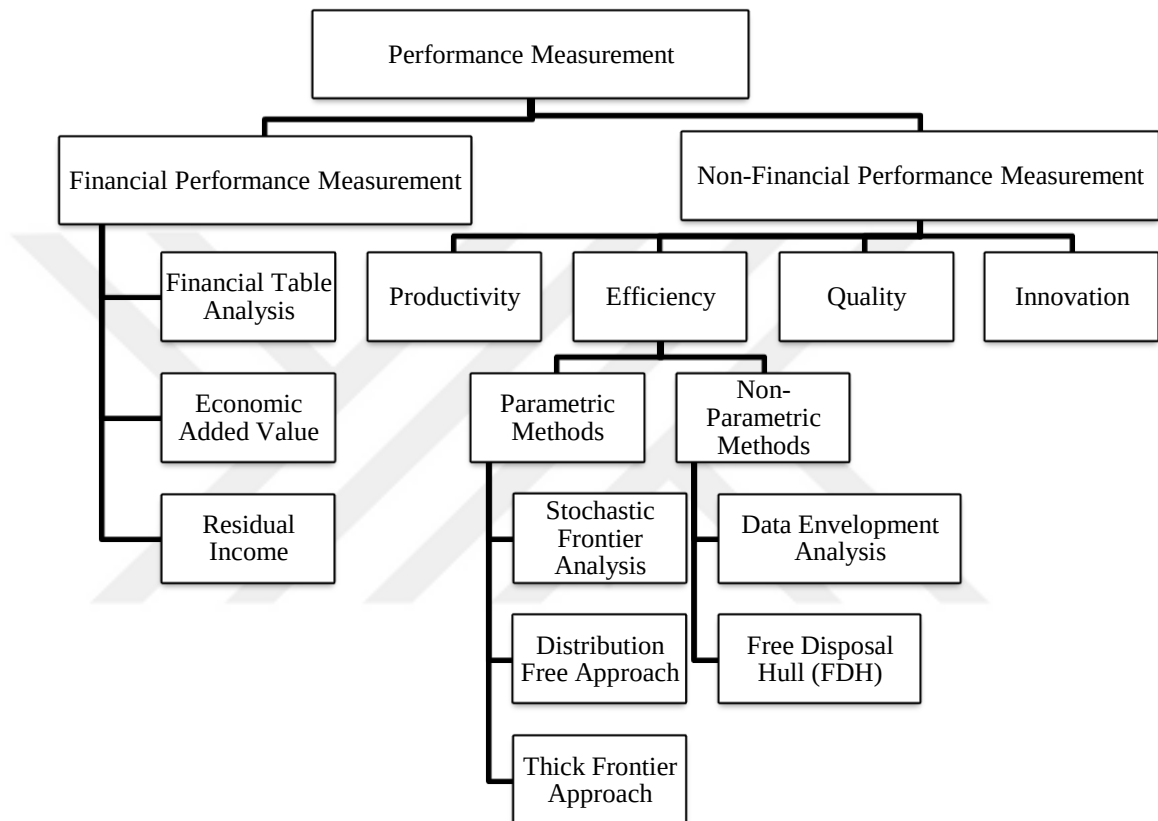
Performance measurement plays a vital role in every organization’s strategic planning and it is one of the cornerstones of business excellence. The purpose of performance measurement is understanding how well an organization performs its activities in terms of being efficient and effective (Mentzer and Konrad, 1991: 10). Performance measurement systems are utilized in order to guide the organizations to make improvements (Wolk et al., 2009: 3).

Performance measurement is defined as “*the process of quantifying the efficiency and effectiveness of action*”. Performance measure is “*a metric used to quantify the efficiency and/or effectiveness of action*”. A performance measurement system is “*the set of metrics used to quantify both the efficiency and effectiveness of actions*” (Neely et al., 1995: 1229).

Traditionally, financial measures were the main tools for performance measuring and evaluating. However in modern business environment, using only

financial indicators is outdated and inadequate (Hoque, 2005: 471). New approaches cover wider areas for performance measurement and the importance of non-financial measures for performance measurement has soared. In the following Figure 18 main performance measurement systems are indicated.

Figure 18: Performance Measurement Systems



Source: Caglar and Oral, 2011: 667.

Many businesses today use both financial and non-financial performance metrics to measure business performances at the same time. Performance measures should vary among enterprises and be changeable over time (Suwignjo et al., 2001). Performance criterias have some advantageous and disadvantageous characteristics. In this context, advantages and disadvantages of financial and non-financial performance measures are listed as it follows (Anderson and McAdam, 2004: 470).

- Non-financial measurements consist of company objectives and strategies.
- Non-financial measurements are more flexible and dynamic.
- There are more non-financial measurements.

- It is easier to determine financial measurements periodically.
- Financial performance measurements are more measurable and accurate.
- Financial measures facilitate continuous development and are more meaningful for the workforce.

Well-conceived performance measurement systems shall seek answers to the questions of what needs to be measured, how it should be measured, when it should be measured and how it can be possible to take the best out of the findings. A proper performance system provides valuable information for feed-forward and feed-back control system for taking corrective actions (Hon, 2005: 139).

3.2.3. Port Efficiency and Productivity Measurement

In many studies, with many methodologies and research scopes, different ports in many countries have been investigated. Studies focusing on port performance measurement have generally aimed for the measurement of efficiency and the effectiveness. Although port efficiency and port productivity seem to be similar to each other, they have different meanings. While efficiency expresses how the resources are being used, productivity deals with the relationship between inputs, processing and the outputs obtained at the end of this process (Korea Maritime Institute, 2005: 72).

One of the first studies on port performance measurement was published by UNCTAD in 1976. The financial and operational indicators are summarized in this guidebook. Financial indicators are related with revenues and expenditures per ton of cargo. Operational indicators mentioned in the paper are mostly focused on the vessel and cargo operation durations such as; arrival time, waiting time, turnaround time, tonnage per ship hour at port, tons per ship hour at berth and so on (Unctad, 1976: 9). Many researchers used these indicators for port productivity and effectiveness measurements. Although the study is out-dated, it has been a cornerstone for the further studies came after that.

Another early study belongs to Suykens who discussed the cargo-handling efficiency of Antwerp Port. Indicators taken into account in this study are the dock labour, dock lay out design and the equipment performances. He noted that there

have been a drop in the number of dock workers which resulted as a productivity increase in port operations. Yet however, in his findings he related the performance increase in West European ports to the introduction of container and the technological developments in cargo handling systems of ships and berths (Suykens, 1983: 39).

First study on the efficiency of ports with DEA was the work of Roll and Hayuth in 1993. However, this study showed a theoretical approach rather than practical. Tongzon attempted one of the earliest studies to measure operational efficiencies using the number of SSG, terminal quay length as inputs and throughput (TEU) as the output. 23 international ports form the sample of this study and provides an empirical basis for the crucial role of terminal efficiency relative to other factors in the overall port performance (Tongzon, 1995a: 245).

ASEAN port performances and efficiencies have been investigated by Tongzon and Ganesalingam (1994) and two types of indicators have been identified: Operational efficiency indicators include containers per net crane hour, container (TEUs) per crane and TEUs per berth length. Customer-oriented indicators include reliability and ship's waiting time.

Bayesian Stochastic Frontier model was used by Notteboom for measuring the efficiency of 36 European and 4 Asian container terminals with the cross-sectional data belonging to 1994. Container throughput was the output and docks, surface area and cranes were the inputs. They concluded that hub port terminals are more efficient than feeder port terminals. The efficiency levels of Northe European Container Terminals are relatively found to be higher than southern terminals (Notteboom et al., 2000: 83).

The efficiency of 2 Greek and 4 Portuguese ports was compared by Barros and Athanassiou (2004) using the CCR and BCC models of DEA. There have been 2 inputs in this study: labour and capital, and 4 outputs: cargo handled, containers handled, number of vessel visits and the movement of freight. Port efficiency levels were determined with the data set between 1998-2000 for the benchmarking purpose in order to find the most efficient port.

Wu and Goh (2010) applied DEA for measuring the relative efficiency of emerging market ports with the more advanced market ports (G7). Andersen and

Pertersen model is applied in this study for ranking the port efficiencies and investigate the relative strengths and weaknesses. Terminal area, berth length and the number of container handling equipments were used as inputs and the only output used in the study is the total container throughput. They concluded that emerging market ports are more efficient than those in advanced markets.

Wanke et al. (2011) analyzed the Brazilian ports and factors that influence their efficiency. Several efficiency factors are identified: port ownership model, hinterland access, port hinterland characteristics, number of access channels, and cargo types handled at the port.

Caglar (2012) determined the efficiency of container, general cargo and bulk cargo terminals of Turkish private ports with the DEA method.

Ates and Esmer (2011) measured the relative efficiencies of 15 Turkish ports using the data from 2010. Storage area, berth length, number of berths and number of cranes were used as inputs and container throughput data was used as the single output. This study has shown while Izmir, Marport, Kumport and MIP container terminals are the most efficient terminals, Alport has been found as the least efficient.

Nguyen applied SFA, DEA and bootstrapped DEA on comparing 43 Vietnamese ports. Results can be summarized as (1) SFA method tends to indicate relatively higher efficiency score (close to 1) compared to DEA methods (2) DEA is sensitive to the number of variables (3) Bootstrap DEA provides consistent and bias-corrected estimates of efficiency scores (Nguyen et al., 2016: 644).

Table 15: Port Efficiency Studies and Methodologies

Author(s)	Year	Method	Inputs	Outputs	Efficiency type
Lopez Bermudez et.al.	2019	SFA	Frequency of ship calls	Throughput (TEU)	Operational
Kutin et al.	2017	DEA	Draft, Terminal area, Quay length, Number of quay cranes and RTGs, Number of trucks	Container throughput	Operational

Table 15: Port Efficiency Studies and Methodologies (continued)

Author(s)	Year	Method	Inputs	Outputs	Efficiency type
Lopez Bermudez et.al.	2019	SFA	Frequency of ship calls	Throughput (TEU)	Operational
Kutin et al.	2017	DEA	Draft, Terminal area, Quay length, Number of quay cranes and RTGs, Number of trucks	Container throughput	Operational
Serebrisky et al.	2016	SFA (Translog function)	Area (sqm), Length (m), Mobile/quay cranes, STS gantry cranes, Ships' cranes (dummy)	Throughput (TEU)	Operational
Almawsheki and Shah	2015	DEA-CCR	Terminal area, Quay length, Quay cranes, Yard equipment, Maximum draft	Container throughput	Operational
Rajasekar and Deo	2014	DEA	Number of berth, Berth length, Number of equipment, Number of employee	Throughput (TEU), Total cargo traffic	Operational
Schoyen and Odeck	2013	DEA	Berth length, Terminal area, Yard gantry cranes, Straddle carriers	Container throughput, Container handling trucks	Operational
Yuen et al.	2013	DEA	Berth length, Total shore length, Port area, Number of SSG, Number of storage yard cranes	Throughput (TEU)	Operational
Bichou	2013	DEA	Terminal Area, Maximum Draft, Total shore length, Quay crane index, Storage yard stowing index, Trucks & Vehicles, Gates	Throughput (TEU)	Operational
Bichou	2012	DEA-CCR, DEA-BCC, Panel data	Terminal area, Maximum draft, Quay length, Quay crane index, Yard stacking index, Gates	Container throughput	Operational

Table 15: Port Efficiency Studies and Methodologies (continued)

Author(s)	Year	Method	Inputs	Outputs	Efficiency type
Hung et al.	2010	DEA-CCR, DEA-BCC, DEA with bootstrap method	Terminal area, Number of STS gantry cranes, Number of berths, Total quay length	Container throughput (TEU)	Operational
Hai-bo and He-zhong	2009	SFA	Net permanent asset, Total employees	Main business revenue	Financial
Cullinane and Wang	2006	DEA-CCR, DEA-BCC	Terminal area, Quay cranes, Yard cranes, Straddle carriers	Container throughput	Operational
Rios and Macada	2006	DEA	Cranes, Berths, Terminal area (sqm), Employees, Yard equipment	Container (TEU), Containers handled per hour and ship (average)	Operational
Lin and Tseng	2005	DEA-CCR, DEA-BCC, FDH	Terminal Length, Terminal Area, Number of cranes, Stacking equipments	Throughput (TEU)	Operational
Barros	2003	DEA-CCR Panel data	Labour, Book value of assets	Throughput, Ship calls, Market share	Operational, Financial
Itoh	2002	DEA	Terminal Area, Number of STS cranes, Number of employees, Terminal Length	Container throughput	Operational, Infrastructure and Superstructure
Notteboom et al.	2000	SFA	Length of Berth, Terminal Area, Number of cranes	Throughput (TEU)	Infrastructure and Superstructure
Martinez Budria et al.	1999	DEA-BCC	Labor cost, Depreciation cost, Other costs	Total throughput, Rent income from port facilities	Financial
Poitras et al.	1996	DEA-CCR, Summative	Ships that call the port, Berthing fee/hour	Throughput (TEU), Crane container handling/hour	Operational
Liu	1995	SFA	Number of employees, Capital	Turnover	Financial

Table 15: Port Efficiency Studies and Methodologies (continued)

Author(s)	Year	Method	Inputs	Outputs	Efficiency type
Tongzon	1995a	DEA	Number of SSG, Terminal quay length	Throughput (TEU)	Operational
Roll and Hayuth	1993	DEA-CCR	Cargo characteristics, Workforce, Capital	Cargo throughput, Service level, Ships that call the port	Operational, Financial

The latest attempt with DEA was made by Gokcek and Senol for measuring the technical efficiencies of the Mediterranean container ports (Gokcek and Senol, 2018: 129). Relative efficiency analysis is conducted based on data from the year of 2016. Findings of the study reveals that subjected Mediterranean container terminals can increase their output by 1,47 times without expanding their inputs. Efficiency slightly increases from eastern ports towards the western ports of the Mediterranean Sea. Other studies related with port productivity and efficiency are expressed in Table 15.

SFA and DEA methods have been widely used by researchers in order to determine the efficiency and productivity of container terminals around the globe. Noticeably, DEA has been the most preferred method for measuring the port and terminal efficiencies (Cullinane and Wang, 2006: 523).

3.3. PORT PERFORMANCE INDICATORS FOR CONTAINER TERMINALS

Performance indicators form a set of data for quantifying both the efficiency and the effectiveness of an organization and its actions. A set of Port Performance Indicators (PPIs) are derived from the literature for the performance and efficiency measurement objective in container ports/terminals.

This study adopts the performance measurement concept from different resources (Kisi et al., 1999; Ha, 2017). Port performance indicators can be classified into four groups as shown in the following Table 16. There are many other classifications provided by different authors.

Table 16: Port Performance Indicators

Ship	Number of ship calls, Average turnaround time
Cargo	Handled cargo (tonnage), Average handling time
Berth	Berth occupancy, Length of berths
Labor	Number of labor units, Total working time

Source: Kisi et al., 1999.

Another author classifies port performance measurement systems into 6 main categories:

- a) Primary activities: level of effectiveness and efficiency of a port on its main role of handling cargo and accommodating vessels
- b) Supportive activities: level of availability for reliable resources on providing primary activities (i.e., human resources, technology, etc.)
- c) Financial strength: financial situation of the container port/terminal
- d) Stakeholders' satisfaction: whether port stakeholders are satisfied with port services and tariffs
- e) Terminal supply chain integration: level of integration with the supply chain members
- f) Sustainable growth: contributions to socio-economic sustainable growth (Ha, 2017: 119).

Since the main focus of this study is measuring the operational efficiency of container terminals, the most suitable category involved is the primary activity dimension.

3.3.1. Primary (Operational) and Support Activities

Business activities can be classified as: primary activities and support activities (Porter, 1985: 11). Primary (core) activities are directly related with the production and the delivery of products or services. Support activities involve human resources, technological development and infrastructure. However, Porter's so called value chain framework cannot be applied to the port industry since port operations are immensely diverse and mostly involved with many different parties. In line with

the value chain concept primary activities of a seaport refer to the operations related with vessel and cargo.

Primary activities are classified as output, productivity and lead-time. Output includes indicators such as port/vessel capacity, throughput and number of ship calls. Productivity in port business means that how efficiently resources are being used. Lead-time represents the vessel waiting time at port and the speed at which port activities are carried out (Bichou, 2006: 578).

Port operational efficiency indicators are directly linked to the port facilities and port activities. Mainly port efficiency indicators are related with the specifications of terminal area and storage area, berths, handling capacity and handling equipments both on quay and storage yard. Further details about the port operational performance indicators mentioned in previous studies are summarized in Table 17, showing the potential indicators for the core (operational) activity dimension.

Table 17: Port Operational Performance Indicators

Potential Port Operational Performance Inputs		
Category		Indicators
Primary (main) activities	Output	Capacity of vessel calls (tons) Throughput (TEUs) Throughput growth Ship calls
	Productivity	Berth occupancy and utilization (ship time/operation time) Crane productivity (lift/hour) Labor productivity (TEU/employee) Ship productivity (ton per ship) Ship loading rate Throughput/number of cranes Throughput/terminal area Vessel working time at berth Yard utilization (throughput /area of container yard)
	Lead time	Cargo transit waiting time Cargo dwell time Containers per working hour and per ship Time for custom clearance Cargo waiting time until next mode of transport Time spent in carrying out value added logistics activities Cargo shifting time Truck turnaround Vessel turnaround Vessel waiting time
Potential Port Operational Performance Outputs		
Category		Indicators
Outputs		Throughput Growth in TEU throughput Maritime traffic The number of vessel calls Vessel output Berth output Crane output Yard output

Source: Adopted from Ha, 2017: 96.

Quantitative data is required for measuring these indicators. The data can be obtained from port/terminal operators. However, similarities can be found between different PPIs. For example, throughput per number of crane and crane productivity

are somehow similar indicators as representing the measurement of the crane productivity.

Additionally in a review article Caglar (2012) identified different input and output functions for port efficiency measurement summarized in the following Table 18.

Table 18: Input and Output Functions for Port Efficiency Measurement

Input functions		Output functions
Berth length	Number of berths	Annual throughput TEU / Ton
Width of berths	Port area	Annual ship calls
Number of crane movement	Number of cranes	Customer satisfaction
Storage area	Number of employees	Level of service
Capital	Berthing fee	Number of turnover
Expenses	Number of Tugboats	Income
Waiting time	Number of storage yard equipments	Ship operation speed

Source: Caglar, 2012: 143.

Port efficiency indicators (inputs) and outputs subject to this study to be selected in the next chapter according to the literature review conducted in this section. There have been plenty of performance indicators utilized in the studies related to port performance measurement. However the data availability for this study is expected to become a limitation for the relative efficiency analysis of the container ports located in Turkey.

Support activities are crucial for the improvement of the primary activities (Porter, 1985: 12). Successfully coordinated primary and support activities lead to organizational efficiency and effectiveness. Support activity performance indicators utilized in the port performance measurement studies are mostly related with the information technologies, human and information capital (skills, training, knowledge, systems, databases, networks) and human resources (Staffing, training and development, worker commitment and loyalty, performance systems, safety and health, labour relations etc.) (Kaplan and Norton, 2004: 52).

3.3.2. Financial Strength

Port business is highly capital intensive and a cost driven industry. Initial investments may require millions and high continuous expenditures occur when running a port business. When setting up an infrastructure, improving superstructure, or upgrading cargo handling equipment, financial power is fundamental.

For this reason financial performance is a fundamental concern of port managers and investors. Various financial performance indicators have been addressed in many studies mainly related with the revenue per ton of cargo, costs incurred by the port, ship revenue and cost per ton of cargo and so on (Unctad, 1976). Financial indicators of Bichou and Gray are the revenue, cost, profit, total cost analysis, value-added, profit from each channel. Mostly financial performance indicators are measured with per ton of cargo or per TEU of container. Financially strong port managements are more likely to take actions in shorter time and if well managed, to achieve greater port efficiencies (Ha, 2017: 80).

3.3.3. Port Stakeholders' Satisfaction

Efficiency and effectiveness outputs are connected and should not be evaluated separately (Brooks, 2006; Pallis and Vitsounis, 2008). In terms of port stakeholder's needs; timing, quantity and quality are the most significant factors to be considered by ports before taking action (Brooks and Pallis, 2008). Ports should be flexible and responsive to the changing market conditions and customer expectations. Customers may have special requests and an agile port can adapt itself to different needs and wants of its loyal customers (Brooks and Schellinck, 2013). SERVQUAL model was used by many studies on measuring service quality in the port industry. Some indicators of port user satisfaction can be listed as reliability, rate of accident, waiting time, responsiveness, efficiency of documentation, gate congestion etc. (Brooks and Schellinck, 2013).

3.3.4. Terminal and Supply Chain Integration

The concept of terminal and supply chain integration is defined as “*the extent to which the terminal establishes systems and processes and undertakes functions relevant to becoming an integral part of the supply chain as opposed to being an isolated node that provides basic ship-shore operation*” (Panayides and Song, 2009: 134). Port/terminal supply chain integration performance indicators are grouped under 4 categories in the literature: Intermodal transport systems, supply chain integration practices, value-added services and information and communication integration.

Among the indicators utilized are: changing the transportation mode of the cargo in the shortest time, providing cost-effective multimodal operations (Woo et al., 2013: 240), adding value to cargoes, new tailored services (Song and Panayides, 2008: 81), integrating IT for sharing data, computerizing port service systems (Panayides and Song, 2009: 141), connectivity of the ship/rail/road interface etc. (Woo et al., 2013: 241).

3.3.5. Sustainable Growth Performance Indicators

For ports, sustainability means “*business strategies and activities that meet the current and future needs of the port and its stakeholders, while protecting and sustaining human and natural resources*” (AAPA, 2007: 25).

Despite the term sustainability is increasingly used in maritime industry, there has been little interest on the issue (Lam, 2015: 70). In many studies, sustainable growth performance indicators are evaluated under 3 categories: safety and security, environment and social engagement (Ha, 2017: 92). Some good examples for port sustainable growth performance measures are: added-value provided by ports to socio-economy, carbon footprint, total water and energy consumption (ESPO, 2010: 6), ISPS Code measures, number of accidents (Woo et al., 2011: 255).

CHAPTER FOUR

BENCHMARKING THE OPERATIONAL EFFICIENCY OF CONTAINER TERMINALS BY USING DATA ENVELOPMENT ANALYSIS

In this chapter we evaluate data of 26 ports that are able to handle containerized cargoes in Turkey. Reasons to focus on this area are; firstly, Turkey is a developing economy and a gateway of a major international trade route (Europe - Asia), i.e. container traffic of Turkey has reached more than 10 million TEUs in 2018 (Turklim, 2018).

Secondly, the number of private container ports in Turkey has increased rapidly in a short amount of time and the privatization process of the state owned ports is still undergoing. These developments in port sector in Turkey, have increased the number of container ports and the concerns of competitiveness. For this reason in recent years, operational efficiency of ports have become a serious issue on gaining competitive advantage in this part of the world.

In this final chapter of this thesis, we discuss the methodological approach for measuring the operational efficiency analysis of the Turkish container ports. Data Envelopment Analysis (DEA) has been selected as the research methodology and the comparative data analysis is conducted. Relative operational efficiencies of ports have been analyzed and the most successful DMUs are taken as benchmarks. The inefficiencies high lightened and the reasons of inefficiencies pointed out in this study are expected to be guidelines for port operators on adjusting their operations to achieve greater efficiencies.

4.1. METHODOLOGY OF THE THESIS

In this section, problem definition, research questions and research goals are explained in detail. Methodological approach is discussed and selection of the methodology regarding to the research questions is concluded.

4.1.1. Research Questions and Research Goals

First research question of the study is that; which indicators in port performance measurement defines the technical efficiency of container ports and do they have significant effects on defining port performances? Which indicators were used in port performance measurement models in previous studies? These questions of the research have been cleared in the previous chapters of this study.

Hereupon, the questions are aiming; which ports handle containers in Turkey and how is their recent situation in terms of selected inputs and outputs for the efficiency analysis?

Third; how is the situation of excess or scarce resources used by inefficient container ports? Which port should be taken as measure (benchmark) and how should be the inefficient ports' adjusted inputs to avoid inefficiency?

Fourth question is that; what is the output level of the inefficient DMUs with the current input levels and which level should be taken as target output?

Research goal of this study is to deepen the knowledge on the port performance measurement by describing the data representing the port performance and efficiency measurement using the most commonly utilized inputs and outputs in previous studies and applying the model to the container ports located in Turkey.

Determining the optimum adjustments for the variables is expected to guide the decision-makers in port management to achieve operational efficiencies.

4.1.2. Discussion on Methodological Approach

Today's managers are aware of that they can only live longer in competitive environment in which they can measure their performance. Therefore; today's enterprises have attempted to develop methods to put light on planning their activities and measuring their past and current achievements. The methods developed in this area can be grouped under three main headings:

The methods commonly used in effectiveness measurement are examined under 3 headings. These methods are; ratio analysis, parametric methods and non-parametric methods. For organizations that use single input and single output in

efficiency measurement, ratio analysis can be preferred for the ease of calculation. With the regression analysis of parametric methods; in case of multiple inputs and single output, efficiency analysis can be performed according to the average performing decision making unit.

In mathematical programming of non-parametric methods; a large number of inputs and a large number of outputs can take place in the comparative analysis. In the following sections; ratio analysis, parametric and nonparametric efficiency measurement methods are explained briefly:

- ‘Ratio analysis’ examines the relationship between two variables or the relationship between an output and the composition of many inputs.
- ‘Parametric measurement methods’ accept the existence of an analytical production function.
- ‘Non-parametric methods’ do not predict the existence of any predetermined analytical form of production function.

There are many types of effectiveness in literature such as; technical, scale, total, price, structural, resource distribution and so on. As this study is concerned, the concept of technical effectiveness will be emphasized in detail. Technical efficiency is the success of producing the maximum possible output by using the input composition in the most efficient manner. Decision-making units that are technically efficient must be located on the production limit. It can be said that the decision-making units that fall below the production limit are relatively wasting their resources, since they can use less input to produce the same amount of output. The production limit (production function or efficient production function) is defined as the effective limit since it is a set of all possible production mixes that are technically effective (Kayalidere and Kargin, 2004: 199).

Predominantly in the literature of port efficiency measurement, SFA and DEA methods have been used. However, two methods provide different results when applied to the same data set (Serebrisky et al., 2016: 31; Suárez-Aleman et al., 2016: 56). SFA is a parametric method requiring a production function while the DEA is a nonparametric method used for its ability to contain multiple inputs and outputs. Also in DEA, production function is not required while it is usually preferred when there are inaccurate or incomplete data in the sample (Bogetoft and Otto, 2010: 63).

26 Turkish container ports form the sample of this study and multiple categories of variables are used as inputs and output for the efficiency analysis. For this reason DEA method would be more accurate for this study's data set and it is applied in order to measure the relative efficiencies of 26 Turkish Container Ports.

4.2. DATA ENVELOPMENT ANALYSIS (DEA)

As a non-parametric approach, DEA aims to weigh the inputs/outputs for measuring the relative efficiencies of decision making units (DMUs) (Ablanedo-Rosas and Ruiz-Torres, 2009, 279).

In 1957, Farrell theoretically presented the DEA, which is widely used today. DEA was first put forward by Charnes, Cooper and Rhodes in 1978 as a mathematical programming method evaluating the relative activities of decision-making units (DMUs), which includes multiple inputs and multiple outputs. DMUs are the units that are evaluated for their ability of translating inputs into outputs by the use of a variety of applications (Charnes et al., 1978: 430).

DEA method is used for performance comparison in multi-output and multi-output production relationships where classical regression analysis cannot be applied directly (Baysal et al., 2005: 5). DEA is a non-parametric method that can eliminate the difficulties encountered in efficiency analysis and its most important feature is its ability to identify inactive input and output sources for each decision making unit. In its earliest times, DEA was used only for measuring technical efficiency under the assumption of constant return on scale, but followed by some changes, it has been used by Banker, Charnes and Cooper for measuring scale efficiency (Yolanan, 1991: 123).

The purpose of data envelopment analysis is to define an envelope boundary surface for all sample observations to measure their production efficiency. Each DMU is evaluated for its radial distance to this surface. Decision-making units on this surface are considered as efficient and out of the surface units are considered inefficient. Individual inefficiency values are calculated for each decision unit (Kocakoc, 2013: 18).

By solving a linear programming model, each decision unit get a relative efficiency score from zero up to one, weights of inputs and outputs, and a reference set that inefficient units can take as benchmark for improvement. Decision-making units with a score of 1 are considered efficient, while others are inefficient. Besides; by Data Envelopment Analysis, technical efficiency and scale efficiency values can be calculated separately so that the DMU can be informed about the source of its inefficiency to take corrective actions.

The results that can be obtained by the DEA approach are summarized as follows (Ulucan, 2000: 405)

- Effective organizational DMUs
- Ineffective organizational DMUs
- Excess resource amounts used by ineffective DMUs
- The output level of the ineffective DMUs with the current input levels and the level that they should produce (output)
- Inefficient organizational decision units and units that make up the effective reference set.

4.2.1. Implementation Stages of DEA

There are some necessary steps to implement the Data Envelopment Analysis. These steps are as follows (Bozdag et al., 2001: 20):

- Selection of decision-making units,
- Selection of input and output clusters,
- Selecting the DEA model and analysis
- Detail analysis for each decision unit,
- Evaluation of results.

In the Data Envelopment Analysis, DMUs are selected first and inputs/outputs are determined. The next step is deciding whether the determined approach should be input or output oriented. The focus of input oriented approach is the minimum input quantity to be used to produce a certain output (input minimization); and in the output oriented approach is the maximum amount of output (output maximization) to be generated using a certain input. Both optimization

problems give the same effective limit, but occasionally there may be differences in inactive units (Kaya, 2005: 7).

4.2.1.1. Selection of Decision-Making Units

The appropriate decision-making units are dependent to the subject matter of the study. Decision-making units can be any economic unit responsible for transforming inputs into outputs. The selection of decision-making units can be made with two decision principles (Kurkcuoglu, 2004):

1. Each decision-making unit should be defined as responsible for the resources it uses and the outputs it produces.
2. The number of decision-making units in the sampling should be large enough so that the result of the efficient frontier estimation can be significant.

With Data Envelopment Analysis, the effectiveness of the decision-making units is compared (relative) with reference to the best decision-making unit. Therefore, in order to make a rational and accurate comparison, homogeneous decision-making units need to be selected (Golany and Roll, 1989: 237).

Homogeneous decision-making units are expected to operate in the same production / service conditions, perform the same tasks for similar purposes and use the same performance indicators (Okursoy and Tezdurucu, 2014: 1).

In addition, the number of decision-making units is also discussed in the literature. Dyson and others argue that the number of DMUs should be at least 2 times more than the sum of the input and outputs (Dyson et al., 2001: 248). Cooper suggests that at least 3 times more DMUs are needed (Cooper et al., 2001: 228).

4.2.1.2. Selection of Input and Output Clusters

Inputs and outputs used in DEA need to be selected with utmost care as they constitute the basis for the comparison of the decision-making units in the study. Although there is no functional assumption, it is necessary to determine the causally linked inputs and outputs to the production process as different input and output groups will have different efficiency values for the same decision unit. However,

adding too much input and output to the model reduces the ability of DEA to distinguish between efficient and inefficient units. In order to increase the number of inputs and outputs, the number of decision-making units needs to be increased (Kurkcuoglu, 2004).

The above-mentioned information indicates that when determining input and output indicators, both a sufficient number of indicators are needed to provide enough information and the number of these indicators should not exceed a certain amount.

For this purpose, there should be no significant relationships within input and output variable sets. This causes two variables carrying the same information to be included in the analysis and the input-output sum to increase. In this case, examining the correlation matrices for input and output sets and deciding to exclude highly correlated variables from analysis are the first considerations in this subject (Caglar, 2003). In addition significant relationships between input and output variable sets are required. If inputs are the resources and the outputs are the products and/or services produced using these resources; statistically significant relationships between these two sets of variables are expected. In the Data Envelopment Analysis, another multivariate statistical technique, correlation analysis can be used for such research (Sengupta, 1990: 128).

4.2.1.3. Selection of the DEA Model and Analysis

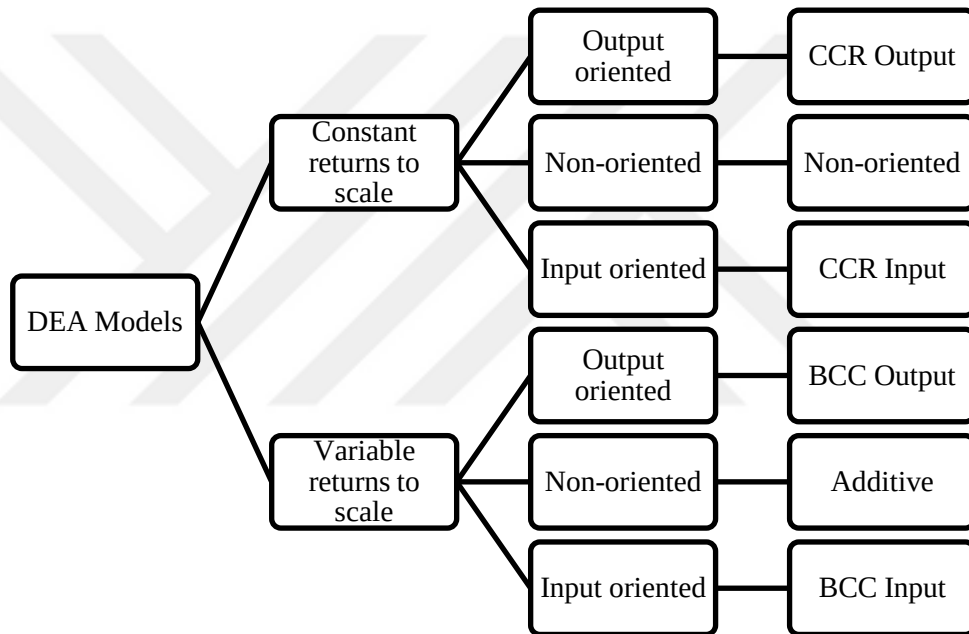
In summary, after determining the decision-making units and selecting the inputs and outputs, there are three DEA models that can be preferred: CCR, BCC and the Additive model. All of these methods can be set as input or output oriented.

Many Data Envelopment Analysis models can be set up according to the application areas and assumptions. Model selection or how to set up the model depends on whether the inputs and outputs can be controlled. An output-oriented model is preferred if the control over inputs is low (or absent); if control over outputs is low, an input-oriented model should be preferred. If, however, a focus cannot be achieved, it would be appropriate to use additive models (Yaralioglu, 2004).

If the analyst is only interested in DMU efficiency scores and does not care about the type of effectiveness, all models can be used. However, additive models should not be used if the decision maker cares about the type of effectiveness. Because such models give mixed effectiveness and do not make effectiveness distinction by type (Yaralioglu, 2004).

Data envelopment analysis models classified by Charnes et al. as “input-oriented, output-oriented and non-oriented” according to the status of return to scale are shown in the following Figure 19.

Figure 19: Classification of DEA Models



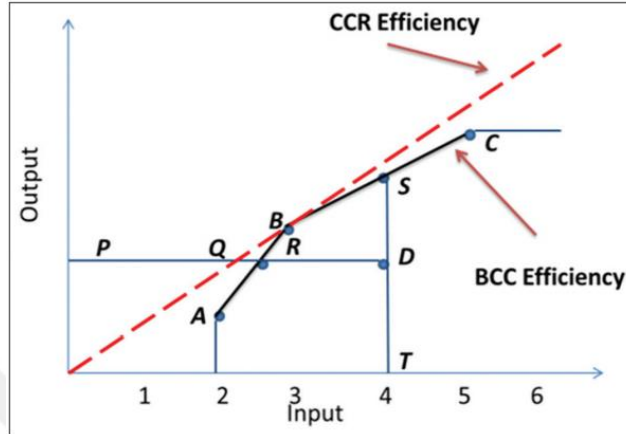
Source: Charnes et al., 2000: 66.

In 1978, Charnes, Cooper and Rhodes proposed a model for measuring efficiencies with a large number of inputs and multiple outputs in an article titled “*Measuring the Efficiency of Decision Making Units*” published in the scientific journal called “*European Journal of Operations Research*” (Charnes et al., 1978). This model is the CCR model named after the initials of Charnes, Cooper and Rhodes. The CCR model measures technical effectiveness under a constant return to scale. The aim is the maximization of the effectiveness of the decision-making unit.

It is observed that the BCC model is used for the measurement of efficiency under the variable return to the scale. Unlike the CCR, the convexity constraint is

added to the BCC envelope model (Cooper et al., 2006). The difference in the production limit of the said constraint added to the BCC model is shown in Figure 20 (Cooper et al., 2006).

Figure 20: CCR and BCC Model Production Limits



Source: Cooper et al., 2006.

Both input and output oriented models can be solved under the assumption of constant return to scale and variable return to scale. When the shape is examined, it is seen that the number of DMUs at the effective boundary increases when the BCC model is used instead of the CCR model. Both CCR and BCC models can be used as input and output oriented (Cooper et al., 2006).

Since the relative efficiency measurement is based on linear programming, optimization programs (GAMS, LINDO, etc.) or special DEA softwares (Frontier Analyst, Warwick DEA software, OSDEA-GUI etc.) that can run under Windows Excel can be utilized. Excel Solver and OSDEA-GUI also can be preferred as it is done in this study. For descriptive statistics SPSS Software has been preferred.

4.2.1.4. Detail Analysis for Each Decision Unit

After the selection of the appropriate model, as a result of the analysis performed, efficiency scores related to decision-making units are interpreted as effective or ineffective according to various types of effectiveness (technical, scale, total). Furthermore, based on the reference groups consisting of effective decision-

making units, various suggestions can be made to enable ineffective units to become effective. Applications such as the efficiency values, group evaluation and target setting for inefficient decision-making units are carried out.

4.2.1.5. Evaluation of Results

After all DMUs have been examined in detail, a general assessment is carried out by taking into account all the variables for each DMU. Although the targets determined by DEA (reduction of inefficient resource usage etc.) cannot be reached by decision makers due to various limitation, study would still provide improvements on understanding the information obtained which is to be evaluated in future studies (Kurkcuoglu, 2004).

4.2.2. Features to Consider in DEA Method

The features to be considered when applying Data Envelopment Analysis method can be listed as follows (Yilmaz et al., 2005: 174);

- DEA method can be used in cases where a large number of inputs and outputs are used.
- There are no assumptions required about the inputs and outputs.
- Can be used to compare compatible and equivalent manufacturers or firms.
- Inputs and outputs do not have to be in the same business unit.

4.2.3. Strengths and Weaknesses of DEA

Strengths of DEA

Data Envelopment Analysis is more favorable compared to other alternative effectiveness measurement methods where a lot of outputs are produced using multiple inputs. For example in the ratio analysis, the degree of importance must be specified by the manager in order to reduce the various ratios to a single effectiveness/efficiency criterion. However, the formulation of the DEA method spontaneously performs this process due to the internal structure of the model.

DEA does not require any preliminary assumptions about the analytical structure of the production function, so it is a non-parametric method. It is more flexible than the classical parametric methods used in estimating the production function (e.g. regression analysis).

For each manager, DEA suggests what they need to do in order to be effective. However, the parametric methods take into account the whole industry and measure according to the average efficiency (Yolalan, 1990).

DEA identifies alternative pathways to increase the performance of an inefficient decision-making unit to the level of decision-making units that are relatively efficient in the cluster. Here, choosing the appropriate path for the DMU is shaped by the judgment and experience of the decision-maker.

DEA assumes that the input and output data are deterministic, not generated by a random mechanism. For this reason, as a non-parametric and non-hypothetical method, it is used as a method of efficiency analysis for deterministic situations.

Boundary function is used in the analysis instead of the average function. Targets are determined by taking the best performing units as benchmarks. This situation strengthens the significance and the validity of the efficiency analysis done with DEA (Kurkcuoglu, 2004).

Weaknesses of DEA

Since DEA is primarily a data-based method, DEA scores are sensitive to the data specifications. The size of the sample must be balanced and the variables must be chosen carefully. If any significant input or output is forgotten or measured incorrectly, the relative effectiveness can be interpreted incorrectly (Nunamaker, 1985: 50).

Since DEA tries to measure the relative efficiency, it is very important that the DMU set is sufficiently homogeneous. Excessive observations in the observation set will inevitably be seen as effective and cause a deterioration in the production frontier.

Although DEA is introduced as a non-parametric method, it leads to the calculation of a large number of DMU variables, as they are individually optimized according to each decision-making unit. In this regard, the degree of freedom is quite high (Yolalan, 1990: 123).

Since DEA is tested with physical input and output measurements, it is generally limited to technical input output efficiency. The capabilities of the method can be enhanced by assigning output and inputs (if possible) to relative quantities or weights.

DEA measures efficiency relative to the best practice within a particular sample, which makes it impossible to meaningfully compare different studies. Also the difference between the observed performance and the best performance is only linked to inefficiency and measurement errors are ignored for outliers (Farrell, 1957).

Qualitative input and output measurements may weaken the results. Reflecting the production process correctly is important for the method to give a healthy result. When a critical input or output is excluded from the review, the results of the method may be misleading and biased.

DEA is a static analysis using the data of the decision units in a single period. An effective decision-making unit may lose its effectiveness or reference in time (Kilickaplan et al., 2004).

The fact that the decision-making units involved in the application group are superior to others makes it difficult to make a comment on whether they are really efficient when evaluated on their own. Therefore, the efficiency results of DEA should be evaluated within the framework of relativity (Kurkcuglu, 2004).

4.2.4. Mathematical Statement of DEA

First standard model of DEA is the CCR (Charnes Cooper and Rhodes) model and the following proportional equation indicates this model:

$$Maks.\theta = \left\{ \frac{\sum_{i=1}^p a_{ki} * Xi}{\sum_{j=1}^m b_{kj} * Yj} \right\} \quad (2)$$

For every decision unit in a container port limitations are formed as;

$k = 1, 2, 3 \dots, n$ and $X_i \geq 0$ and $Y_j \geq 0$

$$\frac{\sum_{i=1}^p a_{ki} * Xi}{\sum_{j=1}^m b_{kj} * Yj} \leq 1 \quad (3)$$

Following statement expresses the model in more detail;

$$\frac{\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1i} \\ a_{21} & a_{22} & \dots & a_{2i} \\ \dots & \dots & \dots & \dots \\ a_{k1} & a_{k2} & \dots & a_{ki} \end{bmatrix} * \begin{bmatrix} X_1 \\ X_2 \\ \dots \\ X_p \end{bmatrix}}{\begin{bmatrix} b_{11} & b_{12} & \dots & b_{1j} \\ b_{21} & b_{22} & \dots & b_{2j} \\ \dots & \dots & \dots & \dots \\ b_{k1} & b_{k2} & \dots & b_{kj} \end{bmatrix} * \begin{bmatrix} Y_1 \\ Y_2 \\ \dots \\ Y_m \end{bmatrix}} \leq 1 \quad (4)$$

Parameters used in this model can be described as;

θ : The efficiency score of the decision unit of (k)

k: number of decision units analyzed,

i: number of output,

j: number of input,

X: Multiplication vector on the a_k ,

Y: Multiplication vector on b_k respectively,

X_i : i. output weighting variable,

Y_j : j. input weighting variable,

A_{ki} : i. output constant of the k. decision unit,

b_{kj} : j. input constant of the k. decision unit,

Z_k : objective equation of the k. decision unit.

From this point of view, it is stated as;

$\sum_{i=1}^p a_{ki} * Xi$: the output function of the k. decision unit,

$\sum_{j=1}^m b_{kj} * Yj$: the input function of the k. decision unit.

When applying DEA method in the CCR model to maximize efficiency; either the inputs are to be considered as the minimum or the output function is

considered to be the maximum. The model is to be applied under any of these two constraints.

In the DEA that is input oriented;

It is accepted that: $\sum_{i=1}^p a_{ki} * Xi = 1$ and the objective equation would be;

$$\text{Minimum } Z_k = \sum_{j=1}^m b_{kj} * Y_j$$

In the DEA that is output oriented;

It is accepted that: $\sum_{j=1}^m b_{kj} * Y_j = 1$ and the objective equation would be;

$$\text{Maximum } Z_k = \sum_{i=1}^p a_{ki} * Xi$$

4.3. RESEARCH IMPLEMENTATION

This section identifies the research direction, explains the DEA model selection processes and DMUs used in the study, defines the input and output variables in detail and provides information regarding to the data resources of the study.

4.3.1. Initial Statements and Limitations

In this study, a comparison of port performances is made only taking the operational indicators of container ports as indicators. The location of the ports, their relations with the customer and other effectiveness issues outside the port operations are not included in the scope of this study.

The data utilized in this study is based on the declarations of official authorities. Measurement processes of these indicators may not have been made according to a certain standard. The introduction of a standard for the measurement of international port performance indicators will make the results of future studies more consistent.

There have been limitations for reaching all the data specified as input and outputs. The number of employee information was obtained via phone calls and e-mails. “TDI Ceyport Tekirdag” is excluded from the analysis since there was no container handling in 2017.

The results of this study, as the nature of the DEA method, would differ if applied with different DMUs added or any excluded, or the analysis is applied in different time.

4.3.2. DEA Models (BCC-CCR) and Decision-Making Units

An output-oriented model is preferred if the control over inputs is low (or absent); if control over outputs is low, an input-oriented model should be preferred (Yaralioglu, 2004). CCR Input and CCR Output oriented models are applied in order to see the minimum input levels of ports and the possible maximum outputs they can produce with the available inputs. Both DEA models are run as input and output oriented and the results are evaluated. Decision-making units subjected to this study are 26 Turkish container ports/terminals.

4.3.3. Defining Input and Output Variables

Lovell (1993) put forward the idea of considering all inputs and outputs since they may be useful. However, he argued that inputs or outputs that have high correlation between each other can be excluded from the calculation by asserting that they do not affect the results of the analysis. Similarly, input / output variables that do not contribute to production and have multiple connections with each other should be eliminated from the calculation (Norman and Stoker, 1991; Kecek 2010; Ateş, 2010). The inputs and outputs must be selected as a composition that is causally linked to the production process and must represent the process in the best possible way (Guclu, 1999; Kecek, 2010).

The variables that affect container terminal efficiency have been derived from literature studies. Although there are different approaches, the general assumption is that the number and length of berths, terminal area, the number and capacity of the

cranes used in container handling (mobile cranes and large quay cranes) and the number of employees are the input variables affecting container terminal efficiency (Marconsult, 1994; Notteboom et al., 2000; Tongzon and Heng, 2005). In this study; the relative efficiencies of the container terminals are calculated and seven inputs and one output variables are used for the calculation. Input variables are; the terminal area (m^2), number of berths, berth length (m), the number of quay cranes, the number of yard handling equipments, draft of the port (m) and the number of employees. The output variable is selected as the annual container throughput (TEU).

Inputs:

Terminal area (m^2)

Greater storage areas in container ports are required as the amount of containerized cargo handled increases. The size of the storage areas of the ports are among the parameters that have a significant impact on the efficiency of the ports (Ates and Esmer, 2013: 78; Altin et al., 2016: 25). In this study, total area of ports is taken into consideration as square meters (m^2).

Number of berths and berth length (m)

Berths are the structures that enable the ships to make loading and unloading safely with the help of cargo handling systems in the port (Ateş and Esmer, 2013: 78). In the literature, this variable has been used as input variable in many studies in measuring the efficiency of ports. In this study, total berth length of ports is taken into consideration.

Number Of Quay Cranes And The Number Of Yard Handling Equipments

Container quay equipments are the vehicles used in container handling. Gantry cranes are the most important equipments that determine the handling capacity of a container terminal. Therefore, it is used in many studies as effectiveness measurement input. In this study, the number of cranes consists of ship to shore gantry cranes (SSG) and mobile harbor cranes (MHC) used for container handling. As well as quay cranes, yard handling equipments and their coordination with the quay cranes determine the performance of a port's cargo handling efficiency. The more efficiently cranes and yard equipments operate, the faster the cargo handling will be and the more containers will be handled. Yard handling equipments taken into the analysis are; RTG and RMG, Empty container handlers, Reach stackers,

Forklifts. Terminal trucks are excluded in the study since the availability of the data. In addition, the performance of crane and yard equipment operators is an important factor for the efficiency of the operations.

Draft (m)

As the sizes and capacities of vessels increased, deeper draft in ports has become an important advantage (Ates and Esmer, 2013: 78; Altin et al., 2017: 25). Different ports and their berths subject to this study have different depths. For this reason, the largest depths of the berths were taken into consideration.

Number Of Employees

The number of employees is an important input in the determination of port effectiveness. In the measurement of the efficiency of a port aiming to maximize its profit, it is stated that labor or labor-related information should be taken as input (Guner et al., 2015: 227).

In order to obtain the highest output from the labor force, they should be monitored at certain periods and productivity rates per hour should be calculated (Acer and Timor, 2017: 347). In this study, the annual number of employees was included in the analysis on the basis of total number of workers and officers working in a port.

Output:

Annual Container Throughput (TEU)

The handling capacity of the container terminals and the carrying capacity of a container ship are determined by TEU (Twenty Foot Equivalent Unit-20 foot equivalent container). Size of container ships is expressed in terms of TEU capacities. The main purpose of the ports is to maximize profit by handling as much cargo as possible. Therefore; the amount of containers handled is one of the most basic and important indicators for measuring the effectiveness of container terminals (Ateş and Esmer, 2013: 79; Altin et al., 2007: 25; Acer and Timor, 2017: 347). It is a widely used variable in the literature as an output for efficiency applications. In this study, annual amount of handled containers (TEU) is taken into consideration as the output.

4.3.4. Collection of Data

The data used in the study has been obtained from various resources:

- Port Operators Association of Turkey (TURKLIM) "Turkish Port Sector Report 2018"
- Port Operators Association of Turkey, website (www.turklm.org)
- IMEAK Turkish Chamber of Shipping, 2017 Maritime Sector Report
- T. C. State Railways Statistical Yearbook (2013-2017)

Container throughput data belongs to the year of 2017. Recent data of container yard equipments was collected from the ports' websites and the calls made by telephone or contacts via e-mail. Personnel data of "TDI Ceyport Tekirdag" could not be obtained due to the reasons of unavailability and this DMU did not make any container handling in the year of 2017. For this reason TDI Ceyport Tekirdag has been excluded from the relative efficiency analysis. Descriptive statistics of the collected data is presented in the following Table 19. Details of the collected data can be found in Appendix 1.

Table 19: Descriptive statistics of variables

Criteria	Output	Inputs						
	Container throughput (TEU)	Terminal area (m ²)	Number of berth	Berth length (m)	Number of Quay Cranes	Number of yard handling equipments	Max. Draft (m)	Number of Employees
Mean	409.403	364.635	3,92	1174	7,4	40,6	16,79	536,6
Standard Deviation	466.817	200.533	2,13	534,14	3,92	31,71	6,08	351,79
Minimum	1.495	50.000	1	330	2	10	10	100
Maximum	1.711.357	1.000.000	9	2174	16	153	36	1501

4.4. FINDINGS

Findings of the analysis are expressed in this section.

4.4.1. Measuring Relative Efficiencies of Container Terminals

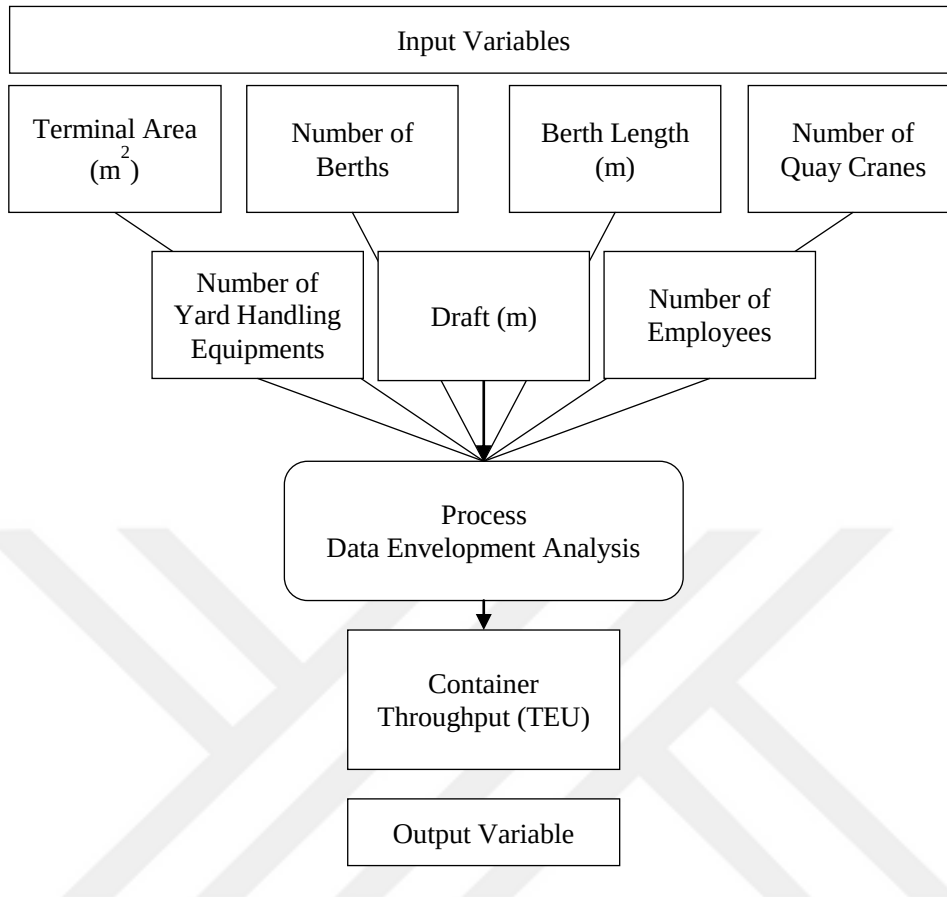
Correlation indicates whether there is a linear relationship between two variables. In other words, it shows whether the changes in the variables affect each other (Kose, 2008: 9).

When calculated, the correlation coefficient takes a value between -1 and 1. If the value is less than zero, there is a negative relationship between variables. If it is greater than zero, there is a positive relationship. When the value is 1, there is an excellent positive relationship (and vice-versa). The degree of relationship decreases as the value gets closer to zero. Although there are a few formulas, the most commonly used is the Pearson's correlation formula:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad (5)$$

In data envelopment analysis, it is desirable that inputs and outputs have a low correlation coefficient within their clusters. High correlations in the input and/or output clusters cause two variables with the same information to be included in the analysis. This situation brings about the degrees of freedom problem. The ratio of the total number of inputs and outputs to the number of decision-making units in the data envelopment analysis is desired to be 1/3. Therefore, one of the two highly correlating variables should be excluded from the analysis. For this reason, correlation analysis is applied to the input and output clusters initially. Then inputs are put into DEA analysis for the relative efficiency measurement. Research model of the study is represented in the following Figure 21.

Figure 21: Research Model



4.4.2. Evaluation of Results

Correlation analysis is conducted in order to identify the linear relationship between variables. Results of the correlation analysis are given in Appendix 2. First, the DEA analysis was performed using all the inputs and outputs. Then, since there is a low and insignificant correlation between the (Annual Throughput and Terminal area) and (Annual throughput and Draft) variables, the analysis was performed again by subtracting these inputs. If the number of inputs is reduced in the DEA analysis, the differences between DMUs can be seen more clearly.

Input-oriented models aim to determine how much ineffective inputs must be reduced in order to achieve a certain level of output. Output oriented models try to determine how much the output should be increased in order to make an ineffective decision unit effective with a given input combination (Kecek, 2010; Ates, 2010).

While the aim of output oriented models is to obtain the maximum amount of output; the aim of the input-oriented models is to have the lowest amount of input (Charnes et al., 1994; Kecek, 2010; Ates, 2010).

BCC input and output oriented results obtained from the research do not represent the market conditions, there are too many efficient ports in BCC results which requires further “Super-efficiency analysis” (Chen and Du, 2015: 381). For this reason, the evaluations were interpreted according to the CCR input and output oriented analysis results. The results and the optimization table of the DEA analysis using all inputs are as follows:

Table 20: DEA Model Efficiency Scores with 7 Inputs, 1 Output

DMUs	DEA Model Efficiency Scores			
	CCR-I	CCR-O	BCC-I	BCC-O
Marport	1	1	1	1
Mersin MIP	1	1	1	1
Asyaport	1	1	1	1
Evyap	0.442	0.442	0.815	0.597
Izmir	0.774	0.774	1	1
Kumport	1	1	1	1
Yilport	0.586	0.586	0.704	0.631
Ege Gubre	0.6	0.6	0.86	0.749
Gemport	0.551	0.551	0.62	0.555
Mardas	0.605	0.605	0.952	0.867
Nemport	0.758	0.758	1	1
Borusan	0.43	0.43	0.926	0.66
Limak Iskenderun	0.724	0.724	1	1
Port Akdeniz	0.566	0.566	1	1
Assan	0.891	0.891	1	1
Haydarpasa	0.153	0.153	0.871	0.264
Roda Port	0.218	0.218	0.804	0.287
Samsunport	0.2	0.2	1	1
DP World	0.974	0.974	1	1
Trabzon	0.026	0.026	0.961	0.055
Limas	0.103	0.103	1	1
C. Bandirma	0.125	0.125	1	1
Derince Safiport	0.002	0.002	0.77	0.003
Akcansa (Ambarli)	0.093	0.093	1	1
SOCAR Terminal Aliaga	0.932	0.932	1	1

Table 21: Percentage Optimizations with 7 Inputs and 1 Output (CCR-I)

DMU Names	Input 1: Terminal Area	Input 2: Number of Berths	Input 3: Berth Length	Input 4: Number of Quay Cranes	Input 5: Number of yard equipments	Input 6: Draft	Input 7: Number of personnel	Output 1: Annual Throughput
Marport	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mersin MIP	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Asyaport	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Evyap	-133,36	-126,42	-133,27	-149,31	-126,51	-272,09	-150,00	0,00
Izmir	-83,17	-29,20	-115,30	-29,24	-76,44	-43,44	-60,00	0,00
Kumport	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Yilport	-102,93	-185,99	-123,32	-70,58	-139,32	-461,80	-70,67	0,00
Ege Gubre	-305,41	-196,52	-153,92	-71,43	-66,82	-506,74	-173,22	0,00
Gempport	-234,85	-169,18	-108,88	-89,98	-146,78	-389,80	-81,52	0,00
Mardas	-201,64	-65,29	-77,04	-203,03	-65,37	-260,36	-71,82	0,00
Nemport	-31,96	-195,64	-54,41	-101,73	-31,96	-308,88	-32,16	0,00
Borusan	-525,87	-132,56	-171,90	-152,10	-132,56	-410,56	-148,76	0,00
Limak Iskenderun	-741,11	-215,46	-66,97	-82,37	-38,07	-270,81	-306,98	0,00
Port Akdeniz	-361,41	-76,83	-77,42	-198,51	-201,61	-431,91	-185,71	0,00
Assan	-54,61	-125,99	-77,08	-73,91	-281,90	-550,68	-12,50	0,00
Haydarpasa	-862,32	-954,85	-556,57	-1011,11	-662,94	-1204,35	-554,17	0,00
Roda Port	-441,00	-1342,31	-566,67	-362,96	-653,01	-958,39	-362,50	0,00
Samsunport	-1450,31	-840,44	-506,25	-406,33	-522,71	-1124,49	-408,33	0,00
DP World	-171,06	-2,67	-25,10	-26,85	-2,68	-178,26	-102,49	0,00
Trabzon	-7549,93	-5669,23	-7161,90	-3746,15	-4900,00	-7400,00	-4185,71	0,00
Limas	-1596,59	-2566,67	-1165,63	-952,63	-2066,67	-8400,00	-900,00	0,00
C. Bandirma	-2140,34	-3806,25	-1118,18	-809,09	-1370,59	-2757,14	-717,65	0,00
Derince Sapiport	-86940,62	-133233,33	-67900,00	-59900,00	-44900,00	-88135,29	-49900,00	0,00
Akcansa (Ambarli)	-976,89	-4661,90	-3620,00	-1150,00	-986,96	-5614,29	-1011,11	0,00
SOCAR Terminal Aliaga	-398,95	-7,30	-77,22	-7,53	-151,20	-369,21	-56,25	0,00
AVERAGE ($\bar{x}$)	-4212,17	-6184,16	-3354,28	-2783,79	-2300,96	-4801,94	-2379,66	0

Table 22: Percentage Optimizations with 7 Inputs and 1 Output (CCR-O)

DMU Names	Input 1: Terminal Area	Input 2: Number of Berths	Input 3: Berth Length	Input 4: Number of Quay Cranes	Input 5: Number of yard equipments	Input 6: Draft	Input 7: Number of personnel	Output 1: Annual Throughput
Marport	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Mersin MIP	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Asyaport	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Evyap	-3,05	0,00	-2,99	-12,50	0,00	-64,10	-10,32	55,84
Izmir	-41,77	0,00	-66,64	0,00	-37,78	-10,99	-23,70	22,60
Kumport	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Yilport	-18,99	-68,07	-30,92	0,00	-41,67	-228,95	0,00	41,36
Ege Gubre	-143,12	-77,78	-52,15	-2,56	0,00	-263,88	-63,40	40,03
Gempport	-84,57	-48,51	-15,13	-4,76	-37,50	-169,87	0,00	44,88
Mardas	-82,47	0,00	-7,18	-83,33	0,00	-117,98	-3,73	39,51
Nemport	0,00	-124,72	-16,99	-55,56	0,00	-209,73	0,00	24,22
Borusan	-169,13	0,00	-16,73	-9,09	0,00	-119,03	-7,07	57,00
Limak Iskenderun	-509,32	-128,57	-21,05	-33,33	0,00	-168,63	-194,12	27,56
Port Akdeniz	-161,00	0,00	0,00	-71,43	-70,59	-200,30	-60,77	43,43
Assan	-37,80	-102,02	-57,77	-60,00	-237,50	-481,04	0,00	10,87
Haydarpasa	-47,52	-61,81	0,00	-66,67	-16,67	-100,00	0,00	84,67
Roda Port	-18,14	-215,79	-44,93	0,00	-66,67	-130,89	0,00	78,16
Samsunport	-209,58	-88,68	-20,87	0,00	-30,77	-142,42	0,00	80,03
DP World	-163,99	0,00	-21,96	-20,00	0,00	-171,19	-97,57	2,61
Trabzon	-100,83	-51,52	-88,97	0,00	-29,41	-93,24	0,00	97,37
Limas	-74,02	-173,97	-26,96	0,00	-116,67	-742,98	0,00	89,74
C. Bandirma	-179,97	-390,20	-50,90	-20,00	-87,50	-256,08	0,00	87,50
Derince Sapiport	-110,73	-204,41	-57,59	0,00	-3,85	-115,83	0,00	99,76
Akcansa (Ambarli)	0,00	-343,46	-236,96	-17,65	0,00	-417,24	0,00	90,71
SOCAR Terminal Aliaga	-364,98	0,00	-65,09	0,00	-133,33	-337,16	-45,23	6,81
AVERAGE ($\bar{x}$)	-100,839	-83,1804	-36,0712	-18,2752	-36,3964	-181,661	-20,2364	44,9864

Since the correlation between inputs of “Number of Personnel – Number of Quay Cranes (0,82)” is very high, the input of “Number of personnel” is excluded from the analysis. Also “Terminal Area - Throughput (0,232)” and “Draft - Throughput (0,12)” variables are not significant and the correlation coefficients are very low (see Appendix. 2). These variables are excluded from the data set and the analysis is run without these variables again. Following are the results of the DEA efficiency scores with 4 inputs (Number of berths, Berth length, Number of quay cranes and Number of container handling equipments) and one output (Annual throughput).

Table 23: DEA Efficiency Scores (4 Inputs, 1 Output)

DMUs	DEA Model Efficiency Scores			
	CCR-I	CCR-O	BCC-I	BCC-O
Marport	1	1	1	1
Mersin MIP	1	1	1	1
Asyaport	1	1	1	1
Evyap	0,442	0,442	0,647	0,491
Izmir	0,774	0,774	0,807	0,785
Kumport	1	1	1	1
Yilport	0,547	0,547	0,683	0,587
Ege Gubre	0,6	0,6	0,831	0,657
Gempport	0,443	0,443	0,536	0,45
Mardas	0,605	0,605	0,852	0,743
Nemport	0,682	0,682	0,918	0,831
Borusan	0,43	0,43	0,802	0,522
Limak Iskenderun	0,724	0,724	1	1
Port Akdeniz	0,566	0,566	1	1
Assan	0,412	0,412	0,876	0,679

Table 23: DEA Efficiency Scores (4 Inputs, 1 Output) (continued)

DMUs	DEA Model Efficiency Scores			
	CCR-I		CCR-I	
Haydarpasa	0,131	0,131	0,574	0,186
Roda Port	0,155	0,155	0,534	0,218
Samsunport	0,172	0,172	0,757	0,29
DP World	0,974	0,974	1	1
Trabzon	0,022	0,022	0,627	0,03
Limas	0,07	0,07	1	1
C. Bandirma	0,079	0,079	0,823	0,206
Derince Safiport	0,002	0,002	0,44	0,003
Akcansa (Ambarli)	0,058	0,058	1	1
SOCAR Terminal Aliaga	0,932	0,932	1	1

In the second analysis, the number of BCC effective DMUs decreased to ten from fifteen. According to the results in Table 23, 4 ports (Marport, Mersin MIP, Asyaport and Kumport) have been identified as effective in their operations. Derince Safiport has been found as the least efficient port, followed by Trabzon and Akcansa. Ports that are away from industrial zones and international trade routes showed less scores of efficiency due to the reason of less container throughputs. Following are the percentage optimization tables for making the inefficient variables efficient:

Table 24: Percentage Optimizations with 4 Inputs and 1 Output (CCR-I)

DMU Names	Input 1: Number of Berths	Input 2: Berth Length	Input 3: Number of Quay Cranes	Input 4: Number of yard equipments	Output 1: Annual Throughput	Average change required in inputs %
Marport	0,00	0,00	0,00	0,00	0,00	0
Mersin MIP	0,00	0,00	0,00	0,00	0,00	0
Asyaport	0,00	0,00	0,00	0,00	0,00	0
Evyap	-127,27	-133,27	-150,00	-123,81	0,00	-133,58
Izmir	-29,31	-115,30	-29,03	-77,14	0,00	-62,69
Kumport	0,00	0,00	0,00	0,00	0,00	0
Yilport	-194,12	-154,78	-86,05	-131,82	0,00	-141,69
Ege Gubre	-198,51	-153,92	-71,43	-63,64	0,00	-121,87
Gemport	-191,26	-176,88	-129,17	-120,00	0,00	-154,32
Mardas	-65,29	-77,04	-205,56	-63,64	0,00	-102,88
Nemport	-181,69	-46,85	-100,00	-50,00	0,00	-94,63
Borusan	-132,56	-171,90	-160,87	-128,57	0,00	-148,47
Limak Iskenderun	-217,46	-66,97	-87,50	-40,00	0,00	-102,98
Port Akdeniz	-76,99	-77,42	-200,00	-205,26	0,00	-139,91
Assan	-159,74	-214,81	-150,00	-237,50	0,00	-190,51
Haydarpasa	-986,96	-664,71	-1150,00	-700,00	0,00	-875,41
Roda Port	-1566,67	-1088,12	-614,29	-525,00	0,00	-948,52
Samsunport	-900,00	-676,00	-471,43	-466,67	0,00	-628,52
DP World	-3,09	-25,10	-27,66	0,00	0,00	-13,96
Trabzon	-7400,00	-10066,67	-4445,45	-2100,00	0,00	-6003,03
Limas	-3233,33	-2150,00	-1328,57	-1200,00	0,00	-1977,97
C. Bandirma	-4445,45	-2061,29	-1204,35	-1400,00	0,00	-2277,77
Derince Sapiport	-133233,33	-67900,00	-59900,00	-2600,00	0,00	-65908,33
Akcansa (Ambarli)	-3603,70	-6100,00	-1718,18	-900,00	0,00	-3080,47
SOCAR Terminal Aliaga	-7,53	-77,22	-7,53	-147,06	0,00	-59,83
AVERAGE ($\bar{x}$)	-6278,17	-3687,93	-2889,48	-451,204	0	-3326,69

Table 25: Percentage Optimizations with 4 Inputs and 1 Output (CCR-O)

DMU Names	Input 1: Number of Berths	Input 2: Berth Length	Input 3: Number of Quay Cranes	Input 4: Number of yard equipments	Output 1: Annual Throughput
Marport	0,00	0,00	0,00	0,00	0,00
Mersin MIP	0,00	0,00	0,00	0,00	0,00
Asyaport	0,00	0,00	0,00	0,00	0,00
Evyap	0,00	-2,99	-10,02	0,00	55,84
Izmir	0,00	-66,64	0,00	-37,78	22,60
Kumport	0,00	0,00	0,00	0,00	0,00
Yilport	-60,73	-39,39	0,00	-27,50	45,30
Ege Gubre	-77,78	-52,15	-2,56	0,00	40,03
Gemport	-28,76	-22,67	0,00	0,00	55,71
Mardas	0,00	-7,18	-83,33	0,00	39,51
Nemport	-91,02	0,00	-34,62	0,00	31,81
Borusan	0,00	-16,73	-9,09	0,00	57,00
Limak Iskenderun	-128,57	-21,05	-33,33	0,00	27,56
Port Akdeniz	0,00	0,00	-71,43	-70,59	43,43
Assan	-7,12	-29,52	0,00	-35,00	58,78
Haydarpasa	-42,45	0,00	-56,25	0,00	86,91
Roda Port	-157,18	-82,65	0,00	0,00	84,50
Samsunport	-73,41	-33,56	0,00	0,00	82,75
DP World	0,00	-21,96	-25,00	0,00	2,61
Trabzon	-36,36	-113,88	0,00	0,00	97,80
Limas	-115,05	-54,58	0,00	-30,00	92,97
C. Bandirma	-257,14	-70,05	0,00	0,00	92,06
Derince Safiport	-199,63	-61,14	0,00	0,00	99,76
Akcansa (Ambarli)	-115,05	-254,96	0,00	0,00	94,17
SOCAR Terminal Aliaga	0,00	-65,09	0,00	-133,33	6,81
AVERAGE ($\bar{x}$)	-55,61	-40,6476	-13,0252	-13,368	48,7164

CONCLUSIONS

Ports are one of the most important building blocks of maritime transport. Ports integrate maritime transport with land transportation modes and offer economies of scale, provide economical benefits and prosperity to the parties they serve and the geography they are located. Efficiency of ports and avoiding waste of resource provide cost and time advantages for port owners and users.

Port investments are long-term and highly expensive investments. Therefore, infrastructure and superstructure planning should be done very well before the port constructions or investments. Port location, capacity, equipments, number of employees and other related parameters are the factors affecting the efficiency and the competitiveness of a port. Inefficiencies resulting from i.e. idle capacity, non-operating equipment, over employment are some of the factors that reduce profitability.

Port efficiency has become a popular subject in recent years. Within the scope of this study, effectiveness of container ports in Turkey has been analyzed. The analysis results compare the ports among themselves and pick the most efficient port(s) from the sample. It would be a wrong statement to say that ports have been found as effective in this study operate hundred percent efficiently. For example, according to the CCR-I model, Marport, which is found to be efficient, cannot be said to be a productive port on a world scale. Appendix 3 and 4 shows the Peer group ports that the ports should take as benchmarks within the scope of this study.

Results showed that the capacity utilization of the container ports in Turkey, as seen in Appendix 5, was calculated as 40.57% which accounts for a huge amount of capacity surplus. Additionally, according to the optimization table of CCR-I model, “number of berths” has been found as the most inefficient input for Turkish container ports, followed by berth length, number of quay cranes and number of container yard handling equipments. In case of full capacity utilization, using the existing resources, ports in Turkey can handle %48,7 more containers annually according to the findings of CCR-Output oriented model. Although the terminals have a certain capacity, low amount of container handling in the year of 2017 had caused the performance of many terminals to be calculated as low.

The highest correlating variable with the container throughput has been found as “Number of personnel” with a score of 0,87 and “Number of Quay cranes” with a score of 0,86. Therefore these variables are the most significant determinants of the operational efficiency in container ports. As a result of this study, Marport, Mersin MIP, Asyaport and Kumport were found to be the most efficient ports with scores of 1. The most inefficient ports are determined as Derince Safiport, Trabzon and Akcansa, respectively. Derince Safiport has made new investments for container handling in 2018 and in 2017 it is found to be inefficient due to the fact that the amount of containers handled was very low. Also Trabzon Port has been found as highly inefficient. Reasons for this situation are that the industrialization rate in the Black Sea Region of Turkey is quite low. Furthermore, another handicap of the port is that the hinterland connection of the Trabzon Port is only possible by roadway. Akcansa which is mainly focused on bulk cargoes has three berths, two serving for various types of cargoes. Container throughput of the port has been 13.310 TEU and the efficiency score was found as 0,058 for container handling.

Located at the crossroads of the East-West and North-South trade routes, Turkey has a significantly important geographical position. Yet however, it is hard to claim that Turkey has grown sufficiently in terms of the proportion of the container transportation which is growing its share year by year in the world maritime trade. Turkey, at the location of Far East-Europe axis located very close to the main trade routes and therefore constitutes a high potential for transit cargoes as well. However, Turkish container terminals cannot get the deserved share from the transit freight market due to lack of infrastructure for accommodating large-scale container vessels operating in main trade routes.

A significant portion of the containers handled at the terminals constitutes Turkey's import and export products. Within the scope of the study, the fact that the terminals with high performances are located close to the industrial zones and/or to large hinterlands cause the throughput amounts and relative performance of these terminals to be higher. On the other hand, the efficiency scores are found to be low for the terminals which do not have sufficient and strong connections (i.e. railway connection) with their hinterland.

Most of the ports in Turkey do not only serve to containerized cargo but to different types of cargoes such as; bulk, Ro-Ro and project cargoes etc. For this reason, Turkish ports do not make the necessary investments in container terminals. This situation creates a lack of specialization on container handling and delays the process of reaching world standards in the services provided for container transportation.

Last but not least, ports need to plan their needs coherently and utilize in particular from the establishment of a strong bond with their hinterlands through rail and road connections. Also ports in Turkey should adapt their infrastructures and superstructures taking the best practitioner ports in the world as benchmarks, focusing on the recent technological developments in container shipping and port management techniques. The most effective and efficient ports are those that can adapt themselves to the rapidly changing market and environmental conditions.

DISCUSSION AND RECOMMENDATIONS

In line with previous studies, ports located close to the industrial zones and/or to the international trade routes have found to be efficient and local ports, and/or ports that have hinterland connectivity problems are found to be relatively inefficient.

Findings of this study overlap with the results of the study done by Alpaslan et al. (2013) which indicates Black Sea ports of Turkey as inefficient compared to the other countries' ports in that region. Ates and Esmer (2011) studied relative efficiencies of 15 Turkish container ports and identified Marport, Izmir, Mersin MIP and Kumport container terminals as relatively efficient and the only Black Sea Region port subject to that study "Alport" as the most inefficient container port. Both studies seem coherent in the essence of ports with highly industrialized and populated hinterlands and/or with a close location to main trade routes are found to be more efficient. On contrary, Izmir Port is replaced by Asyaport in the findings of this study as efficient and similarly the Black Sea ports are found to be the least efficient ports.

As mentioned by Cetin (2010) the ultimate goal of container ports is to increase their profitability. Increasing the port efficiency and effectiveness are of many cornerstones towards achieving this goal. Fiskin et al. (2016) emphasized that there are numerous elements that affect the competitiveness of container ports. These can be summarized as; time spent at port for a container vessel, location of the port, port service quality, port facilities and equipments, port tariff, intermodal connections and port draft. Competitive advantage is only possible when all these elements are optimally utilized and combined towards achieving port operational efficiency and effectiveness.

The DEA analysis used in this study is a very sensitive analysis method and is extremely sensitive to inputs and outputs and their accuracy. Increasing the number of DMUs used in the analysis would boost the sensitivity of the analysis and make things more clear in terms of the separation of efficient ports from the inefficient. This study comprised all container ports in Turkey. 4 ports were found to be relatively efficient. In future studies, efficiency of these ports can be revealed by making super efficiency analysis among themselves. Also comparing Turkish ports with best practitioner international hub port equivalents would help to understand the condition of Turkish ports in a better way.

One of the facts determined in the study is that the inputs and outputs used in the efficiency analysis might not be measured by every port in accordance with certain standards, in the same and comparable way. The declarations of the official institutions were taken as basis. Therefore, as a need, a guidebook can be constituted by the authorities or port organizations to standardize the international port performance criteria measurements.

Further studies may increase the number of inputs and outputs, making the study more sensitive and more accurate. Although this study avoids the human factor, it is also a significant determinant on port efficiencies. Number of handling equipments and quay cranes are used as inputs in this study but the performance of these equipments depends on the operators. It can be discussed in further studies how to integrate the human capabilities and skills into the performance measurements.

Most of the ports compared in this study handle different types of cargoes, such as dry and liquid bulk, Ro-Ro and so on. Further studies can examine ports as a

whole system in a comprehensive approach. Overall efficiencies of ports can be measured by combining the cargo amounts as total handled tons of cargo.



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APPENDICES

APPENDIX 1: DMUs' Inputs and Outputs

Port Name	Terminal Area (m ²)	Number of Berths	Berth Length (m)	Number of Quay Cranes	Number of Handling Equipments	Draft (m)	Number of Employees	Annual Throughput (TEU)
Marport	530.000	7	1.972	15	75	16,5	1501	1.711.357
Mersin MIP	350.000	9	1.485	16	153	15	1400	1.591.983
Kumport	468.909	5	2.174	13	40	16,5	680	1.063.246
Asyaport	300.000	2	2.010	13	95	18	700	1.002.133
Izmir	360.000	3	1.843	8	62	10,5	856	639.300
Yilport	338.000	6	1.465	8	51	30	710	499.283
Gempport	700.000	6	2.024	11	44	36	550	474.019
DP World	460.000	2	922	6	31	16	650	437.047
Evyap	265.000	3	1.171	9	47	16	770	369.659
Mardas	330.000	2	910	11	36	16	500	357.264
Nemport	160.000	4	840	7	18	17,5	300	313.596
Ege Gubre	513.000	4	1.488	6	18	27	500	286.926
SOCAR Terminal Aliaga	420.000	1	700	3	42	16	350	274.870
Limak Iskenderun	1.000.000	4	920	6	14	15,5	700	269.583
Borusan	465.000	2	900	6	32	14,5	500	241.971
Port Akdeniz	203.000	2	330	6	58	10	500	200.117
Assan	128.280	2	680	4	27	19	135	188.132
Roda Port	211.000	6	1.200	5	25	14,5	259	88.438
Haydarpasa	219.360	5	650	10	56	12	471	86.709
Samsunport	445.000	3	776	4	17	12	244	70.027
C. Bandirma	268.348	5	670	3	15	12	139	27.162
Limas	120.000	2	405	2	13	20,4	100	16.038
Akcansa (Ambarli)	50.000	2	930	2	10	12	100	13.310
Trabzon	361.000	3	1.525	5	22	12	300	11.419
Derince Sapiport	450.000	8	1.360	6	27	15	500	1.495
TDI Ceyport Tekirdag	114.700	8	2.219	8	10	12	-	0

APPENDIX 2: Correlation Matrix Between Inputs and Outputs

		Terminal Area	Number of Berths	Berth Length	Number of Quay Cranes	Number of Yard Equipments	Draft	Number of Personnel	Annual Throughput
Terminal Area	Pearson Correlation	1							
	Sig. (2-tailed)								
Number of Berths	Pearson Correlation	,245	1						
	Sig. (2-tailed)	,238							
Berth Length	Pearson Correlation	,373	,453**	1					
	Sig. (2-tailed)	,066	,023						
Number of Quay Cranes	Pearson Correlation	,253	,507**	,671**	1				
	Sig. (2-tailed)	,223	,010	,000					
Number of Yard Equipments	Pearson Correlation	-,009	,416**	,415**	,779**	1			
	Sig. (2-tailed)	,965	,038	,039	,000				
Draft	Pearson Correlation	,290	,222	,364	,181	-,010	1		
	Sig. (2-tailed)	,160	,287	,074	,386	,963			
Number of Personnel	Pearson Correlation	,406**	,510**	,603**	,824**	,756**	,049	1	
	Sig. (2-tailed)	,044	,009	,001	,000	,000	,817		
Annual Throughput	Pearson Correlation	,232	,434**	,651**	,860**	,782**	,120	,876**	1
	Sig. (2-tailed)	,264	,030	,000	,000	,000	,567	,000	
** . Correlation is significant at the 0.05 level (2-tailed). Note: Grey painted cells represent the extracted variables from the analysis due to very high (in the same cluster) or very low (between different clusters) correlations.									

APPENDIX 3: Peer Groups for CCR-I Model

DMU Names	Peer Group
Marport	Marport
Mersin MIP	Mersin MIP
Asyaport	Asyaport
Evyap	Marport, Asyaport
Izmir	Marport, Asyaport
Kumport	Kumport
Yilport	Marport
Ege Gubre	Kumport
Gemport	Marport, Kumport
Mardas	Marport, Asyaport
Nemport	Marport, Kumport
Borusan	Marport, Asyaport
Limak Iskenderun	Kumport
Port Akdeniz	Mersin MIP
Assan	Marport
Haydarpasa	Marport, Mersin MIP
Roda Port	Marport
Samsunport	Marport, Kumport
DP World	Marport, Kumport
Trabzon	Marport, Kumport
Limas	Marport
C. Bandirma	Marport
Derince Sapiport	Marport, Kumport
Akcansa	Marport
SOCAR Terminal Aliaga	Marport, Asyaport

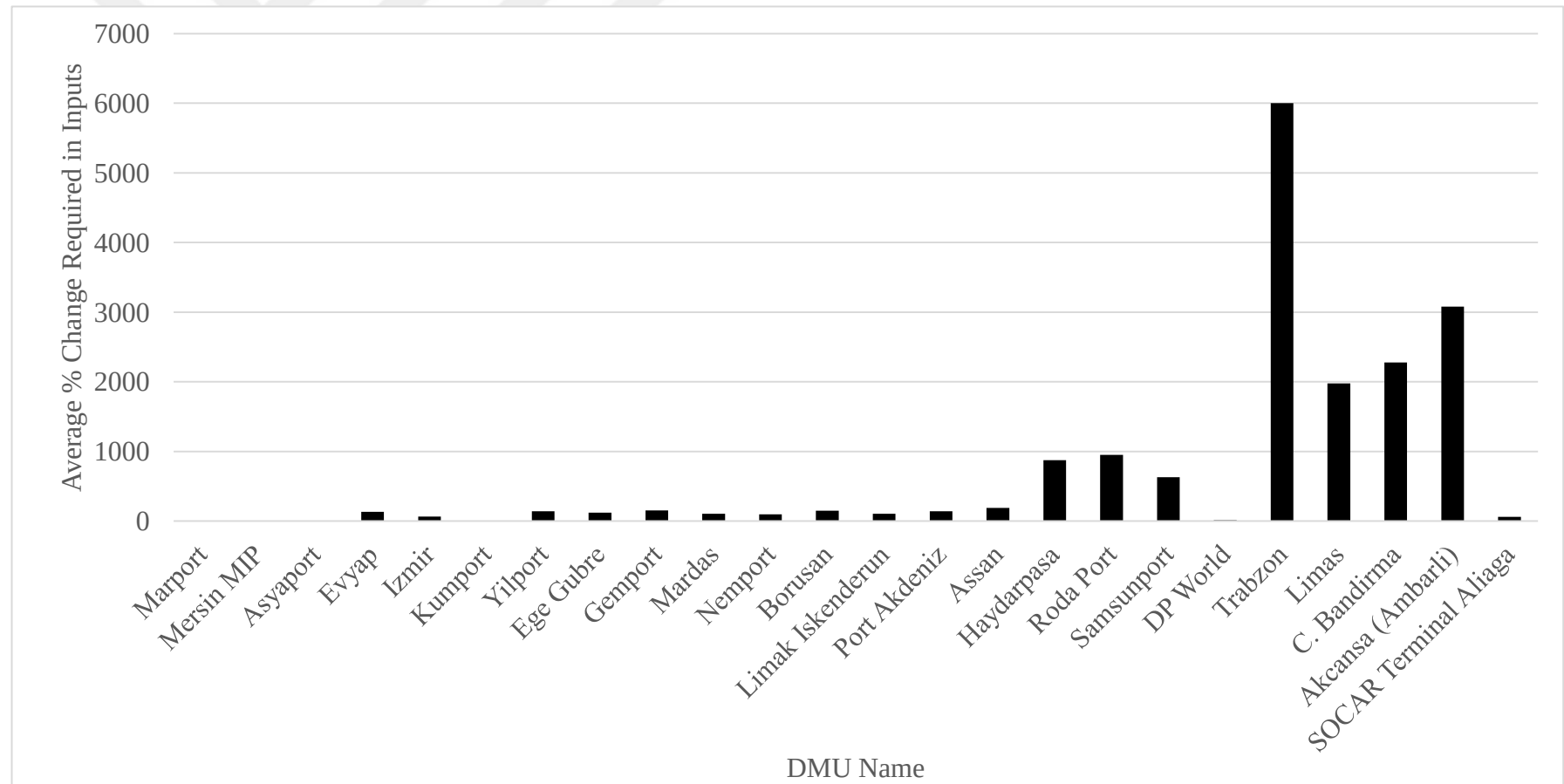
APPENDIX 4: Peer Groups for CCR-O Model

DMU Names	Peer Group
Marport	Marport
Mersin MIP	Mersin MIP
Asyaport	Asyaport
Evyap	Marport, Asyaport
Izmir	Marport, Asyaport
Kumport	Kumport
Yilport	Marport, Kumport
Ege Gubre	Kumport
Gemport	Kumport
Mardas	Marport, Asyaport
Nemport	Marport, Asyaport, Kumport
Borusan	Marport, Asyaport
Limak Iskenderun	Kumport
Port Akdeniz	Mersin MIP
Assan	Kumport
Haydarpasa	Mersin MIP, Kumport
Roda Port	Kumport
Samsunport	Marport, Kumport
DP World	Marport, Kumport
Trabzon	Marport, Kumport
Limas	Kumport
C. Bandirma	Kumport
Derince Sapiport	Marport, Kumport
Akcansa	Marport, Asyaport, Kumport
SOCAR Terminal Aliaga	Marport, Asyaport

APPENDIX 5: Capacity Utilization Ratios of Container Ports in Turkey

DMU Names	Capacity	Throughput (TEU)	Capacity Utilization
Assan	250.000	188.132	0,752528
Marport	2.300.000	1.711.357	0,744068
Izmir	1.025.624	639.300	0,623328
Mersin MIP	2.600.000	1.591.983	0,612301
Borusan	450.000	241.971	0,537713
Kumport	2.100.000	1.063.246	0,506308
Yilport	1.000.000	499.283	0,499283
Mardas	800.000	357.264	0,44658
Roda Port	200.000	88.438	0,44219
Ege Gubre	657.000	286.926	0,436721
Evyap	855.000	369.659	0,43235
Nemport	750.000	313.596	0,418128
Asyaport	2.500.000	1.002.133	0,400853
Port Akdeniz	500.000	200.117	0,400234
C. Bandirma	70.000	27.162	0,388029
DP World	1.300.000	437.047	0,33619
Gempport	1.600.000	474.019	0,296262
Samsunport	250.000	70.027	0,280108
Limak Iskenderun	1.000.000	269.583	0,269583
SOCAR Terminal			
Aliaga	1.300.000	274.870	0,211438
Haydarpasa	481.008	86.709	0,180265
Limas	200.000	16.038	0,08019
Akcansa (Ambarli)	187.500	13.310	0,070987
Trabzon	350.000	11.419	0,032626
Derince Safiport	2.500.000	1.495	0,000598
TOTAL	25.226.132	10.235.084	$\bar{x} = 0,4057$

APPENDIX 6: Average Optimization Requirements for DMUs (CCR-I)



Note: Derince Safiport: %65.90

