Benchmarking the technical efficiency of container ports against the port co-opetition concept in the East – West trade route

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UNIVERSITY OF RIJEKA

FACULTY OF MARITIME STUDIES

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VREDNOVANJE TEHNIČKE UČINKOVITOSTI KONTEJNERSKIH LUKA U SURADNOM ODNOSU NA TRGOVAČKOM PRAVCU ISTOK-ZAPAD

DOKTORSKA DISERTACIJA

Mentor: prof. dr. sc. Damir Zec

Komentor: prof. dr. sc. Alen Jugović

Rijeka, 2019

DECLARATION

I certify that all the materials in this dissertation that is not my own work have been identified, and that no material is included for which a degree has previously been conferred on me. The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University of Rijeka.

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The doctoral thesis is defended on the day of 11 July 2019 at the Faculty of Maritime Studies, University of Rijeka before the following Committee for the defense of doctoral thesis:

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I dedicate this work for the soul of my father, who waited so long in his life for this moment.

SAŽETAK

Tržište pomorskih kontejnera svojom dinamičnom prirodom i porastom trgovine snažno utječe na snagu i međusobni utjecaj ključnih dionika. Brodarske kompanije stalno povećavaju tržišnu koncentraciju linija, posebice u pogledu svojih kapaciteta, ostavljajući pritom kontejnerske luke s manje izbora, a da pritom ne povećavaju ulaganja i ne jamče pozitivne financijske rezultate. Kontejnerske luke uvijek nastoje poboljšati svoju učinkovitost, jer se ona smatra jednim od važnih čimbenika atraktivnost luke. Značaj učinkovitosti potakla je ovo istraživanje, ponajprije u cilju pronalaženju rješenja za poboljšanje učinkovitosti luka kroz povezivanje regionalnih luka te primjenom koncepta suradnje u cilju povećanja učinkovitosti luka.

Istraživački pristup temelji se na procjeni relativne tehničke učinkovitosti glavnih kontejnerskih luka na trgovačkom putu Istok-Zapad. Sukladno ovom pristupu, izabrane su 42 luke koje se nalaze među 50 najvećih kontejnerskih luka na svijetu. Relativna tehnička učinkovitost mjerena je pomoću analize omeđivanja podataka (Dana Envelop Analyses - DEA) odnosno odgovarajućih modela (CCR, BCC, super efikasnost, analize slaba varijabli i analize osjetljivosti) za razdoblje od 2011. do 2016. Procjena je provedena dva puta, prvi put za pojedinačne luke dok je drugi put analiza provedena za ujedinjene luke. Klasterizacija luka provedena je primjenom K-srednje tehnike. Nadalje, ispitana su tri scenarija klasterizacije luka za odabir optimalnog rješenja. Prvi se pristup temeljio samo na rezultate dobivene DEA modela, dok su preostala dva scenarija izvedena uz pomoć modela klasterizacije u kombinaciji s DEA modelom

Rezultati istraživanja su pokazali da samo korištenje DEA modela nije dalo razumne i konzistentne rezultate. S druge strane, uporaba oba modela DEA i te pridružene klasterizacije rezultiralo je s razumnim i pouzdanim rezultatima. Ovaj je pristup primijenjen dva puta, prvi put uz izuzeće učinkovitih luka iz razmatranih klastera, dok su drugi put sve promatrane luke grupirane u 14 skupina. Konačno, ovo istraživanje jasno dokazuje da će klasterizacija luka pozitivno utjecati na relativnu tehničku učinkovitost luka, a suradnja među lukama mogla bi biti dobar pristup za poboljšanje njihove učinkovitosti. Nadalje, on ukazuje na korištenje koncepta suradnje te njegovo mjerenje opipljivim mjernim alatom za procjenu relativne učinkovitost luka.

Ključne riječi: Tehnička učinkovitost luka, Suradnja, klasterizacija luka, DEA

ABSTRACT

The maritime container market with its dynamic nature and the increase of its seaborne trade is reshaping its player's power and influence on each other. Shipping lines are increasing market concentration in terms of carriers' capacities leaving container ports with fewer choices rather than increasing investments with no guaranties of the positive balance sheet. Container ports always aim to improve their efficiency as it is considered one of the important element that reflects ports attractiveness. This triggered the aims and objectives of this research in finding a better solution to improve ports efficiency through cooperation between regional ports and apply the coopetition concept for the objective of increasing ports efficiency.

The research approach was to assess ports relative technical efficiency of the main container ports in the East-West trade route. Accordingly, 42 ports among the world's top 50 container ports were selected. The relative technical efficiency was measured by the aid of the Data Envelop Analyses (DEA) models (CCR, BCC, Super efficiency, Slack variable analyses and sensitivity analyses) for the period from 2011 to 2016. Assessment was applied twice, the first time for individual ports while the second time between clustered ports. Ports clusterization was performed by a clusterization model and the use of K- mean technique. Moreover, three scenarios of ports clusterization were tested to select the optimum applicable one. The first was by relying only the results obtained from the DEA models in forming ports clusters, while the remaining two scenarios were performed with the aid of a clusterization model coupled with the DEA models.

The results showed that only the use of DEA models with manipulating its results to reach the research objective was not providing reasonable consistent results. On the other hand, the use of both models the DEA and a clusterization model showed reasonable reliable results. This approach was implemented twice, the first time with the exclusion of the efficient ports from proposed clusters while the second time all the study ports were grouped to form 14 clusters. Finally, this research concludes that ports clusterization could positively affect ports relative technical efficiency as well as coopetition among ports could be a good approach for improving ports efficiency. Moreover, it paves the way for introducing the coopetition concept with a tangible measuring tool which is benchmarking ports relative efficiency.

Keywords: Ports technical efficiency, Coopetition, ports clusterization, DEA

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CHAPTER ONE

INTRODUCTION

1.1. Research problem

Today's container port-operating landscape is characterized by sharp port competition. Decisions by shipping alliances concerning ports of call, capacity deployed, and network arrangement can control the calling of a container port. Strategic liner shipping alliances with gigantic vessels reshaped the relationship between container lines and ports. This led to complex dynamics, whereby shipping lines have stronger bargaining power and influence than container ports and terminals. Therefore, ports need to re-evaluate their role in global maritime logistics and cope with this significant transformation. In addition, they need to the distribution of costs and benefits between shipping lines and ports as well as to strengthen their bargaining power (UNCTAD,2018).

Europe - Far East trade route is considered one of the main container routes in which a lot of the main container ports are located. These ports are developing rapidly to increase their efficiency and capture more market share. Accordingly, competition among them and other regional ports are strongly taking place with a lot of investments and rarely cooperation with other ports is approached. The main problem is that the practice of applying a win-win strategy through co-opetition concept is not widely used in spite of its advantages to face the rapid changes in this dynamic industry.

Moreover, cooperation between ports should be seen as a tool to add a competitive edge for its objectives to improve port operations, management of resources and information as well as reducing destructive competition (UNCTAD,1996). This introduces the co-opetition concept to formulate port clusters to keep ports less vulnerable to the uncertain of the international business environment. Accordingly, the question of why many ports are not taking a clear step toward co-opetition to perform a win-win strategy, in spite of its benefits, should be raised. Nevertheless, can the word cooperation replace competition or divert to co-opetition.

1.2. Research questions

Container ports need to consider the status of their attractiveness by optimization of service and level of efficiency provided. However, to a large extent, ports are competing in order to increase its market share and throughput. A few researchers have tried to study the relationship between port efficiency and port competition (Cullinane et al, 2004; Cullinane et al, 2005; Wang et al, 2005;

Elsayeh, 2015). However, none of these studies addressed the co-opetition concept on one of the main trade routes. In order to accomplish the above-stated research aim and objectives, the research will try to answer the following questions:

1. What are the ports technical efficiency and how it can be obtained?
2. what are the main factors governing ports efficiency scores?
3. What are the dynamics of ports cooperation and how to introduce the co-opetition concept with ports efficiency?
4. What is the optimum platform to evaluate ports efficiency on cooperating ports clusters?
5. What are the restraints that slow or ban ports co-opetition?
6. What will be the future characteristics of port co-opetition between container ports in the main East-West trade route and accordingly how this could help to increase its efficiency?

The rationale for research question 1 and 2 rises from the necessity to provide a theoretical background about port efficiency. Moreover, to analytically understand the different efficiency models and techniques used in evaluating ports relative technical efficiency. This is to pave the way for the rational of the third question which is to find the optimum use of efficiency models to group ports and apply co-opetition concept. The rationale for research question 4 arises from the need to find the algorithm to cluster ports based on their complementary factors that affect their relative technical efficiency. The rationale for research question 5 is to find the factors that can slow or prevent cooperation between ports. Finally, question 6 is to predict the proposed scenarios of cooperation of ports and forming better efficient port clusters in the East-West trade route.

1.3. Research hypotheses

The efficiency of container ports is a significant tool in determining ports competitive advantage (Kim H.,2011). Usually, the efficiency of a container port has been measured by calculation and for the purpose of optimizing the technical efficiency of cargo handling (Cullinane &Wang, 2007). As such, in the context of this research, the main hypothesis is that *ports relative technical efficiency will improve with the implementation of a co-opetition strategies with neighboring ports.* From that it is also expected that, a) The efficiency of study ports is enhancing over time. b) Container ports; deployed in different countries, policies, framework are able to cooperate and perform a win-win strategy if a clear platform of co-opetition is presented and proved.

1.4. Research aims and objectives

This study aims to benchmark relative technical efficiency among the main container ports in the East-West trade route to find the best practice to apply the co-opetition concept. This could help port decision makers to optimize the use of their resources, by establishing strategic cooperative plans with their traditional competitors.

As such, the research objectives are:

1. Study the contemporary changes in the liner shipping market.
2. Critically analyzing the previous studies of port efficiency.
3. Benchmark the technical efficiency of main container ports in the main East-West trade route.
4. Introducing the optimum practice of efficiency obtained throughout co-opetition and clustering of ports
5. Forecasting the future co-opetition of the main ports in the East-West trade route with highlighting constraints and proposing solutions

1.5. Review of previous researches

This research objective requires reviewing the literature that address many fields in the container ports sector. This is to precisely identify the research gap analysis. Accordingly, two chapters were prepared to present the previous researches that pave the way for this research contribution and findings. Chapter 2 that will present the container ports market dynamics, changes and contemporary condition which affects ports policies and competitiveness. This will be through researching on the liner shipping dynamics as well as ports competition and its landscape. finally presenting researches on the historical and existing cooperation between ports that investigates its challenges and benefits.

Moreover, chapters 3 was designed by twofold objectives to provide the previous researches that investigates ports co-opetition and ports technical efficiency measurements. In the first fold of this chapter will present studies that addresses ports competition, cooperation and co-opetition. This is important to increase the understanding of co-opetition by finding various ways that shows how collaboration and competition exist simultaneously and to suggests aspects that impact the co-opetition.

The second fold of this chapter will review researches that investigates ports technical efficiency. This was with emphasis on the DEA models and applications in the maritime ports sector. Digging in such researches was very important to stand on the inputs and outputs commonly used in the DEA models as well as the pros and cons of each model application. Finally, by reviewing researches in this two chapters the research gape analysis was clear as well as the research contribution and originality was clearly identified and presented.

1.6. Research methodology

This study can be categorized as quantitative analytical research. The methodology that shall be used in this research is the non-parametric models of Data Envelopment Analysis (DEA) that evaluates the relative technical efficiency scores of the 42 study ports according to their relative technical efficiency for a period of 6 years from 2011 to 2016.

Container ports are carrying up their operations through complex and extensive activities. Therefore, this research focuses only on the technical efficiency at the level of container terminals in the port. As such, the term port refers to the collective activities of all container terminals that operate inside the ports of study.

Benchmarking the technical efficiency of the selected container ports will be measured by the port's throughput in TEUs (twenty equivalent unit) as output measures in the models. However, the input measures will include ports infra/ superstructure, represented by 5 controlled inputs and one uncontrolled input. The controlled inputs are a terminal area, maximum depth, quay length, number of yard equipment and number of gantry cranes, while the uncontrolled input is the ports deviated distance from the main trade route which is used as a model environmental factor.

Models of the DEA will be applied twice in this research for the reason of finding the impact of co-opetition between ports. The first model's application will be done to ports individual data (inputs and outputs) to find the relative technical efficiency of each study port. The second application of models will be by the use of the collective data (sum of inputs and outputs) of the complementing ports which will form a cluster. The comparison between the efficiency scores of the two results will identify the impact of port clustering on their ports technical efficiency scores. In benchmarking container ports technical efficiency five non-parametric DEA models will be used. These models are:

1. The CCR model that measures the ports' aggregate technical efficiency.
2. The BCC model analysis the ports' pure technical efficiency.
3. The super efficiency (A&P) model that ranks the efficient ports.
4. The sensitivity analysis model that checks the sensitivity of ports' efficiencies through verifying whether the efficiency scores of ports under study are affected significantly if only one input or output is eliminated from the DEA analysis.
5. The slack variable analysis model that clarifies the amount of utilization of input and output variables by determining in what way inputs should be decreased, and/or how many outputs should be increased, so as to optimize the under optimize port to become an efficient port.

All previously mentioned stages of research methodology will be based on collecting data from secondary sources mainly from issues of the Containerization International Yearbooks and ports official sites. To estimate the efficiency of the port separate study, data for the years from 2011 to 2016 were used. The Banxia Frontier Analysis software was used to solve the DEA models that explain ports return to scale production function, the CCR model has an assumption of constant returns to scale (CRS) model and BCC model has an assumption of variable returns to scale (VRS) model.

Throughout available information and results of the analysis of benchmarking technical efficiency between the cooperating ports clusters, this research shall try to provide a platform that can explain the port co-opetition measures and conditions that could enable ports to apply win-win strategy through optimizing their resources and operation costs all through sharing resources and enhancing efficiency.

1.7. The research area of study and limitations

The global maritime container shipping system operates through main strategic equatorial trade passages covering the whole world. These trade routes are the Trans-Atlantic between Europe to west America, Trans-Pacific between Asia and west America and the Trans-Indian route from Asia to Europe which is commonly named the main East-West trade route. Rather than the main previously mentioned trade routes, there are the north-south routes that are used to serve smaller markets.

This research will focus on the main East-West trade route that links Asia to northern Europe. This route is considered the second largest trade route, from Port of Hamburg in Northern Europe till port of Busan in Northern-East Asia. The significance of that route is that it contains ports from three continents and various main trading regions like Northern Europe, Mediterranean, Middle East, South East and North East Asian regions. Moreover, it contains the main shipping passages and Canals in the world, for instance, the Strait of Malacca, Bab el-Mandab, Gibraltar and Suez Canal. Furthermore, ports along that route are managed and operated by different management policies based on the variety of countries and policies governing each and every port. Nevertheless, more than 80% of the world top 50 container ports are serving that route beside the rest of the main routes. Therefore, selecting the study ports with such diversity could lead to more practically reliable results.

Figure (1-1) shows the 42 selected study ports, among the world's top 50 ports, which are geographically positioned on the main East-West trade route from Hamburg in northern Europe to Pusan in north east Asia. Even though the study ports are geographically on the main East-West trade route but they also serve the rest of the world either on the main routes as trans-Pacific or trans-Atlantic as well as on the smaller routes as the North-South directions. Therefore, simply these selected 42 ports in this research are connecting and serving nearly all markets worldwide.

This research is limited to the assessment of the relative technical efficiency and the co-opetition of the main container ports in the main East-West trade route within the top 50 container ports worldwide for 6 years' period from 2011 till 2016. Data envelop analyses (DEA) models will be applied to the study container ports with the valuation of relative technical efficiency since economic estimates are not combined in the study as the research emphasis on evaluating the extent to which physical facilities, as well as resources, are optimally used. Nevertheless, improving technical efficiency will positively be radiated in the improvement of economic efficiency (Cullinane &Wang, 2007). Finally, the assessment and analysis will be limited to benchmarking technical efficiency and co-opetition of these ports before and after clustering with neighbouring ports.

Figure 1-1 World largest container ports in the main East-West trade route (42 study ports)

1.8. Research importance and contribution

The co-opetition concept with its advantages of providing win-win situation and maintaining economies of scale as well as improving the port bargaining power was not widely implemented among ports. Moreover, the use of technical efficiency as a tool of applying co-opetition was not presented so far in any research, making this research significant in presenting a new platform for co-opetition application among seaports. Moreover, this study seeks to extend the use of relative technical efficiency in ports to introduce the co-opetition concept between seaports

This research assesses the relative technical efficiency of container ports and aims to find an appropriate methodology to group ports into clusters, that can perform with better relative technical efficiency among competitors. This requires a deep understanding of ports strengths and weakness in terms of infra/superstructure as well as their contribution to port technical efficiency. Nevertheless, this research should propose appropriate structured steps to build port clusters based on ports capabilities to complement with each other and perform better optimization results.

The selection of the study ports in this research is among the world largest 50 container ports worldwide. This gives strength to this research as studying the relative technical efficiency of the top container ports means that we are analyzing the efficiency of the world's top operational equipment, strategies and management patterns. This could give more reliability to results and contribution. It is very significant to analyze the technical efficiency of individual container ports for the existence and effectiveness of the industry and its stakeholders (Cullinane et al, 2006). Accordingly, this analysis will provide not only a management tool for port decision makers in the selected ports regional markets but it will also provide important information and analysis to ports worldwide, to optimize planning and operations as well as introduce a new approach of co-opetition. However, this research aimed solely to linking numerous estimates of the technical efficiency of ports and Suggestions for the greatest degree of co-opetition through cooperation within the industry provides simply an explanation and reasoning to implement such approach.

The significance of this research is to find the optimum procedures and practice to establish a maritime port clusters to apply the co-opetition concept. This research could be important in both the academic field and the industrial fields. Introducing the co-opetition concept with technical efficiency 'which was not vastly used' could create a new methodological approach that could be applied to different sectors in the maritime field. Nevertheless, to find the best methodology to measure how ports clustering will affect technical efficiency. Moreover, how clusterization could help the decision makers in the maritime industry to perform more cost-effectively by reducing the need of investment to enhance efficiency.

1.9. Research structure and plan

The research structure demonstrations the plan that has been carrying out to test the hypothesis, answer the research question and achieve the aim and objectives. This research is arranged in 7 chapters divided into 5 main sections. These sections are the theoretical framework, background, Models, calculations and conclusion. Figure (1- 2) illustrates the chapters in the research embedded from the previously mentioned sectors. Chapter one shows the research theoretical outline. Chapters 2 and 3 establish the background of this research. Chapter 4 represents the methodological and models used. Chapters 5, provide the application of the assessment of relative technical efficiency analysis of the study port. Chapter 6, provides the main contribution of the research that shows ports clustering technical relative efficiency and results. Chapter 7, delivers research conclusions, recommendations and areas for further proposed research areas.

This thesis can be outlined as follows:

Chapter 1 constitutes a general introduction to the research topic. It also provides an overview of the research significance, problem, aim, objectives, methodology, hypotheses and uniqueness. To sum up, it outlines the thesis structure and originality.

Chapter 2 provides a comprehensive theoretical background on the theoretical definition of port competition, different types of port competition and factors affecting port competition. Moreover, it presents a global view on the contemporary dynamics in shipping lines and how it affects ports operations. This chapter is important in understanding the global container market parties' changes and how these changes can impact ports efficiency.

Chapter 3 provides a detailed understanding of the concepts, definitions, types and theories of port efficiency. It reviews and studies and previous literature on port efficiency and efficiency measurement and assessment tools. This chapter also indicates the variable specifications in the existing literature and conducts a gap analysis between the previous researches and this existing study.

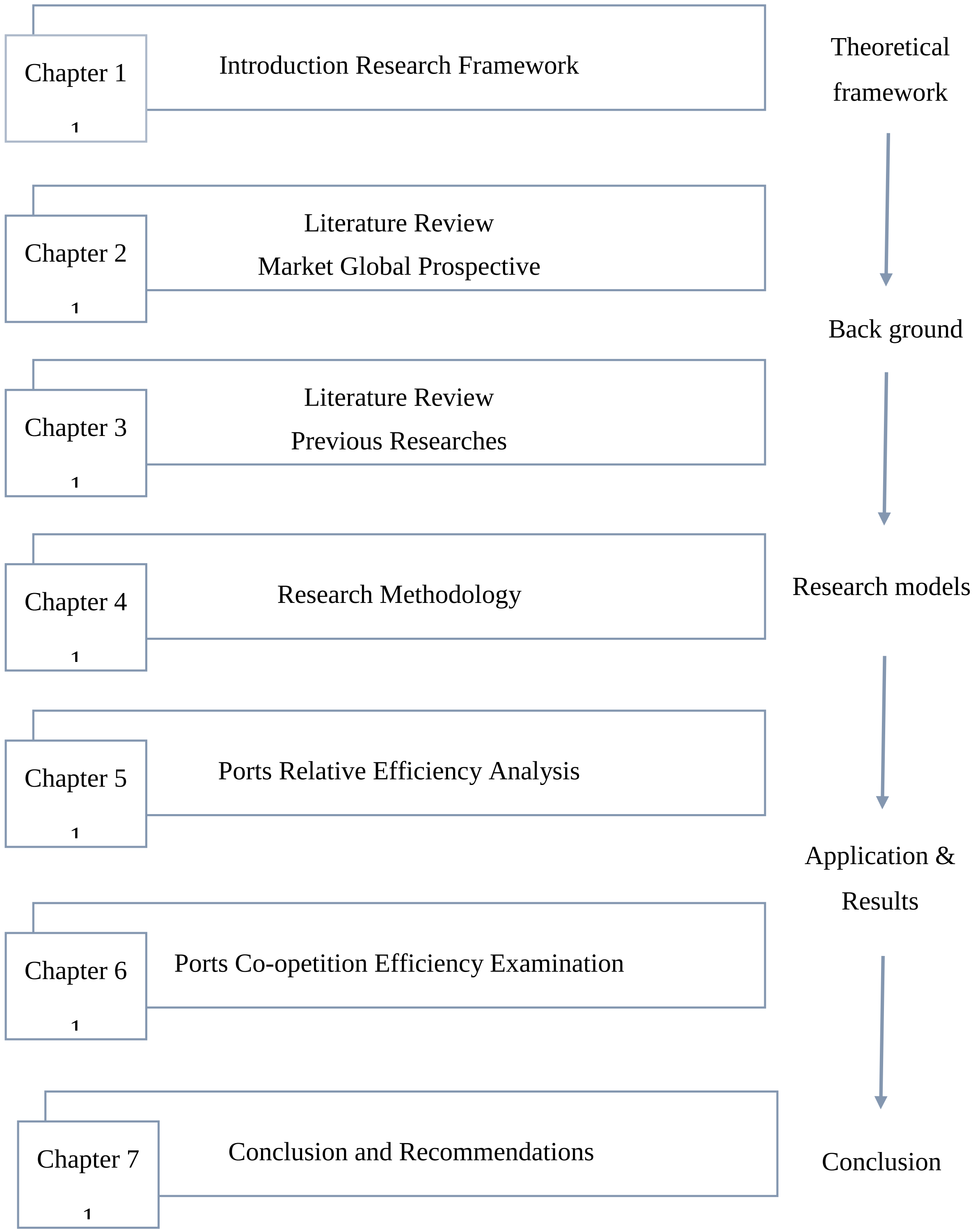

Figure 1-2 Research sections and structure

Chapter 4 identifies the research philosophy, approach and methodology. Likewise, it formulates the theoretical framework and the models and techniques used. It also validates the specifications of variables that are used to measure ports efficiency and provide a brief clarification on data collection and software used to measure ports relative efficiency, in particular, the technical efficiency.

Chapter 5 benchmarks the relative technical efficiency of study ports using five DEA models. The DEA-CCR (CRS) model to assess the aggregate technical efficiency. The DEA-BCC (VRS) model to evaluate the pure technical efficiency as well as the return to scale analysis of each study port. Super-efficiency (A&P) analysis is conducted to rank the efficient ports. Sensitivity analysis to distinguish between variables that have larger weights in terms of efficiency. Finally, for the identification of ports potential improvement areas the slack variable analysis will be performed.

Chapter 6 test the research hypotheses that examine the impact of ports co-opetition on ports efficiency. It also proposes different scenarios of ports clustering with its relative technical efficiency results.

Chapter 7 summaries the research and presents the study conclusions and recommendations for ports decision makers and operators that allow them to improve their ports technical efficiency through co-opetition and cooperation. The chapter also highpoints the possible areas for further research.

1.10. Chapter summary

This chapter presents the research topic based on the defined research aim and objectives. It highlighted the research problem and hypotheses. Moreover, presents the significance and clarified research contributions to knowledge. Besides, it presents the research area of study and research limitations. It also presents the research methodology and processes by which the aim and objectives will be achieved. Finally, the outline of the research structure and plan was presented.

The next chapter will synthesize published literature of port competition provides a comprehensive theoretical background on the hypothetical definition of port competition, different types of port competition and factors affecting port competition. Moreover, it presents a comprehensive overview of the current dynamics in shipping lines and how it affects ports operations. Based on a literature review, the study gap will be known in a way that explains how this research will contribute to knowledge. This chapter is important in understanding the global container market parties’ changes and how these changes can impact ports efficiency.

CHAPTER TWO

CONTAINER PORTS CO-OPETITION IN LIGHT OF LINER SHIPPING MARKET DYNAMICS

2.1. Introduction

This chapter is based on the researcher's published paper that paved the way to this thesis objectives and contribution. It was very important to study and analyze the container market and analyze the recent changes that can reshape the market or change the balance of power between market stakeholders. Therefore, this chapter will mainly emphasis on the two main players in the container market which are the shipping lines and container ports. Studying the shipping lines contemporary strategies and its impacts on container ports was very important. As it highlights the importance of this research in finding better cost-effective ports strategies, to increase their efficiency as well as their competitiveness and bargaining power.

In recent decades, globalization, market integration, and global reorganization of investment and labour forces reshaped the world production and consumption map. Moreover, containerization and inter-modality fueled the development of the international transport network as on 2016 the seaborne containerized cargo reached around 1.7 billion tons transported by container ships and container ports handled around 0.7 billion TEUs (Drewry, 2017a). This increased the role of ports in the global supply chain and extensively impacted port completion.

Container shipping lines growing trend of mergers, acquisition, alliances and deployment of huge vessels magnifies shipping market concentration besides increases bargaining power against ports. In addition, reduces the number of weekly liner services as for the North Europe-Far East weekly services declined from 35 in 2006 to 26 in 2012, 21 in 2015 and only 17 in 2017. This concept of larger ships with fewer services fueled the completion among container ports, knowing that one weekly service of such giant vessels contributes to around 450,000 TEU in ports throughput annually (Notteboom et al., 2017).

Moreover, Port rivalry has become so vigorous and multi-faceted concept due to continuous changes in the ports and shipping market condition. This is due to the increase of competition between terminal operators within one port, between neighbouring ports and also between whole port ranges (Notteboom et al., 2015). Privatization of ports and injection of private investments also powered competition between ports as from 2000 till 2016 the privet sector invested in 292 projects with approximately $ 68.6 billion in 63 countries with emerging and developing economies (UNCTAD, 2017).

This chapter aims to analyze the present container market condition with emphasis on its two main players shipping lines and ports. Moreover, it will present the concept of ports co-opetition as a solution to ports aggressive competitive policies through studying market players' strategies. This will be carried out through four main sections. The first section will present and analyze the current carriers' market dynamics. The second section will discuss the port competition conceptual definition, types and landscape and their consequences in real life on presenting the concepts, definitions and deep analyses to the market condition. The third section will discuss the possible outcomes of different policies adopted and implemented by shipping companies and how they affected ports competition. Finally, the last section will discuss the conceptual definition of co-opetition and ports clustering with presenting some cases of the previously applied ports cooperation and clustering.

2.2. Liner shipping market dynamics

2.2.1. Liner shipping market overview

Since the beginning of containerization in the mid-1950s, it transformed the liner shipping industry in all its functional, physical, organizational scopes. As Adam Smith's words "By using containers to mechanize the transport of general cargo, it has opened the whole world to a market for the produce of every sort of labour" (Stopford, 1997). By the beginning of 2016, the fully cellular container fleet reached 5,239 vessels with a total nominal capacity of 19.7 million TEUs (ISL, 2016). Moreover, the predicted growth rate of containerized trade is expected to be 6% until 2023. This requires deep analyses of all stockholder's dynamics in this growing sector. (UNCTAD,2018)

Container vessels are deployed worldwide through main routes (core routes) and secondary routes as shown in figure (2-1). The main routes are serving the major markets, linking the world between, Europe, Asia. North and south America through main canals and straits for instance. the Suez and Panama Canals as well as the Strait of Malacca, while the secondary routes are serving smaller markets (Rodrigue, 2017). Figure (2-2) shows the total TEUs predicted to be transported on the main trade routes in 2018 as well as its growth rate between 2017 to 2018. It is clear that the total estimate containerized trade across the main East-West trade route from Europe to Far-East shows transportation of 24.8 million TEUs making it the second trade route for nearly 1/3 of the world container trade, with the largest container ships deployed on service (UNCTAD,2018). Moreover, about 75% of the biggest 50 container ports are providing services to the East-West trade route (World shipping council, 2017). The importance of this route made all shipping lines and ports compete and invest a lot to increase their market share.

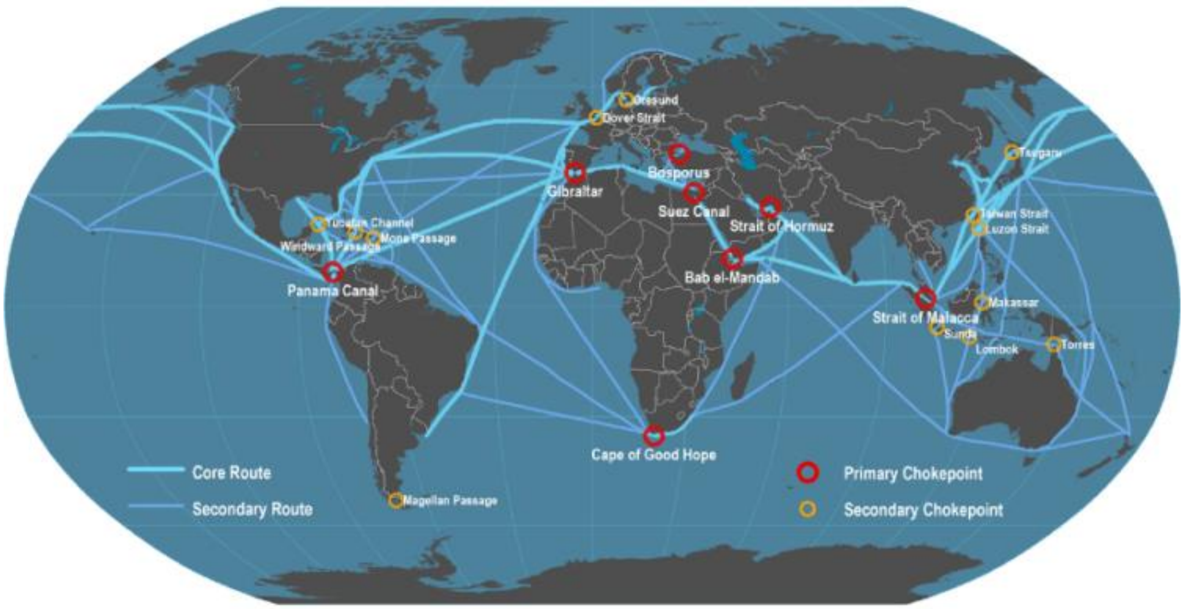

Figure 2-1 Main maritime shipping routes

Source: Rodrigue P. (2017), The geography of transport systems, fourth edition, New York

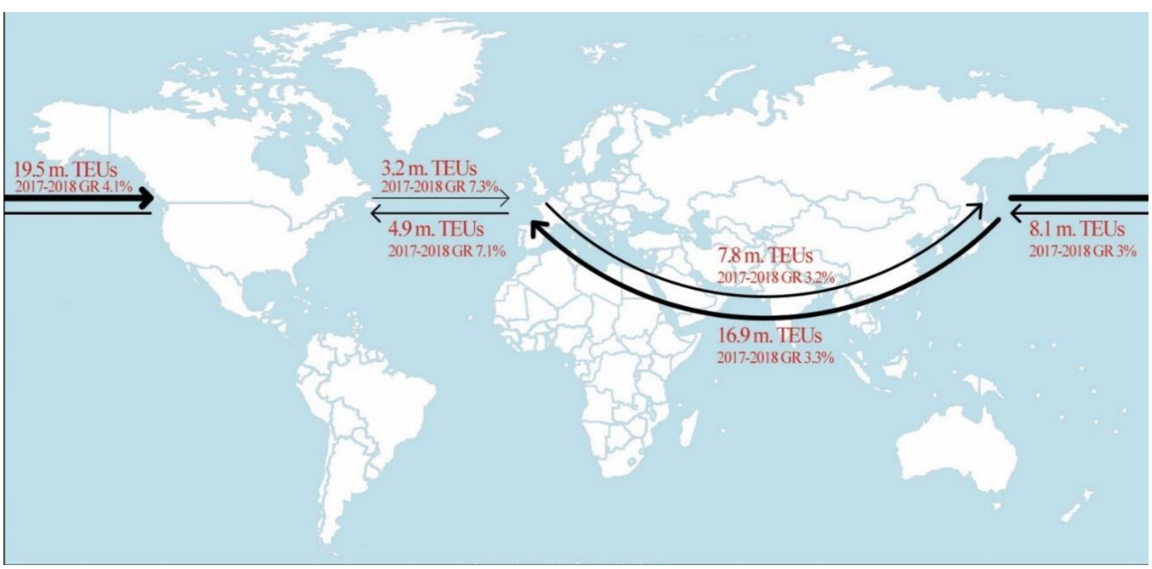

Figure 2-2 Total estimated TEUs transported on the main container trade routes in 2018

The maritime industry is a highly capital intensive industry and directly affected by its shipping sector which is so volatile and sensitive to world economic and political changes. Nearly, 873 container ports all over the glob in 141 countries are receiving fixed schedules of fully container vessels with more than half million vessel calls (UNCTAD,2018). Therefore, container ports are developing in their infra/superstructure to captive more cargo and increase their market share. These development policies require a lot of capital investment with a long term return on this investment. Container ports should continue development and investment to perform more efficiently and be more competitive among their competitors.

The ongoing dynamics in the highly competitive container markets made competition among container ports is highly connected to shipping lines dynamics and changes. Alliances and shipping lines merging are having a great influence on inter-port competition as it affects the balance of bargaining power between ports and carriers (Notteboom et al., 2017). Container shipping lines in the first ten years of containerization were not facing any problem with profitability as they were secured by the revenue pooling agreements founded on conference tariffs (Notteboom, 2004). But Over the last decade container carriers have significantly drifted financially in comparison to other industries and made them focus more on optimizing their economy of scale through horizontal and vertical integration.

Horizontal integration was performed by mainly three forms: Trade agreements like liner conferences, operating agreements (that is vessel sharing agreements, slot chartering agreements, consortia and strategic alliances) and mergers as well as acquisitions which resulted to consolidation that made 70% of the market is governed only by the biggest 7 operators on the year 2016 (ISL,2017). While the vertical integration was achieved by many shipping lines since the late 60s as Mitsui OSK Line (MOL), Evergreen, K-Line and Maersk in which they were involved in the terminal operation and logistics activities (Parola et al., 2015). This was to take advantage of the economy of scale, customer retaining as well as steadiness of revenue (Rodrigue and Notteboom, 2010). Vertical integration made the competition is not only between ports but between the whole supply chains.

Recently, competition among carriers pushed them to increase the market supply with gigantic vessels, which leads to a negative balance sheet to many of them. Consequently, they rushed toward mergers, acquisitions and alliances to save their existence as well as they strengthen their businesses in port operation as a toll of reducing cost and gain control.

2.2.2. Liner shipping companies financial condition

The containerization industry was increasing dramatically as it increased by about 8% from 1990 till 2010 Shipping lines were competing for the ordering of gigantic container ships causing the fleet to grow by almost 15% according to the expectation of the global container trade growing in double digits, but unfortunately the world economy grew slow. Consequently, the global container demand grew less than 1 per cent in 2015 and a huge overcapacity of container shipping tonnage was deployed in the market. In the same context, since 2007 the industry is witnessing a very poor financial outcome as a result of the severe competition between carriers causing the bankrupt of Hanjin Shipping Co. at end of 2016 which was having 2.9% of the market share. Moreover, Drewry believes that in 2017 carriers' financial results and profitability will continue to fall and forcing carriers with weak financials to address their cost structures in the absence of growth. In the same context, the operational pressure of challenging market situations, inflating debt and bad cash flows for a long period of time will apply serious tension on carrier commercial capability causing further industry consolidation (Power T., et al, 2016).

Figure (2-3) shows the shipping industry average Altman z- score from 2010 till 2016. Altman Z-score is the output of a credit-strength test that gauges a company's likelihood of bankruptcy based on a number of metrics from a company's public statements. The safe score is above 3 while a score below 1.8 means the company is probably headed for bankruptcy. It is clear that the industry score since 2011 is showing a high tendency for companies' bankruptcy, which reached 0.9 on 2016 before Hanjin figures were excluded, and the score increased only to 1 after Hanjin was eliminated. This means that the industry could lose more companies if the industry financial situation is not improved. Shipping lines are always seeking a way to drop down coasts and slim down operating costs and capital expansion as between 2011 and 2016 the industry reduced its capital expansion (CAPEX) by half to fall from 25.2 million to only 12.4 million (Blaeser J., et al., 2017). Finally, in 2017 the only way for this industry to survive after cutting capital expansion costs and operation costs is to shelter among each other by mergers and accusations as it could be the only lifeboat for many of them as well as engagement in alliances to optimize their economy of scale.

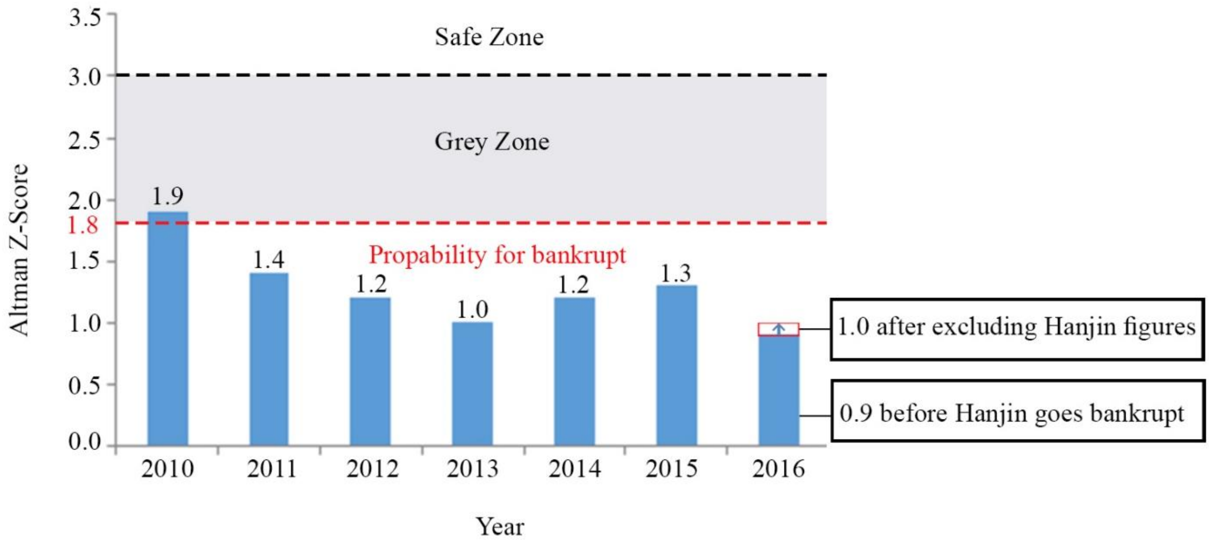

Figure 2-3 Shipping Industry Average Altman Z- Score from 2010 till 2016

Source: Author, adopted from: Blaeser J., et al. (2017) Global container shipping outlook for 2017: Rearranging the deck chairs—with only a few seats in the sun. Alixpartners.

2.2.3. Shipping lines alliances and market concentration

Container shipping liner horizontal integration policy and backing up themselves through alliances is not a new act, but the recent pace of consolidation could be driven to overcome their financial deficiencies and for geopolitical reasons. Figure (2-4) shows the consolidation and partnerships that strongly took place in the shipping lines since the late 90s until now. During that period many companies have disappeared as they were swallowed or merged with other companies. Until 2001 the top 30 container liner companies in addition to the alliances did not exceed 50% of the market share, by 2011 this percentage increased to 70%. In 2014 the market share of the alliances only reached 50 % (Sanchez J. and Mouftier L., 2017). In the same context, in 2017 only 3 alliances were controlling nearly three-quarters of the whole market. The significance of the resent alliances is the change of market leaders' policies, like Maersk and MSC, from operating solely to engagement into alliance and forming the 2M alliance that control nearly one-third of the market share. This act significantly increases the market concentration and strengthens shipping lines bargaining power toward ports.

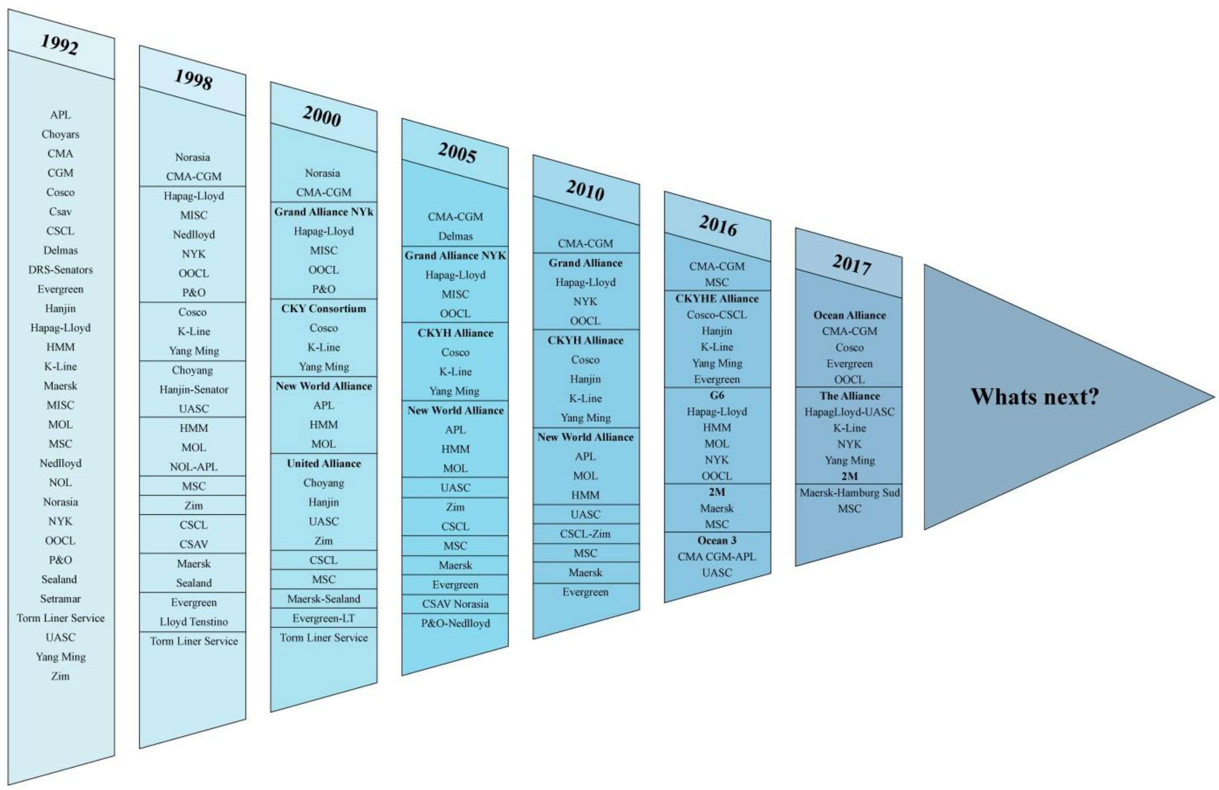

Figure 2-4 Evolution of shipping line alliance

Author: data-driven from: Enna Hirata (2017) Contestability of Container Liner Shipping Market in Alliance Era. The Asian Journal of Shipping and Logistics, Volume 33, Issue 1, March 2017, Pages 27-32

Geopolitical reasons are also strongly present in this wave of alliances as the economic superpowers usually need and want to secure their supply chain. The new shipping alliances are showing a geopolitical flavor as each alliance is dominated by a flag of country or continent in the sense that the 2m is European and the Ocean Alliance is mainly Chinese, in spite of the presence of the French CMA CGM as a leading share in the Ocean alliance with its11.6% market share. China is in control of about 16.6% of the market share either directly through the owning of its Chinese own state company " COSCO shipping line" or indirectly through the presence of the Hong Kong company (OOCL) and Taiwanese company (Evergreen). Moreover, COSCO already proposed $6.3 million to buy OOCL by which COSCO will be the third largest carrier (Buxbaum P., 2017). In the same context, the Chinese state-owned company "China Merchants Holding" owns 49% of the terminal operating company "Terminal Link" and the remaining 51% is owned by CMA CGM (Lopez E., 2017). This means that if any future accusation made by another Chinese state-owned company the distribution of power within the alliances and even in the whole industry will be changed. This raises the question of how concentration in the shipping industry will affect the port operation business and competition.

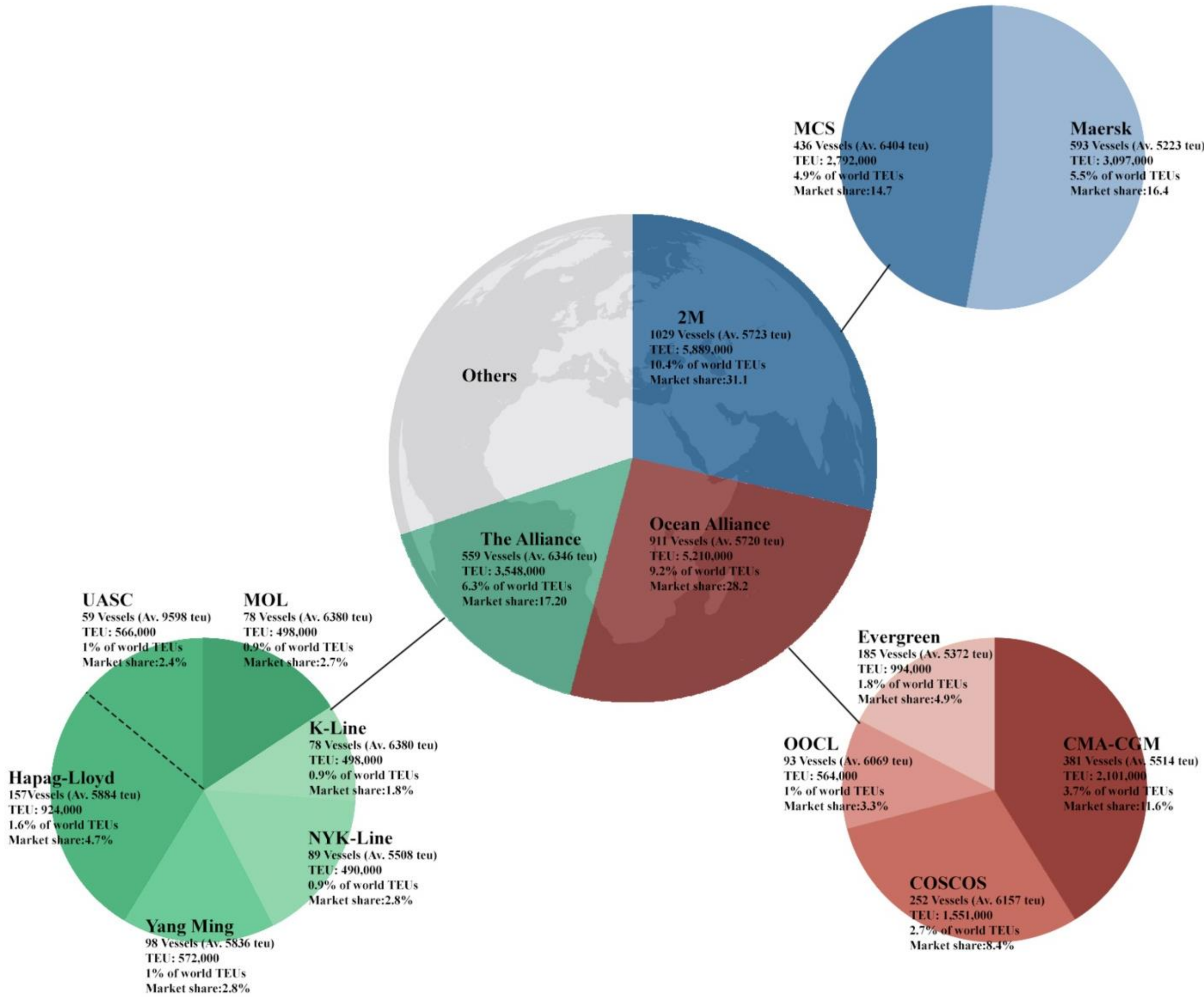

Figure 2-5 Alliances carrying capacities and market share in 2017

Source: Author, Data-driven from ISL (2017), “shipping statistics and market review 2017”, Institute of shipping economics and logistics, Vol. 61 No.7

Figure (2-5) shows the carrying capacities of the main three alliances member and their market share. It is clear that the overall carriers are operating 2499 vessels (overcapacity of 1000 TEUs) representing 60% of the world fleet fully container vessels and controlling around 77% of the container market business. Moreover, 2M alliance and Ocean Alliance each is controlling nearly 1/3 of the market share, while The Alliance is operating with the biggest vessel with an average of 6346 TEUs/ ship, and controlling 17% of the world market share.

2.2.4. The strength of shipping alliances in port operations

Table 2-1Alliances shipping companies' activities in the terminal operation business in 2017

Alliance	Carrier	Terminal operation business
2M	Maersk Line	Owns "APM Terminals" which operates 76 port and terminal facilities in 95 countries
	MCS	Owns "Terminal investment limited" which operates 35 terminals in 22 countries
Ocean Alliance	CMA-CGM	Owns "CMA Terminals" which operates 13 terminals worldwide
	COSCO	Operates 158 Container berths in 30 ports worldwide
	OOCL	Operating 6 berths in the USA and one Berth in Taiwan
	Evergreen	Operating 2 terminals in Taiwan and one in Panama
The Alliance	MOL	Operates 10 container terminals in 5 countries
	K-Line	Owning "Nitto Total Logistics" which operating 7 berths worldwide
	NYK-Line	Operates Container Terminals in 23 ports
	Yang Ming	Operates one terminal with 4 berths in Taiwan
	Hapag-Lloyd UASC	N/A

Since the 90s shipping lines are involved in container terminal operations for the sack of controlling their business and squeezing cost on their supply chain, but with the previously stated carrier's market concentration port competition will strongly be affected. Table (2-1) shows the alliance's members' involvement in port operation business in which nearly all carriers own and operating container terminals or berths except Hapag-Lloyd and UASC. Moreover, Drewry prediction that by 2020 port operation will be led and dominated by carrier's companies. In the same concept, table (2-2) present the development of terminal operators ranking in which it is clear that COSCA will lead the industry by 2020 followed by APM Terminals. In addition, the industry will witness 2 more shipping lines sister companies in the top seven operators. Nevertheless, Carriers are also having joint projects and own shares in some terminals managed by only terminal operators' companies in which port operations is their core business (Drewry, 2017b).

As a result of the previously stated facts, container ports are struggling to survive and are severely competing with each other. Therefore, understanding the port competition concept, strategy and landscape is very important to recognize the container market behaviours.

Table 2-2 Ranking of Terminal operators from 2010 till 2020(forecast)

Terminal operator	Capacity Rank		
	2020(forecast)	2016	2010
COSCO China shipping	1	4 & 8*	6
APM Terminal	2	2	4
PSA International	3	3	1
Hutchison	4	1	2
DP World	5	5	3
Terminal Investment Ltd	6	6	7
CMA - CGM	7	9	> 10

Source: Author data driven from various sources including, Drewry (2017), Global Container Terminal Operators Annual Review and Forecast 2017

2.3. Ports competition

Ports with their importance and nature of nodes in the supply chain are situated into a dynamic competitive environment. Understanding the conceptual meaning of competition, types of competition, as well as ports competition landscape, are very important to evaluate the influence of carrier's market behaviour on ports competitiveness.

2.3.1. Conceptual definition

Port competition concept was not a well-defined concept for its complex nature. Henceforth, the characteristics and nature of competition depend upon additional things rather than the type of port involved, for example, is it a gateway port, local port or transhipment port as well as the type of cargo handled for example containers, wet bulk or dry bulk. In the same concept, most researchers attempt to define competition as either a process or a state of affairs. When competition is demonstrated as a process, some researches express entrepreneurs as the key to success (Haezendonck & Notteboom, 2002).

Knight (1921) focused on the notion of risk. He asserted that risk-taking is the function of the entrepreneur success for their efforts. The common theme of this debate is that a competitive market system is one where entrepreneurs compete without obstruction with each other for success. The struggle characterizes market contestability in which strong competition is the theme of the market. Another definition of port competitiveness is the ability of the port to create added value, create core business and produce productive activity within its market. As such, the most competitive port will be able to establish a differentiated policy and gaining more customers than its competitors (Castillo-Manzano et al, 2009).

2.3.2. Port competition types

The factors influencing port competition may vary according to its level. The competitive strength of single undertakings inside a port is determined mostly by the aspects of production (labour, capital, technology, and energy). Rivalry among ports, port clusters and port ranges is mainly affected by regional factors, for instance the geographical location, the existing infrastructure, the industrial development, government policy and the port performance (measured in terms of proxy variables, such as the number and frequency of liner services, and transshipment cost, storage and hinterland transportation) which is with considerable importance in this research. (Meersman, H., et al., 2010)

Port competition can be categorized into three main categories that show the complete concept of seaport competition and explain the relationship between ports and port activities (Wang et al, 2005). Figure (2-6) presents the types of port competition categories that most ports are likely to face all or some of them in their business, which are inter-port competition, intra-port competition, and inter-port competition at port authority level. Inter-port competition can be defined as competition between different ports. The main factor that shows if ports are experiencing inter-port completion is the sharing of common hinterland or foreland. (Cullinane et al, 2005; Ng, 2006).

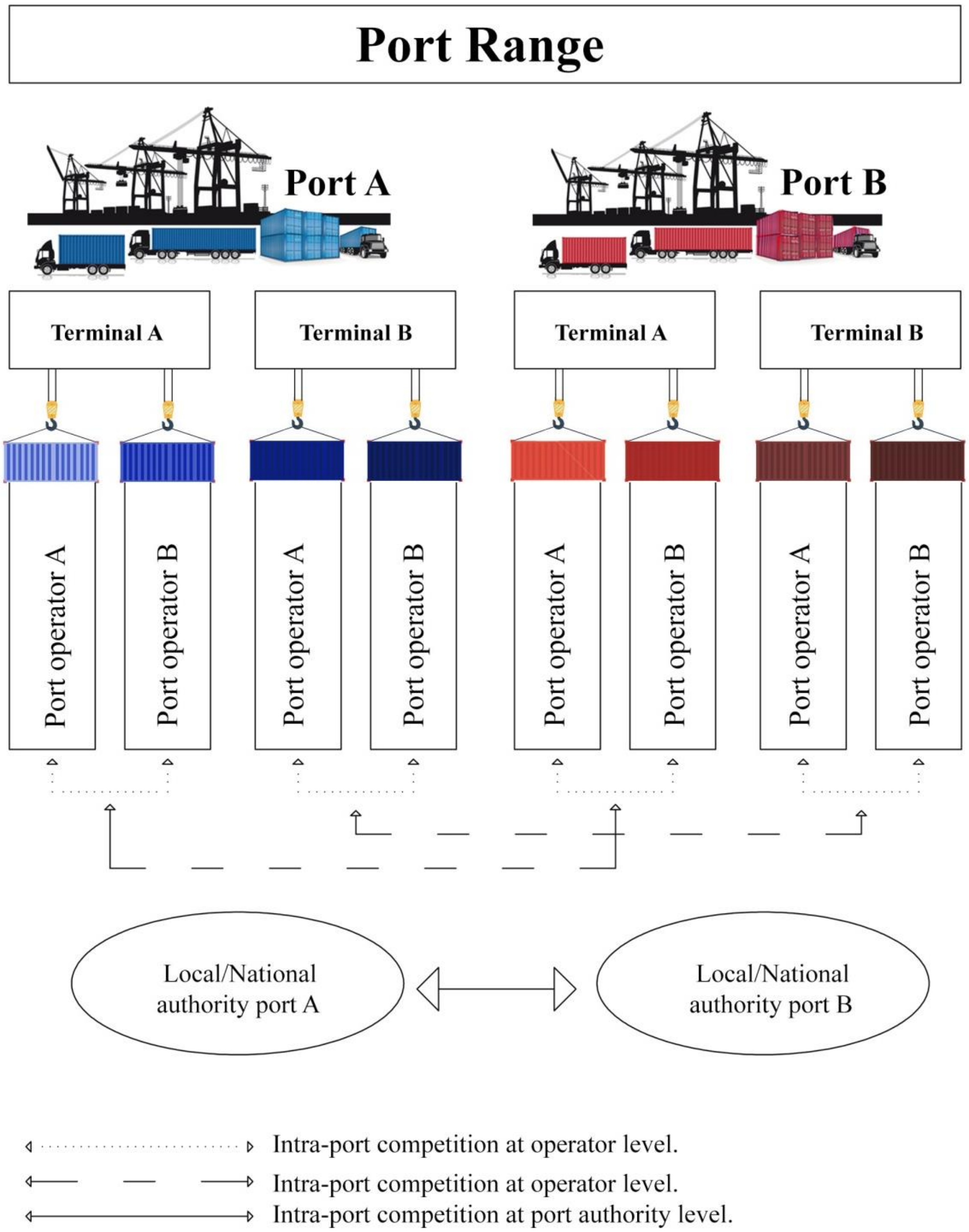

Figure 2-6 Types of port competition.

Source: Author: Adapted from: Meersman, H., Van de Voorde, E. & Vanelslander, T. (2010). "It's all about economics! Port competition revisited" in *Review of business and economics,* 55(2). 210-232

2.3.2.1. Inter-port competition

This can be classified into three subcategories. The first is competition between whole port range and coastlines; a concrete example is shown in competition between container ports on the East and West coast of North America as well as in Europe we can see the competition among ports in the Hamburg-Le Havre range. This competition has been greater than before by the expansion of both the multimodal and long-distance transport systems. The second type is the competition between ports in different countries such as the case of competition between Vancouver in Canada against Tacoma and Seattle in the United States; in Europe, we can witness the severe competition between Rotterdam in Netherlands and Antwerp in Belgium. The third type is in the national scale where competition takes place between different ports within the same country as ports are serving the same overlapped hinterlands, such as the competition between Los Angeles and Long Beach in California or between Qingdao and Dalian in Northern China. (Wang et al, 2005).

Inter-port competition may exert high risk on ports of losing traffic (Cullinane et al, 2005). Therefore, ports should keep their competitive edge especially with the increasing scale of container vessels as well as the high consolidation of shipping lines and their bargaining power. Ports should have the same pace as shipping line and invest in infra/superstructure to accommodate their mammoth container vessels. Moreover, ports should continuously improve their efficiency of cargo handling and maintain shorter ships turnaround time port, to avoid the risk of losing customers, as shipping lines are more flexible and mobile than ports so they can change destinations to other competitive ports. Shipping lines vertical integration policies also influences intra-port competition. For instance, the agreement between CMA CGM and PSA in Singapore to establish a new joint venture company to operate 4 berths in the port of Singapore to handle nearly 3 million TEUs annually, will defiantly affect port Kelang because 20% of the Malaysian Port Kelang's throughput is CMA CGM traffic. (Gavin M. 2016)

2.3.2.2. Intra-port competition

Intra-port competition is mainly linked to terminal operators, ownership and port administration. This type of competition can be performed by two types. The first is the competition between terminals operating in the same port, similar to the situation in the port of Antwerp between container terminals operators Hessenatie, Noord Natie and Katoenatie. Similarly, in Rotterdam port, we can find the rivalry between APM and ECT. However, intra-port competition at a micro level occurs when operators in the same terminal compete among each other. The level of competition determines the flexibility of terminal operators in the sense that the lower the level of intra port competition, the higher the flexibility of the port as far as pricing is concerned (Slack, 2007). Also, port authorities could be a competitor and indirectly compete within its port if a port authority has shares in port undertakings or terminal operators.

In this context, national port policies should always aim to enhance the performance and the efficiency of the whole port activities within the country. As clearly explained that intra-port competition occurs within a port, therefore, it is not directly affected by specific aspects of national policies and regulations. Nonetheless, port authorities must guarantee contestable within the internal port market. Meanwhile, Wang et al. (2005) argued that a port authority should play an active role in encouraging cooperative activities that optimize port economies of scale and scope.

2.3.2.3. Inter-port competition at port authority level

The inter-port competition at port authority level focuses on the utility mission of seaports. This type of competition exists between port authorities at a national, local, regional or international level. It can be clearly identified when the rival ports share the same market and handle the same cargo type. A clear example of that kind of competition is the competition between ports within the Hamburg-Le Havre range, container ports in the Mediterranean, Hong Kong and Singapore in the Far East and between New York and Halifax on the East coast of North America (World Bank, 2001). These ports, to a large extent, compete for containers and are investing to keep pace with the future demand and to increase their throughput and market share.

2.3.3. The Landscape of port competition

Before the existence of containerization, the inter-port competition was not significant, as most of the ports were known for being either monopolistic or oligopolistic for its traffic which was limited and concentrated upon the port's geographical area. Nevertheless, the development of containerization and multimodal transportation has considerably reformed this situation and made ports work on improving their attractiveness factors in terms of hinterland accessibility, productivity, quality of services, reputation and reliability. Recently, competition and competitiveness are crucial for any port or terminal operators as this will radiate in all operation, planning and development strategies.

Moreover, the landscape of ports competition is very important for decision makers. Figure (2-7) shows the five main forces that shape the completion in any port, which are:

1) The rivalry among existing competitors.

2) The threat of new competitors.

3) The potential for global substitutes.

4) The bargaining power of port users.

5) The bargaining power of port service

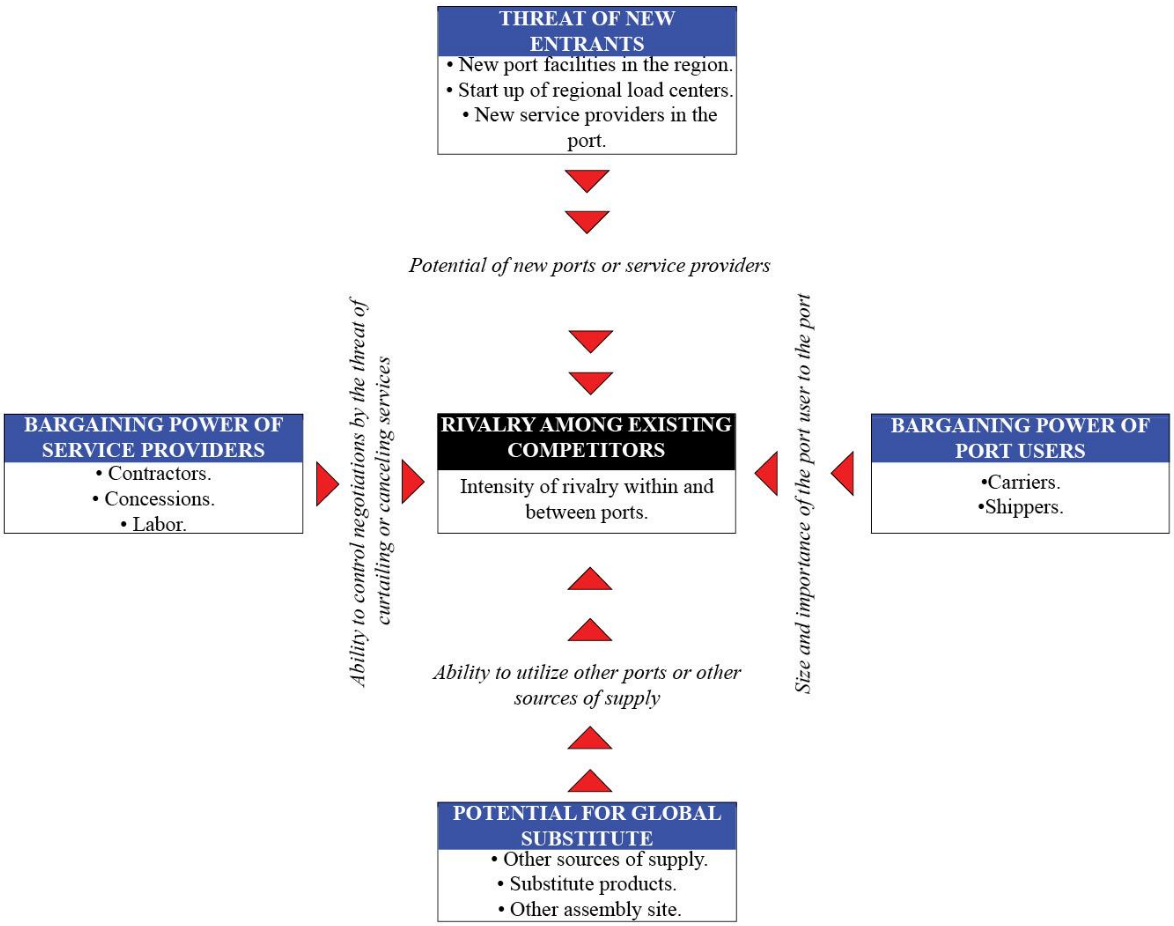

Figure 2-7 Ports competition landscape

Source: Author, Adopted from: World Bank (2007). Port reform toolkit, The Evolution of ports in a competitive world.

These forces will affect nearly all ports in all sizes and will have influence in the port investment plan, efficiency, pricing policy. Finally, ports profitability will mainly depend on how dealing with these forces and how decision makers tackle these challenges in the evolving port competitive landscape. Shipping market dynamics and how it affects the carriers bargaining power and exert pressure on ports competition is very important to be investigated before port managers take any strategic decision.

2.4. Impact of shipping dynamics on port competition

This severe changes happening in the shipping industry could strongly affect port competition as ports are a crucial part of this game. Carriers' policy to survive by cooling down the competition among them will exert pressure on many ports struggling to achieve their throughput targets. For instant, the Malaysian port "Port Kelang" will probably lose 10% of its annual throughput due to the new alliance formation as CMA CGM will shift destinations to Singapore (Mooney T., 2017). This was due to the operation of the jointly-owned Singapore container terminal between CMA-CGM and PSA International in the port of Singapore (Barnard B.,2017).

This change in market dynamics increases the market concentration and the shipping lines bargaining power as well, which will defiantly affect ports competition. Accordingly, for how long terminal operators who are not part of or operated by shipping line will sustain with the positive balance sheet, as the impact of shipping concentration will affect them sooner or later? Moreover, ports should take proactive measure by forming port alliances or cluster that would be the way to survive and sustain more bargaining power in this dynamic market. And here raises the question of is it the time to apply the co-opetition concept "cooperative competition" and imitate the carrier's new policy especially with the nature of ports in the sense of not being flexible and mobile as shipping lines.

Moreover, ports are very essential for every country supply chain in which policymakers and governments should be hand in hand with ports to overcome the domination of shipping lines which was previously explained that they were not only for financial reasons but some are for geopolitics objectives and try to make regional agreements that help and facilitate ports alliances not only to serve their ports existence but also to secure their countries national objectives.

On the other hand, Cooperation between container terminals and shipping alliances could increase the efficiency of terminal operations. Experts say "There is a need for more operational collaboration between terminals and shipping lines to help deal with issues such as peaking and productivity" (Davidson, 2015,). Moreover, some ports worldwide have started some sort of cooperation to face these market conditions, by combining certain resources and utilize them jointly in an effort to maintain a competitive edge.

This was firstly applied in 2001 between Copenhagen and Malmo port and was the first of a kind to have a cross border alliance between ports. On 2015, another national example of cooperation took place between Port of Seattle and Port of Tacoma in the USA, with a focus on upgrading its terminal facilities and rail connections to further its competitive position. (Mongelluzzo, B., 2015). Therefore, Co-petition concept must have a footprint on the ground as an easy fast effective solution that will perform a win-win strategy between all partier either governments and regional ports.

2.5. Port co-opetition and emerging strategies

Various approaches of ports collaboration have been more and more observed worldwide in the latest years, with these dramatic changes in the container market, (Notteboom et. al, 2009). The common threats and needs of competing ports are among the important reasons for their cooperation. Nearly the same threats are common between neighbouring ports within the same region, or when experiencing loss of mutual market share for the entrance of a shared rival. Almost, similar needs are also shared among ports, such as when fronting same necessities, internal and external, development of hinterland entree, public affairs and port environment issues.

This introduces the co-opetition concept which is simply the grouping of competition and co-operation. Or in other words, the cooperation for the favour of competition with others. Song (2003) mentioned that 'co-opetition' is a way of cooperating to compete and cooperation may escape from mutually negative rivalry among players. A strategic alliance be able to reinforce in cooperation allies against others even if it fades companion individually (Hamel et al.,1989). Moreover, a cooperative strategy is more preservative than a competitive one. when players work together with the Interfirm 'co-opetition' is extremely companionable, besides implementing jointly useful strategies with different purposes that can be reinforced.

This approach can be applied in the configuration of container ports of different sizes, technical features and regions. Besides, port co-opetition generates benefits that help in negotiating with governments, shipping alliances as well as mega-carriers (Song, 2003). Therefore, understanding the benefits and typology of ports cooperation is very important in understanding the importance of port co-opetition.

2.5.1.1. Benefits of port cooperation

There are many benefits and drivers of ports cooperation. Among the most important drivers of port, cooperation is to evade replication in facilities, however an additional broad planning procedure which vindicates the use of resources of the combined authorities. From the business prospective cooperation should be reflected on the company's balance sheet by one way or another. ports cooperation and benefits include and not limited to:

1) Efficiency improvements/cost reduction
- Avoidance of overcapacity;
- Reducing threats;
- Provides economies of scope and scale
- The decrease in business costs.

2) Improving capabilities
- Entree to each other's capabilities
- Encouraging the exchange of knowledge and experience.
- Technology transfer

3) Positioning of port
- Market arranging (i.e. accessibility to wider hinterland);
- Cut of (global) rivalry;
- Formation of a market standard;
- Countervailing power; and
- Combined political shield of benefits.

Furthermore, collaboration could be present and impact nearly all port activities in the operational, tactical or strategic level(KleinWoolthuis,1999). In the operational level, collaboration assists in daily operations as it helps in optimizing all human resource management. On the tactical level, cooperation could provide backing up for organizational policy, for instance in the joint research and development plans. In the strategic level cooperation support ports long-term competitive advantage as it provides common product and service development otherwise network management. Moreover, Cooperation is essential for both horizontal as well as vertical levels. The formal is about affairs with competing ports on the same level within the same supply chain, for instance by means of a trade association. Another form of horizontal collaboration is among companies in other production chains to mutually make a new product. While the vertical cooperation particularly develops arrangements with sub-contractors and customers for the aim of optimizing added value services in the entire production chain.

2.5.2. ***Cooperation among different seaport market parties***

Rivalry in and among parties in the seaports always trigger collaboration among seaport authorities. to attract more cargo to their ports and to develop national and regional economy. Port authorities always develop policies to offer cutting-edge attractive port with reliable hinterland transport services. The utmost significant progress that added to the increasing competitive forces is as follows:

- Collaboration among container shipping lines;
- Augmented transportation as well as transhipment efficiency
- Changed property organizations of stevedores.

Shipping lines are mainly the most important party for ports that create demand as well as they are having more bargaining power than ports in many cases. Accordingly, port authorities usually try to attract them and place them on the top of their priorities in port authorities' strategies. Liner shipping lines are considering to work in an oligopoly market and they are the one who chose the port and not vice versa. Therefore, port authorities should understand the carriers market behaviours and dynamics in order to make decisions that comply with their needs and to sustain demands for their ports. (El Kalla et al., 2017)

Hinterland transport system efficiency also influences ports to demand as more efficient the inland transportation system the larger the port hinterland (Song, 2003). Hinterland transportation efficiency also plays an important role in ports competition as the shipping lines with mega carriers always call ports with deep water channels that occupy the deep draft vessels. This results in a peek pressure on port terminals in which the alternative of shifting some of this cargo to another port with less congestion in its terminals will be feasible if efficient inland transportation is present.

Stevedoring companies are the backbone of ports operations, efficiency and throughput generation. Recently, the changes of stevedoring companies from the public sector to private sector as well as introduce more technological solutions and investments to cargo handling and operation, directly influences port authority decisions and planes. Moreover, stevedoring companies are strongly tied physically to ports in which they strongly exert pressure on port authorities in the selection and managing operation with shipping lines as well as forming agreements of cooperation or joint venture between them and shipping lines.

Table 2-3 Cooperation between and within port authority parties

Market Parties	Shipping Lines	Stevedoring companies	Hinterland Transportation	Port Authority
Shipping line	- Capacity sharing agreement - Joint ventures - Consortia - Alliances - Merger - accusations - Conferences			
Stevedoring companies	- Joint ventures - Exclusive terminals concessions - Capital participation - Consortia	- Mergers - Takeover - Join Venture		
Hinterland Transportation	- Capacity sharing agreement - Alliances	Join venture	Takeover of railway companies	
Port Authority	- Exclusive terminals Concessions	- Concession - Join venture	Participate in hinterland terminals	Alliances

Source: Voorde, E. Van De, 2006, Which way to the sea? Landlocked countries, sea transport and port competition. Presentaties Department of Transport and Regional Economics. The University of Antwerp.

As a reason for shipping lines and stevedoring behaviours and the efficiency change in hinterland transportation port authorities has changed their management and operational strategies. Many port authorities that formally was found and bounded to a specific geographical location are looking for cooperation with other competitive regional ports or overseas ones. Moreover, they seek for cooperation with parties within the port for the favour of performing stability and consistency in their activities. Table (2-3) shows this potential cooperation that could be performed within or between port authorities.

2.5.3. ***Typology of ports cooperation activities***

The type of cooperation activities depends on many factors including the objective of cooperation, the degree of autonomy and the degree of commitment they chose. The objective of cooperation must be carefully thought out, as the cost of various options and alternatives are not the same, as such they should be highly considered when assessing the need for cooperation. The degree of independence and concern of initiating collaboration will strongly determine cooperation, for instance, many public ports cannot cooperate with bodies except associations as well as approvals from ministries and governments need a very long time to be discussed and approved. These limitations in the business environment could slow or ban any cooperation plans.

Cooperation can be carried out in different forms based on their functional type. Accordingly, the merger of alliance formation can be selected. the merger is dissimilar than alliance, as the first give up their individuality as well as whole business entities into a new corporation pursuing a single, clear set of objectives. The second retains the companion companies autonomous in linking services in pursuit of mutual objectives. Furthermore, they realized from many cases of business alliances formed between contestants that there are three practical forms of alliance

1) Quasi-concentration alliances in which partners mutually change, produce and market a finishing product.
2) Shared-supply alliances take partners together to produce an agreed part, that is used for the partners' defined products rival straight in the market.
3) Complimentary alliance cohorts' joint forces of their dissimilar resources and skills to bring out a combined task

The degree of commitment is another feature of cooperation. Cooperation with parties can be considered as a future development plan that needs support and approval from all related stockholders and pass through many phases like preliminary study, feasibility evaluation, preparation of cooperation program, Project, budget and contract. Therefore, formalization of cooperation is a precondition for obtaining support from all parties including international and regional organizations, private investors and governments for public port authorities. (UNCTAD.1996)

Cooperation between ports could take many shapes between the formal and informal cooperation. The formal cooperation partners are bounded financially, commercially and legally while the informal cooperation is only limited to the exchange of ideas and exchange of information with occasionally working meetings.

Table 2-4 Typology of port cooperation activities

Activity	Formal	Informal
Advertising and Commercial Development	- Joint promotion activities - Founding a combined marketing activity	- Looking for shared clients - Interchange of specialists - Helping using each other's services and facilities
Operations	- Joint training agreements Joint use of different communications skills - Ports expansion strategies - Partnerships with other players - Combined increase in similar working practices	- Info. discussion on terminal management - Sharing of data on port growth - Exchange of specialists - Cooperative studies
Administrative	- Port representatives contributing in other ports - Shared investments in hinterland and infrastructures - Combined management of port development - Creation of (inter)national supportive organizations	- Technical support in port managing - Shared positions at international forums
Regulatory	- Joint environmental protection initiatives - Coordinated investment in safety and security	- Data sharing environmental plans

Source: Brooks M.R.,Mccalla, R., Pallis A.A. and Vanerlugt, L. (2010). Strategic Cooperation in peripheral Ports: The Case of Atlantic Canada's Ports,Canadian Journal of Transportation,4(1), 29-42

Table (2-4) shows the differentiation between the formal and informal cooperation as the formal agreements always applied when legal agreements or memorandum of understanding (MOU)is performed while the informal cooperation always happens as ad hoc as a response to a nominated task or as a trial phase before the formal agreements are done.

*2.5.4. **Practices of ports cooperation and challenges***

2.5.4.1. Performed ports cooperation

The concept of ports cooperation, and even managing ports by a unified or one board is not a new concept. Port of London Authority which was formed on 1909 managed ports for over 95 miles along Thames river. The same policy was adopted by the United States of America (USA) by the Virginia Port Authority, Massachusetts Port Authority as well as the Georgia Ports Authority to manage marine terminals and sometimes other logistical nodes. Nevertheless, the case of Port Authority of New York with New Jersey, as they were formed by two state authorities in 1921, which can be considered as a cross-jurisdiction alliance. Also in 2001, across border alliance was formed between two different countries, Sweden and Denmark, in the case of Copenhagen Malmö Port (CMP).

Moreover, the latest changes in market players' consolidation strategies through vertical and horizontal integration, triggers many ports to divert their policies toward cooperation. on 2015, Ports of Seattle and Tacoma, which are only 30 miles away, changes their strategies from competing against each other's to form the PNW seaport alliance. This bold step eliminated the competition between the two ports and shifted all their competitive strategies toward the Canadian ports to the North and California ports to the South. Moreover, after the Panama Canal expansion they are also competing with the American's East Coast ports which became more accessible to the Asian trade. The Ports of Seattle and Tacoma shows a good row model in forming an alliance between competitors that have been in fierce competition for the past several decades (Yoshitani,2018).

Furthermore, ports cooperation could be on a national scale, taking the Japanese example a clear case that could be a milestone for many cooperation strategies. Japan is a maritime company with nearly 950 ports serving the country. Since the presence of containerization in the late 60^{th} and its rapid growth, the national and local government could not afford to build all the required Japanese ports with the same pace as their neighbouring countries especially China and South Korea. This was because of the Japanese legislation that prevent the lease of public owned terminals to a private sector to form container dedicated terminals. (El Kalla et al., 2017)

Nevertheless, Japan adopts the system of tool-ports-system in which the government own the infrastructure and only the private sector invest in the superstructure. This made more pressure on the government to finance all the required ports development plans and conversion of traditional terminals to dedicated container terminals. In the 90^{th} the Japanese ports lost more and more competitive advantage among their traditional Asian competitors, as Japan failed to predict the future of containerization and build deep-sea container terminals to receive mega container vessels.

As a result, by 1995 there was not a single deep-sea terminal in Japan to receive mother containers at that time, leaving the field to South Korea and China who were more dynamic and proactive in developing their ports. By 2004 Japan adopted a new policy of cutting 30% of ports dues and consolidation of terminal operators to operate at least 3 terminals to get privilege from the economy of scale. But this was not enough to solve their ports throughput decline problem as the number of main lines services declined from 120 in 1998 to only 80 calls in 2008.

On 2010 the Japanese administration was forced to introduce the alternative port policy, named “Strategic International Container Ports (SICP)”. This is which they see that cooperation is the most strategic solution for their ports as they introduce a grouping of major ports, namely the Keihin Port in the Keihin Bay formed up by the ports of Keihin, Yokohama and Kawasaki, and the Hansen Port in Osaka Bay formed by Kobe and Osaka. In 2014, the ports of Kobe and Osaka together with national government recognized a port management company, the Kobe-Osaka International Port Corporation (KOIP). This was to unify their dedicated Container terminals businesses. This was recognized as the first of the container ports alliance in Japan. This alliance is only concerning by the container terminals business, while the remaining port's activities are running separately by the two port authorities (Satoshi ,2018)

The elaboration of the previously stated ports cooperation experiences especially the Japanese case highlights the importance of cooperation strategies as well as the applicability of such practice to reduce ports competition. But cooperation among ports is not always successful as we are experiencing various unsuccessful examples due to many reasons

2.5.4.2. Challenges of ports cooperation

Cooperation between ports is difficult and complicated to be implemented for the fact that ports are having a fixed geographical location and land resources. Moreover, political, social and economic factors are strongly affecting decision makers in negotiating ports cooperation policies. For instance, the lately Italian port authorities’ merger, Genoa-Savona and Naples-Salerno experienced difficulties in harmonizing actions concerning land use preparation and granting of concessions. As the use of land, development and explanation of present terminals needs usually turn out to be politicians in locally controlled ports.

Moreover, in China, there is a destructive competition among Dalian and Yingkou, although they belong to the same province in China, and they were in action for integration between each other.

But, both ports implemented individual strategies to strengthen their ports condition by joining in terminals inside their jurisdiction, emerging relationships with inland ports, encouraging port-related businesses besides working with shipping companies on funding infrastructure development. These individual policies increased the competition between both ports and made them reshape their agreements and proceed for the second round of negotiations for proper integration planes (Notteboom et.al,2018).

In the USA, on 2001 ports of Houston and Galveston failed to attempt to merge between each other. they explaining this failure for the reasons for the diversity of activities as Galveston was mainly a cruise port besides Houston, mainly a cargo port. Moreover, port of Los Angeles in addition to Long Beach port failed to establish good cooperation for the absence of transparency and lack of feasible economic studies that highlight the benefits of cooperation (Notteboom et.al,2018).

2.6. Conclusion

This chapter introduced a clear understanding of the main container market players' strategies. Carriers rivalry in the last decade generated the surplus in market carrying capacities with mega young vessels, together with fragile market condition with depressed recovering signs. This upsurges the desire for merger, acquisition and consolidation, by forming alliances to cool down the race besides backing up each other. This policy presents a double edge sort in the market as a whole, it protected the shipping lines and consolidated their efforts and resources as well as optimize their scale, but on the other hand, weakened the position of the port in reducing its bargaining power and fueled competition among them to sustain with positive balance sheets.

Moreover, with the presence of modernized supply chain, container port became no longer a simple crossing point between sea and land transport but is a connection of combined logistics systems. In other words, ports compete with neighbouring ports on the core of terminal operations and through ports end-to-end logistics system. Accordingly, to cope with these new changes, ports should gain more benefits by cooperatively improve hinterland entree and develop efficient jointly ports logistics hubs rather than doing that individually (Notteboom et.al,2001).

Furthermore, some ports worldwide started again to consolidate and reapply the old practice of cooperation to pool resources and forming clusters that satisfy customers and reduce costs. In addition, it improves the ease of use by unifying and simplifying procedures required for the use of any port. Moreover, it willpower the balanced of facilities and functions and may be a good tool to improve ports efficiency and competitive position.

The previously presented approach of ports cooperation was presented as a shelter from the wave of domination of shipping lines. Therefore, understanding how this cooperation will influence ports relative technical efficiency is very important to determining its impact on the port operation and competitiveness. Next chapter will review the previous researches that tackle ports efficiency. This will be important for this research as with the understanding of the previous scholar's results and approaches in measuring relative technical efficiency a better approach to this research objective will be achieved.

CHAPTER THREE

LITERATURE REVIEW ON PORT CO-OPETITION AND EFFICIENCY

3.1. Introduction

The complexity of the maritime sector and in particular the container ports exerts more pressure on decision-makers to implement competitive strategies. These strategic approaches are either competitive or cooperative with reveals in the national, regional or global scale. Correspondingly, merging both approaches could also be presented in which the co-opetition approach is performed. Policy achievement and success evaluation are also essential by efficiency measurement as it could indicate any deviation in the planned and implemented operation and development strategies.

The measurement of port or terminal efficiency is important for many reasons. Ports need to know how effectively they are operating. What resources they have to achieve their tasks. For instance, their human resources, equipment, land area… etc. Also, how does its performance is developing over time as well as to benchmark its performance with contestants? (Thomas & Monie, 2000).

The purpose of this chapter is twofold. First, it reviews some studies on ports competition and cooperation to expand the knowledge of co-opetition by finding numerous ways showing how collaboration and competition exist at the same time and to proposes factors that impact the co-opetition. Accordingly, this piece of research is expected to propose a clear understanding of co-opetition besides offer useful insights into understanding complexities in maritime industry relations. Moreover, review scholars research in measuring efficiency and to review and study the literature in port efficiency from numerous perspectives. In doing so, this chapter is organized into two main sections. The first section will review researches on the co-opetition concept. While the second section will research measuring efficiency. Finally, the gap analysis conclusion is provided in the last section.

3.2. Literature review on ports competition and co-opetition

This section will deliberate the notions of competition, cooperation and co-opetition. Secondly, present the literature review on port competition and co-opetition. Then, analyses the literature on port co-opetition.

Rivalry and collaboration are the two main examples of top management strategies. Competition infers a specific firm's search of its specific objectives by whipping other firms in the same market. Therefore, the competitive model highlights competitive benefits which allow a firm to appreciate above its usual revenues at the cost of rivals as its main success factor in the industry. On the other hand, cooperation infers the combined focus on common objectives through others and look for collaborative advantage as businesses can improve performance throughout cooperating with others. Both Competition and cooperation are always considered incompatible as well as they are treated independently in the zero-sum relations. Actually, both of them are not totally independent, as, in the era of globalization, businesses are involving in tandem in rivalry and collaboration (Kim, 2018).

Since 1990 when the book *Co-opetition* by Brandenburger and Nalebuff was issued, co-opetition concept highlights the cooperation between rivals. Nevertheless, co-opetition has varied practices as there are many practices on how cooperation and competition can concurrently exist within firms in the same industry. For instance, cooperation can indirectly happen between rivals competing in many markets. When there is an overlap market in which firms compete, they lean towards to be cooperative by slowing their competitive movements. Therefore, such actions in one market may promote cooperative actions among firms in other markets. Accordingly, rivalry can serve as a mechanism to improve cooperation. (Kim, 2018)

Although competition and collaboration can simultaneously occur, in some multipart business world things might become complex. Co-opetition concept remains to be fragmented and imperfect by seeing co-opetition as cooperation between competitors in a dyadic relationship among many companies. In this context, reviewing previous researches that studied competition, cooperation and co-opetition in the maritime industry are important for the objectives of this research.

One of the main reasons for ports development and investment decisions is to increase port attractiveness and competitiveness level. Various researches addressed ports competition that mainly concerns with port selection criteria and port attractiveness. Pearson (1980), Slack (1985) recommended different mechanisms of selecting ports in Europe, America and Asia. In the 90s, various researches show that the major factors for ports selection are the geographic position of ports, inland railway connectivity, investment in port facilities and the strength of port labour

(1990), UNCTAD (1992), McCalla (1994). Starr (1994) highlighted more aspects like safe handling of cargoes, port tariffs, the reliability of port schedules as well as port service.

Yuen et al. (2013) studied the effect of intra- and inter-port competition among the Chinese container terminal and regional countries ports by the use of ports efficiency. The operational efficiency of selected container terminals was measured by DEA panel data for 2003 to 2007. The study concluded that Chinese port-ownership may enhance container terminal efficiency. It also highlighted that that intra- and inter-port competition could help in developing the efficiency of the container terminal.

Moreover, customs service level, rapidity of handling processing, port documentation simplicity, skills of port labour as well as the percentage of cargo damage show more influencing factors in port competitiveness. Tae, *et al.* (2008) used 40 variables that can be used in measuring port competitiveness level in Korean and Chines ports. They concluded that the main factors that affected port competitiveness levels of container ports are the are service of port, hinterland accessibility, availability, convenience, regional centre and logistics cost. Moreover, they highlighted that ports competitive characteristics can be sorted in internal and external factors. Which are deeply influenced by port government's policies, operation strategies, port equipment, and the efficiency of a cargo ship to shore handling?

Few ports worldwide implemented a completely different concept rather than focusing on investment or improving the previously mentioned items. They focused on cooperation with neighbouring ports in order to increase their ports attractiveness, profitability and market share for the purpose of changing the win-lose situation among neighbouring ports to a win-win situation to face their potential competitors. This created a new concept revealing the scope of horizontal integration in the port market known as a co-opetition concept.

Noorda (1993) defines co-opetition as a mixture of competition and co-operation, thus having a strategic implication that those engaged in the same or similar markets should consider a win-win strategy, rather than a win-lose one. Moreover, Brandenburger, (1996) identify that *a win-lose approach ultimately becomes a lose-lose one.*

This was also highlighted by Beth (2000) that ports should focus on new approaches for cooperation to create a countervailing power. Therefore, Co-opetition' is cooperating to compete to prevent mutually destructive rivalry among the competitors. A strategic alliance could support cooperation partners against outsiders, even if it causes weakness to one partner against the other (Hamel, et al, 1989).

In Northern Europe, this pattern of co-opetition was highly obtained between the Danish port Copenhagen and the Swedish port Malmo in all management and operational aspects. Magnificently, this collaboration converted the drawbacks maintained from the bridge connecting both countries that negatively impacted their bilateral ferry activities to gains in the sense of using it to transfer operation equipment and goods between the two ports. Moreover, CMP (Copenhagen Malmo Ports) claimed that this cooperation helped them to improve their competitive advantages among competing ports.

Furthermore, Dong-Wook, (2003) proposed the ports co-opetition concept in South Asia among Hong Kong port in addition to South China ports. He concluded that some Port co-opetition, in theory, is strongly related to economic, social and global business strategies. Moreover, he claimed that there must be a sustainable balance between competition and co-operation, as this is necessary to overcome any legal obstacles like anti-competition regulations. He also stressed in the factors to be taken into consideration in performing the co-opetition concept. As some might go for more competitive measures to performing their coopetitive strategies, while others may go for excessive cooperative measures in initiating coopetitive tactics.

Furthermore, Yap and Notteboom (2009) examined the complementary issues in ports, as well as competitive factors in the relationships of the inter-container port. They used the annualized slot capacity (ASC) to determine the gains incurred or losses obtained due to container port competition or complementarily. The research evaluated ports in several regions, Inter-Port dynamics in the Malacca Strait, Pearl River Delta In East Asia as well as ports in Antwerp-Hamburg Range. They concluded that there will be always missing opportunities when container ports or shipping lines focus only on competition aspects and forget cooperation aspects

Dong G. et al. (2018) quantitatively studied the influence of regional port integration in the multiport region. the research used three layers non-cooperative game theoretical model in which every container port sets its throughput in the same timing of port integration, with the presence of different levels of regional port integration. They conclude that with a higher degree of regional port integration, lesser handling charge with more handled as well as the development of regional port integration will be promoted.

Yang Z.et al (2019) studied Port integration in a region with multiport gateways (R-MPG) in the case when the supply of ports is more than the demand of shipping lines. They analyzed the possible paths for overcapacity ports to change and promote their industry. Moreover, they studied the method for defining the optimal port clusters scale based on a continuous approximation approach. They concluded to the design of port integration scheme seeing the influences of port industry transformation and promotions.

Niavis and Tsekeris (2012) benchmarked and identified major factors of the technical efficiency that directly affect competition of container ports in South-Eastern European area, with the Italian ports included in the eastern Mediterranean Sea. The study used the CCR, BCC and super-efficiency DEA models. The results showed that the relatively low average aggregate technical efficiency of the selected ports can be related to ports' scale efficiency and the level of managerial skills.

To sum up, co-opetition concept with its advantages of providing win-win situation and maintaining economies of scale as well as improving the port bargaining power was not widely implemented among many ports. Moreover, the use of technical efficiency as a tool of applying co-opetition was not presented so far in any research making this research significant in presenting a new platform for co-opetition application in seaports.

Therefore, the next section reviewing previous studies that addressed ports efficiency as well as the models and techniques used. This is very important for the originality of this research, in the sense of providing previous researches scope and objectives and if any studied the effect of co-opetition on ports efficiency.

3.3. Port efficiency as a concept

The performance evaluation is very important for any industry or business, whether it is the assessing of accomplishments against established objectives or, against competitors. Ports are not an exempted to that, in which only by evaluating performance assessment will be achieved. Ports are, however, complex multifaceted business with different sources of entities including inputs and outputs. Ports efficiency is a tangible tool in assessing ports performance, especially the relative efficiency that takes many collective inputs and outputs factors in consideration to stand on ports efficiency position among its peers.

This section will firstly, deliberate the concepts, definitions, types and theories of port efficiency. Secondly, present the literature review on port efficiency. Then, analyses the literature on port efficiency measurement techniques in the third section. Then, indicates the variable specifications of the existing literature in the fourth section

3.3.1. Efficiency concept

In microeconomic philosophy, the definition of production function is the extreme output that can be performed from an identified inputs set, given the current obtained technology to an identified firm. This will answer the economic question of how to measure a firm's efficiency. This introduces the frontier production purposes that estimates the extreme maximum output as a function of inputs. That also presents the concept of efficiency which is, in a broad logic, used to illustrate the utilization of resources, (Finn et al.,1974).

Although efficiency is very close to Productivity and in many cases, they are used interchangeably, but efficiency and productivity are providing completely different concepts. Productivity is the ratio of output to input with the respect of one input and output. If we have multiple inputs and outputs, we will have an inconsistent situation. However, efficiency is considered as a comparative concept that results due to the comparison process or benchmarking process (Infante & Gutiérrez, 2013). As well as it was claimed by Rogers (1998), that productivity normally provides more precise meaning than efficiency.

Efficiency concept can be classified into two main types, allocative efficiency and technical efficiency, which is grouping presents a broad evaluation of economic efficiency. Also, economic efficiency can be defined as a firm's capability to make a pre-planned output quantity at the minimum cost for a given technology level (Farrell 1957). Technical efficiency and productivity are considered the first element of economic efficiency (Infante & Gutiérrez, 2013). Moreover, any unit can be considered technically efficient when input minimization or output maximization requires addition in at least one input or removal in at least one output (Koopmans,1951).

Commonly, the term efficiency refers to technical efficiency. Allocative efficiency happens when a company succeed to make the optimum input combination of production technology and prices. Therefore, the allocative inefficient companies fail to optimize technology and price, although it could be technically efficient (Coelli, et al. 1998).

Lansink et al. (2001) showed that technical efficiency could be able to be expressed as relative productivity over a given time and/or space. It could be categorized into intra and inter-firm approaches of efficiency. Intra-firm measures include measuring the potential production of a firm by calculating its level of productivity over time in relation to the productivity of the firm's highest historical level. In contrast, inter-firm measures of productivity assess a firm's given a performance with relative to its best correspondents within the business.

The technical efficiency concept is also linked with two main notions which are the production and/or cost frontier. The first presents the latest status of technology in an industry and it is associated with the set of extreme outputs given various inputs levels. Whereas the cost frontier infers the set of minimum inputs given dissimilar output levels. Technical efficiency can be eminent by way of output and input-oriented efficiency. The company could either increase outputs using the same amount of inputs or decrease the inputs using the same amount of outputs (Schøyen & Odeck, 2013).

The scale of the firm could also be assessed by the scale efficiency measurement. This is used to examine if the firm reaches its optimum scale efficiency. Scale efficiency results from equally rising the quantity of altogether measures affect the production function (De Borger et al.,2002). Scale efficiency can be explained as the difference between actual and best output, this could be applied when production technology gives a variable return to scale. Varian (1998) stated that there are three kinds of scale efficiency. First is the Constant Return to Scale (CRS) that means if the value of each component increases, production increases in the same percentage. Second is the Decreasing Return Scale (DRS) which means when the value of each element rises, production increases in a smaller percentage. The third is the Increasing Return to Scale (IRS) that means if the value of each element increases, production rises in a greater proportion (Infante & Gutiérrez, 2013).

Hernandez-Laos (1981) described that allocative efficiency as the distribution of resources. In other words, a certain number of resources is modified in order to increase the quantity of output, whether the analysis highlights the consumption or the production area. Yarad (1990) argued that allocative efficiency linked to the total investment in inputs needed to produce a minimum amount of products according to the price of that inputs.

Infante and Gutiérrez (2013) demonstrated the behavioural theory of allocative efficiency, in which they highlight the production costs in the case that prices information is available, for instance, cost minimization or profit maximization, that might be properly recognized and so appropriate assumption can be formulated. Allocative efficiency can be accomplished under three main conditions: Consumer Efficiency when consumers numbers fail to improve after re-evaluating their budgets. In other words, reach saturation in the number of consumers. Marginal cost equality such as the cost of producing an added product plus minimal social benefit and external costs. Economic Efficiency, which includes technical efficiency and the use of production factors in such proportions in which costs are reduced (Infante &Gutiérrez, 2013).

Gonzalez-Paramo (1995) declared that allocative efficiency happens when a firm minimizes costs or maximizes profits: when a company succeeded to reaches the production frontier with the selection of a set of influences that permits them to minimize costs at a certain level of production (Bosch et al, 1999). Therefore, clearly that allocative efficiency differs from technical as well as scale efficiencies as the former emphases on matters of costs or revenues, whereas the latter definitely deals with physical measures besides technical relationships (Infante & Gutiérrez, 2013). For example, allocative efficiency for input choices rises after the choice of inputs such as labour, materials and capital provides a certain amount of output at a minimum cost, given the current expenses of total inputs (Coelli et al., 1998).

3.3.2. Approaches to calculating efficiency

Efficiency determination with its broader meaning as the ratio between all outputs to all inputs passes through various development stages in term of techniques and calculations. It was primarily performed by understanding the average inputs production, then the efficiency index is constructed. Economists were not satisfied with this method as it suffers from weaknesses compared to others. This led researchers to develop a better efficiency measurement method which is the frontiers models that provide a lot of advantages over the non-frontier models. Mainly, the results estimated is strongly influenced by frontier achievement in doing the same task. In other words, taking the most efficient firm as a frontier for benchmarking others, will include all direct and indirect factors into consideration while estimating the firm’s efficiency. This made the frontier methodology more popular as it implicitly includes cost, profit and production functions in estimates. (Liu Q., 2010)

Generally, there are two common methods based on the efficient frontier. The first is the parametric methods, alike Stochastic Frontier Analysis (SFA), Thick Frontier Approach (TFA) as well as Distribution-Free Approach (DFA). The econometric theory is used to model inefficiency as an additional stochastic term in which pre-specified functional form is used to estimates. While the second method that includes the Free Disposal Hull (FDH) or Data Envelopment Analysis (DEA) is the non-parametric methods. These methods created from operations studies as well as it uses linear programming for the purpose of calculating an efficient deterministic frontier against compared units. In this sub-section, that follow, we review the Stochastic Frontier Analysis (SFA) and the Data envelop analyses (DFA) in the classified frontier parametric and non-parametric methods respectively. As these two methods are broadly used in studies on ports efficiency measurements.

3.3.2.1. Stochastic Frontier Analysis (SFA)

The parametric method includes a measurement of a functional form for the production technology as well as supposition about error terms distribution. the parametric approach is having the main importance compared with the non-parametric method for its ability to present the frontier technology in an easier mathematical form. Nevertheless, the parametric approach may enforce an unnecessary structure on the frontier, and it always enforces a constraint on the observations number that could show technically efficient (Liu Q., 2010).

Stochastic frontier analysis (SFA) can be considered as an improved parametric and stochastic approach for efficiency estimate, over deterministic frontiers as well as average functions. In the deterministic frontiers, all differences in the performance of a firm are individually credited to differences in efficiencies of the firm in relative to the frontiers, in whatever it is cost, profit or production frontiers. Therefore, the idea of a deterministic frontier in which many firms ignores is the real practical influence of external factors in firm’s performance these uncontrolled factors are for instance bad weather conditions, input resource failures …. etc. (Liu Q., 2010).

3.3.2.2. Data envelop analyses (DEA)

For the non-parametric approaches, they neither identify a functional technique of production nor creates an assumption around error terms distribution. Simply, it is forceful with respect to the norm of distribution as well as the specific functional form. The non-parametric analysis does not need any particular functional form condition to define the surface of envelopment or efficient frontier. (Charnes et al.,1978).

One of the main non-parametric approaches is the Data Envelop Analysis (DEA) that was developed by Charnes et al. in 1978. DEA is a defined nonparametric technique to determine the Decision Making Unit (DMU) efficiency with many inputs and outputs (Cullinane K. et al., 2006). This technique obtains the frontier from observed production potentials envelopes. Accordingly, efficient firms are the best among a group in spending a certain quantity of inputs to produce a certain quantity of outputs. This approach computes the efficiency frontier as a piecewise-linear curved hull in the input coefficient area to many outputs. (Charnes et al. 1978).

DEA analysis purpose is not limited to define the calculation of unit's efficiency, but also to present inputs and outputs improvement values for incompetent units. After identifying and improving these values, an inefficient unit or firm will be an efficient one. The main drawback of the DEA method is that it does not take into account the effect of measurement error in addition to data noise. It has been contended that it gives biases in estimates when statistical noise and other measurement error exists. But, it is important in eliminating the need to make arbitrary assumptions for the frontier's functional practice and error term distribution assumption. (Liu Q., 2010).

3.3.2.3. The differences between SFA and DEA

Figure (3-1) shows the difference between the presented efficiency approaches estimates. It is clear that methods in assessing efficiency deliberated for gross measures of productivity for DEA and the SFA. The DEA makes virtual estimates to help in benchmarking for the purpose of assessing DMUs or units comparative efficiency includes noise in the efficiency score. The SFA approach is an assumed function to compute efficiencies estimates of separate units or DMUs. To sum up, SFA regression approaches disclose total sample-based data while DEA discloses unit-specific returns to scale data form (Cordeiro et al.., 2008).

Next section appraisal and analyses the literature in port efficiency from different perspectives. The analysis reveals the development of research in port efficiency over time in terms of research scope, objective, methodology and factors used to measure and benchmarking port efficiency

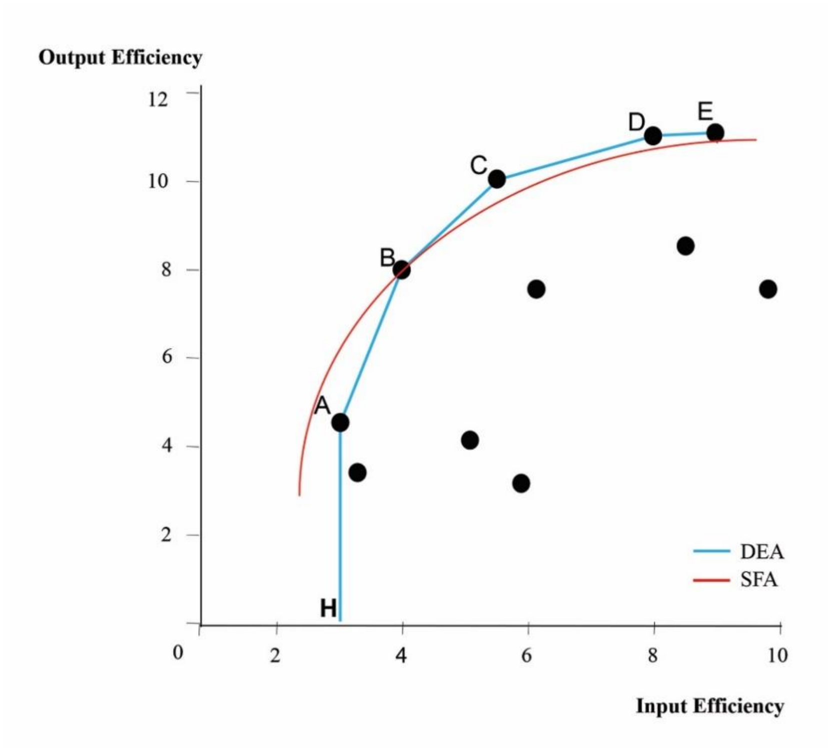

Figure 3-1 Comparison between DEA and SFA and to OLS Regression

Source: Author adopted from: Cordeiro J., Vazquez D., & Dijkshoorn J., (2008) A Stochastic Frontier Analysis of Estimates and Correlates of the Efficiency of Solid Waste Management in Welsh SMEs, GIN conference 2008, Leeuwarden, Netherlands. retrieved from the world web 0n 29 December 2018 from: https://gin.confex.com/gin/responses/2008N/207.ppt

3.4. Literature review on ports Efficiency Measurement using DEA models

Port development decisions are being taken according to a strong analysis for the port existing situation internally and externally by obtaining SWOT (strength, weakness, opportunities and threats) analyses, to find out significant strengths, weaknesses, opportunities and threat. Evaluating efficiency enables the adoption of appropriate response measures (Liu, 2008). Therefore, benchmarking efficiency measurement can be a powerful tool (Park & De, 2004). Efficiency is a comparative theory that needs a clearly defined benchmark to enable ports comparison with each other's as well as with their own performance during a given period (Liu, Q., 2010)

A number of studies in the maritime sectors have applied the frontier models to benchmark efficiency in the maritime ports sector. Recently, researches examining ports efficiency has been vastly developed. This is due to the importance of measuring ports efficiency in respect to determining ports competency as well as due to the technological operational development and innovations achievements. Nevertheless, ports production and efficiency were promoted due to the transformation in ports organization and structure as a result of modification in ports operation nature (Gonzalez and Trujillo,2009).

Beatriz L., et al (2019) study the efficiency besides productivity of 20 Brazilian container terminals for the period from 2008 to 2017, by using Stochastic frontier analysis (STA) approach. This research studied both concepts. They stated that efficiency and productivity in a corresponding way come close to the businesses efficiency measurement, by partial productivity indicators, that are the ratio between a nominated product and a factor. In the calculation of productivity, two important applications were derived. The first one contains gaining its temporal evolution as well as the second one was in fragmenting the productivity growth into its main causal factors, wherever efficiency change plays an important part. As from different perspectives, production efficiency relies on comparing the company's actual performance toward its optimal performance. This optimizes ports' targets that could be reached based on accurate reasons on optimal results obtained from other ports.

Researches objectives and scope has evolved over time. It has studied the purposes of efficiency, benchmarking ports relative efficiency and examines the impact of ports ownership and administrative structure on ports efficiency. The methods of assessing ports efficiency were commonly made by either the Stochastic Frontier Analysis (SFA) or the Data Envelopment Analysis (DEA). The methodology obtained relays on the objective and hypotheses in which each study considers.

In this context, Cullinane et al. (2005) examined the technical efficiency development of the world's main container ports by using panel data with DEA approaches to benchmark ports efficiency. As a result, the efficiency development of each container port in the study possibly will be traced over time. Wanke et al. (2011) used DEA and SFA, on data collected from 25 Brazilian ports in 2008. The results presented that most of the Brazilian ports have lacked in capacity due to the augmented export that has taken place over the last few years and the lack of investment in capacity development.

Bichou (2013) applied a succession of DEA models to assess the operational efficiency of 420 international container terminals from 2004 to 2010. The study formulated some operational suggestions to test ports benchmarking results sensitivity such as production scale, transhipment ratio, cargo mix, operating configurations, as well as working procedures. The outcomes revealed that differences in operating conditions considerably affect terminal efficiency. Lu et al. (2015) benchmarked the 20 top world container ports technical efficiency for the year 2009, by the aid of the DEA models. They concluded that container ports under study show substantial excess in the procedures of production.

The efficiency of the port market has extraordinarily developed over time due to technological changes and innovation developments in the maritime and port businesses. various researchers have tried to study the relation between the size of ports and their efficiency (Sohn & Jung, 2009; Cullinane et al, 2002; Notteboom et al, 2000; Martinez-Budria et al, 1999 and Liu, 1995). Generally, they concluded that ports efficiency is highly related to their size as a result of the activity level of ports.

In this context, Martinez-Budria et al. (1999) sorted the ports authorities of Spain into three groups (large, medium, and small) by applying standards of complexity that take into account port size and constitution of the output vector. They examined the port efficiency by means of the DEA model. They determined that the more efficient ports are the larger ones while medium-size ports are the least efficient. Wang and Cullinane (2006) used the DEA models to measure the efficiency of 104 European terminals, with a throughput greater than 10,000 TEU in 2003. The study revealed that most of the big scale container ports are showing a high score of efficiency.

Moreover, Sohn and Jung (2009) witnessed that great Asian ports with bigger transhipment market share are more efficient than the minor ports in the same market. Opposing to that, Al-Eraqi et al. (2010) used the DEA analysis model for benchmarking seaports efficiency of 22 ports of the Middle East and East Africa. They concluded that minor ports are more efficient than big ones but they highlighted that this market experienced instability due to the unsteadiness in the region, consequently, ports throughputs was highly affected.

On the other hand, Coto-Millan et al. (2000) evaluated the of the port authorities efficiency and tried to find out whether the type of organization and port size can justify the variances observed in the economic efficiency measures. They found that the large ports in their study are the least efficient than the small ports. Nevertheless, after studying various elements that could affect the degree of economic efficiency, they declared that port size is not the major factor in evaluating economic efficiency.

Notteboom et al. (2000) took the approach to compare the technical efficiency of the main container terminals in European with the largest four Asian container terminals. They studied the impact of several components that can affect the operational efficiency including terminal size, main services (hub or spoke), ownership structure (private or public) and geographical location (Northern Europe, Southern Europe). They concluded that small terminals within a port are more efficient because of the tough intra-competition between them. Moreover, they also highlighted that hub ports are more efficient than feeder ones due to inter-port competition between hub ports.

Furthermore, Gonzalez & Trujillo (2009). Concluded that big Ports are intensely investing a lot to develop their infra/superstructure to reach their estimated growth of future demand which might lead to excess capacity at the time of making such investment. Therefore, satisfactory levels of scale efficiency can difficulty be achieved. Moreover, whereas several large ports reach their maximum substantial limit of growth, and more increase in their efficiency cannot be achieved, smaller ports could find opportunities and take the lead for more growth and reach optimum scales. Accordingly, they highlighted that All these factors make it problematic to find a rational relation between efficiency and port size.

The influence of organizational structures, ownership and management systems on port efficiency had gradually become an interesting topic for transport researchers. Valentine and Gray (2001) measured the efficiency of 31 container ports among the top 100 container ports in the world in 1998 by using the DEA models. This was to analyze the relationship between port efficiency and specific types of ownership as well as organizational structures. The study concluded that ports organization and ownership directly affect efficiency and could lead to higher efficiency. Cullinane et al. (2002) focused on the ownership structure besides the conversion from public to private sector. He concluded that the level of deregulation has a positive impact on port efficiency and that privatization of ports in the main container terminals in Asia positively impacted their economic efficiency of terminals. They also indicated that terminal size and efficiency are directly related.

Cullinane and Song (2003) also determined that the greater the level of private sector participation in the port operation and management, the higher the level of efficiency. Nevertheless, they noticed that according to competition in the market of South Korea terminal efficiency was enhanced and promoted. Cullinane et al. (2006) used the two methods of DEA and stochastic production frontiers on the top world container ports to analyze the influence of privatization on port efficiency. The study concludes that the most efficient ports are those with a high percentage of private participation this was asserted from the port of Singapore.

Gonzalez & Trujillo (2009) Concluded that there is no consensus on whether there is a correlation between port ownership and efficiency, but container port/terminals efficiency has enhanced with the increasing trend towards privatization. Wanke (2013) also studied the efficiency of 27 Brazilian ports in 2011 by using two-steps of analysis. The first step was the infrastructure efficiency followed by the shipment consolidation efficiency. They concluded that the private sector management policy provides higher physical infrastructure efficiency levels.

Lu, B., et al. (2015). applied three types of DEA models, to study operational efficiency of the worlds' top container ports. The aim was to provide port decision makers with understandings into the allocation of resources as well as to optimize their operating performance. This research finds out the reason for inefficiency, identified the deficiencies in inputs and potential improvement areas by using the slack variable technique. Moreover, the return to scale method was used to measure whether a port is in a state of decreasing, constant, or increase return to scale. Then, at last, the sensitivity analysis was applied to identify which output variables or input ones are more important to the model and has an influence on the study results.

Suárez-Alemán et al (2016), studied performance analysis of container ports in the developing countries for the period between 2000 to 2010, using both nonparametric and parametric methods for 70 countries including 203 ports. They concluded that the productivity growth rates in the study period vary considerably as well as that this heterogeneity is described by pure changes in efficiency rather than scale efficiency resulting from technological change. Moreover, they carry out a comprehensive analysis of efficiency to conclude the reasons for port’s efficiency. Also, they found that ports that belong to the developing regions are having a rising trend in their efficiency, as it improved by 10% from 2000 to 2010 showing 51 % and 61 % respectively

Kutin N., et al. (2017) measured 50 container ports and terminals relative efficiency ports in the ASEAN region. These ports are classified upon their location as well as ports equipment system. DEA models were used with output-oriented, and of super-efficiency was performed to distinguish the efficiency of frontiers. The main objective was to help port decision makers in the ASEAN region to make choices to increase container traffic, developing operations and to improve the trans-ASEAN transport network

Merkel and Holmgren (2017), made uses of 52 types of research and collected estimates of a compounded dataset of port efficiency. Then retreats these estimates on the characteristics of the port's country. They concluded that there is no care made for ports from their users' side and this has a critical implication on efficiency estimates. At the level of countries, they find a non-positive relationship between GDP per capita and port efficiency estimated as well as the negative relationship among intra-port rivalry and estimated efficiency. The research deliberates the explanation of such results in the partial production functions context, in addition, it concludes that a great share of the applied approaches does not capture substitution concerning user inputs and producer.

3.4.1. Literature review on port efficiency DEA valuation techniques

Researches on port efficiency can be categorized into three main groups. The first group that use particular productivity indicators of ports systems. The second group uses simulations and queuing theory. The third group, which is the most recent, uses frontier estimates that derive ports efficiency indicators. (De Neufville and Tsunokawa, 1981; Sachish, 1996). Chang (1978) took the first step to study efficiency in the ports sector to measure production functions. Irrespective to the approach used he focused on developing instruments to help in the ports decision-making process from the perspective of management and economic policy (Gonzalez & Trujillo, 2009).

Different methods and practices have been used to measure and assess the numerous types of port efficiency, the performance of ports was vastly measured by assessing berth cargo-handling productivity (Ashar 1997, Tabernacle 1995, Bendall et al. 1987). by assessing single productivity factor (De Monie, 1987) or by benchmarking actual productivity with optimal throughput in a particular period of time (Talley, 1998). Lately, an important development was made in measuring the efficiency of productive activities. Two complex holistic models have been extensively used to perform port efficiency measurements. These models are data envelopment analysis (DEA) besides the stochastic frontier analysis (SFA).

Farrell (1957) was the first to use the DEA concept. This was mainly limited to the performance assessment of companies with many inputs and a single output. Then this model was developed to incorporated multiple inputs and multiple outputs by Charnes, Cooper & Rhodes in 1978. This is a non-parametric method that uses DEA models in performance measurement which applies the "Pareto optimization" concept for efficiency measurement. It enables to find out the inefficient DMUs and the efficient ones as well as how to improve the inefficient DMUs (Lin & Tseng, 2007).

Research developments in the field of DEA since Charnes et al. paper was issued in 1978 was remarkably observed. Emrouznejad et al, (2015) noted that the published researches of DEA were nearly 7000 articles in 2008 with an increasing pace. For instance, (sicencedirect.com) database presents that researchers who published in the field of DEA are nearly 1600 researches from 2013 till 2015. Between this enormous literature of theoretical articles as well as experimental studies, there is a subsection of research work that only focused on ranking techniques in DEA models. This subdivision of studies has become an important section of any efficiency valuation process that uses DEA. The core of ranking methods in DEA as well as decision science has risen from the poor ability of the classical DEA model to differentiate between strong DMUs and others. In most of the time, researchers in addition to decision makers need full valuation rather than categorizing DMUs in either efficient or inefficient. (Aldamak et al.,2017)

DEA technic having two main models to assess efficiency. The first model is the CCR model which was established by Charnes, Cooper and Rhodes in 1978, to assess the collective technical efficiency under the condition of constant return to scale (CRS). The second common model is the BCC model to compute the pure technical efficiency (PTE) under the condition of variable return to scale (VRS), which was developed by Banker, Charnes and Cooper (1984)

The DEA-CCR model was used by various scholars in studying ports efficiency. These model results were criticized by Bonilla et al. (2002) who said that this model present scores which are deterministic due to lacks in the statistical base. Similarly, the study of Bonilla et al. (2002) is an original contribution, as the use of bootstrap techniques allows statistical implication to be made in the non-parametric estimates, reaching confidence intervals of the efficiency scores. Sharma and Yu (2009, 2010) and Gao et al. (2010) used the DEA-CCR output-oriented model to compare container ports operational efficiency, with an objective of overall efficiency assessment and pointed out the reasons of inefficiencies.

Yip et al. (2010) used the Ordinary Least Square (OLS) model in addition to the DEA-CCR model. The importance of that research arises from the use of the DEA and regression applications. This approach was explained in Arnold et al. (1996) as it needs to take two-stage procedure. Stage one uses DEA to find out the efficient and inefficient DMUs while Stage two is to integrate these results in a dummy variable forms in the equivalent regression.

Various scholars worked on comparing the results of both DEA models. They compared the aggregate technical efficiency (BCC- CRS) against pure technical efficiency, (CCR- VRS) with various research scopes and objectives. for instance: Martinez-Budria et al. (1999) Barros and Athannasiou (2004),Park and De (2004), Cullinane et al. (2004, 2005a, and 2006), Wang and Cullinane (2006), Liu (2008), Koster et al. (2009), Wu and Goh (2010), Jiang et al. (2012), Ju and Liu (2015), Elsayeh (2015) Holdena et al..,(2016), and Aldamak et al.,(2017)

Furthermore, Researchers have more developed port efficiency benchmarking methods by associating the outcomes obtained by the DEA and other calculation technique. Cullinane et al. (2005a, 2005b), Wang et al., 2003) likened the outcomes achieved by the DEA-CCR and the BCC models with those gotten by the Free Disposal Hull (FDH), which is considered more traditional calculating tool than DEA. The FDH model assumes robust input and output disposability. Which means any given output(s) maintain possible if some or any of the inputs is augmented, likewise, with assumed inputs it is always feasible to decrease output(s). Both analyses declared that FDH model was an insufficient method due to the nature of its basic logic and step function solution algorithm. Definitely, the FDH model shows that DMU was efficient though it was truly not. (Elsayeh,2015)

The above-stated studies were limited to the study of only the cross-sectional data. The role of time was ignored as DEA implies the benchmarking of one DMU with the rest of all other DMUs at the same time. But, this can be rather confusing since dynamic settings might highlight the unwanted resources use which is presented to produce useful outcomes in future times (Cullinane & Wang, 2010). To overcome the misleading and limited analyses of the DEA when using cross-section data. Alonso and Bofarull (2007), Cullinane and Wang (2007 and 2010) used the DEA-CCR/BCC output-oriented model to panel data as well as window analysis to benchmark the relative technical efficiency of container ports as well as additive models to panel data to evaluate container ports scale efficiency.

Moreover, previous research reveals one vital characteristic. That is the ports, are identically treated. This is the so-called similarity, which is the main principle for DEA based efficiency valuation models. However, in port efficiency measurement, diversity of ports usually occurs due to uncontrollable elements alike geographical location. Container ports in Europe for example could be totally different from those in Asia, although they all run a similar business with the equivalent sets of inputs and outputs (Wu et al, 2009). Their efficiency should not be equally assessed as the two regions represent totally different economic markets. Thus, it is vital to further analyses the impact of the particular group of elements on the port efficiency.

Barros and Managi (2008) analyzed efficiency drivers of a sample represents 39 Japanese seaports from the year 2003 till 2005 by applying the two-stage method established by Simar and Wilson (2007). In the first stage, the technical efficiency of ports is assessed by means of DEA models the CCR, BCC and scale efficiency models. In the second stage, their technique is applied to bootstrap the DEA assessments with a truncated bootstrapped regression to decide efficiency drivers. The implementation of this approach enhanced both the efficiency of estimation and implication. Thus, benchmarks can be made for improving the performance of inefficient ports. Consequently, Al-Eraqi et al. (2010) extended their approach and used same models with input-oriented model as well as window analysis to measure the super-efficiency scores of 22 seaports in East Africa and the Middle East from the year 2000 to 2005.

Yuen et al. (2013) also used the same efficiency models to calculate the efficiency development of 21 Chinese container terminals from 2003 to2007. Regression models were applied to learning the factors that affect container terminal efficiency and improvement estimates. Both the bootstrapping with Tobit model in addition to a regression model as explained by Simar et al. (2007) were applied. The results revealed that there is a remarkable difference between the efficiency assessments achieved from both models, which proves that procedures of bootstrapping are vital to attaining reliable efficiency scores in regression models. Similarly, Bichou (2013) examined the relationship between port efficiency and the operating situations of container ports. the efficiency of 420 container terminal for the panel data from 2004 to 2010 by using DEA-CCR/BCC models The study explained that a large number of terminals show increasing return to scale (IRS) as well as that the bigger ports show increasing return to scale (DRS).

Tovar and Wall (2015) studied the efficient for 20 port authorities in Spain from the year 1993 to 2012 by applying a directional technology distance function to examine the technical efficiency production technology. The study shows the flexibility and strength of the directional distance technique for the scope of this research. Moreover, when measuring port technical inefficiency in addition to production technology, the traditional Shephard input-oriented and output-oriented shows more rigidity than the distance functions.

Throughout the previously mentioned efficiency measurement methods, the collection of data is essential. These data differ from research to another based on the scope and objective of this research. Therefore, the description of variables is essential as well as the used of inputs and outputs in efficiency measurement technique. This will be widely explained in the coming subsection.

3.5. Variables used in the efficiency measurement literature

When port efficiency measurement is assessed, study ports resources and activities should be careful considered. Nevertheless, the availability of data besides its quality, strongly determine variables to be incorporated in the empirical efficiency analysis studies. Also, the milestone for any efficiency measurement depends mainly on the DMUs as well as its inputs and outputs.

Wang and Cullinane (2006) stated that when efficiency measurement is performed, the DMUs should be carefully selected as they must be homogenous with respect to production functions. For instance, the relative efficiency between the container terminal and the dry bulk terminal will be illogic. Similarly, most of the literature seems to highlight production at the terminal level. This corresponds to Alderton (1999) argument that *"there is little that can be measured on a whole port basis. Most comparable data must concentrate on a terminal basis".*

Inputs and outputs selection incurs a significant role in any research reliability and applicability. For instance, the definition of port outputs depends on port activities, and as such, it can include the port the volume of transhipment traffic, a number of vehicles or cargo throughput (Cullinane & Wang, 2007; Lu et al, 2015). Similarly, the input variables that strongly reflect the scope of research which is categorized into two broad types which are the technical and the allocative efficiency categories. The former constitutes inputs related to ports' operation factors from infra and superstructure, as land, equipment and labour. The latter presents the ports financial and economic measures such as capital, labour and operation costs as well as investment (Gonzalez & Trujillo, 2009).

The output and input variables should accurately reveal actual purposes as well as the production practice of container port. for instance, some ports objective is to increase throughput, so it's more likely to utilize expensive equipment to increase its productivity. On the contrary, other ports aim to maximize profit, thus they may use cheaper equipment to have a better positive balance sheet.

Accordingly, the objectives of ports are of vital significance to the selection of variables used for measuring efficiency. for example, if the port objective is to make the most of its profits, then information on labour and employment would be considered as an input variable. Nevertheless, if the port objective is to contribute in increasing the national employment rate as part of the national or regional plan then labour data should be used as one of the output variable (Cullinane et al., 2004).

Port objectives are commonly expected to maximize its output(s) and minimize its input (s). Since, it is really difficult to obtained confidential data which is habitually varying between corporate units, countries, etc., the corresponding costs of outputs or inputs are not counted in the empirical analysis. Therefore, this presumed objective might not be completely reliable with that of income maximization. Nonetheless, this supposed objective is defensible not only by its logical tractability but among other things, the facts that modern container ports depend heavily on information technology and state-of-the-art sophisticated equipment rather than being labour-intensive. In doing the empirical analysis to define in what way the assumed objective has to be reached, the level of utilization of high-tech resources, as well as the managerial general quality, can be concluded. This has an understandable inference and probably a high correlation with, the accomplishment of additional conventional business aims like that for profit maximization (Cullinane et al, 2006).

Moreover, in the light of the vigorous intensive competition among container ports, to attain this goal of profit maximization is commonly more vital than any other goals. Container ports contest on mutually their direct costs, in which they could pass to customers, as well as their indirect costs associated with the level of productivity. Given a standard cost per unit, price attractiveness is challenged by the failure to reduce its inputs use. Likewise, a failure to make the most of outputs for a certain level of input will, regardless of prices charged, weaken the ability of the port to attain productivity maximization through economy of scale as well as through the failure to collect reserved profits for further developments (Cullinane et al, 2006).

Furthermore, this objective similarly follows the results of the utmost studies in the field of container ports efficiency. The production of container port depends significantly on the effectual use of land, equipment besides human resources. Thus, terminal area, quay length, quayside gantry cranes total numbers, yard equipment number are the most appropriate fundamentals to be combined as input variables into DEA efficiency models. As a reason of unreliability or unavailability of direct data on human resources (HR) inputs obtained from a pre-determined as well as the highly correlated relationship to ports or terminal facilities. It is important to be cautious that any pre-determined relationship is not commonly valid to all study ports or terminals type with dissimilar production characteristics. It is also uncertain to relate this relationship to dissimilar ports in terms of production scales as the probability of usage of different cargo handling equipment which is operated with different labour employment configurations is highly present (Cullinane et al, 2006).

On the other flip of the coin, for the outputs, container throughput is indisputably the utmost important and extensively known indicator for ports or terminals. Nearly all preceding researches used throughput as an output variable, since it is related to the necessity for cargo related services in addition to it is the main basis for container ports comparison, particularly in evaluating their investment scale, relative size, or activity ranks. Additional deliberation is that it is the most applicable and logically controllable indicator of port effectiveness production (Cullinane et al, 2006)

Table 3-1 Multiple outputs used to measure technical efficiency.

Researcher	Outputs used
Barros (2005)	cargo tons, ship-calls number
Rodriguez-Alvarez et al. (2007)	TEUs , General cargo tons
Trujillo and Tovar (2007)	TEUs, No. of passengers
Gonzalez and Trujillo (2008)	TEUs, No. of passengers, liquid bulk tons
Chang and Tovar (2014)	TEUs, (General cargo, Ro-Ro, Dry Bulk tons)
Tovar et al. (2015)	General cargo, Liquid, Dry Bulk in tons & No. of passengers
Tovar and Wall (2015)	General cargo, Liquid, Dry Bulk in tons & No. of passengers

Moreover, various scholars, Jara-Diaz et al, (2005), Gonzalez & Trujillo (2009), argued that the use of single output will cause bias in the analysis for a multiactivity port. This point of view was supported for two reasons. The first is the production units are different, for instance, measurement of container activities are with a number of containers (TEU). The Second, point is the handling equipment used for operation is not the same for the two cargo systems and even for the single cargo category for instance container handling operations for the: Ro/Ro, Roll On/Roll is different than those for Lo/Lo, Lift On/Lift Off. As such, they need to be counted as different outputs. Table (3-1) shows some researches that used multiple outputs for assessing port efficiency.

To sum up, the selection of DMUs homogeneous activities as well as reliable inputs and outputs are very important in concluding realistic results, coupled with their relation to the scope of research and hypotheses.

3.6. Conclusion

This chapter with its twofold purpose could provide a clear understanding of the research gape analyses. As with reviewing researches of ports, co-opetition and port efficiency measurements and techniques, highlights the significance of this research. Moreover, it presented that the previous researches on the previously mentioned areas were not integrally studied as it is presented in the main objective of this research.

Researches analyze the ports Competition and cooperation reveals that those two concepts strongly exist as a strategic management decision for various ports. Although competition among ports highlights ports competitive advantage to increase their revenues at the cost of contestants, the contradicting concept of cooperation concludes the combined pursuit of mutual objectives of producing advantages, that can improve the performance of collaborative parties. Moreover, with the presence of globalization competition and cooperation are not totally independent but businesses are engaged mutually in competition and cooperation as parties can share the outcomes they jointly produced.

Furthermore, it was clear that there were a few numbers of published works of literature that address ports co-opetition concept in spite of its usefulness in the existing ports market and industry situations. Although it is an old concept but due to the presence of regional, political, economic and social diversities the co-opetition concept was not vastly implemented. Now a day's various ports are approaching this concept to overcome various market conditions produced by unnecessary completion. Nevertheless, various state governments are pushing ports in the direction of cooperation to save national resources from being burned by the fire of national ports competition.

On the other hand, measuring ports technical efficiency was vastly studied by scholars with different techniques to estimate ports technical efficiency. This was to assess ports performance among competitors as a sort of finding evidence of success that could be proved. Moreover, benchmark ports relative efficiency was used to assess ports from different perspectives, for instance, organization structure, size, operational patterns, the objective of ports (hub vs spoke) nevertheless, the scope was applied on a global scale to compare ports globally and /or regionally.

From the previously reviewed researches, the gape analyses of this research are significantly clear that no research addresses the co-opetition concept influence on ports technical efficiency. Therefore, assessing ports relative technical efficiency from the scope of evaluating the implementation of co-opetition concept will be a new approach to evaluate ports cooperation strategies. That will pave the way, further in this research in chapter six, to examine the impact of port co-opetition on port efficiency.

In this context, the next chapter reviews the DEA methodologies and models used to assess port efficiency from various perspectives. It also provides a complete overview of research structure and methodologies that are maintained to assess port technical efficiency and examine various research hypotheses in the defined research areas.

CHAPTER FOUR

RESEARCH DESIGN AND METHODOLOGY

4.1. Introduction

The methodology is essential in designing and examining methods that demonstrate resources, limitations, assumptions that describe the potentialities to research developments (Nachmias, 2008). The selection of research model, data type with its collecting method as well as the measurement tools are very important in the research analyses and results obtained. This chapter will present the research methodology through four main sections. The first section illustrates the study design; the second section demonstrates the various data envelopment analysis (DEA) models that are obtained to evaluate ports efficiency. The third section reveals the specifications of variables that are used to assess ports' efficiency and offer a brief description and clarification on data collection and software used to measure port efficiency and ports clusterization. The fourth and final section is the chapter conclusion.

4.2. Research design and strategy

Churchill (1979) emphasis on the importance of any research design as it paves the way for the data collection, analysis and concluding to reasonable results. The implication of research design is to link the philosophy, argument, research analyses as well as collected empirical data (Nachmias ,2008). The selection of study design specifies decisions about the importance being given to an array of magnitudes of the study procedure (Bryman et al., 2007), and this will affect the lower-level methodological processes as statistical tools and population sample. Therefore, it is a plan that includes, limitations, constraints of the study that enables researchers to find appropriate research questions answers (Saunders et al. 2007).

The aim of this research is to evaluate the impact of ports co-opetition, by forming clusters, on port efficiency in the main East-West trade route. In order to perform this aim, the research philosophy is based on the positivist approach. The positivism main concept is that the reality is unchanging and can be observed and established from an objective perspective without interfering with the study phenomenon (Cohen et al, 2007). Positivists declared that phenomena must be isolated and observations have to be repeatable. This needs manipulation of reality with changes in a single independent variable to recognize regularities to form relations among some of the of the social world basic elements (Saunders et al. 2007).

The implications for selecting the positivist philosophy is for many reasons. Firstly, its methodology, that relies on quantitative researches, as valid generalizations can only be based on quantitative research. Secondly, its value-freedom, which means that human beliefs and interests are not counted as the identification of objectives is the main pillar to select the study and its implementation. Thirdly, causality, which reveals that the key objective must be to determine causal relations and main laws that clarify a particular behaviour. Fourth is operationalization, that reviles that concepts must support facts to be quantitatively measured. Fifthly, independence, as the researcher should study independently the research phenomenon. finally, reductionism, which means that problems are well known if they are not complex to their basic elements (Hughes, 1994).

Basic positivist approaches require experiments, observations, and survey techniques, and frequently include a complex statistical analysis that makes the findings and results and empirically tests hypotheses (Schiffman and Kanuk 1997). Moreover, the researcher with the positivistic deductive approach entails that the determined theory must be examined by empirical observations, if the theory is proved to be false then it should be ignored, changed or replaced. The choice of the deductive explanatory is characterized by its match to the basic features of the positivist approach in terms of variables causal relationships, developing and testing of hypothesis, generalization as well as operationalization (Easterby-Smith et al, 2002).

Figure (4-1) shows the broad research stages and application of software used to answer the research question and examine the hypothesis. This is simply based on assessing every individual port relative efficiency by the aid of DEA models which produce a deep analysis for each input in every port in terms of its contribution to port efficiency, as well as the potential improvement percentage to every single input to change that port from inefficient to efficient status. Then, grouping ports based on their similarity in DEA results which will take place using clustering software. Afterword, the complementary phase will take place by grouping ports from different clustered groups in which this complementing cluster will include a variety of ports for instance highly efficient, medium efficient and poorly efficient ports will all be grouped in one cluster. This complementing cluster will be selected on a geographical basis in which it could practically be applied. Finally, an examining phase will take place where another efficiency analyses by the use of DEA models will be performed to examine the impact of this complementing clusterization process, in which analyses and conclusion will be conducted.

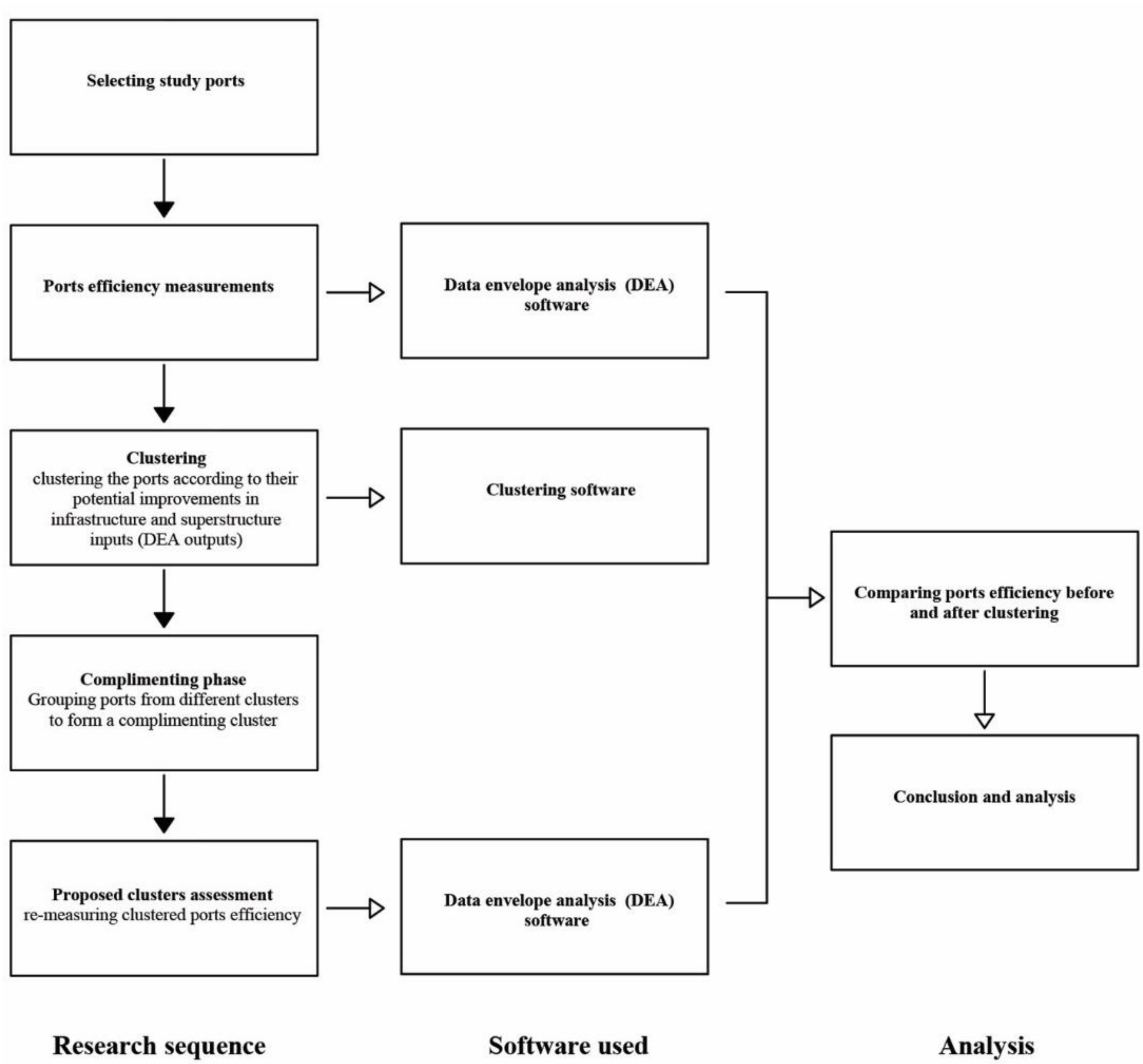

Figure 4-1 Research sequence and generic idea

After that, the research strategy involves an empirical investigation of a current particular phenomenon in its actual life situation using evidence from multiple sources. Accordingly, the East-West trade route container port market is considered as an area of study to analyse the influence of port co-opetition on port technical efficiency. Therefore, to answer the research questions and study the market dynamics of the main trade route. The research model is applied to the world top 42 container ports (among the world top 50 ports) in the East-West Trade route for the year of 2016. Data for ports infra/superstructure and annual throughput for 6 years' period between 2011 till 2016 will also be used. Cross section data will be for the year 2016 and the panel data will be from 2011 and 2016. As an outcome of selecting the above-clarified paradigm, this study will test the philosophy of industrial organization in order to assess the influence of ports clustering to perform co-opetition in the study area on ports technical efficiency.

Figure (4-2) shows the research procedures which consist of four main stages. The first stage ports selection and data collection. This stage concluded to the selection of the 42 container ports limited to the East-West main trade route. Moreover, the collecting of required secondary data (inputs and outputs for model application) from containerization international issues as well as ports official sites. The main reason for depending on secondary data is due to the unavailability of primary data from the direct sources of ports. This is due to the fact that most ports are dealing with their production and facilities data with confidentiality police, afraid from their competitors to identify their weaknesses or strengths.

The second stage is for analyzing the market performance by benchmarking selected container ports' technical efficiency through the use of DEA non-parametric models. These models are:

1) CCR - CRS model for measuring the ports' aggregate technical efficiency (AE)
2) BCC - VRS model for assessing the ports' pure technical efficiency (PTE)
3) Super efficiency (A&P) model to ranks the efficient ports with 100% scores
4) Sensitivity analysis model to find the sensitivity of inputs on ports efficiency
5) Slack variable analysis model that determine the values to be decreased in every single input, and/or values to be increased in every single outputs, to shift ports from the inefficient to the efficient status.

The third stage is the formation of ports clusters by using the outputs data from the DEA models and using clustering software to group ports with similar inputs utilization figures then forming clusters of complementing ports by grouping ports geographically from the previous clusters to perform a new ports cluster with different ports capabilities. The fourth and final stage a comparison step to finding out the change of ports efficiency from the individual port operation to the proposed clustered form. This will identify the impact of ports co-opetition on their efficiency results. Finally, testing research reliability and validity.

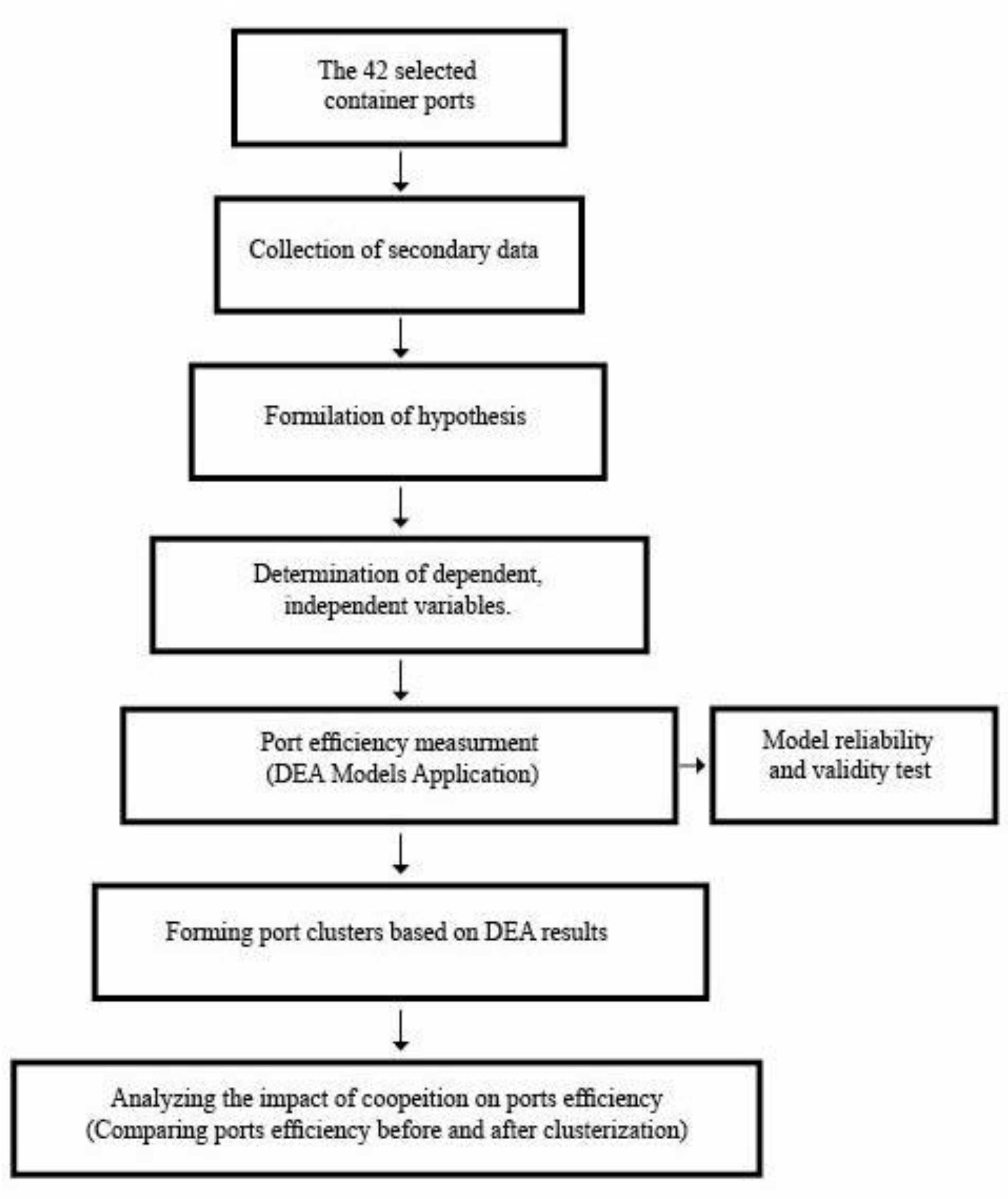

Figure 4-2 Research methodology process

4.3. Efficiency measurements background

4.3.1. Technical efficiency

Efficiency can be observed and assessed from two perceptions: an output or input oriented. the output-oriented is based on the DMUs probability of increase output to using a given input level. The input-oriented is based on the likelihood of reducing the input package given a fixed output level. These two perceptions are presented in figure (4-3) for the input orientation and for the output orientation.

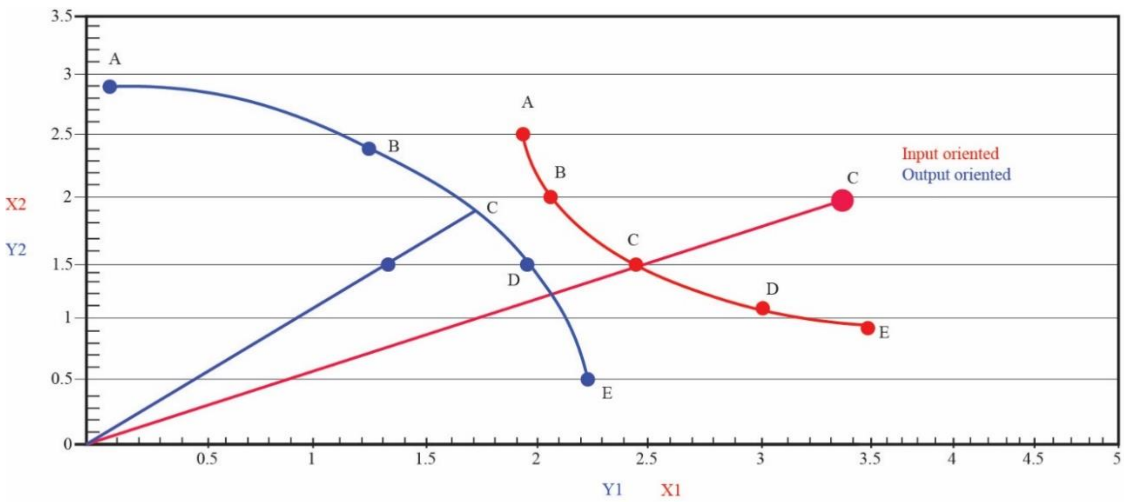

Figure 4-3 The DEA the input orientation and for the output orientation.

Figure (4-4) illustrated the technical and allocative efficiency of a DMU using 2 inputs (x_1, x_2) to create one output (q), by constant returns to scale orientation. The efficient DMU unit isoquant is represented by the curve SS' that enables the technical efficiency assessment. If for an instant a DMU uses inputs amount at point (P) to produce certain output unit, then QP represents the distance of DMU's technical inefficiency in which all inputs could be removed and the output stays the same. This is signified via the QP/0P ratio in which all inputs could be subtracted to achieve efficient production. Therefore, DMU's technical efficiency (TE) can be explained by the ratio TE = 0Q/0P, that is equivalent to 1- QP/0P, which will be a value between one and zero. DMU is said to be technically efficient when it obtains (1) value or 100%. However, allocative efficiency could also be considered if a given input price ratio is present, and is represented by the AA line'.

Therefore, the ratio AE = 0R/0Q can express allocative efficiency (AE) (Emrouznejad and Cabanda, 2015).

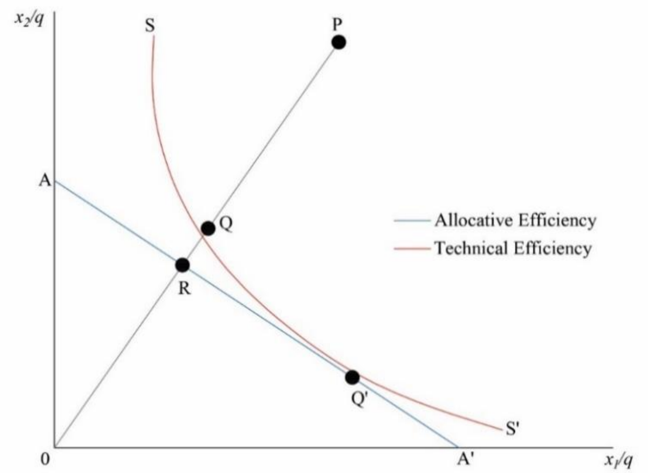

Figure 4-4 Technical and allocative efficiency

Source: Emrouznejad A. and E. Cabanda (2015). Introduction to Data Envelopment Analysis and its applications, in Osman et al. (Eds.) Handbook of Research on Strategic Performance Management and Measurement Using Data Envelopment Analysis: 235-255. IGI Global, USA.

4.3.2. Scale efficiency

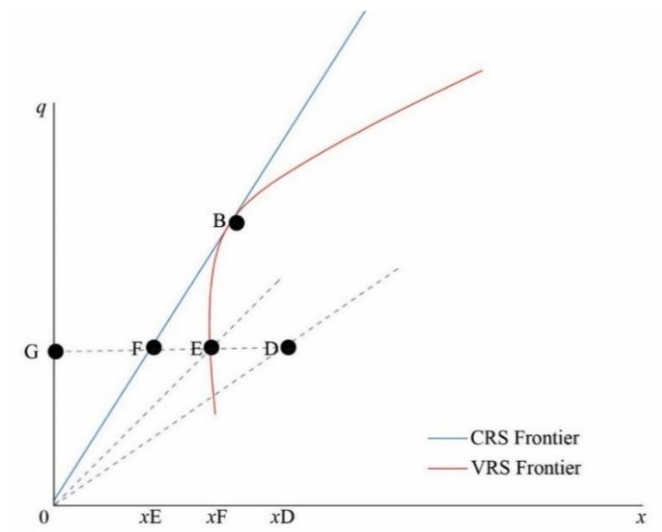

Figure 4-5 Scale efficiency

Source: Emrouznejad A. and E. Cabanda (2015). Introduction to Data Envelopment Analysis and its applications, in Osman et al. (Eds.) Handbook of Research on Strategic Performance Management and Measurement Using Data Envelopment Analysis: 235-255. IGI Global, USA.

Scale efficiency measurement is important to specify the amount of development in productivity by shifting to the technically optimal productive scale (TOPS) points (Coelli et al. 2005). Figure (4-5) shows the scale efficiency, in which point D is representing a technically inefficient DMU (present under the production frontier), in which this firm could improve by shifting from D to E below the variable return to scale (VRS) efficient DMU as well as from E to F below the constant return to scale CRS efficient DMU. Moreover, the scale efficiency (SE) of the DMU (D) is stated as SE = GF/GE, that is represented by means of the distance from technical efficiency of E to the CRS technology.

4.4. Efficiency analysis measures and DEA models

4.4.1. Data Envelopment Analysis (DEA) concept

DEA is defined by way of a linear programming technique founded on mathematical programming theory with a nonparametric tool of calculation to evaluate the efficiency of DMUs with various inputs and outputs (Poitras et al, 1996). This is made through creating a virtual single output to a virtual single input without the need to pre-defining a product function. DEA models do not need information or measurement of a priori weights for the outputs or/and inputs. Therefore, these features have characterized DEA as a flexible technique in comparison to other efficiency methods obtained from SFA or economic value added (EVA), in which they are based upon production function estimate regarding numerous inputs but only single output (Cullinane & Wang, 2007).

The DEA has two main models. the first model is recognized as the CCR model developed by Charnes, Cooper & Rhodes in 1978 that can be either input or output orientation with supposed constant returns to scale (CRS). While, BCC is the second model which was recognized by Banker, Charnes & Cooper in 1984, that used the variable return to scale (VRS) assumptions (Wang & Cullinane, 2006b). Moreover, there are four other DEA models which are:

1. Additive model
2. Multiplicative model
3. Cone-ratio DEA model
4. Assurance-region DEA model.

The latter two models encompass prior information like specialists' opinions, rate of substitution or opportunity cost, to limit the results to the optimum DMU as in the Assurance Region DEA model that could link to the DEA model by the multi-criteria analysis such as in model of Cone Ratio DEA model (Barros & Athanassiou, 2004). The term relative efficiency is used in DEA for the reason for comparing the efficiency of each measured DMU in relation to the selected sample DMUs. The envelopment surface could also be multidimensional when using multiple inputs and/or outputs. DMUs that are positioned on the frontier have an efficiency estimate of one and are considered DEA efficient, while others with fewer scores than one will be categorized as DEA inefficient (Tongzon, 2001b).

Although Infante and Gutiérrez (2013) described the use of the DEA method has been used for efficiency evaluation on the field of production. But, in this present research, they are used to assess the relative technical efficiency among dedicated container terminals or ports as it was vastly used for this purpose in various researches.

Efficiency = Total outputs / Total inputs

Overall, efficiency can be described as:

$$E = Outputs/Inputs$$

Or

$$\mathrm{E} = \frac{\Sigma_{\mathrm{i}}^{\mathrm{N}} = 0^{\mathrm{V}}\mathrm{i}^{\mathrm{y}}\mathrm{i}}{\Sigma_{\mathrm{i}}^{\mathrm{N}} = 0^{\mathrm{u}}\mathrm{i}^{\mathrm{x}}\mathrm{i}}$$

Where E is the efficiency, xi and yi are the inputs and outputs, whereas ui and vi indicate factors that describe the relative meaning of every one of the factors. Assessment of efficiency usually includes many inputs and outputs; therefore, they must be selected in relation to the nature of the study problem. Methodologically, the research layout of DEA models, in which factors are detected is not only linked to efficiency analysis based on the DEA models but also to a different proposal to improve efficiency (Infante & Gutiérrez, 2013). The previously shown explanation to the DEA technique offers an indication about its main features.

4.4.2. DEA models and Efficiency analysis procedures

From the previously reviewed literature, it was clear that many researchers used the DEA (CCR& BCC) models in all regions including developed, emerging or international market, in spite of the gap of technology or managing systems between them. (Emrouznejad et al, 2008). Therefore, this research applies mainly to these models. Wang et al. (2003) stated that the orientation of model reflects the scope of research, for instance, models with input-oriented are more related to operational as well as managerial sides, while models with output-oriented are more related to planning besides strategy making.

Although this research mainly focusses on ports co-opetition which is mainly a strategic decision, it is supposed to use the DEA with output oriented setting. But this research is also seeking a way to increase ports efficiency through cooperation and ports clustering with the existing port's facilities and throughput. Therefore, to know in depth ports existing weaknesses in term of super/infrastructure, this research will adopt the DEA model with input oriented mode. From that viewpoint, this research applied the input-oriented CCR besides BCC models to assess the technical efficiency of dedicated container ports in the East-West route.

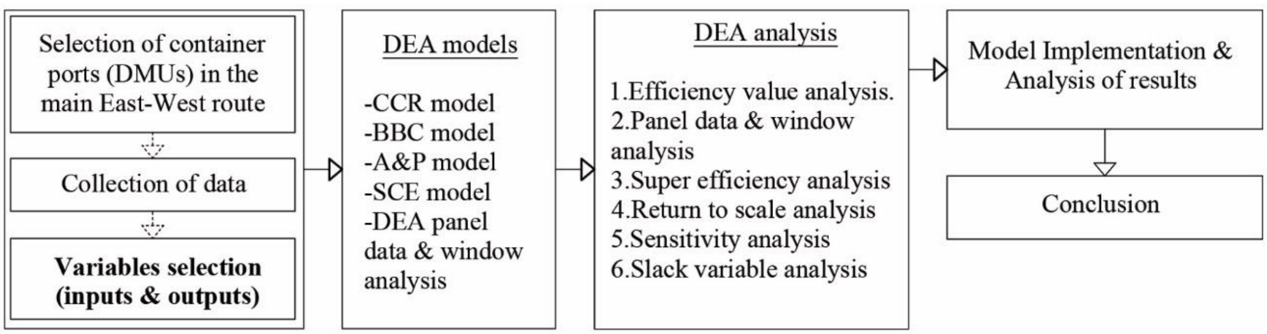

Figure 4-6 Research procedures and models analysis

The current study process is summarized in figure (4 - 6). The 42 container ports in the East-West route, representing the research's DMUs were first selected based on their geographical location and their presence in the top world 50 container ports. Then gathering data for the selected ports including their infrastructure and superstructure facilities that represent the technical drivers for container ports operations. Then an application of correlation analysis to select inputs and outputs variables to determine the best combination of inputs and outputs. The second phase was to apply the relative technical efficiency analyses with the aid of DEA models including the DEA (CCR & BCC) models to conduct relative technical efficiency value.

Charnes et al. (1978) highlight that the CCR model presumes that the production practice is produced with CRS, as the returns to scale differ, production combinations determination changes accordingly. Then, less efficient DMUs can be related to operations through different returns to scale. Charnes model was then developed by Banker (1984) who established the BCC model with variable returns to scale. Moreover, there was a problem to distinguish efficiency ranking in case we are having more than one DMU with efficiency score equal to one using either CCR or BCC models. Therefore, the super efficiency model, A&P (Anderson and Petersen, 1993) model, was developed to solve such problem and rank the efficient DMUs (Wu et al, 2010).

Figure (4 - 7) shows the procedure of DEA efficiency evaluation and analysis. when DMUs has technical efficiency score less than one they are considered to be inefficient in relative to the rest of DMUs. Accordingly, inputs should be reduced or outputs should be increased to shift the inefficient DMU to become an efficient one. Nevertheless, when the scale efficiency of the designated DMUs shows less than one values, that is scale inefficient which means that the scale of operational is not reaching an ideal value as well as that the scale of operational should be reduced or extended. Moreover, it is feasible to compare the values of technical efficiency with that of scale efficiency score. (Lin & Tseng, 2007).

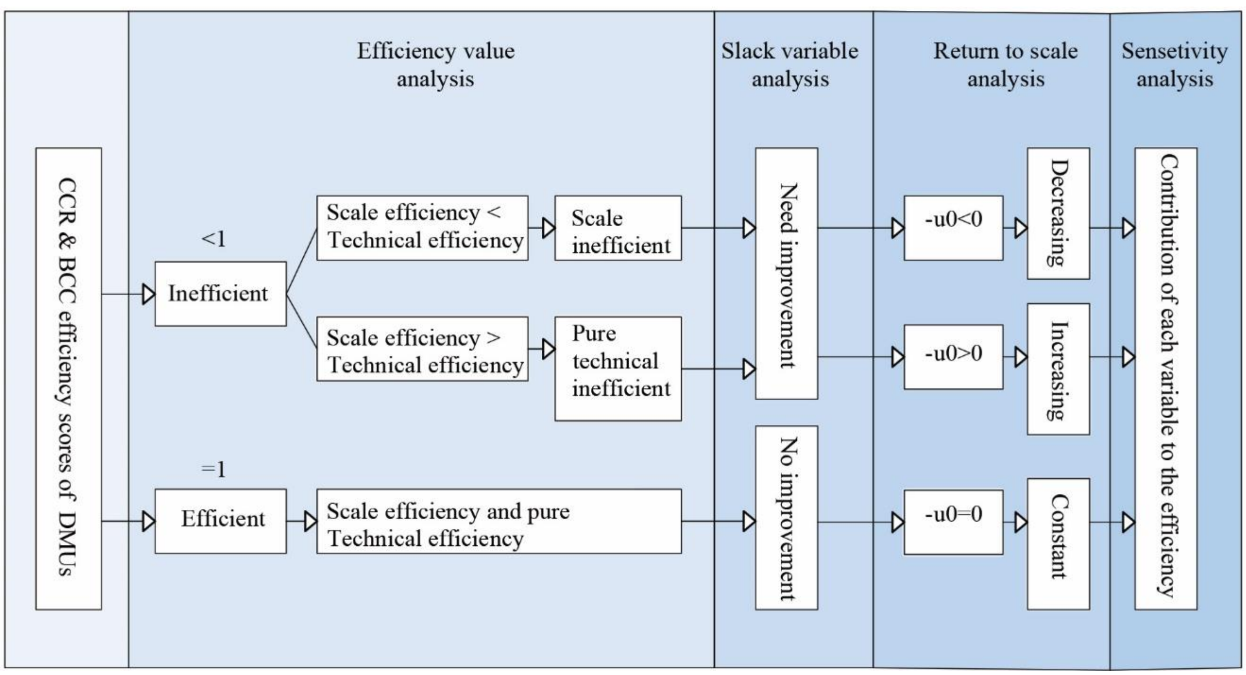

Figure 4-7 Procedure of DEA efficiency evaluation and analysis

Source: Adapted from, Lin, L.C., Tseng, C.C. (2007) 'Operational performance evaluation of major container ports in the Asia-Pacific region'. *Maritime Policy and Management*. 34 (6), pp. 538.

Moreover, when the DMU shows less than one efficiency score, the inefficiency reasons should be identified by applying the scale efficiency models besides the pure technical efficiency. When determining the causes of incompetence, the model of slack variable analysis could be used for determining how to enhance the less efficient DMUs. Then the return to scale analysis could be used, as it is likely to test the $u0$ value obtained from the BCC model, then assign the return to scale intended for every DMU as constant, decreasing, or increasing (Lin & Tseng, 2007).

Then sensitivity analysis is performed to eliminate the output as well as input variables one by one, before re-calculate the aggregate efficiency. This is to allow resolving of finding the output as well as input variables which are accountable for the variation in any DMU operational efficiency. This indicates a clear comprehensive identification of which variable (output or input) is significant for improving efficiency. Finally, the slack variable analysis model is performed to evaluate how to enhance the operational efficiency of the less efficient DMUs by representing values of inputs to reduce, and/or values of outputs to increase, toward changing the incompetent DMUs into efficient ones. The analysis of variable weights, reflects their contribution to the DMU efficiency scores as variable weights and efficiency scores are directly proportional to each other, Therefore, managers should focus on improving variables with greater values to rapidly reach their development objectives.

The selection of analyses using the data in terms of cross-section or panel is very important to serve the research objective. The cross-sectional data was used to benchmark DMUs by the aid of DEA models to score ports efficiency in a particular fixed time, neglecting the operation development or equipment advancement per time. However, this can be rather confusing as dynamic settings may emphasize the extreme use of resources which are predictable to produce beneficial results in the future (Wang et al, 2005).

On the other hand, the panel data was used to cover the developments in operations as well as the enhancement of equipment in a particular period. In this research, the DEA panel data and window analysis uses are performed to not only benchmark the efficiency of DMUs but also to recognize the changes of the DMUs' efficiency in a particular period between the year 2011 till 2016. Finally, DEA models implementation and empirical results analysis will be shown in the last research phase.

4.5. Variables and measures of ports inputs and outputs

The selection of input and output variables to assess ports efficiency should precisely reveal the real procedure of container port operation. For example, a port could use advanced, expensive machines to improve its efficiency if it just aims to make the most of ports throughput. Correspondingly, another port may be intended to use inexpensive operating machines if its aims is to make the most of profits. The drives of every port are significant to the choice of efficiency analysis variables. For instance, if the goals of a port is to maximize its incomes, then any data on labour must be used as variables in the inputs. Similarly, when the port goals is to increase the national employment rate ,therefore, labour should be considered as an output variable (Cullinane et al., 2006)

Also, an important part in the judgment of benchmarking ports efficiency is the variable definition. Researches concerning ports depends on the recognition of the relationship between controllable and uncontrollable elements. Controlled factors that directly affect efficiency analyses should be included in the comparison analysis. But, the uncontrollable factors that indirectly affect port efficiency could also be considered in the efficiency assessment (Cullinane & Wang, 2010).

Figure (4-8) and (4-9) shows this study selected inputs and outputs to determine ports efficiency. Ports annual throughput, the total number of TEUs handled, was selected as model output as it is indisputably the most vital and extensively believed indicator of terminal or port output. Also, most of the aforementioned research considered it as the most appropriate and analytically tractable index (Wang et al, 2005). besides, it is directly relating to the necessity for container-related facilities that benchmark container ports, mainly in assessing their total investment size and service levels.

Nevertheless, as in many types of research investigates the container ports efficiency, container throughput has been chosen as the most appropriate output for the DEA models. The presence of transhipment cargo then rises as a probable problem in the calculation of total container traffic. But, according to (Wang and Cullinane, 2006a; Demirel et al, 2012), in many cases, this factor is largely reduced since the amount of work done to the handling of a transhipment container within that equate, is likely related with import or export containers. (Demirel et al, 2012).

Dowd and Leschine (1990) clarified that container port operations be determined by crucially on the well-organized use of human resourses besides infra/superstructure and capital. Thus, this study includes six Input variables used in the model representing ports' infra/superstructure for the period between 2011 till 2016. They are container ports terminal area, terminal length, maximum depth, Number of Gantry cranes and yard handling equipment. The first three inputs reflect ports infrastructure and the last two indicates the superstructure of the port. Knowing that the six input is the deviation distance which is used as an uncontrolled environmental factor.

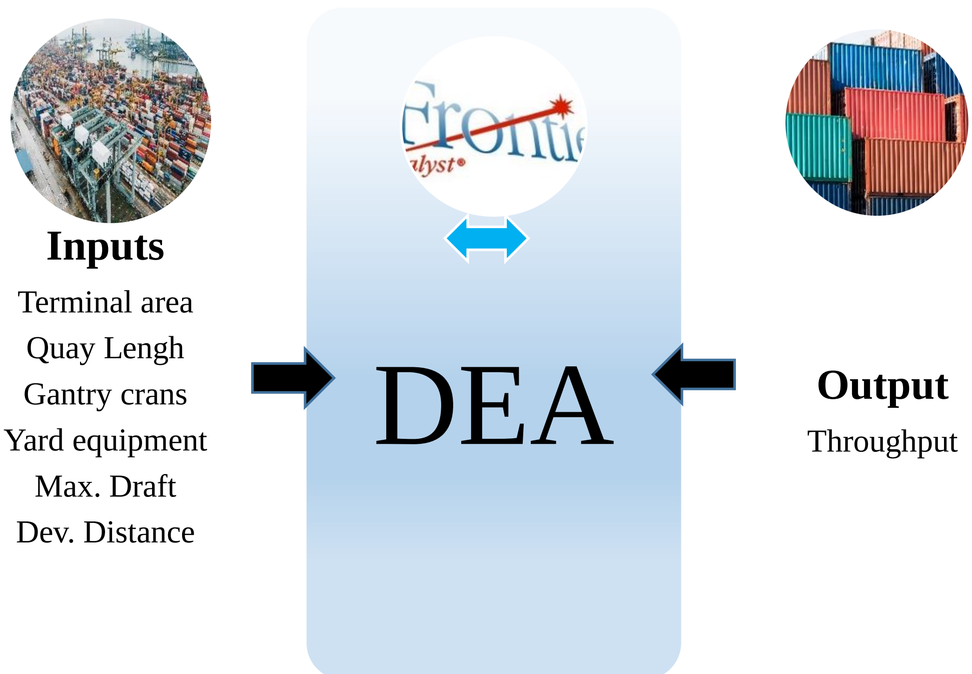

Figure 4-8 Study selected inputs and outputs

There is a logic rule, that every input should be standardized and equal in measuring units in all DMUs, for instance, all ports maximum depth should be measured in meters and not counting some in feet and some in meters. But technically, this is very difficult to perform if we are counting machines or production facilities. This rule is easily performed when considering the ports infrastructure. But some researchers used another input which is the number of berths in the terminal or port like, Cullinane et al. (2002), Tongzon (2001a) and Notteboom et al. (2000). However, reasonable comparability is an important principle for performance and efficiency measurement (Vancil, 1973, Wang et al, 2005). As such, it might not be suitable to trust the number of berths rather than total quay length because there is no standardization for berth lengths as every port identify its berths according to port requirements by reconfiguring the quays within a port or terminal. Another drawback in that the number of berths will not reflect the actual port vessels' reception capacity. For instance, the Italian port Gioia Tauro has berth length with 3011 m while the Turkish port Izmir is having berth with only 1325 m (El Sayeh, 2015)

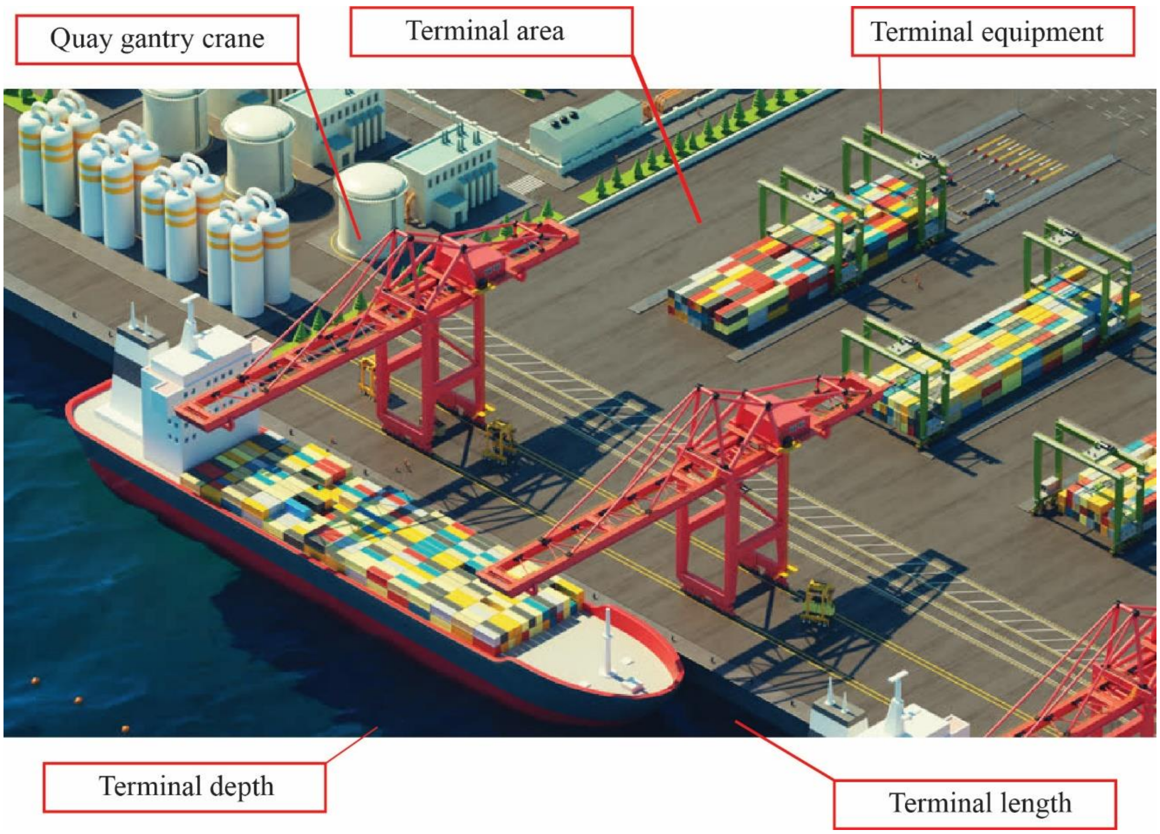

Figure 4-9 Study selected inputs and outputs

For the superstructure standardization of equipment should be carefully considered. As the handling equipment that includes the quay-side gantry cranes, which is a very important piece of equipment in the production process, that resolves the efficiency score of a port and directly influences the number of containers handled in the port, could be miss leading to the efficiency results. This is due to the presence of many types of gantries with various production capabilities, for instance, Panamax cranes, post Panamax cranes, single speeder or double speeder. Moreover, in a single port or terminal, we could find a mix of cranes brands and sizes with various production capabilities.

But the number of cranes is normally being used as an input variable (Notteboom et al, 2000). In spite of the fact that This may be tricky as practically sorting separate data of cranes is very difficult to be applied. Additionally, some of the study ports were equipped with mobile cranes with different carrying capacities. But due to the fact of inconsistency presence of such equipment in all study ports and the gape of the rate of handling containers of mobile cranes in comparison to the quayside gantry cranes. the count of mobile gantry cranes was eliminated from the study.

Correspondingly, the same problem arises with the yard equipment estimates as terminals are operated with various yard operation systems, for instance, front-end loaders, straddle carriers, Rubber tiers gantries (RTG) and Railway mountain gantries (RMG). Therefore, one solution is to count the total number of all equipment types present in a container terminal. However, problems directly rise regarding comparability and equitable treatment. For instance, the capacity of RTG is much more than straddle carriers. Therefore, a container terminal with more RTGs will show a higher level of assessed efficiency, even though this high efficiency does not reveal its actual input levels (Wang et al, 2005).

The solution applied in this research was to focus only on the most important container handling equipment systems. This was limited to counting the numbers of RTGs, RMGs, and straddle carriers and neglecting any other yard equipment like front end loaders, forklifts etc... Then an equalization process was made and is explained in chapter 5 to reduce the equipment production variation. Furthermore, equipment numbers were used and not equipment capacities as the numbers to some extent reflect labour power for each port, considering that the study ports are among the top word ports supposing that the variation in technology is not significant. Also, Notteboom et al. (2000) stressed that expert studies emphasise that there is a nearby relationship among the number of handling equipment with the number of labour in a container terminal with the exclusion of commercial and administrative staff. Consequently, labour statistics can be used as a mathematical function of container terminals facilities either directly by counting them from the official sources. Knowing that this process is extremely difficult to perform for the confidentiality of data (Cullinane and Song, 2003).

Furthermore, the last input variable used in this research was the deviated distance which was used as an uncontrolled environmental factor that influences port efficiency in an indirect way. This means the relative significance of geographical position that may favour one port above another

(Lu & Marlow, 1999, Bichou, 2013). In other words, the closer the port is to the main trade route, the greater its competitive advantage is in a given market (Guy & Urli, 2006). As such, port deviated distance from the main East-West trade route was used as an exogenous factor that could influence port efficiency.

4.6. DEA software used in the research

The obtainability of software to do the rigorous empirical analysis is vital for applied scholars as well as the broader researcher's community. There is a wide range of methodological reviews available on this DEA models literature with vast amounts of empirical applications. These software are used in many sectors as in agriculture, banking, health care as well as ports. Perhaps Chang and Sueyoshi (1991) took the initiation to be the first to document a software for DEA models. Afterwards, frontier software has been offered by a multitude of researchers and developers. (Daraio C.et al., 2019).

Table 4-1 Commercial and academic DEA software

Software	Developer
DE Frontier	Joe Zhu
DEAP	Tim Coelli
DEA-Solver	SAITECH, Inc, USA
EMS	Holger Scheel
FEAR	Paul W. Wilson
Frontier Analyst	Bonxia Software Ltd, Uk
Max DEA	Beijing Res. & Con. Com. Ltd China
PIM-DEA	Emrouznejad A. and Thanassoulis E.

Source: Iliyasu, A., Mohamed, Z.A., Terano, R. and Malaysia, S.M. (2015) Data envelopment analysis models and software packages for academic purposes. *Pertanika Journal of Scholarly Research Reviews* **1**(1): 27–32.

The vastly used and available DEA software for commercial or academic uses are presented in table (4-1). The first five models are mainly for commercial purposes in which, three out of them commercial corporations adopted for development (Frontier analyst, DEA Solver and MaxDEA). The remaining two (PIM-DEA and DEA Frontier) universities/polytechnics developed them. on the other hand, the last three programs are academic in the sense that they are free to download and use. The main difference between academic and commercial programs is the capabilities of the software to analyze certain data quantity as well as the options and presentation facilities (Iliyasu, A. et al., 2015).

In this research, the Frontier Analyst software (Bonxia Software) will be used as it is a powerful software in its capability to display a variety of outcomes. These contain graphs of technical efficiency scores, frontier plots, distribution of efficiency tables pie charts, X-Y plots, efficiency plots and reference set frequency.

Moreover, the Banxia Frontier Analyst software offers a comprehensive analysis on how DMUs, container ports, are performing and how their efficiency can be improved. Also, improvement targets are realistic as the measurement is founded on peer-group assessments. One of the best options of Frontier Analyst is the variety of produced outputs. It supports all ordinary output information offered by DEA adding to some outstanding graphic demonstration of the relationships between DMUs.

The software has the next key characteristic, that mark it as an effective DEA program that comprises weighting facility to confirm that vital elements are always included. It is capable to benchmark the efficiency from 75 to 20,000 DMUs. It has a flexible import feeding data tool from both file and spreadsheet using an individual "wizard". Finally, the software correspondingly permits for tabular scores report with various sorting methods and graphical summary (El Sayeh, 2015)

4.7. Clustering applications and software

4.7.1. Clusterization concept

Data grouping is a technique in which groups are create by objects that are one way or another are having the same or similar characteristics. The standard for similarity examination is implementation dependent. Grouping is often mixed up with cataloguing, but there is nearly dissimilarity concerning the two. As in classification, the entities are allocated to pre-defined classes, while in clustering , classes are as well to be defined. Exactly, Data Clusterization is a practice in which, the data that is reasonably alike is really kept together.

cluster analysis is a statistical method that is used to solve complications in data by grouping similar entities into clusters. The clustered members are more like each other than other clusters members. Therefore, the goal of cluster analysis is to understand the inputs by retaining them into different collections that can be simply understood (Aaker et al 1995). It is used in a gathering of disciplines such as engineering and business, economics and other social fields (Hair et al 1995).

By clustering the results, it is easier to understand what each cluster characterizes and accordingly its place in the complete picture. At the same time as it is frequently used in an exploratory part, it can also be used to check hypotheses by comparing the consequences with the researcher's anticipations. For instance, with factor analysis, grouping analysis is not a statistical interpretation technique in which factors from a model are said to be revealing of the whole population. On the other hand, a cluster method is an objective approach for quantifying the physical features of a set of observations. Hair et al (1995) highlighted that caution should be conceded while relying on the results of cluster analysis due to the degree of input and understanding needed by the researcher. They said that cluster analysis is rather an art than only science, then carefully use the useful results.

4.7.2. Types of clustering approaches

Figure (4-10) represents the main clustering techniques types which are the Hierarchical based clustering, Density-based clustering, Partition Based Clustering, in addition to the Grid-based clustering. The Hierarchical based clustering is a connectivity-based clustering. It is a technique to construct a hierarchy of clusters. This type merges small clusters into a bigger one besides also large cluster could be splinted to smaller ones. The clusters are created by partitioning the cases into a bottom up or top down method which can be seen as a tree alike chart called a "Dendrogram" that accounts the arrangement of splits or merges as well as demonstrations how such clusters are connected. When the required clusters numbers have been made, the procedure of merger or splitting will stop. Every cluster nodes comprises small or child nodes besides the node that goes to the same bigger or parent which are named as sibling nodes (Neha et al., 2015).

The technique of Partition Based Clustering, is a number of items which are assumed besides the data figures will be divided into a number of groups where each comprises alike objects. It generates an exact number of uniform plus dis-joint groups as well as the clusters which are made will be characterized by centroid or group representative. Moreover, the Density-based clustering is a sort of grouping separated data founded on its connectivity, its region or boundary. Where it plays a important part in getting a non-linear profile structure created on the density. This sort of clusterization aid to the separation of the low dense region or simply the noise data as of high dense area of clusters. Finally, the Grid-based clusterization which is a kind of grouping that split the space by limited number of cells that are identified as grids, as well as all this processes of grouping, is performed on these cells. Afterword, the grids are joint together to make a grid similar format (Neha et al., 2015). Moreover, for every clustering technique, there are too much software applied to fulfil the concept or expected outputs as shown in figure (4-10)

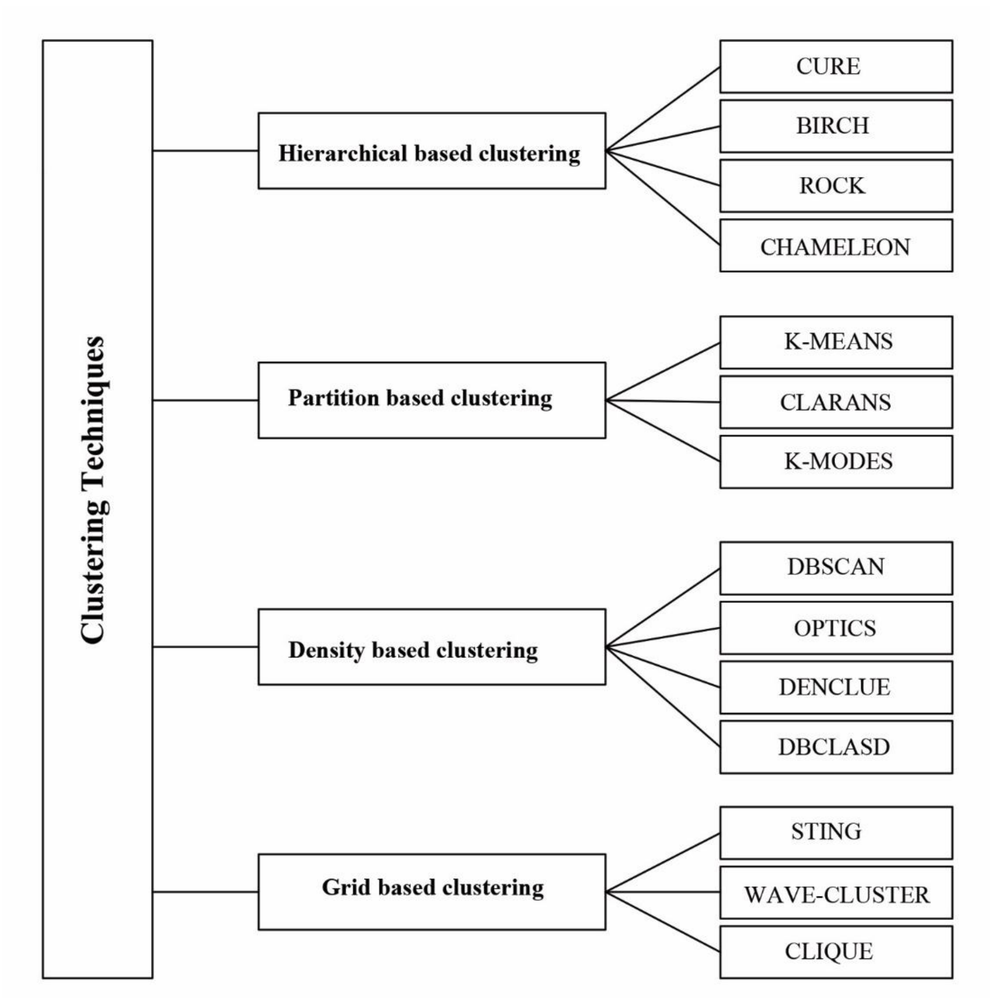

Figure 4-10 Types of clustering techniques

To conclude it is clear that all the clusterization types are used in grouping the given data into different clusters with similar tendencies and outlines shared data. The quality of groups created by the clustering technique is measured by their capability to determine all or some of the unseen patterns. It was perceived that the utmost common type of grouping method that has been applied by different uses of data sorting is the k-means clusterization method. As it is most broadly used as it produces good cluster outcomes in comparison to the rest of clusterization methods. Nonetheless, there are other sorts of grouping methods employed by the applications.

For this research, the K-mean clustering method will also be used in sorting the study ports for its advantages. As, it was proved to be easy to understand, simple, flexible, and can be simply applied. Moreover, (Hartigan & Wong 1979) mentioned that it is the best clusterization tool used in industrial and scientific uses. its name derives from representing respectively of k clusterization of C by the mean or by ,weighted average, c of its centroid or points. Whereas this clearly does not perform well with a categorical quality, it has perfect geometric as well as a numerical elements statistical sense. The sum of inconsistencies among a point besides its centroid expressed finished suitable distance is used by way of the objective purpose. Each point is allocated to the cluster with the nearby centroid Number of groups, K, essentially be identified (Rai et al., 2010).

4.7.3. Clustering software

Clustering software is widely available either the commercial or academic programs. In this research, the XLSTAT software will be used as it provides an array of options and in-depth data analyses. It provides an optimization summary in which it shows a table of the evolution of the within-class adjustment. If numerous repetitions have been demanded and display the repetition for each result. Also, it could provide the development of miscellaneous statistics calculated such as the iterations for the repetition progress, particular the best result for the selected criterion. besides a chart viewing the progress of the chosen criterion as the iterations proceed is displayed.

Moreover, it provides data to present variance decomposition for the optimal classification within-class, inter-class and total variance. Beside, Class centroids that show the cluster centroids for the numerous descriptors. The Distance between the class centroids that shows the Euclidean distances among the clusters centroids for the various descriptors and the coordinates of the adjacent object to the centroid for each cluster. Therefore, in this research, it will provide results for ports clusters and descriptive statistics for the clusters (number of ports in each, the sum of weights, within-cluster variance as well as minimum, maximum and mean distance to the centroid

4.8. Conclusion

This chapter gives a complete illustration of the study design, approach, strategy and time frame. The research design discloses the importance of the used methodology to measure port efficiency and ports clustering techniques. From the literature revised in the preceding chapters, it can be determined that not any of the previous academics have studied the relation between port co-opetition and port efficiency by such methodology, software and approach.

As explained above, the research institutes three phases. The first phase comprises the identification of the area of study, a collection of data and inputs specifications. The second stage constitutes the benchmarks the technical relative efficiency of the main container ports in the East-West main trade route. The third phase examines the impact of ports clusterization and grouping on ports efficiency. The following chapter applies the DEA models on the selected ports in the study area as well as analyzing the outputs results.

CHAPTER FIVE

BENCHMARKING THE RELATIVE TECHNICAL EFFICIENCY OF THE TOP CONTAINER PORTS IN THE MAIN EAST-WEST ROUTE

5.1. Introduction

Ports with their nature as gateway to countries trade as well as their important role in the supply chain should always assess their performance and efficiency in order to control ports operations and improve their competitive advantage. Port performance is always related to actions of partial internal productivity, usually well-defined as relations of input volume to output volume, as well as with various methods of efficiency. For instance, cargo handling speed. Examples of these indicators comprise moves per crane-hour, moves per ship-hour, ship delays, ship productivity as well as dwell time. This port indicator type provides vital operational efficiency measures besides can provide a detailed analysis of performance at every operation stage in the port. Nevertheless, it is difficult to know how good is the port with respect to other ports. Therefore, a relative concept that benchmark ports to compare their performance toward others in addition with their own performance over time. Efficiency could be defined in numerous ways, Economical, Allocative and technical efficiency. (Liu, Q., 2010).

This chapter aims to explore the aid of ports technical efficiency through benchmarking the relative efficiency of the biggest container dedicated ports in the main East-West route which are included in the top 50 ports worldwide according to containerization international ranking. The research analyses 42 container ports in Asia, middle east in addition to Europe using a cross-sectional and panel data. Also, the application of output-oriented models of data envelop analysis (DEA) for the period between 2011 till 2016.

In order to have a comprehensive view on study ports, five DEA models will be applied for this container ports with a detailed analysis and description to the results to stand on the weaknesses and strengths of ports in relation to each other. Firstly, a clear presentation for the study ports data and assumption used in the efficiency model will be presented. Secondly, showing the results of the DEA – CCR model under a constant return to scale (CRS) to calculate the aggregate technical efficiency will be presented, also BCC model under Variable return to scale (VRS) then super efficiency analyses to distinguish between the efficient port will be discussed. Thirdly, sensitivity analyses to distinguish the weights of inputs, which leads to identifying the best input in each port that largely contributes to enhancing ports efficiency will be discussed. Fourthly, the slack variable analyses application to determine the percentages of reduction of ports inputs or/and the increase in outputs required to change such port from inefficient to the efficient port will be presented. Finally, the conclusion to sum up the results of models application will be obtained.

5.2. Ports data description and statistical analyses

This research focused on the mega-ports that lay on the main East-West trade route. Selection of study ports was among the top-ranked 50 container ports in 2017, in accordance with the Institute of shipping economics and logistics (ISL) periodical report (ISL, 2017a). Appendix (5-1) shows the 42 selected ports in this research with their infra and superstructure facilities, which will be used in the DEA analyses as controlled inputs except for deviation distance input which will be uncontrolled input. Deviation distance figures are calculated as the added distance needed to reach this port from the main trade route, the main trade route was calculated from Pusan port in South Korea in the far east area till the European port Hamburg in Germany passing through port said port in Egypt. Deviation distance was used as an environmental input that could affect the relative efficiency of ports.

Variables selection to be used is very critical and wrong inputs or outputs could perform biased results as well as inappropriate conclusions (Panayides et al., 2009). And so, based on preceding studies in assessing container ports technical efficiency input variables was using the infrastructure and superstructure of the study ports. For instance, the use of, total quay length, port total area (container terminals). number of gantry cranes, the number of yard equipment and quayside water depth as well as for output variables container throughput was widely used. The type of data is also very important as it enables the researcher to compare and evaluate the appropriate ports as well as their technical efficiency. Cross-sectional data and panel data were also widely used in the previous research as the cross-section data provide a clear picture on the efficiency at a single point of time while the panel data present the progress of efficiency over multiple time periods.

Ports data was collected from the port authority official sites and from terminal operator's official sites, as these figures represent all terminals operated within the port authority. Maximum depth figures are showing the maximum water depth in the port that reflects the capability of the port to receive and serve mega vessels.

5.2.1. Data collection and interpretation

Lower discriminatory power of DEA could be present and many DMUs achieve efficiency equal to one if DMUs number is less than half the number of the sum of inputs in addition to outputs. (Norman & Stoker, 1991). Therefore, this research uses 42 ports, and hence the sum of input in addition to output measures could not be greater than 21 only. Infrastructure and superstructure inputs selected are the main used inputs in calculating technical efficiency in container ports in various studies. The infrastructure factors are the total terminal areas, total quay length and the maximum depth. While the superstructure is represented by total ship – to - shore gantry cranes and the yard equipment represented by rubber tier gantries(RTG), Railway mounted gantries (RMG) and straddle carriers (SC).

5.2.1.1. Data assumptions

Operations efficiency in ports in general and container ports, in particular, are due to various factors as human wear and equipment. In this research, equipment is very important as they represent the superstructure inputs in the DEA calculations and analyses. Therefore, the main problem is to unify these inputs in the calculation which was very difficult as the 42 ports in our study are using various equipment with different capacities and technologies. Table (2) shows some of the technical capabilities and stacking density of the commonly used yard equipment in the container terminals. Accordingly, we used some assumptions that should be considered.

This research did not take into account the presence of any yard equipment except the RTGs, RMGs and the straddle carriers (SC), in other words, the count of number of forklifts, reach stackers, front end loaders and empty loaders were not counted as they are not used as main equipment in the medium or large ports, consequently ports not always declare their numbers and types in their official sites

Ship - to - shore gantry cranes are having various types as well as capabilities as we are having Panama, post Panama and super post Panama gantry cranes, moreover, some of them are fitted with single speeder and others are fitted with twin speeders where they can move two containers per move. Nevertheless, most of the ports are having a mixture of these cranes operated in the same ports. Therefore, in this research, we assume that all the cranes are with the same capabilities because finding the exact number and technical capabilities for all the cranes in the study was very difficult and this data was not available.

For the yard equipment cranes, the problem was that each and every port is using different equipment system as well as many were using a mixture of operating systems. Generally, we are having four operational systems. Straddle carrier system which can use them in the transfer operation from the quayside and also stuff containers in the yard, this system is usually used in the medium to large size ports. The second system is the RMG system in which transfer operations are carried out by trucks and all the yard operations are carried out by RMGs which are moving on railways. This system is the highest in land utilization as it provides operation of more than 1000TEU per hectare and usually used in the large to very large size terminals. Similar to the RMG system is the RTG system but the gantries are more fixable in moving between different areas in the yard as they are moving on tires instead of moving on rails as well as they serve large to very large size terminals. Finally, we are having the combined system which were a combination of equipment is performed and this combined system is usually present in the large to very large terminals.

Table 5-1 Yard handling equipment activities and stacking density

	Activity	Units/ Ship to shore crane	Tractors Needed	Stacking density	Assumption Numbers
Straddle carrier system	Transporting and stacking	5-Apr	NIL	500 – 650 TEUS / hectare depend on stacking high	0.5
RTG	Stacking	3-Feb	5-Mar	1000 TEU in 4 high	1
Combined RTGs with Shuttle carriers	Transporting and stacking	2-3 RTGs	3-4 Shuttle carriers	900 TEU in 4 high	
RMG	Stacking	3-Feb	6-Mar	1100	1.1

The total equipment used in the study ports is 1100 SC, 475 RMGs and 5188 RTGs. Therefore, to unify the capabilities of the three equipment their land utilization factors was the main factor to calibrate the three equipment. as shown in the table (5-1) the land utilization of the RTGs, RMGs and SCs are 1100, 1000 and 600 TEUs/ hectare respectively. Therefore, the RTGs were been took as datum as they present the maximum number of equipment then the RMGs and SCs were calibrated on them. The assumption was by considering every SC as 0.5 of the RTG and the RMG as 1.1 of the RTG. Table (5-2) shows the assumed numbers of yard equipment in the study ports.

Table 5-2 Assumed numbers of ports Yard handling equipment

Port	No	Port	No	Port	No	Port	No	Port	No
Shanghai	297	Tianjin	178	Laem Chabang	119	Keihin	140	Tanger	49
Singapore	410	Port Kelang	274	Saigon port	89	Manila	76	Keelung	28
Shenzhen	426	Rotterdam	409	Saigon new port	59	Jeddah	101	Kobe	58
Ningbo	345	Kaohsiung	179	Bremerhaven	83	Gioia Tauro	50	Yokohama	40
Hong Kong	204	Antwerp	150	Valencia	103	Piraeus	79	Ambarli	63
Busan	311	Dalian	112	Tanjung Priok	132	Felixstowe	85	Inchon	64
Qingdao	218	Xiamen	147	Khorfakkan	33	Salalah	68		
Guangzhou	217	Hamburg	208	Algeciras	15	Port Said East	65		
Jebel Ali	189	Tanjung Pelepas	180	Jawaharlal Nehru	9	Marsaxlokk	45		

Finally, in calculating variable technical efficiency by using DEA we need the input data represented by ports super and infrastructure as well output represented by ports throughput. In using the panel data to determine ports efficiency change over time, there was a problem to find the exact amount of equipment for every year for the study port. Therefore, we assume that the existing figures were constant in these ports during the study period knowing that span time for container terminals equipment is between 10 years for SCs and 25 years for the RMGs and thus the probability of finding dramatically changes in these equipment numbers in any port during a 5 years' study period would be very rare.

5.2.2. Descriptive statistics of cross-section data

This study depended on the cross-sectional data for the year 2016 published on the Containerization International Year Book 2017 to get the trustworthiness results. Moreover, the other data were gathered from ports official websites besides container ports publicity booklets then revised into the data for the analysis to surge the precision of information.

Descriptive statistics for the DEA variables estimation are presented in the table (5-3). The selected output variables in the study ports are with high dispersion in which the standard deviation reached 8,066800 TEUs for the throughput values for 2016. Moreover, the skewness and kurtosis reach positive 3 and 11.2 respectively for the total areas input. But the rest of the inputs are showing acceptable values not exceeding three for the skewness and kurtosis.

Table 5-3 Descriptive statistics of cross-sectional data inputs and output variables for the year (2016).

	Quay Length (m)	Max Depth (m)	Total Area (ha)	Gantry Cranes	Yard equipment	Dev. Dist. (nm)	Throughput (000) (2016)
Min.	1600.0	12.0	31.6	16.0	27.9	1.0	2679.0
Max.	19173.0	22.0	2454.0	223.0	425.6	1658.0	37132.0
Range	17573.0	10.0	2422.4	207.0	397.7	1657.0	34453.0
Mean	6301.5	16.6	389.5	59.9	149.6	354.1	9565.6
Std. Dev.	4375.7	1.9	441.6	45.1	107.3	415.9	8066.8
Skewness	1.2	0.4	3.0	1.6	1.2	1.3	1.6
Kurtosis	0.9	0.9	11.3	2.9	0.7	0.9	2.5
Number of DMUs	42	42	42	42	42	42	42

For ensuring better discrimination between DMUs it is preferable to use fewer input values. Therefore, some inputs could be excluded from the frontier analyses. The best practice to identify the inputs that should be excluded is by knowing the relative correlation coefficient between inputs, this was performed by calculating the relative coefficient between every two inputs in the study as shown in the table (5-4). After finding the strength of the relationship between each and every two inputs then one of the strongly correlated inputs could be excluded from the frontier analyses to reduce the number of inputs.

Table (5- 4) clearly show that the highest correlation is between yard equipment and gantry cranes giving 92% and between gantry Crane with quay length giving 0.89 as well as between yard equipment and quay length giving 0.87. Moreover, the lowest correlations are between the deviation distance and all inputs with poor negative values.

Table 5-4 **Correlation between inputs**

Input Variables	Quay Length	Max. Depth	Total Area	Gantry Crain	Yard equipment	Dev. Distance
Quay Length	1					
Max. Depth	0.34	1				
Total Area	0.74	0.35	1			
Gantry Crain	0.89	0.37	0.64	1		
Yard equipment	0.86	0.41	0.69	0.92	1	
Dev. Distance	-0.08	-0.19	-0.18	-0.20	-0.27	1

5.2.2.1. Ports Throughput

The throughput of ports is very important in determine ports efficiency as it is used in many types of research as output values in calculating ports technical efficiency by using DEA methods. Therefore, the study ports throughput for the study period between 2011 till 2016 is presented in the appendix (5-2). This panel data will be very important in identifying the change in relative technical efficiency during the study period

The next section will be benchmarking the technical efficiency of the selected ports. The DEA-CCR model is adopted to assess the aggregate technical efficiency under (CRS), also the DEA-BCC model will be used to assess the pure technical efficiency under the (VRS), also the super efficiency (SE) will be assessed among the efficient ports

5.3. Ports relative technical efficiency

Assessment Ports on their throughput or technological operation or inventions are not always accurate as the efficiency of operation should be a very important indicator on assessing ports production as it indicates how ports resources are efficiently performing (Wang et al, 2005). In this research, the Banxia Frontier analyst software was used to solve the DEA models. Two types of DEA models, that is the CCR besides BCC models of cross-sectional and panel data analysis, were take on to analyse the selected container ports relative technical efficiency in the East-West trade route. DEA-CCR model with a supposition of constant returns to scale offers information on the aggregate technical efficiency including pure technical as well as scale efficiency, whereas, DEA-BCC model with the supposition of VRS to identifies alone technical efficiency as well as it was used also to calculate the super efficiency (SE).

DEA models be able to distinguish the type of orientation whether it is the input- or output-oriented. The input-oriented is normally linked to operational as well as managerial decisions, whereas output oriented is further associated to macroeconomic strategies and planning. Both orientations have their importance in the industry of container port. For instance, building new terminals, ports should know if the existing port's facilities are fully used and that productivity has been maximized throughout the given the input. From that prospective, the output-oriented model offers a benchmark for the container industry in the regional or global area of study. Finally, input-oriented models have been chosen to fill the gaps and fulfil this research main objective. To find inputs efficiency lacks then selected ports by cooperate with each other’s accordingly.

5.3.1. Cross section relative technical efficiency for the year 2016.

Ports efficiency is normally associated with ports performance and productivity as well. Nevertheless, relying only on these factors will mislead the judgment as there are other elements to be considered. The production organizational side, such as how ports are efficiently using its resources or inputs to generate its outputs is very important in analyzing port efficiency. Moreover, identifying the relative efficiency is very important in this context as it could help in ranking ports in term of efficiency among each other’s.

The Banxia Frontier analyst software is used to solve the DEA models of cross-sectional and panel data were used to analyze the efficiency of the top 50 container ports in the world in the East-West trade route. efficient ports or super-efficient with efficiency 100% and above as well as the inefficient ports that need improvement in their relative efficiency will be presented in the next sections all for the year 2016.

5.3.1.1. Efficient ports

Efficient ports in the relative efficiency studies are very important as they act as a datum to the rest of the inefficient ports, thus identifying them and knowing for how many ports they are used as reference port in the DEA models is important. The Reference Set Frequency shows how many times a given efficient port has been counted as a reference port for the inefficient ports. The higher the frequency with which an efficient port performs in reference sets the most likely it is a standard of good performance. Efficient ports which appear in limited reference sets are expected to have an uncommon combination of inputs and outputs and as such are not likely to offer the best example for inefficient ports to follow. The efficient unit which performs in many reference sets can be called the "Global Leader" as well as should offer an example of a good model for inefficient ports to follow (Bill, et al, 1997)

Table 5-5 Efficient ports in the top container ports in the East-West trade route in 2016

	Port	CCR-CRS	R. P	BCC-VRS	R. P	SE-VRS	R. P
1	Singapore	100%	5	100%	9	1000%	12
2	Shanghai	100%	29	100%	8	1000%	15
3	Keelung	100%	2	100%	11	244%	13
4	Port Said East	83%	0	100%	12	167%	17
5	Algeciras	100%	5	100%	4	162%	6
6	Tanger	75%	0	100%	5	149%	11
7	Khorfakkan	100%	6	100%	6	148%	10
8	Saigon port	100%	14	100%	18	138%	22
9	Busan	100%	9	100%	3	130%	2
10	Hong Kong	100%	1	100%	3	128%	3
11	Tianjin	100%	6	100%	2	116%	2
12	Qingdao	100%	9	100%	1	114%	1
13	Bremerhaven	88%	0	100%	1	110%	0
14	Gioia Tauro	67%	0	100%	1	106%	1
15	Ambarli	69%	0	100%	1	106%	0
16	Guangzhou	100%	3	100%	1	104%	2
17	Jawaharlal Nehru	76%	0	100%	3	104%	4
18	Saigon new port	92%	0	100%	1	101%	1
19	Marsaxlokk	63%	0	100%	1	100%	1

Table (5-5) demonstrates the efficiency scores for the cross-sectional data of the 42 ports in the study area. Nearly 25% of them represented by 11 ports can be classified as efficient ports when using the CCR-CRS model. This percentage of efficient ports increase to reach nearly 45% with 19 efficient ports when using the BCC-VRS model. The top-ranked ports in efficiency are Singapore and Shanghai which bath shows significant results in using the CCR, BCC and SE models. On the other hand, Marsaxlokk was 65% efficient in the aggregate efficiency while it shows 100% efficiency results in the pure technical efficiency model (BCC). Shanghai port was the most frequently used port as a reference in assessing the efficiency of other ports as it was used as reference port in the CCR, BCC and SE models for 29,8 and 15 times respectively. Also, Vietnam's port Saigon port was among the highest ports to be referenced especially in the SE model as it referenced 22 ports and 18 for the BCC model and 14for the CCR model. On the other hand, Bremerhaven was referenced only for one port in the BCC model and zero times for the rest of the models.

5.3.1.2. Super efficiency (A&S) analysis

DEA models either CCR - CRS or BCC - VRS can identify container ports to be either efficient or inefficient DMUs, but it is difficult to verify the relative rankings between the efficient DMUs with relative efficiency equal to 100%. In this research, we are experiencing 19 ports with relative efficiency 100% in which it is difficult to determine the most efficient ports and to categorize these ports in relation to each other. In order to solve such problem, reinforce the discriminatory power of the DEA-CCR model and to determine the rank of each container port in terms of technical efficiency, the research uses the DEA-CCR (CRS), A&P, Super-Efficiency scores in an input-oriented model.

Table (5-5) show the DEA-CCR cross-sectional super efficiency scores for 2016 for the 19 efficient ports. Singapore and Shanghai ports are the most efficient ports among all efficient ports while Saigon new port and Marsaxlokk ports are the least efficient ports among efficient ports.

5.3.1.3. Inefficient ports

Identifying the inefficient ports in this study is very important as it determining the ports that need improvement in utilizing its inputs and increase efficiency. Moreover, these ports will be the scope of building port clusters to perform co-opetition. Table (5-6) present results of the DEA-CCR model with a supposition of CRS as well as a DEA-BCC model with the supposition of VRT.

Table 5-6 Inefficient ports in the top container ports in the East-West trade route in 2016

	Port	CCR-CRS	BCC-VRS	Scale efficiency	Returns to scale
1	Tanjung Pelepas	0.997	0.997	1.00	DRS
2	Hamburg	0.730	0.995	0.87	IRS
3	Port Kelang	0.931	0.963	0.97	IRS
4	Yokohama	0.492	0.956	0.51	IRS
5	Tanjung Priok	0.610	0.930	0.66	IRS
6	Piraeus	0.582	0.926	0.63	IRS
7	Inchon	0.451	0.925	0.49	IRS
8	Xiamen	0.715	0.924	0.77	IRS
9	Manila	0.589	0.923	0.64	IRS
10	Kaohsiung	0.801	0.921	0.87	IRS
11	Kobe	0.381	0.916	0.42	IRS
12	Salalah	0.565	0.915	0.62	IRS
13	Jeddah	0.634	0.912	0.70	IRS
14	Shenzhen	0.664	0.905	0.73	IRS
15	Jebel Ali	0.659	0.879	0.75	IRS
16	Laem Chabang	0.758	0.858	0.88	IRS
17	Felixstowe	0.441	0.855	0.52	IRS
18	Valencia	0.556	0.845	0.66	IRS
19	Antwerp	0.535	0.839	0.64	IRS
20	Dalian	0.819	0.826	0.99	IRS
21	Ningbo	0.803	0.817	0.98	IRS
22	Rotterdam	0.417	0.708	0.59	IRS
23	Keihin	0.244	0.609	0.40	IRS

It is clear that all the ports are having an increase return to scale except a single port which is "Tanjung Pelepas" which has a decreasing return to scale. Moreover, this port is the best efficient port among all inefficient ports. Kobe and Keihin ports are the least efficient ports when using the aggregate technical efficiency as they perform by 0.38 and 0.24 respectively, but when measuring the pure technical efficiency Kobe port shows efficiency exceeded to 0.91 while Keihin port still in the last position by 0.6 after port of Rotterdam. Hamburg port shows noticeable improvement in its pure efficiency figures that nearly reached 1 while it shows only 0.7 in its aggregate efficiency. Dalian, Kaohsiung and Ningbo ports are having nearly the same efficiency when using both the pure and aggregate technical efficiency models. In general, pure technical efficiency results are showing only 9 ports with efficiency less than 0.9 with 7 of them having efficiency more than 0.8.

5.3.1.4. Scale efficiency

A scale efficiency assessing was used to show the quantity by which production could be developed by shifting to the technically optimal productive scale (TOPS) point. (Coelli et al. 2005). Size of ports is not always relevant in assessing ports relative efficiency. Smaller ports can produce outputs with the same ratios of inputs to outputs as bigger ones. This is due to the absence of economies or diseconomies of scale present, as doubling the inputs will produce a doubling of outputs. However, this hypothesis is incorrect for services which have the economy of scale. Therefore, ports that have the economy of scale (or increasing return to scale) can produce more than double of outputs when only doubling the inputs, and controversy ports that can produce less than double of outputs when doubling the inputs should have diseconomy of scale (or decrease return to scale).

For the calculation of scale efficiency, this research applied the method suggested by Coelli et al. (1998). scale efficiency (SE) of the port can be measured as:

$$[\ CCR / BCC]$$

if SE = 1 infers scale efficiency besides SE > 1 indicates scale inefficiency. The scores of scale efficiency are limited between 1 and ∞. Nevertheless, scale inefficiency can be according to the existence of either IRS or DRS. To identify the type of return to scale (RTS), first the CCR- CRS efficiency score is related with BCC- VRS efficiency scores. For certain port, if the BCC- VRS score matches the CCR- CRS score, this port is considered to be operating in a constant return to scale (CRS). On the contrary, if the scores are unequal, more step is needed to determine whether the port is performing at IRS or DRS. This is done by running the non-increasing returns to scale (NIRS) DEA model. (Coelli et al. 1998).

The incompetent ports scale efficiency is presented in figure (5-1) and it is clear that Tanjung Pelepas port is operating in the highest scale efficiency while Keihin port is the least scale efficiency port. Moreover, table (5-6) shows the 23 inefficient ports and their scale efficiency and either they have an IRS or DRS. It is clear that the inefficient ports are only having Tanjung Pelepas which has DRS while all the rest are with IRS. For all the ports that practice an operational IRS could achieve significant gain efficiency throughout operational scale increase. The scale could be changed with inputs increase or sector consolidation. On the other hand, ports that shows operational DRS, more inputs increase would only effects in a smaller comparative rise of outputs. Moreover, ports that show efficient values when obtaining the BCC-VRS model and shows inefficient values when applying the CCR-CRS model are presented in table (5-7). It is clear that all ports are showing IRS.

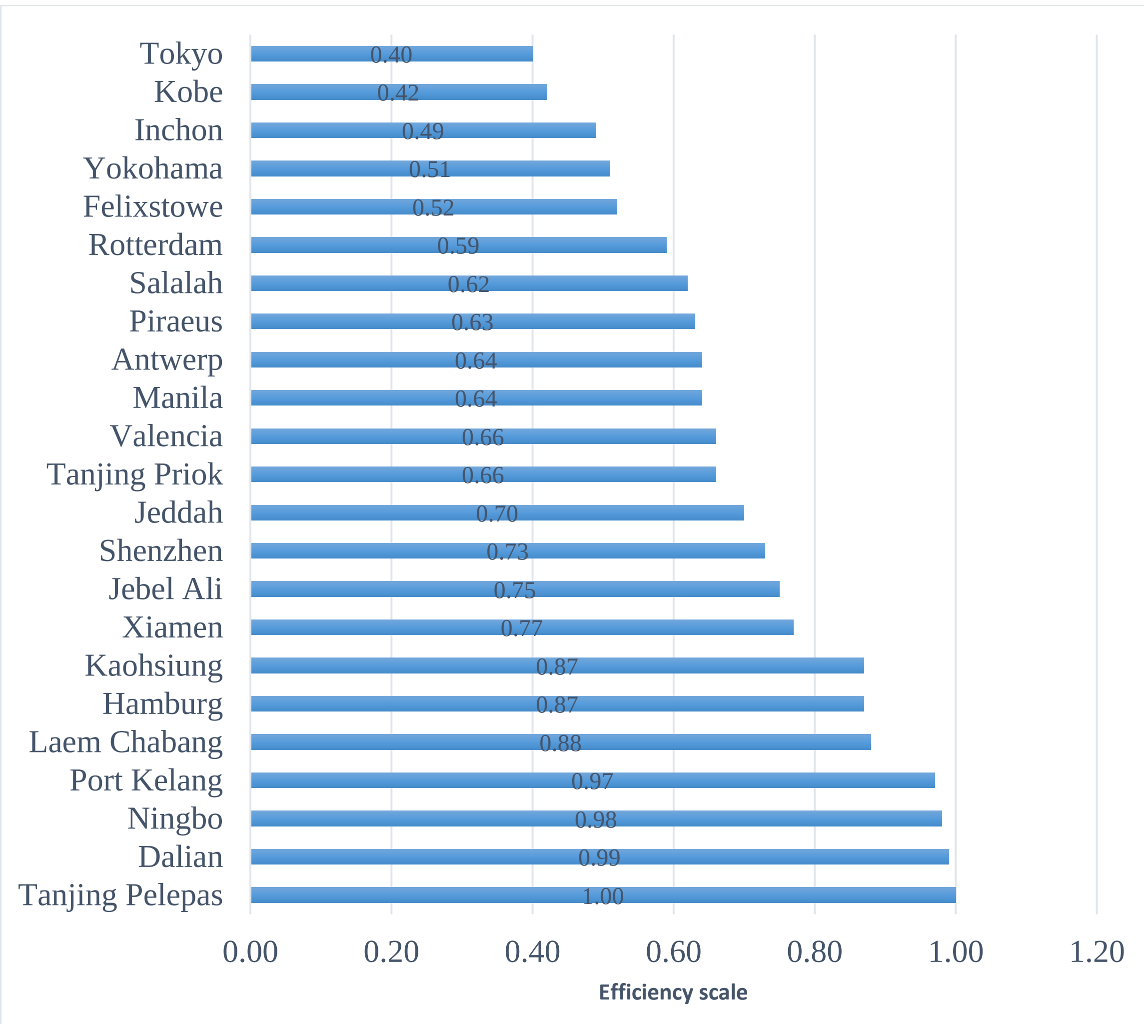

Figure 5-1 Scale efficiency of inefficient container ports in the East-West trade route

Moreover, the results in a table (5-7) show that 8 efficient ports with 19 % are working at most productive scale size with IRS. Furthermore, 30 ports with 71 % are operating under their optimum scale, therefore, experiencing IRS. The policy suggestion of this result is that such ports can improve operational technical efficiency (OTE) by growing their size. The remaining port have been observed to be operating with DRS, therefore, economizing seems to be an appropriate strategic choice for this port.

Table 5-7 Efficient ports scale efficiency

	Port	CCR-CRS	BCC-VRS	Scale efficiency	Returns to scale
4	Port Said East	0.830	1.000	0.83	IRS
6	Tanger	0.750	1.000	0.75	IRS
13	Bremerhaven	0.880	1.000	0.88	IRS
14	Gioia Tauro	0.670	1.000	0.67	IRS
15	Ambarli	0.690	1.000	0.69	IRS
17	Jawaharlal Nehru	0.760	1.000	0.76	IRS
18	Saigon new port	0.920	1.000	0.92	IRS
19	Marsaxlokk	0.630	1.000	0.63	IRS

To sum up, one of the ports main targets is to operate at maximum optimum scale size with CRS in order to minimalize costs and maximize revenue. ports may operate in the area of IRS or DRS in the short run. Nevertheless, in the long run, they should shift towards CRS by becoming either larger or smaller to continue in this competitive market. This strategy could be by changes in ports operational approach in terms of scaling up or down of their size.

Furthermore, economies of scale results analyses should be with caution due to the inconsistent investment in port infrastructure (Wang et al, 2005; Cullinane et al, 2006). Highly capital Investments are rarely made and, with an objective to provide future growth in port's demand, repeatedly have the influence of growing capacity more than ports current needs especially for large ports, rather than for smaller ports. Thus, ports often design their capacity and additional investments to be higher than its current market demand, even if port traffic increases gradually over time. Therefore, this should be accounted as a possible limitation of some cross-sectional analysis besides offers support for methods made on panel data that might capture the dynamics linked to the features of the port industry (Cullinane & Wang, 2006).

Practically, increasing or decreasing return to scale is a strategic investment decision as for ports with increase return to scale more investments should be obtained to increase port outputs. On the other hand, ports that have constant or reduce the return to scale should postponed investment plans and limit expansions in their inputs because the return on these investments will be a little bit slow.

5.4. Window analysis of relative technical efficiency

Evaluating the progress of technical relative efficiency is important through analyzing port efficiency trend over the study period. Window analysis offers the assessment of the "steadiness" of efficiency inside windows by the "column view" adoption. By using this insight, it is conceivable to detect that the DMU efficiency within the different windows could similarly vary significantly. The study of "stability & trend" in window analysis reveals both the relative efficiency of a port in judgement to the rest of ports in the sample and the absolute efficiency of a port over time (Cullinane & Wang, 2007).

It is preferable to select the window width to match the standard technological changes cycles or innovations to ensure that the efficiency scores reflect solely the difference between the actual port production level and the best coexistent level of production (Wang et al, 2002). However, in practice, technological innovations and technological changes are not commonly noticed to enable researchers to draw an exact innovation time cycle within the port industry. Therefore, many types of research similar to this kind of research found it difficult to find a concrete reasoning for the selection of window size (Cullinane & Wang, 2010).

Accordingly, the length of the window used in this research is defined as one cycle of the present average cycle of the shipping and port market (Stopford, 2009). Moreover, this period was selected to avoid the effect of the world economic crises in 2008 as the economy in crises effects the consumption as well as production, therefore, the demand for transport to fall. Taking this time into justification as the beginning of a new shipping cycle (Sanchez, 2017).

Table (5-8) shows the relative technical efficiency (DEA-BCC) for the 42 ports from 2011 till 2016. It is clear that 15 ports are efficient with scores 100% in the study period and 2 ports are considered as efficient ports with inconsistent efficiency scores during the whole study period which is Hamburg and Tanjung Pelepas. During the study period, 3 ports have turned out from inefficient ports to efficient ports which are Saigon new port and Guangzhou that shifted from 90% technical efficient to 100% while Qingdao port efficiency increased from 82% till 100% in the same period. On the same hand, the rest of ports show inefficient scores and failed to reach the optimum use of their inputs during that period, moreover, Keihin port continued to be in the last efficiency ranked scores during the study period with a sustained score of 61% efficiency.

Table 5-8 Window analysis of relative technical efficiency from 2011 to 2016

s/n	port	Relative technical efficiency scores (DEA-BCC)					
		2011	2012	2013	2014	2015	2016
1	Algeciras	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
2	Ambarli	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
3	Bremerhaven	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
4	Busan	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
5	Gioia Tauro	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
6	Hong Kong	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
7	Jawaharlal Nehru	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
8	Keelung	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
9	Port Said East	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
10	Singapore	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
11	Saigon port	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
12	Shanghai	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
13	Tanger	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
14	Tianjin	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
15	khorfakkan	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
16	Marsaxlokk	100.0%	100.0%	100.0%	99.6%	100.0%	100.0%
17	Hamburg	100.0%	99.7%	99.6%	99.6%	99.5%	99.5%
18	Tanjung Pelepas	100.0%	99.7%	95.1%	100.0%	100.0%	99.7%
19	Yokohama	95.6%	95.6%	95.6%	95.6%	95.6%	95.6%
20	Guangzhou	89.9%	90.6%	96.1%	97.1%	98.4%	100.0%
21	Tanjung Priok	96.9%	98.3%	96.4%	93.0%	93.0%	93.0%

s/n	port	Relative technical efficiency scores (DEA-BCC)					
		2011	2012	2013	2014	2015	2016
22	Saigon new port	90.7%	90.7%	91.5%	94.0%	95.5%	100.0%
23	Salalah	93.6%	96.0%	92.6%	91.5%	91.5%	91.5%
24	Jeddah	91.6%	97.8%	92.3%	91.3%	91.5%	91.2%
25	Inchon	92.5%	92.5%	92.5%	92.5%	92.5%	92.5%
26	Qingdao	81.9%	85.6%	90.4%	96.1%	100.0%	100.0%
27	Manila	92.3%	92.3%	92.3%	92.3%	92.3%	92.3%
28	Kobe	91.6%	91.6%	91.6%	91.6%	91.6%	91.6%
29	Kaohsiung	89.9%	90.3%	90.4%	91.4%	92.2%	92.1%
30	Xiamen	89.8%	90.2%	90.5%	90.5%	91.9%	92.4%
31	Port Kelang	87.7%	87.9%	87.9%	87.9%	91.4%	96.3%
32	Shenzhen	86.6%	88.1%	89.4%	90.3%	91.1%	90.5%
33	Jebel Ali	85.4%	86.0%	87.0%	88.3%	88.1%	87.9%
34	Piraeus	85.2%	86.6%	86.8%	86.5%	86.6%	87.2%
35	Dalian	75.2%	79.9%	94.7%	97.4%	84.8%	82.6%
36	Felixstowe	85.5%	85.5%	85.5%	85.5%	85.5%	85.5%
37	Valencia	84.6%	84.7%	84.3%	83.7%	83.7%	84.5%
38	Laem Chabang	82.5%	83.9%	84.2%	83.8%	84.6%	85.8%
39	Antwerp	82.6%	82.4%	82.1%	81.6%	83.6%	83.9%
40	Ningbo	61.1%	65.3%	69.0%	76.8%	79.3%	81.7%
41	Rotterdam	71.5%	71.0%	70.6%	70.4%	70.8%	70.8%
42	Keihin	61.4%	60.9%	60.9%	60.9%	60.9%	60.9%

Table 5-9 Descriptive statistics of panel data

Year	2011	2012	2013	2014	2015	2016
Mean	91.6%	92.2%	92.6%	93.1%	93.2%	93.5%
standard dev.	0.101	0.097	0.090	0.087	0.086	0.086
Min	61.1%	60.9%	60.9%	60.9%	60.9%	60.9%

Table (5-9) shows the descriptive statistics of panel data for the study ports in the selected years which indicates the overall progress of the ports within the period from 2011 to 2016. It is clear that the mean of ports efficiency scores is showing a continuous increase in the which is a result of the increase of ports throughput during the study period. Moreover, the standard deviation is in a continuous decrease for its yearly bases calculation which indicates that the gaps between ports technical efficiency are closing and ports are becoming more and more competitively efficient. In nutshell, we can conclude that the port industry is improving and less efficient ports should exert more and more effort to increase its relative technical efficiency.

5.4.1. Malmquist Index

Malmquist Analysis is used to measure DMUs over time efficiency change. The Malmquist index represents the change in a unit's efficiency over a period of time. This index is the product of two terms - a "frontier shift" term and a "catch-up" term. It is the product of the frontier shift and the catch-up values of ports over the study period from 2011 till 2016. The “catch-up” value is the change over time of every port efficiency compared to the rest of ports, in other words, the change in distance between the frontier and the unit. The “frontier shift” is the change in efficiency of the whole ports in the study, the degree to which the context has changed as a result of Technological change new inventions, operational pattern etc. in other words, how far the port was from the frontier at 2011 versus how far it was from the frontier at 2016.

Simply Malmquist Indices can be explained as three output columns:

- **Catch-up**

- If the Catch-up >1, the unit has got closer to the frontier over that period of time
- If the Catch-up < 1, the unit has got further from the frontier, i.e., less efficient.
- A catch-up value of 1 means that the unit has not moved relative to the frontier over that period of time.

- **Frontier Shift**

The efficiency change across the whole industry

- **Malmquist Index (MI)**

- MI = 1, no change in efficiency
- MI < 1, Decrease in efficiency

- MI > 1 Increase in efficiency

Table (5-10) shows the progress in the study ports relative efficiency for the study period from 2011 till 2016. This progress is represented by the average change of the Malmquist index for the 42 ports, it is clear that there is no significant change in all the ports relative efficiency as most of them are nearly very close to one. This could be a result of the relatively small study period as well as the scale and ranking of these ports as top ports worldwide. It is clear that the Chinese ports Ningbo and Dalian are the first and second ports with increasing relative efficiency while Bremerhaven and Hong Kong are the least in improving their relative efficiency.

Table 5-10 Average Malmquist index from 2011 to 2016

Rank	port	Malmquist index	Catchup	Frontier shift
1	Ningbo	1.064	1.061	1.004
2	Dalian	1.050	1.024	1.027
3	Guangzhou	1.044	1.022	1.022
4	Saigon port	1.041	1.000	1.041
5	Qingdao	1.041	1.041	1.000
6	khorphakan	1.041	1.000	1.041
7	Tianjin	1.039	1.000	1.039
8	Saigon new port	1.035	1.020	1.015
9	Busan	1.031	1.000	1.031
10	Algeciras	1.029	1.000	1.029
11	Tanger	1.023	1.000	1.023
12	Ambarli	1.019	1.000	1.019
13	Tanjung Pelepas	1.018	1.000	1.018
14	Keelung	1.017	1.000	1.017
15	Port Kelang	1.017	1.019	0.998
16	Laem Chabang	1.015	1.008	1.007
17	Piraeus	1.010	1.005	1.005
18	Port Said East	1.010	1.000	1.010
19	Gioia Tauro	1.009	1.000	1.009

Rank	port	Malmquist index	Catchup	Frontier shift
20	Jebel Ali	1.008	1.006	1.002
21	Jeddah	1.008	1.000	1.008
22	Marsaxlokk	1.007	1.000	1.007
23	Xiamen	1.007	1.006	1.001
24	Shanghai	1.006	1.000	1.006
25	Antwerp	1.005	1.003	1.002
26	Kaohsiung	1.004	1.005	0.999
27	Shenzhen	1.004	1.009	0.995
28	Valencia	1.003	1.000	1.003
29	Jawaharlal Nehru	1.002	1.000	1.002
30	Felixstowe	1.002	1.000	1.002
31	Rotterdam	1.001	0.998	1.003
32	Singapore	1.001	1.000	1.001
33	Salalah	1.000	0.996	1.005
34	Inchon	1.000	1.000	1.000
35	Manila	1.000	1.000	1.000
36	Yokohama	1.000	1.000	1.000
37	Kobe	1.000	1.000	1.000
38	Hamburg	1.000	0.999	1.001
39	Keihin	1.000	0.999	1.001
40	Tanjung Priok	0.996	0.992	1.005
41	Bremerhaven	0.992	1.000	0.992
42	Hong Kong	0.944	1.000	0.944

5.5. Sensitivity analysis

Sensitivity analyses are to find out the degree of contribution of each variable to ports efficiency using the DEA-CCR efficiency scores. This method is performed by testing how efficiency scores will be affected after eliminating one input. Therefore, a repetitive possess of DEA-CCR score calculation will be done wherein every time one input will be eliminated. In this research we cannot eliminate the output values as we are only using one output value, knowing that this method can also be performed by eliminating output if we are having more than one output. In order to deeply explain the results, we should first analyse the comprehensive observations of the results than analyze the results of the efficient ports as well as the scores of the inefficient ones. Finally, every input of input will be individually analyzed to identify its effect on study ports efficiency.

Appendix (5-3) shows that in general, we are having 12 efficient ports and 30 inefficient ports when using all input without eliminating any of them. Moreover, all ports did not show any improvement in efficiency when eliminating any input in the sense that all ports are having its best efficiency when considering all 6 inputs. Efficient ports relative efficiency did not show any change when removing Quay length or maximum depth inputs as they continued to show 100% efficiency. Yard equipment elimination only affected one port (Khorfakkan port) and reduced its efficiency by 6%, showing its relative efficiency by 96% and removed it from the efficient ports category. The gantry cranes affected 2 ports while the Total area and the deviation distance affected 4 ports and removed them from the efficient ports category. Only two ports were unaffected when eliminating one input which is Shanghai and Saigon port, this could indicate the efficiency strength of these ports, while on the other hand, Tanjung Pelepas shows a very sensitive efficiency score as it shows inefficient results under the elimination case of 3 inputs.

Among all the inefficient ports, it is clear that only one port did not show any change in its efficiency when any input was removed which is Keihin port that maintain its ranking position at the very last in the list with no sensitivity to any input, while efficiency of Shenzhen port and Yokohama port were slightly sensitive to only one input as the efficiency of the first decreased by 2% when eliminating the maximum depth input factor and the second port experience reduction by 1%. When eliminating the Gantry cranes input. Moreover, nearly 50% of the ports represented by 20 ports are sensitive to 2 inputs and 7 inefficient ports are sensitive to 3 inputs.

Quay length elimination affected 7 ports all belong to the inefficient ports category. A slight effect was made to 3 ports in which their efficiency reduced only by 1% which are Dalian, Manilla and Salalah. The remaining 4 ports port Kelang lost 15% of its efficiency and showed 78%. Jawaharlal Nehru lost 10% and showed 66%, Laem Chabang lost 9% and showed 67% and finally, Tanjung Priok lost 9% and reached 52% of relative technical efficiency.

Maximum depth showed the least effective factor in benchmarking ports relative technical efficiency as only 2 ports showed a reduction in their level of technical efficiency when eliminating the maximum depth. These ports are Shenzhen and Jebel Ali in which the first showed 64% and the second showed 65% by a reduction of 2% and 1% respectively.

Total area input affected 16 ports and caused 4 efficient ports to become inefficient. Nevertheless, it dramatically deducts 31% from Keelung port leaving it with 69% efficiency and if this input was not accounted from the beginning Keelung port would fall among the least efficient ports in the study. Moreover, the rest of the ports are sensitive to this input shows an effect between 14 % to 1% reduction in their relative technical efficiency.

Gantry cranes input is considered as the most effective input in the study ports technical relative efficiency scores, as 24 ports are sensitive to the number of gantry cranes in their ports. This input contributes strongly in the efficiency of 3 ports in the efficient ports category in which one of them relays strongly on the count of its gantry cranes which is Tianjin port as it lost nearly 1/3 of its efficiency when eliminating gantry cranes from the calculation to reach 63% relative efficiency score. While Guangzhou port lost 17% of its score and reached 83% technical efficiency. Moreover, Rotterdam port is also sensitively affected with this input and reached 29% if gantry grains input was not considered in the calculation of DEA-CCR model.

Yard equipment slightly affected ports technical efficiency, although it reduced the efficiency of 11 ports but with a little effect between 16% and 3% reduction in their efficiency. It reduced the efficiency of khorfakkan port by 6% and was the only input that affected this port and removes it from the efficient ports category. While the rest of the ports sensitivity to this input is affected slightly with no remarkable scores.

Deviation distance input which is the only uncontrolled input as it was considered as the environmental inputs that could affect efficiency indirectly, shows an effect to 15 ports and remarkably improved the relative technical efficiency of them. It is clear that it is the reason of marking 4 ports as efficient ports as it contributes to increasing the efficiency of Singapore port by 19%, Algeciras and Busan by 17% and for Tanjung Pelepas it increases 37% of its relative efficiency. It is clear that the deviation distance inputs are having a remarkable effect on ports positioning on the main trade route and contributes significantly on their relative technical efficiency scores, for example, Bremerhaven, Singapore, Port Kelang, the port said, Port Kelang etc…

On the other hand, ports away from the main trade route are less efficient to the deviation distance input.

5.6. Ports potential improvement identification by using slack variable analysis

DEA models are powerful in identifying the reasons for inefficiency in each DMUs, as it provides the deficiency in every input or output represented by its increase or decrease percentage to meet its referenced efficient DMUs. Ports that shows inefficient scores benefit from the potential improvement figure in prioritizing the investment plan in resources or selected inputs, in other words, inputs that present the highest negative percentages should be the least to inject investments in as their effect on improving efficiency will be the least among other inputs. similarly, in this research increasing efficiency will be by reducing some of the ports inputs. Practically ports always invest in their infra and superstructure to meet the future demands of the port, country and region as well as to meet port's peak time traffic to avoid congestion.

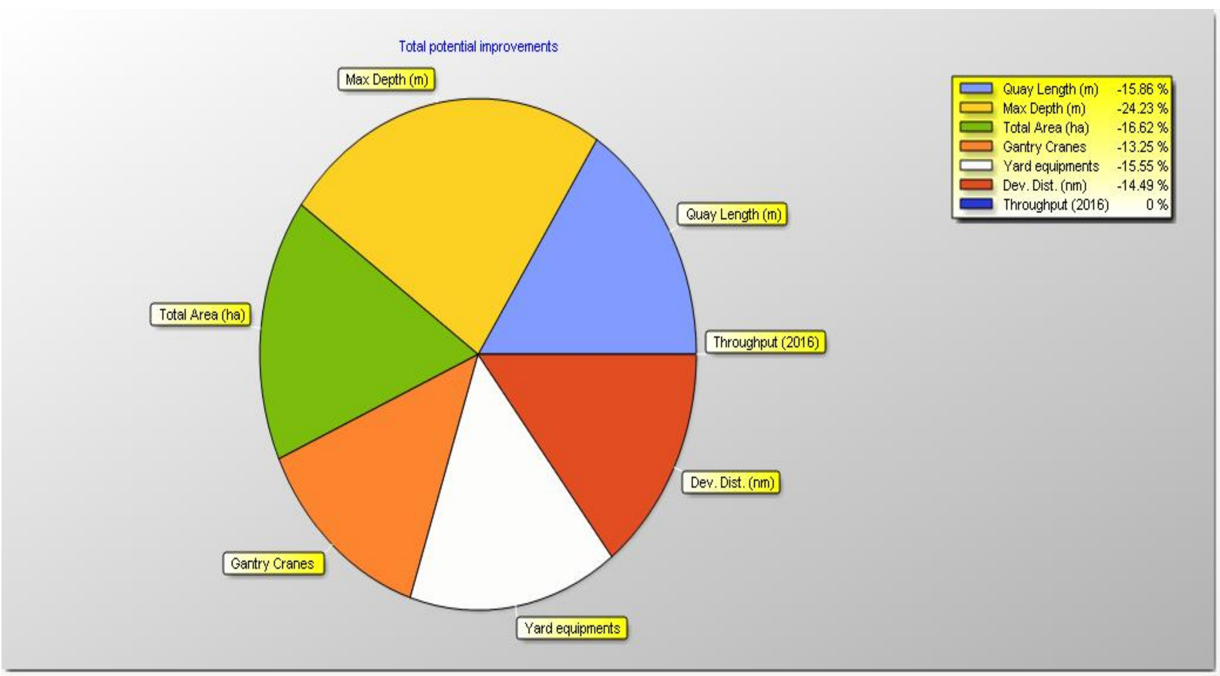

Figure 5-2 Summary of all ports potential improvement

Moreover, it is not easy for any port to give up some of its resources for the favour of increasing technical efficiency, but this highlights the need of utilizing this surplus in inputs by cooperating with other ports that lack such input.

Table 5-11 Total number of ports and their potential inputs improvement % in different models

Variable	Model	No. of ports and their improvement (-)% under different models									
		00 to 10%	11% to 20%	21% to 10%	31% to 40%	41% to 50%	51% to 60%	61% to 70%	71% to 80%	81% to 90%	91% to 100%
Quay Length	CCR-CRS	12	3	4	5	7	3	4	2	2	0
	BCC-VRS	23	3	8	3	2	2	0	1	0	0
	SE-VRS	13	3	10	6	6	2	1	1	0	0
Max. Depth	CCR-CRS	13	0	1	2	1	1	6	11	6	1
	BCC-VRS	31	8	1	1	1	0	0	0	0	0
	SE-VRS	23	14	2	2	1	0	0	0	0	0
Total Area	CCR-CRS	13	1	5	3	9	5	3	1	1	1
	BCC-VRS	23	4	2	4	3	3	1	0	2	0
	SE-VRS	11	7	4	5	7	3	2	0	2	0
Gantry Crain	CCR-CRS	13	3	6	8	4	5	2	1	0	0
	BCC-VRS	24	5	5	6	1	0	1	0	0	0
	SE-VRS	13	9	9	7	2	0	2	0	0	0
Yard equipmen t	CCR-CRS	12	2	4	6	8	6	2	2	0	0
	BCC-VRS	23	6	5	3	4	1	0	0	0	0
	SE-VRS	14	7	9	4	6	1	1	0	0	0
Dev. Distance	CCR-CRS	26	1	0	1	1	0	0	4	2	7
	BCC-VRS	34	1	1	0	1	2	0	1	1	1
	SE-VRS	29	1	1	2	1	2	1	1	2	2

Figure (5- 2) shows the overall summary of percentages of potential improvement for the whole study ports input, in which every input need to be improved by reducing the potential improvements percentage from its existing figures. It is clear that all input variables are nearly having similar weights between -14.5% to -16.6% of potential improvement except the Maximum depth variable that should be improved by - 24.2%. In general, we can see that the potential improvement in the study ports is not significant which could be because of their selection from the top 50 ports worldwide.

Moreover, table (5-11) presents the number of ports that need improvement in every input as well as the percentage of improvement needed when using different models (CCR, BCC and SE). It is clear that the majority of ports need to improve its inputs by less than - 10% while around 25 ports need improving by more than - 50% in their max depth variable when using the CCR model, in the same hand when using the BCC model no ports need improving more than 50% for the same variable.

Accordingly, it is clear that all our inputs in this research are having nearly equally potential improvement percentages between -20.4% and -16.2% for the maximum depth and the yard equipment respectively, except the deviation distance input (uncontrolled input) which shows -10% potential improvement.

4.4.1 Slack variable analysis

DEA models provide important information relevant for inefficient terminals. The slack variable analysis offers a set of precise references to assist each incompetent port to increase its effectiveness, by reducing the resources of inputs to generate a certain output (TEU) efficiently, as we used the model with input-orientation in this study. It must be well-known that this info is described only for the incompetent terminals, and the efficient terminals tend not to deliver any slack. Figure (5-3) presents the steps that should be followed to identify the inefficient ports and find the potential improvement inputs to increase port efficiency.

In this context, this research is only having one output and six inputs, we may have at most one output shortfall and one or more inputs excesses for relatively inefficient ports. Therefore, we should show where potential efficiency improvements could be higher, providing a clear understanding of ports development strategies that retain more efficient port in the business.

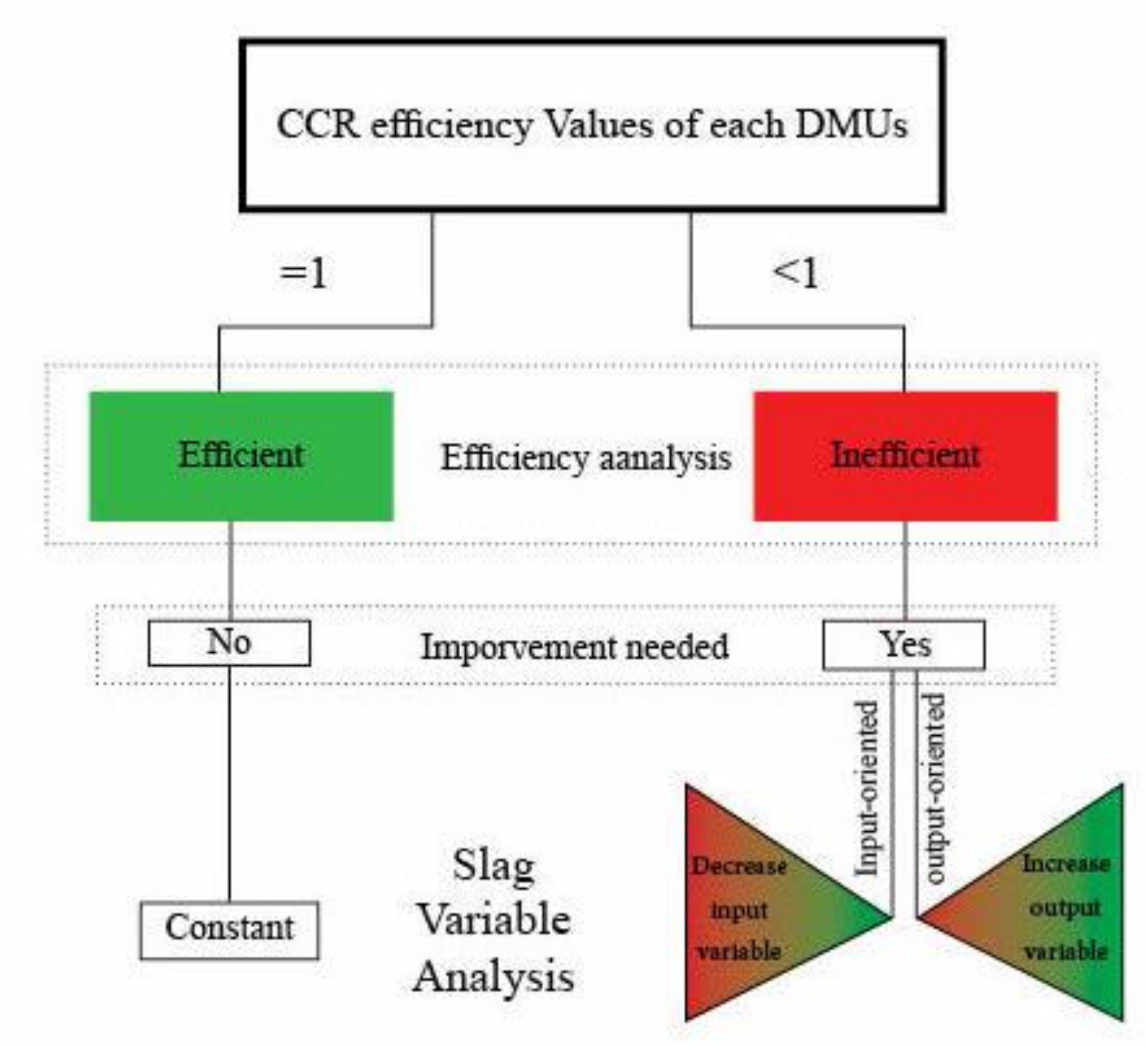

Figure 5-3 Steps of determining the potential improvement inputs by using slack variable analyses model.

5.6.1.1. Slack variable analysis DEA (CCR-CRS) model with input oriented

Among the 42 ports in this research it is clear that in the year 2016, we are experiencing 12 efficient ports under the DEA-CCR model, where the ratios of input variables to output variable were appropriate. Moreover, these ports are capable of applying their input resources effectively that led to achievement in improved efficiency. These ports are Algeciras, Busan, Guangzhou, Hong Kong, Keelung, Qingdao, Singapore, Saigon port, Shanghai, Tianjin and khorfakkan. These ports are having zero potential improvements for their inputs, therefore, they are eliminated from the table (5-12) which represent only inefficient ports except Tanjung Pelepas port which shows 100% efficiency which is actually 99.7% efficient.

On the other hand, the rest of the study ports represented in the table (5-12) by 30 ports are considered as inefficient ports that need either to increase their outputs or reduce their inputs to increase their relative efficiency scores.

Table 5-12 DEA - CCR slack variable analysis (input oriented) of main container ports in the East-West trade route in 2016

rank	Port	DEA-CCR (2016)	Throughput (2016)	Quay length (m)			Max Depth (m)			Total Area (ha)		
				Actual	Target	%	Actual	Target	%	Actual	Target	%
12	Tanjung Pelepas	100%	8013	5040	4537.14	-10	19	18	-5.3	180	179.41	-0.3
13	Port Kelang	93%	13201	8100	7542.15	-6.9	17.5	16.29	-6.9	549.1	413.7	-24.7
14	Saigon new port	92%	5987	3226	2828.66	-12.3	16	4	-75	146.75	135.26	-7.8
15	Bremerhaven	88%	5518	4930	3210.89	-34.9	16.5	3.53	-78.6	303.8	138.5	-54.4
16	Port Said East	83%	3203	2400	1806.33	-24.7	14.5	3.07	-78.8	121.5	101.29	-16.6
17	Dalian	82%	9735	5700	4669.21	-18.1	17.8	7.25	-59.2	411	228.57	-44.4
18	Ningbo	80%	21586	9500	7628.44	-19.7	22	11.24	-48.9	820	423.39	-48.4
19	Kaohsiung	80%	10465	6897	4515.19	-34.5	16.4	6.67	-59.4	371.16	244.03	-34.3
20	Jawaharlal Nehru	76%	4500	1992	1516.03	-23.9	14	4.46	-68.2	134.53	102.39	-23.9
21	Laem Chabang	76%	7430	3400	2577.74	-24.2	16	4.43	-72.3	188.49	142.91	-24.2
22	Tanger	75%	2964	1600	1030.06	-35.6	18	2.35	-86.9	80	60.13	-24.8
23	Hamburg	73%	8907	7535	5206.67	-30.9	15.3	11.17	-27	325	237.28	-27
24	Xiamen	72%	9630	6865	4197.53	-38.9	16	6.05	-62.2	648.95	222.89	-65.7
25	Ambarli	69%	2780	3200	1038.93	-67.5	16.5	3.65	-77.9	80	55.32	-30.8
26	Gioia Tauro	67%	3833	3391	1862.05	-45.1	18	2.22	-87.7	160	84.5	-47.2
27	Shenzhen	66%	23949	14590	8384.6	-42.5	17	11.29	-33.6	794.5	434.06	-45.4

rank	Port	DEA-CCR (2016)	Throughput (2016)	Quay length (m)			Max Depth (m)			Total Area (ha)		
				Actual	Target	%	Actual	Target	%	Actual	Target	%
28	Jebel Ali	66%	15736	9737	5622.48	-42.3	15.5	10.22	-34.1	670	282.78	-57.8
29	Jeddah	63%	3957	4500	2247.03	-50.1	16	3.62	-77.4	302	126.74	-58
30	Marsaxlokk	63%	3079	2483	1207.83	-51.4	17	3.44	-79.7	77.1	48.56	-37
31	Tanjung Priok	61%	4935	2800	1707.97	-39	14	3.1	-77.8	158	96.38	-39
32	Manila	59%	4427	3625	2135.01	-41.1	14	4.06	-71	217.2	111.4	-48.7
33	Piraeus	58%	3325	2204	1244.55	-43.5	18	2.2	-87.8	95	53.64	-43.5
34	Salalah	57%	5222	4310	1883.09	-56.3	16	5.12	-68	184.7	102.76	-44.4
35	Valencia	56%	3736	3300	1812.66	-45.1	19.5	5.29	-72.9	85.44	46.93	-45.1
36	Antwerp	54%	10037	11555	3521.66	-69.5	17	4.92	-71.1	1596.5	181.75	-88.6
37	Yokohama	49%	2801	3590	1195.25	-66.7	16	6.63	-58.6	144.4	46.17	-68
38	Inchon	45%	2679	2448.5	908.87	-62.9	16	3.06	-80.8	138.45	62.49	-54.9
39	Felixstowe	44%	3635	3274	1263.92	-61.4	16	3.38	-78.9	173.4	76.47	-55.9
40	Rotterdam	42%	12385	15650	4405.27	-71.9	20	6.21	-69	2454	245.91	-90
41	Kobe	38%	2801	4800	997.71	-79.2	15	1.74	-88.4	160.41	50.4	-68.6
42	Keihin	24%	4251	9310	1504.06	-83.8	20	2.02	-89.9	355.64	77.5	-78.2

Cont. Table 5-12 DEA - CCR slack variable analysis (input oriented) of main container ports in the East-West trade route in 2016

rank	Port	DEA-CCR (2016)	Throughput (2016)	Gantry Cranes			Yard equipment			Dev. Dist. (nm)		
				Actual	Target	%	Actual	Target	%	Actual	Target	%
12	Tanjung Pelepas	100%	8013	58	57.81	-0.3	180	143.41	-20.3	1	1	0
13	Port Kelang	93%	13201	93	75.22	-19.1	273.5	221.33	-19.1	1	1	0
14	Saigon new port	92%	5987	26	23.97	-7.8	59.1	54.47	-7.8	405	96.06	-76.3
15	Bremerhaven	88%	5518	41	36.11	-11.9	83	73.1	-11.9	3	3	0
16	Port Said East	83%	3203	21	17.51	-16.6	65	50.61	-22.1	1	1	0
17	Dalian	82%	9735	47	38.5	-18.1	112	91.75	-18.1	695	170.65	-75.4
18	Ningbo	80%	21586	112	89.94	-19.7	345	180.11	-47.8	113	113	0
19	Kaohsiung	80%	10465	61	48.85	-19.9	178.7	114.2	-36.1	31	31	0
20	Jawaharlal Nehru	76%	4500	27	17.66	-34.6	99.1	45.07	-54.5	468	45.01	-90.4
21	Laem Chabang	76%	7430	46	30.72	-33.2	119	63.02	-47	823	43.68	-94.7
22	Tanger	75%	2964	16	12.03	-24.8	49	27.89	-43.1	28	28	0
23	Hamburg	73%	8907	80	58.41	-27	207.7	140.68	-32.3	1	1	0
24	Xiamen	72%	9630	64	45.76	-28.5	146.7	104.9	-28.5	28	28	0
25	Ambarli	69%	2780	16	11.06	-30.8	63	34.74	-44.9	961	70.22	-92.7
26	Gioia Tauro	67%	3833	23	15.49	-32.6	50	33.68	-32.6	90	61.11	-32.1
27	Shenzhen	66%	23949	156	100.62	-35.5	425.6	191.56	-55	123	109.64	-10.9
28	Jebel Ali	66%	15736	102	66.4	-34.9	189	124.59	-34.1	1658	234.86	-85.8
29	Jeddah	63%	3957	34	21.57	-36.6	101	62.51	-38.1	1	1	0

rank	Port	DEA-CCR (2016)	Throughput (2016)	Gantry Cranes			Yard equipment			Dev. Dist. (nm)		
				Actual	Target	%	Actual	Target	%	Actual	Target	%
30	Marsaxlokk	63%	3079	21	13.23	-37	45	28.34	-37	212	126.77	-40.2
31	Tanjung Priok	61%	4935	39	20.32	-47.9	131.5	42.49	-67.7	1062	30.72	-97.1
32	Manila	59%	4427	29	17.08	-41.1	76	44.76	-41.1	308	87.86	-71.5
33	Piraeus	58%	3325	25	14.12	-43.5	68	31.7	-53.4	302	47.4	-84.3
34	Salalah	57%	5222	38	21.14	-44.4	103	55.43	-46.2	84	84	0
35	Valencia	56%	3736	37	17.95	-51.5	79.2	43.5	-45.1	224	206.22	-7.9
36	Antwerp	54%	10037	103	42.19	-59	150	80.19	-46.5	57	57	0
37	Yokohama	49%	2801	25	12.31	-50.8	40.6	19.99	-50.8	1220	321.32	-73.7
38	Inchon	45%	2679	23	10.38	-54.9	64	28.89	-54.9	496	35.53	-92.8
39	Felixstowe	44%	3635	33	14.55	-55.9	85	36.48	-57.1	43	43	0
40	Rotterdam	42%	12385	124	51.69	-58.3	409	103.15	-74.8	63	63	0
41	Kobe	38%	2801	31	11.81	-61.9	58.3	22.21	-61.9	583	37.36	-93.6
42	Keihin	24%	4251	73	17.84	-75.6	139.5	34.09	-75.6	1090	20.78	-98.1

5.6.1.2. Slack variable analysis DEA (BCC-VRS) model with input oriented

Table 5-13 Inefficient ports input potential improvement with input oriented mode

SN	Port	Controlled Inputs BCC-VRS									
		Quay Length		Max Depth		Total Area		Gantry Cranes		Yard equipment	
		m	%	M	%	Ha	%	N	%	n	%
1	Tanjung Pelepas	4537	-10%	18	-5%	179	0%	58	0%	143	-20%
2	Hamburg	5854	-22%	15	-1%	250	-23%	63	-22%	136	-35%
3	Port Kelang	7796	-4%	17	-4%	434	-21%	74	-20%	219	-20%
4	Yokohama	2554	-29%	15	-4%	83	-43%	24	-4%	39	-4%
5	Tanjung Priok	2605	-7%	13	-7%	147	-7%	26	-33%	72	-46%
6	Piraeus	2602	-21%	17	-12%	73	-7%	28	-23%	68	-15%
7	Inchon	2265	-8%	15	-8%	119	-14%	21	-8%	59	-8%
8	Xiamen	5462	-20%	15	-8%	256	-61%	59	-8%	133	-9%
9	Manila	2631	-27%	13	-8%	150	-31%	26	-11%	70	-8%
10	Kaohsiung	5214	-24%	15	-8%	253	-32%	56	-8%	126	-30%
11	Kobe	3058	-36%	14	-8%	103	-36%	28	-11%	53	-8%
12	Salalah	2017	-9%	17	-9%	87	-9%	21	-16%	57	-17%
13	Jeddah	2857	-37%	15	-9%	138	-54%	27	-22%	74	-26%
14	Shenzhen	9687	-34%	15	-10%	496	-38%	114	-27%	232	-45%
15	Jebel Ali	5352	-45%	14	-12%	341	-49%	63	-38%	63	-38%
16	Laem Chabang	2917	-14%	14	-14%	161	-15%	32	-30%	81	-32%
17	Felixstowe	2327	-29%	14	-15%	148	-15%	22	-33%	73	-15%
18	Valencia	2533	-41%	14	-16%	156	-16%	25	-34%	78	-25%
19	Antwerp	4832	-58%	14	-16%	256	-84%	53	-49%	125	-16%
20	Dalian	4499	-21%	15	-18%	225	-45%	39	-18%	93	-18%
21	Ningbo	7743	-19%	17	-22%	408	-50%	92	-18%	185	-46%
22	Rotterdam	6726	-57%	14	-29%	327	-87%	76	-39%	169	-29%
23	Keihin	2260	-76%	12	-39%	192	-46%	24	-67%	45	-39%

One of the main objectives of this research is to identify the inefficient ports in relative to the study ports and to try to analyses the weaknesses or the reasons for their inefficiency. Table (5-13) shows the 23 inefficient ports with relative technical efficiency less than 100% when using a pure efficiency model (BCC-VRS) in the input-oriented mode. Moreover, the table presents the optimum figures for each input to reach the best port efficiency as well as it shows the required change by percentage from the existing port figures. The best inefficient port is Tanjung Pelepas that requires reduction of its quay length, max depth and yard equipment by 10%, 5% and 20% respectively. While Keihin port is ranked as the least inefficient port that requires a reduction in its yard equipment and max depth by 39% and in its quay length, total area and gantry cranes by 76%,46% and 67% respectively. All the inefficient ports are having a surplus in their infra and superstructure in which eliminating some of these resources is not practically feasible as well as they cost a lot of investments in building and instillations. But the analyses are showing some ports are performing very poor relative to other ports. This highlights the need increases their throughput or better use their resource by providing these capacities to other ports through cooperation.

5.6.1.3. Slack variable analysis DEA (CCR-CRS) model with output oriented

Calculating ports efficiency can be done either by output or input oriented mode, in which the program calculates the efficiency for either maximizing output or minimizing inputs for the favour or improving DMUs efficiency scores. Previously in this research, the input minimization (input oriented) methods were used in order to stand on the existing ports efficiency situation, keeping in mind that increasing ports throughput is performed as a reason of many external economic, operational and political factors.

Although, applying the co-opetition concept among ports and forming port clusters could result in increasing clustered ports throughput as a result of flexible ports operation and expose to bigger markets as well as the increase in ports hinterland and foreland. As well as, could triggered the idea of widening up the scope and provide more flexibility in using all ports inputs and output to improve ports efficiency score by using output oriented mode or maximizing outputs models. But this will not provide a real idea in terms of the required input reduction values and will rely on increasing an imaginary throughput results that could actually be difficult to obtain in real life, as the increase of throughput relies on the economical and demand factors.

Table (5-14) shows the DEA - CCR slack variable analysis with output oriented mode. It is clear that inefficient ports could gain efficiency when increasing ports throughput. With output orientation model there are no significant changes as we are experiencing the same efficient and inefficient ports as input-oriented model. Moreover, Appendix (5-4) shows the comparison between both orientations either input or output-oriented model. It is clear that we can't find significant changes in overall ports efficiency scores but for the variables representing the inputs and output we can experience dramatic changes in the output improvement percentages as we can find that for the output-oriented mode we are experiencing an increase in percentage of outputs inversely proportion to ports efficiency reaching nearly 300% required increase in Keihin port throughput to turn to an efficient port. In the same hand, Keihin inputs reduction percentages are less required than what needed when using the input orientation model. For instance, the yard equipment and gantry cranes are required to be reduced by nearly three quarters if the same output will continue to perform and the port needs to operate efficiently. Therefore, it is preferable to apply the DEA models with input orientation mode if we want to test clustering of ports as it will be more practical to apply with practical results

Table 5-14 DEA - CCR slack variable analysis (output oriented mode) of main container ports in the East-West trade route in 2016

Port	The required change in % to reach efficiency							
	Score	Quay Length (m)	Max Depth (m)	Total Area (ha)	Gantry Cranes	Yard equipment	Dev. Dist. (nm)	Throughput (2016)
Tanjung Pelepas	99.68	-9.7	-5.3	0	0	-20.2	0	0.3
Port Kelang	93.16	0	0	-19.1	-13.2	-13.1	0	7.3
Saigon new port	92.17	-4.9	-72.9	0	0	0	-74.3	8.5
Bremerhaven	88.58	-26	-75.8	-48.3	0	0	0	12.9
Port Said East	83.69	-9.7	-74.3	0	0	-6.3	0	19.5
Kaohsiung	82.63	-16	-46.7	-14.8	0	-16.1	0	21
Ningbo	82.5	0	-40	-39.6	0	-35.7	0	21.2
Dalian	81.92	0	-50.2	-32.1	0	0	-70	22.1
Xiamen	77.22	-13.9	-48.8	-53.3	0	0	0	29.5

Port	The required change in % to reach efficiency							
	Score	Quay Length (m)	Max Depth (m)	Total Area (ha)	Gantry Cranes	Yard equipment	Dev. Dist. (nm)	Throughput (2016)
Jawaharlal Nehru	76.11	0	-58.2	0	-14	-40.2	-87.4	31.4
Laem Chabang	75.82	0	-63.5	0	-11.9	-30.1	-93	31.9
Tanger	75.42	-15.5	-84.4	0	0	-28.2	0	32.6
Hamburg	73.18	-5.3	0	0	0	-7.2	0	36.6
Shenzhen	72.05	-8.9	0	-17.5	0	-28.4	0	38.8
Ambarli	69.15	-53.1	-68	0	0	-20.3	-89.4	44.6
Gioia Tauro	67.36	-18.8	-81.6	-21.7	0	0	0	48.4
Jebel Ali	65.92	-12.4	0	-36	-1.3	0	-78.5	51.7
Jeddah	63.74	-21	-64.1	-33.6	0	-1.9	0	56.9
Marsaxlokk	62.98	-22.8	-67.8	0	0	0	-5.1	58.8
Antwerp	61.81	-41.9	-52.5	-80.1	-22.6	0	0	61.8
Tanjung Priok	61	0	-63.7	0	-14.6	-47	-95.3	63.9
Manila	58.9	0	-50.8	-12.9	0	0	-51.6	69.8
Salalah	56.47	0	-78.3	0	0	-17.4	-72.2	77.1
Valencia	56.11	-24.7	-56.5	0	0	-16.6	0	78.2
Piraeus	55.53	-11	-63.5	0	-16.3	0	0	80.1
Yokohama	49.24	-32.4	-15.9	-35.1	0	0	-46.5	103.1
Rotterdam	48.11	-24.8	-11.2	-73.8	0	-25.5	0	107.9
Felixstowe	45.77	-12.8	-74.2	-4	0	-20.2	0	118.5
Inchon	45.13	-17.8	-57.6	0	0	0	-84.1	121.6
Kobe	38.1	-45.4	-69.5	-17.5	0	0	-83.2	162.5
Keihin	24.44	-33.9	-58.8	-10.8	0	0	-92.2	309.2

From the previous analysis, it can be observed that the DEA technique determines the slacks related with the container ports that have been known as inefficient, and so provides a reference set of precise references for each port to improve efficiency. Nevertheless, DEA does not express any possible root causes of the projected efficiency.

In fact, many factors affecting the efficiency of a container port could be hypothesized. In this context, the co-opetition concept application and clustering of ports will be used in the next chapter to examine the effect of ports clusters on container ports efficiency.

5.7. Conclusion

Ports relative technical efficiency is important for all ports as it significantly indicates to ports decision makers the strengths and weaknesses of their ports as well as it helps in obtaining a good comprehensive development strategy. The significance of this research that it applies the DEA models not only for measuring relative technical efficiency but it is using the power of DEA models to construct a practical applicable methodology to help port's decision makers to build port clusters based on efficiency-enhancing objectives. DEA models were used to measure the relative technical efficiency for the top world 42 container ports positioned on the main East-West trade routes, for the cross-section data for the year 2016 and the panel data for the period between 2011 to 2016.

The use of five DEA models enabled a comprehensive assessment of the relative efficiency was through the application of DEA-CCR/BCC models benchmarked the technical and pure technical efficiency of the study ports. The analysis shows that quarter of the ports under study represented by 11 ports are efficient in both their technical and pure efficiency. When the application of the super-efficiency (A&P) model port of Singapore and Shanghai port were the top efficient ports. However, the rest of the study ports were considered as relatively inefficient with the Japanese port Keihin was the least efficient port. To be efficient, they have to either increase their output or minimize their inputs to increase their efficiency scores to be equal to one.

The results obtained when adopting the scale efficiency model to determined trends in port efficiency besides their established return to scale (constant, decreasing or increasing) for every port showed that all ports are having IRS except Tanjung Pelepas port which is having DRS. Using sensitivity analysis and slack variable analysis has also delivered useful information that validates how a relatively incompetent container port could increase its technical efficiency. The former identified the utmost significant variables that affect the technical efficiency of each port, while the latterly provided solutions to port managers of inefficient ports that let them achieve the best utilization of port infra and superstructure resources.

The results also signify the existence of 31 inefficiency ports. Although we are having nearly three-quarters of the study ports are inefficient but the overall average technical efficiency of all study ports is 75% in both aggregate or pure technical efficiency and 66% in average for the inefficient ports only. Moreover, all the inefficient ports are experiencing surplus in their inputs represented by their super and infra superstructure. Practically, with the consolidating strategy of industry main players like shipping lines, those ports which are showing inefficient results should seek improvement and better utilization to their resources which could be strongly applied through cooperation with other ports and improve their efficiency and competitive position. These strategies could be by co-opetition concept application

CHAPTER SIX

EFFICIENCY OF PORT CLUSTERS

6.1. Introduction

This chapter aims to fulfil the research aim to introduce the optimum practice of efficiency gained throughout co-opetition and forming ports clusters and forecasting the future co-opetition of the main ports in Europe - Far East trade routes with emphasizing on the constraints and proposing solutions. This will be carried out by introducing the optimum scenarios for ports cooperation and clustering to perform the best practice to enhance ports efficiency. This research is looking for finding the most reliable, easy and applicable way to initiate ports clusters among different proposed methods.

Accordingly, this chapter will firstly propose clustering by only manipulation of the DEA models results to examine the impact of port clustering on their efficiency. Secondly, enhancing ports clusters efficiency will be examined by the aid of clustering software in addition to the results obtained from the DEA slack variable analysis technique. Finally, the conclusion and analyses that show the optimum methods to be followed in order to perform the research objectives .

6.2. Ports clusters using DEA results

Previously DEA models were meticulously applied on the study ports. Therefore, by understanding the pros and cons of every model as well as how to get used of its results to serve our research objective. This is to find out the best practice to form port clusters with the main objective of enhancing clustered ports relative technical efficiency as a fruitful outcome of such port cluster. In this approach, we will rely only on the DEA models results to form ports clusters. Figure (6-1) shows the steps that will be applied to form ports cluster and how to examine the efficiency of the proposed ports clusters and their effect on ports efficiency. Accordingly, the following steps have to be followed to reach the research objective and examine their consistency and reliability in the sense that we can apply the same technique on any given area or zone.

Step 1: Correlation of inputs should be made in which we should eliminate one input with high correlation with another to reduce input items

Step 1.1: based on the sensitivity analyses figures eliminate the input that affects fewer DMUs

Step 2: Calculating the CCR –CRS and the BCC-VRS models to determine the scale efficiency and the IRS and DRS DMUs in which cooperation could be with IRS ports only

Step 3: Exclude efficient ports as they are efficient and will not have the incentive to cooperate with less efficient ports, based on the slack variable analyses model.

Step 4: Divide ports according to their geographical region (where cooperation could be practically applied) and calculate relative efficiency of ports in each region

Step 5: Apply the sensitivity analyses to find out the less sensitive inputs and eliminate them from the calculation and again run **BCC – VRS** model to find out the proposed suitable ports for cooperation

Step 6: Form proposed clusters and gather cluster inputs and outputs and deal with them as one port and re-run the DEA (CCR –CRS) model for all study ports.

Using 6 inputs to benchmark ports relative technical efficiency is good in determining a reliable result in knowing the exact score of ports relative efficiency, but to cluster ports in the bases of complementing ports inputs is very difficult with the presence of 6 input. Therefore, the best practice is to minimize the inputs as possible as we can with a minimum effect on the initial ports efficiency scores, when using the maximum used inputs (in our case the 6 inputs). Therefore, elimination of inputs should be applied as shown in figure (6-1). Accordingly, Yard equipment, Quay length and deviated distance inputs will be eliminated.

The elimination of **yard equipment** is due to the presence of another input that can reflect its effect which is the gantry cranes as the correlation between yard equipment and gantry cranes is (0.92). Moreover, the sensitivity analyses show that ports are more sensitive to the gantry equipment input rather than the yard equipment input as for the yard equipment 24 ports are sensitive to its elimination, while 11 ports were affected by eliminating the yard equipment inputs. Accordingly, the decision of relying only on gantry cranes and eliminating yard equipment was maintained. Similarly, we can remove the **quay length** input as its correlation with the gantry cranes figures is (0.87) as well as only 7 ports are sensitive to the quay length input. Finally, we can also eliminate the deviation distance input as it was used as an uncontrolled environmental factor, which has no direct effect on ports technical efficiency, in spite of its role in ports efficiency and competitiveness.

Afterword we have to examine the effect of eliminating these three inputs on ports efficiency in order to examine the reliability of the elimination decision.

Therefore, another DEA analyses were performed as shown in the appendix (6-1) in which the change of ports relative efficiency scores before and after reducing three inputs variables. It is clear that the relative efficiency of ports did not change dramatically when using 3 inputs instead of 6 inputs.The average change of study ports relative technical efficiency is 8.8% in which 12 ports did not show any changes in their efficiency while 12 ports have their efficiency changed more than 10%, 3 ports show changes by more than 15% and 4 ports more than 20%. Accordingly, using 3 inputs could reflect the efficiency of the port with no significant changes relying on the total average efficiency change figure.

6.2.1. Proposed clusters variables and model orientation

The inputs and output data of the clusters is performed by adding all the numbers of inputs and outputs in the proposed cauterized ports. For instance, add all areas in ports that form cluster A to get this cluster total area input, and similarly to all inputs and outputs. The exception was made to the maximum depth and deviated distance. For, the cluster maximum depth input it was performed as the max depth obtained in all ports within this cluster. For the deviated distance the following formula was implemented to give the approximate overall deviated distance for a nominated cluster from the main trade route.

$$Cluster\ dev.Dist = \sqrt{(dev.dist\ port1)^2 + (dev.dist\ port2)^2 + (dev.dist\ port3)^2}$$

While for the model orientation , it was mentioned before that the output orientation models are normally used to perform strategic decisions and the input oriented mode for the operational assessment. Therefore, if we are aiming for the assessment of clusterization then by default we should use the output oriented mode. But this stage in the research will be implemented by the input oriented mode and not output oriented one because this research aims to assess how efficient the port is utilizing its resources and how to optimize such uses through complementing cooperation. On the same hand if it adopt the output oriented mode the model will present the % of output to be increased to change the cluster status from inefficient to efficient by increasing the output which is the throughput and does not show the accurate surplus in the infrastructure and superstructure variables. Therefore, to find the surplus in outputs the optimum is to use input oriented mode.

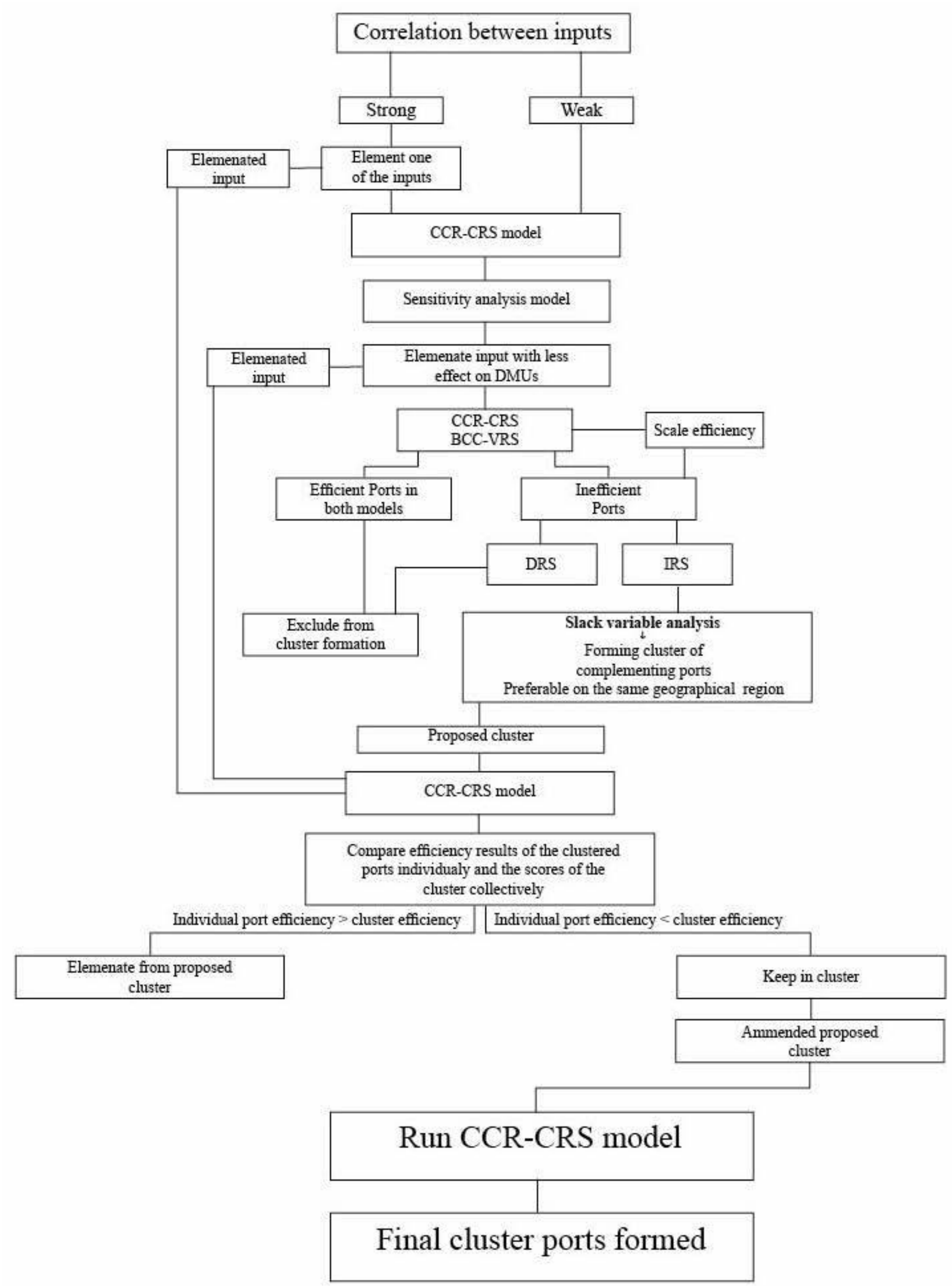

Figure 6-1 Building Port clusters based on DEA models

Table 6-1 DEA (CCR & BCC) efficiency of study ports using 3 inputs

Decreasing return to scale			Increasing return to scale			constant return to scale		
Port	CCR	BCC	Port	CCR	BCC	Port	CCR	BCC
Guangzhou	96%	99%	Singapore	81%	83%	Hong Kong	100%	100%
Khorfakkan	94%	100%	Dalian	74%	75%	Keelung	100%	100%
Saigon new port	89%	91%	Ningbo	73%	77%	Qingdao	100%	100%
Tanger	74%	100%	Busan	72%	72%	Saigon port	100%	100%
Ambarli	69%	100%	Kaohsiung	67%	67%	Shanghai	100%	100%
Laem Chabang	67%	67%	Port Kelang	56%	56%	Tianjin	100%	100%
Jawaharlal Nehru	66%	80%	Manila	55%	56%			
Shenzhen	66%	70%	Xiamen	54%	54%			
Gioia Tauro	62%	66%	Bremerhaven	49%	50%			
Jebel Ali	62%	63%	Jeddah	41%	41%			
Marsaxlokk	62%	88%	Rotterdam	40%	41%			
Algeciras	61%	75%	Antwerp	38%	39%			
Tanjung Pelepas	59%	60%	Keihin	24%	24%			
Port Said East	59%	100%						
Salalah	56%	68%						
Valencia	55%	55%						
Piraeus	54%	61%						
Tanjung Priok	52%	60%						
Hamburg	47%	48%						
Inchon	45%	100%						
Felixstowe	43%	45%						
Yokohama	43%	48%						
Kobe	36%	38%						

6.2.2. Results of the clustered ports under the DEA models results only

Table 6-2 Results of the proposed clusters efficiency

	Ports	BCC – VRS	CCR - CRS	Cluster BCC – VRS	Scale efficiency
Cluster A	Singapore	100%	100%	100%	1
	Port Kelang	92.10%	93.10%		0.97
Cluster B	Dalian	82.60%	81.90%	100%	0.99
	Ningbo	81.70%	80.30%		0.98
	Xiamen	92.40%	71.50%		0.77
Cluster C	Kaohsiung	92.10%	80.10%	89%	0.87
	Manila	92.30%	58.90%		0.64
Cluster D	Busan	100%	100%	93.90%	1
	Kaohsiung	92.10%	80.10%		0.87
Cluster E	Rotterdam	70.80%	41.70%	88.80%	0.59
	Antwerp	83.90%	53.50%		0.64
	Bremerhaven	100%	88%		0.88
Cluster F	Antwerp	83.90%	53.50%	81.1	0.64
	Bremerhaven	100%	88%		0.88
Cluster G	Rotterdam	70.80%	41.70%	80.20%	0.59
	Antwerp	83.90%	53.50%		0.64
Cluster H	Rotterdam	70.80%	41.70%	76.8	0.59
	Bremerhaven	100%	88%		0.88

As stated in figure (6-1) ports with efficient scores on both CCR and BCC models will be excluded from the clusterization process. As they will perform constant return to scale as well as practically they will not be willing to cooperate with less efficient ports. Then sorting ports according to their return to scale results in which the prediction is to group ports with increasing return to scale. As the combination of their resources will generate more efficiency scores than the decreased or constant return to scale. Accordingly, table (6-1) represents the ports sorted according to their return to scale. At that time clusterization of ports under the increasing return to scale category was maintained based on ports geographical position. Consequently, the 8 clusters named from A to H were made as shown in the table (6-2). Then grouping each cluster inputs together was performed to compare the clustering efficiency with individual cluster ports efficiency.

By analyzing the efficiency scores of proposed clusters, it is clear that there is no consistency in the clusters efficiency. In other words, in some clusters we can find that the cluster score is giving intermediate values of clustered ports individual scores like the case of cluster D, E, G and H. While in other cases the efficiency of clustered ports is more than the values of individual ports like the case of cluster B. On the other hand, clusters C and F show decrease in efficiency below the scores of the clustered ports values. Finally, we can conclude that clusterization based on the above-mentioned steps in figure (6-1) by using only DEA models results and following the proposed steps in figure (6-1) is not giving reasonable understood results.

In the coming section, another method of ports clusterization will be examined in which the use of additional software to cluster ports based on the DEA models results.

6.3. Two steps modelling for ports clusterization

In this approach ports, clusterization will be carried out by the use of two models the first model is the DEA model and the second model is the K-mean clusterization technique. From all the DEA models used previously, this approach will use only the slack variable analyses results as by knowing the percentages obtained from the slack variable analysis results we can know the percentage of required reduction in every input variable in every port. In other words, it will provide the percentages of deficiencies in every input in which by their improvement the nominated port will change its status from inefficient to efficient port.

The K-mean clusterization technique will be using the values of the slack variables results (obtained from DEA model) as inputs, besides setting the number of required groups. Accordingly, the software will group ports with similar slack variable analyses results will be grouped in the number of set groups. Hence, we will have a number of groups with similar features in terms of deficiencies in their inputs. Then ports clusterization will take place in which each cluster is containing ports from different groups. This approach is tried to test the applicability of finding complementing ports in which each of them could cover the gapes on another port.

6.3.1. K- mean algorithm application

The K-mean software must be fed by input data and the number of required groups. Therefore, the software can simply generate results by computing the upcoming steps:

1. The procedure starts with k centroids set at random.
2. The nominated centroids are used to give points to its closest cluster.
3. Then mean of all points inside the cluster is used to appraise the position of the centroids.
4. The previously stated steps are recurrent to the values of the centroids become stable.

In this research, the k-mean algorithm was fed by input data of the 42 study ports to group them according to their DEA slack variable results into 5 groups. At the beginning, the data for the 6 inputs were used in the software but the result was grouping ports in the 5 groups with a remarkable difference in a number of ports in each group in which we were having 2 groups out of the 5 set groups containing only 2 ports. As a result, the clustering of ports will be very limits in terms of ports selection. Therefore, reducing the number of inputs to only 3 inputs was performed on the same bases applied on the previously mentioned sector which are the Maximum depth, Total area and Number of gantry cranes in which their statistical figures were shown in the table (6-3).

Table 6-3 Statistics summary for the 3 selected inputs:

Variable	Minimum	Maximum	Mean	Std. deviation
Max Depth (m)	1.74	18	8.528	5.837
Total Area (ha)	31.58	744	215.414	197.038
Gantry Cranes	10.38	223	45.791	43.108

Accordingly, we had little bit of homogenous groups in term of ports per group. The number of ports selected in the 5 groups was 5, 7, 8, 10, and 12 ports in each. Moreover, the values of centroids for every single input in which the groups were founded is shown in the table (6-4) as well as the variation within each group.

Table 6-4 Groups centroids

Class	Max Depth (m)	Total Area (ha)	Gantry Cranes	Sum of weights	Within-Group variance
1	5.719	99.389	20.6	7	141.792
2	15.353	574.181	108.598	8	21096.724
3	11.007	234.687	56.842	10	1447.563
4	5.397	57.183	15.607	12	259.37
5	4.1	145.032	30.912	5	529.133

Moreover, the table (6-5) shows the distance between group centrioles. It is clear that the maximum distance is between ports in group 3 and 4, while the closest distance is between group 1 and group 3 and the centroid ports which are the reference for each group are as follow: Group 1, Salalah - Group 2, Busan - Group 3, Hamburg - Group 4, Piraeus -Group 5, Laem Chabang

Table 6-5 Distances between the group's centroids

	1	2	3	4	5
1	0	14709	2409	31463	5203
2	14709	0	17103	16757	9511
3	2409	17103	0	33858	7594
4	31463	16757	33858	0	26264
5	5203	9511	7594	26264	0

6.3.2. K- mean algorithm results

Table (6-6) shows the results of the K-mean grouping software in which ports were grouped in the preset 5 groups. It is clear that group 4 contains the largest number of ports by 12 ports with the second average distance from centroid by the value of 13 as well as with reasonable grouping variation with a value of 259. On the other hand, the smallest group was the 5th one with the values of 16 of average centroid distance and 529 in grouping values results. At the same time group, 2 shows the maximum values of the average distance from centroid and group variation as it shows 127 and 21096 respectively.

Table 6-6 Results of groups by the K-mean model:

Group	1	2	3	4	5
No. of ports	7	8	10	12	5
Group variance	141	21096	1447	259	529
Min. distance to centroid	3	54	3	4	2
Av. distance to centroid	9	127	30	13	16
Max. distance to centroid	19	204	61	30	38
	Algeciras	Busan	Hong Kong	Keelung	Saigon new port
	Port Said East	Guangzhou	Qingdao	Khorfakkan	Bremerhaven
	Jawaharlal Nehru	Singapore	Saigon port	Tanger	Laem Chabang
	Gioia Tauro	Shanghai	Tanjung Pelepas	Ambarli	Jeddah
	Tanjung Priok	Tianjin	Dalian	Marsaxlokk	Antwerp
	Manila	Port Kelang	Kaohsiung	Piraeus	
	Salalah	Ningbo	Hamburg	Valencia	
		Shenzhen	Xiamen	Yokohama	
			Jebel Ali	Inchon	
			Rotterdam	Felixstowe	
				Kobe	
				Keihin	

6.4. Ports clustering on the K- mean bases technique

In this section, the DEA model will be used twice and K-mean clusterization model will be implemented once. The DEA model will be applied on the ports secondary data using 3 inputs then the application of the k-mean software to group ports based on their slack variable analyses results. Accordingly, ports will be groups into clusters (containing ports from different groups). finally, another use for the DEA models will be used to find the efficiency of clustered ports and comparing its results with that of individual ports among the same cluster. Accordingly, the visibility and reliability of such an approach will be clear whether the efficiency of the port has improved or not.

Moreover, the same approach will be implemented twice the first will be the clusterization of inefficient ports while the second will be clusterization of all study ports. For the first approach, ports with efficient scores will not be included in clusters (but will be included in benchmarking the relative technical efficiency) and ports with inefficient scores for both CCR and BCC model will be clustered. The second implementation will be among clusters containing all 42 ports. For both scenarios, the selection of cluster members will be according to their geographical location, geopolitical reasons and from different groups obtained by the k-mean model.

6.4.1. Inefficient Ports clusterization

Table 6-7 Efficiency scores of inefficient port clusters

Port Clusters	Efficiency BCC	Efficient ports	Efficiency BCC
Jebel Ali - Salalah - Jawaharal Nehru	752%	Singapore	1000%
Jeddah - Port Said east	111%	Shanghai	1000%
Shenzhen - Xiamen	102%	Algeciras	648%
Hamburg – Bremerhaven	100 %	Keelung	250%
Laem Chabang - Saigon new port	82%	Saigon port	162%
Ningbo – Dalian	81%	Khorfakkan	157%
Tanger –Valencia	78%	Busan	131%
Manila - Kaohsiung	73%	Hong Kong	128%
Marsaxlokk - Gioa Tauro – Piraeus	66%	Tianjin	116%
Port Kelang - Tanjung Pelepas - Tanjung Priok	66%	Qingdao	114%
Kobe - Yokohama - Keihin – Inchon	52%	Guangzhou	104%
Feliixstowe - Rotterdam – Antwerp	45%		
Mean		236%	

Table (6-7) shows the efficiency scores of inefficient ports clusters as well as the efficiency of the predefined efficient ports, but after benchmarking with proposed clusters. It is clear that with this approach the number of efficient ports (DMUs) increased from 19 when ports were individually measured to 21 ports when inefficient ports were clustered. This means that the overall efficient ports or DMUs increased from ~ 45% to 50% under this scenario. Therefore, with the implementation of this approach, an increase in overall efficiency of the study ports was observed by 5% in the number of ports or DMUs.

6.4.2. Clusterization of all study ports

Table 6-8 Port clusters selected on geographical location

Groups				
1	**2**	**3**	**4**	**5**
Algeciras	Busan	Hong Kong	Keelung	Saigon new port
Port Said East	Guangzhou	Qingdao	Khorfakkan	Bremerhaven
Jawaharlal Nehru	Singapore	Saigon port	Tanger	Laem Chabang
Gioia Tauro	Shanghai	Tanjung Pelepas	Ambarli	Jeddah
Tanjung Priok	Tianjin	Dalian	Marsaxlokk	Antwerp
Manila	Port Kelang	Kaohsiung	Piraeus	
Salalah	Ningbo	Hamburg	Valencia	
	Shenzhen	Xiamen	Yokohama	
		Jebel Ali	Inchon	
		Rotterdam	Felixstowe	
			Kobe	
			Keihin	

In this approach, the same previously mentioned approach was implemented but the geographical and political conditions were accounted with the inclusion of all 42 study ports. To account the geographical condition and the geopolitical situation into consideration as well as to cluster the 42 ports, clusters could include more than one port from a single group. Table (6-8) shows the proposed ports clusters with different colours in which a total of 14 clusters were proposed, each with different number of ports. The reason for forming this number of clusters is to fulfil the DEA model requirements as the DMUs should be at least double of the sum of inputs and outputs. The largest cluster contains 5 ports and the smallest one contains 2 ports. China is the only single country that can formulate 3 national clusters with a total of 9 ports, in which this could be the easiest clusters to be implemented as they belong to a single national government and jurisdictions.

Following China, we can have the European Union that can formulate 4 clusters with 12 ports containing only 2 ports outside the European Union which are Tanger in Morocco and Ambarli in Turkey. This is with ignoring the BREXIT that could also exclude the British port Felixstowe from our proposed clusters. The remaining 6 clusters were made according to the geographical and geopolitical conditions. Keeping into considerations that in every cluster there are ports from different countries with different national laws, as such this could be a constraint in the clustering implementation and operations.

Table (6-9) shows the relative technical efficiency of all port clusters. This result show a remarkable overall increase in ports relative technical efficiency giving an average of 249% efficiency of ports by using the super efficiency (BCC- VRS) scores as we are experiencing a lot of efficient clusters. By analyzing the relative efficiency results for the 14 clusters with the aid of the DEA model and including the initially 6 inputs in the model. it is clear that 71% of the clusters containing 30 ports out of 42 ports are showing efficient results. The remaining 25% that contain 12 ports are not showing 100% efficiency but they are showing very high-efficiency scores as two of them are showing efficiency scores above 94% and 92% and the least efficient cluster is showing 81% efficiency score.

In comparing the results of ports efficiency before and after clusterization we can find that when ports were operating individually we were having only 11 efficient ports, while after clusterization we are having 30 efficient ports with efficiency score over 100%. Therefore, it is quite clear that co-opetition between ports and working among a cluster to share resources in term of infrastructure or superstructure will develop ports operations and services as well as increase ports efficiency without spending a single penny.

Table 6-9 Efficiency of all ports clusterization

Cluster	No. of ports	Unit name	Score
1	4	Shenzhen - Hong Kong - Guangzhou - Xiamen	1000%
2	2	Port Kelang - Tanjung Pelepas	1000%
3	2	Jeddah - Port Said east	275%
4	3	Algerciras - Tanger –Valencia	147%
5	3	Laem Chabang - Saigon port - Saigon new port	135%
6	2	Ningbo – Shanghai	132%
7	3	Dalian - Qingdao – Tianjin	113%
8	2	Tanjung Priok – Singapore	108%
9	2	Hamburg – Bremerhaven	107%
10	3	Manila - Keelung – Kaohsiung	106%
11	4	Marsaxlokk - Gioa Tauro - Piraeus - Ambarli	102%
12	4	Jebel Ali - Khorfakkan - Salalah - Jawaharal Nehru	94%
13	5	Busan - Kobe - Yokohama - Keihin – Inchon	92%
14	3	Feliixstowe - Rotterdam – Antwerp	81%
Total	42	**Mean**	249%

6.5. Conclusion

This chapter presented various approaches to group ports into clusters based on their relative technical efficiency results. Firstly, it was proved that the use of many input variables to cluster ports is not easily possible, in the sense of the presence of many variables confuses the selection of ports that could complement with each other and operate under the umbrella of one cluster. Therefore, limiting the number of inputs as possible as we can, without magnificently affecting the overall efficiency scores could be a good practice. Accordingly, for this research objective and circumstances reducing the inputs from 6 to 3 inputs was optimum in selecting clustered ports.

Furthermore, it was clear that only using the DEA models results to sort ports into complementing clusters was giving inconsistent results. This was observed from the comparison between ports efficiency score before and after clusterization. As the clusterization proved that efficiency in some clusters increased for all grouped ports, while for other clusters the overall cluster efficiency was less than the least individual port efficiency in that cluster, meaning that all ports in that cluster suffer from a reduction in efficiency caused by clusterization. Accordingly, this approach cannot generate reasonable explained results in which applying it on different area or region could produce unreliable results

When introducing the second approach for ports clusterization based on the use of K-mean clustering model and the DEA model significant results were observed. The use of both approaches either with including or excluding the efficient ports, with the input of only 3 variables for the K- mean software. The results show increase of ports overall efficiency with including the initial 6 inputs for assessing ports final efficiency scores. Accordingly, using this approach and clustering ports either when including or excluding the efficient ports, the results show an increase in relative ports technical efficiency.

It is well clear that clusterization of ports plays a very important role in increasing their efficiency. Ports efficiency increased dramatically when clusterization was obtained. When ports were operating individually we experienced ~45% efficient ports, when we clustered only the inefficient ports we experienced an increase of efficient ports to nearly 5% of the study ports. Then when clustering the 42 study ports efficiency scores showed that nearly 70% of the ports were showing efficient results. Therefore, it is quite clear that co-opetition between ports and working among a cluster to share resources in term of infra /superstructure will improve ports operations and services as well as increase ports efficiency without the need for extra investments.

This chapter concluded that ports clustering could be a good approach to increase ports relative technical efficiency in which ports competitiveness could also increase. By reaching such result the main research question of whether cooperation between ports will increase their efficiency could be answered. In the way that we could say that ports cooperation and the introduction of co-opetition concept could be a good practice to increase ports efficiency without the need to invest individually by port authorities.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1. Introduction

This chapter shows the overall research conclusions and findings concluded from this research as well as the recommendations for further researches. It starts by presenting the research aims, objectives and processes that have been made to address these objectives. Then it determines the research significance and contribution. The research limitations and study area were clearly presented and also the research methodology and processes by which the aim and objectives were achieved. Finally, it will present the research recommendations for further researches.

7.2. Realization of the research objectives and hypotheses

Chapter two introduced the main container market players' strategies as well as the market dynamics and changes. Also, the increasing desire for carriers' merger and consolidating by founding alliances to cool down the market competition. Moreover, it shows the pros and cons of such policies and how it affects container ports markets. This police weakened the position of the port and reduces its bargaining power and increased competition between them. Furthermore, it also highlights the proposed solutions for ports to improve their efficiency by adopting the co-opetition concept. This was to improve the balance of facilities and functions and to improve ports efficiency that will radiate on its competitive position. This chapter fulfilled the first research objective of studying the contemporary changes in the liner shipping market.

Chapter three was mainly to review the previously published researches investigating ports technical efficiency. This was to identify the gape analysis in which this research should cover to provide an added contribution to this field. Also, this chapter was to fulfil the second research objective that is to critically analyze the previous studies of port efficiency. Furthermore, this chapter was with twofold purpose as besides understanding the gape analyses to also review researches of port's co-opetition and port efficiency measurements as well as techniques, that highlights the importance of this research. It clearly shows that the previous researches did not show any research that integrally investigates the co-opetition and efficiency approach.

Furthermore, it shows that there were a few numbers of published works of literature that presents the ports co-opetition concept in the port's market. Nevertheless, it demonstrates that many state governments are encouraging ports to cooperate to save their national resources. This was done in tandem with keeping their competitive policies to fulfil national and international laws. On the other flip of the coin, it shows that ports technical efficiency was enormously studied by scholars using different techniques. This was used to assess ports from various perspectives but this research perspective was not introduced at all. This fact strengthens the originality of this research as well as it proves its unique contribution. As assessing ports relative technical efficiency from the scope of evaluating the implementation of co-opetition concept can be considered as a new approach.

chapter four gives a complete illustration of the study design, approach, strategy and time frame. The research design discloses the importance of the used methodology to measure port efficiency and ports clustering techniques. This chapter was very important in introducing benchmarking the technical efficiency and understanding the different techniques and models of the DEA. Also, it helps in introducing the 3rd research objective of Benchmarking the technical efficiency of main container ports in East–West trade route. Moreover, it helps in examining the first research hypotheses.

Chapter five deeply focused on finding the 3rd research objective which is to benchmarking the technical efficiency of main container ports in East–West trade route. As well as to prove the first research hypotheses that predicted that the efficiency of ports is enhancing over time. Also, it presents the significance of this research by the application of the DEA models to construct a practical applicable methodology to build port clusters based on efficiency-enhancing objectives. DEA models were used to measure the relative technical efficiency for the 42 study ports, for the cross-section data for the year 2016 and the panel data for the period between 2011 to 2016. The use of five DEA models enabled a comprehensive assessment of the relative efficiency was through the application of DEA-CCR & BCC models for benchmarking the technical and pure technical efficiency of the study ports.

The analysis shows that nearly 25% of the ports under study were efficient in both their pure technical efficiency, as well as when using the super-efficiency (A&P) model port of Singapore and Shanghai were the top efficient ports. However, the rest of the study ports were considered as relatively inefficient and Keihin port was the least efficient one. Moreover, when using the scale efficiency model, results show that all ports are having IRS except Tanjung Pelepas port which is having DRS. Correspondingly, sensitivity analysis and slack variable were obtained to analyse the information to improve the relatively inefficient container port. Moreover, all the inefficient ports are experiencing surplus in their inputs represented by their superstructure and infrastructure in which they could apply the co-opetition concept to improve their efficiency and competitive position.

chapter six presented various approaches to group ports into clusters based on their relative technical efficiency results. This was to cover the last two research objectives to introduce the optimum practice of efficiency throughout co-opetition and to estimate the future cooperation of the study ports. Moreover, to examine the research hypotheses that the application of co-opetition between ports could improve their technical efficiency. Also, that container ports could be able to cooperate and perform a win-win strategy if a clear platform of co-opetition results is well presented and proved.

Firstly, chapter six proved that the use of many input variables to cluster ports confuses the selection of ports that could complement each other. Therefore, limiting the number of inputs from 6 to 3 inputs could be a good practice as far as it didn't affect the overall efficiency scores. Besides, it was clear that only using the DEA models to sort ports into complementing clusters was giving inconsistent results. As the clusterization proved that efficiency in some clusters increased for all grouped ports, while for other clusters the overall cluster efficiency reduces efficiency to be less than the least port in that cluster (considering individual ports efficiency scores). Accordingly, this approach cannot generate reasonable explained results in which applying it on different area or region could produce unreliable results

Then a second approach for ports clusterization was introduced, based on the geographical, geopolitical and results of the K- mean clustering model. The slack variable analysis results obtained from the DEA model (3 input variables) for single ports benchmarking was used as inputs for the K-mean clustering model. this shows an increase of ports overall efficiency. When using this approach and clustered ports either when including or excluding the efficient ports, the results show an increase in relative ports technical efficiency for 70% of the study ports.

Finally, this research concluded that ports clustering could be a good approach to increase ports relative technical efficiency and increase ports competitiveness as well as their bargaining power. By reaching such a result the main research question of whether co-opetition between ports will increase their efficiency could be clearly answered. that we could say that ports cooperation and the introduction of co-opetition concept could be a good practice to increase ports efficiency without the need to invest individually by port owning bodies.

7.3. Research main contribution to the development of knowledge

The research findings sheds light on the largest ports on the East-West container port market with important policy and managerial suggestions. Administrations could be influenced by framing policies with reference to the research conclusions. the most significant contribution of this research is that it investigates the connection between port co-opetition and relative technical efficiency of the dedicated container port. Given the empirical findings herein, port administrators and operators may get valuable understandings into the state of their own relative technical efficiency as well as to pick up where inadequacies be present by recognizing the causes which may be affecting their ports technical inefficiency. This research, showed on a purely objective and technical basis, in which it contributes to formulating a base for ports to improve its relative technical efficiency without spending unnecessary costs, to the

Moreover, the implementation of two models to perform port clusters for the objective of enhancing ports efficiency was not previously studied. This could be a good approach to be deeply studied to produce a more practical and reliable methodology to help ports decision makers in enhancing their ports efficiency as well as providing them with an additional tool to implement in their strategic plans for the sack of increasing their competitiveness and bargaining power among the rest of market players.

Methodologically, this research present a different approach to understand the results of the DEA models as well as the manipulation of such results. It was a rule of thumb that using many inputs will perform better reliable results when using the DEA models, but this research highlights some advantages on using the least number of inputs as well as it proposed some important measures for the selection of input data. Moreover, the introduction of two models, DEA and K- mean models, in this complementing manner is unique in the field of ports relative efficiency studies, where its development could provide more depth in port efficiency studies.

Practically, this research introduced a very important approach for the ports decision maker to focus globally to enhance their supply chain efficiency rather than focus only on their ports. This was clear that with the application of ports clusterization the whole ports supply chain experiences efficiency improvement. This approach could positively improve ports future strategic planning to be more global and comprehensive with the focus on cooperation and not only limited to competition.

7.4. Research recommendations

This research can introduce recommendations for both the academic and industrial fields. For the academic field, DEA available models in the market for either commercial or free usage are offering efficiency results that can only identify the deficiencies in the input or output variables. This is good or enough for the decision-makers in both the operational or the strategic levels, but developing this software in the sense of grouping DMUs could also be a good option. This will provide an additional tool when using DEA models in the sense that it will also give additional solutions besides its default function of determining deficiencies in variables.

Moreover, a calibration function should be added to DEA software to overcome the necessity of unifying variables. This could be helpful for all fields of DEA applications. For instance, in the field of assessing ports efficiency while using the existing models, standardizing the yard equipment as well as the quay gantry cranes figures obtained from different study ports was difficult and needed some sort of assumption, to nearly obtain reasonable results. But if so is made by a function in the software, this sort of calibration could be much more reliable and accurate.

Moreover, for researchers, this research could pave the way for more researches in the field of ports co-opetition and collaboration. This could be extended to more areas rather than only technical efficiency. Furthermore, the cooperation between ports could be among clusters containing different ports sizes in the sense each cluster could have hub ports and its regional spoke ports. Moreover, similar researches could be implemented between different terminals within the same port or operating in the same region. Accordingly, the industry could gain multiple research conclusions about ports co-opetition in which this could sheds light for co-opetition implementation.

For the industry, this research highlights that the shipping lines negative balance sheet reports are not away from the ports sector and it will defiantly radiate on ports sector by one way or another. Therefore, ports should take a proactive measure to find a way to focus more on cooperation to reduce developing expenses as well as to increase their efficiency. Moreover, the industry should clearly realize that cooperation could be one of the few solutions that could enhance ports competitive position through efficiency increase with zero cost.

Furthermore, ports cooperation will not only enhance ports existing operations but it could be a very good approach to release pressure and congestion in ports in case of seasonal reasons or emergency ones. In other words, the optimum port planning and constructing planes is to prevent ports congestion in case of peak periods with only focusing on the ports area and facilities, but with the clusterization of ports these plans could be amended and modified as the scoop will be on the total clustered ports facilities rather than only one ports. This will trigger regional cooperative development strategies with much easier transfer of knowledge and technologies within the region.

Finally, supply chain with efficient ports in whatever geographical location will help all nations in the sense of providing them with services and goods with optimum prices and quality. This should be the moral of researchers to serve humanities with any mean to enhance their life and positively introduce the concept of cooperation in all and every aspect of life.

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Symbol	Abbreviation
AE	Aggregate Efficiency
APM	Danish A.P. Moller-Maersk Group
ASC	Annualized Slot Capacity
ASEAN	Association of Southeast Asian Nations
BCC	Model That Measure Pure Efficiency
BREXIT	British Exit From The European Union
CAPEX	Capital Expansion
CCR	Model That Measures Aggregate Efficiency.
CMP	Copenhagen Malmo Port
COSCO	China Shipping Company
CRS	Constant Returns To Scale
DEA	Data Envelopment Analysis
DEAP	Name Of Data Envelop Analysis Software
DMU	Decision-Making Unit
DP	Dubai Ports
DRS	Decreasing Rate Of Scale
ECT	European Container Terminals

EMS	Name Of Data Envelop Analysis Software
EVA	Economic Value Added
FDH	Free Disposal Hull
FDH	Free Disposal Hull
FEAR	Name Of Data Envelop Analysis Software
GDP	Gross Domestic Product
IRS	Increasing Rate Of Scale
ISL	International Symposium On Logistics
KOIP	Kobe-Osaka International Port Corporation
Lo/Lo	Lift On/Lift Off
MI	Malmquist Index
MOL	Mitsui O.S.K. Lines, Ltd
MOU	Memorandum Of Understanding
MSC	Mediterranean Shipping Company
NIRS	Non-Increasing Returns To Scale
OLS	Ordinary Least Square
OTE	Operational Technical Efficiency
PIM-DEA	Name Of Data Envelop Analysis Software
PNW	Ports Of Seattle And Tacoma Alliance

PSA	Port Of Singapore Authority
PTE	Pure Technical Efficiency
PTE	Pure Technical Efficiency
RMG	Rail Way Mountain Gantries
R-MPG	Port Integration In A Region With Multiport Gateways
Ro/Ro	Roll On/Roll
RTG	Rubber Tiers Gantries
RTS	Return to Scale
SC	Straddle Carriers
SFA	Stochastic Frontier Analysis
SICP	Strategic International Container Ports
SWOT	Strength, Weakness, Opportunities And Threats Analyses
TEU	Twenty Equivalent Unit
TFA	Thick Frontier Approach
TOPS	Technically Optimal Productive Scale
UASC	United Arab Shipping Company
UNCTAD	United Nation Conference For Trade And Development
USA	United States of America
VRS	Variable Return To Scale

XLSTAT	Name of Cluster Analysis Software

Appendix 5-1

Ports infra/superstructure data of the 42 study ports which are used as DEA model input data

Rank 2016	Port	Country	Quay Length (m)	Max Depth (m)	Total Area (ha)	Gantry Cranes	Yard equipment			Dev. Distance (nm)
							RMG	RTG	S.C	
1	Shanghai	China	13000	17.5	673	156		297		170
2	Singapore	Singapore	19173	18	744	223	100	300		0
3	Shenzhen	China	14590	17	795	156	16	408		123
4	Ningbo	China	9500	22	820	112		345		113
5	Hong Kong	China	7694	15	279	99	36	164		113
6	Busan	S. Korea	11123	18	629	106		311		0
8	Qingdao	China	7500	17.5	225	78		218		554
7	Guangzhou	China	7600	15	700	71	7	209		192
9	Jebel Ali	UAE	9737	15.5	670	102	60	123		1658
10	Tianjin	China	16000	15.5	577	47		178		987
11	Port Kelang	Malaysia	8100	17.5	549	93		255	37	0
12	Rotterdam	Netherlands	15650	20	2454	124		383	52	63
13	Kaohsiung	Taiwan	6897	16.4	371	61	42	127	11	31
14	Antwerp	Belgium	11555	17	1597	103		20	260	57

Rank 2016	Port	Country	Quay Length (m)	Max Depth (m)	Total Area (ha)	Gantry Cranes	Yard equipment			Dev. Distance (nm)
							RMG	RTG	S.C	
15	Dalian	China	5700	17.8	411	47		112		695
16	Xiamen	China	6865	16	649	64	2	139	11	28
18	Hamburg	Germany	7535	15.3	325	80	17		378	0
19	Tanjung Pelepas	Malaysia	5040	19	180	58		180		0
20	Laem Chabang	Thailand	3400	16	188	46		119		823
21	Saigon port	Vietnam	2166	12	202	24	7	81		123
24	Saigon new port	Vietnam	3226	16	147	26	1	58	0	405
25	Bremerhaven	Germany	4930	16.5	304	41			166	3
26	Valencia	Spain	4310	16	185	38		88	30	84
27	Tanjung Priok	Indonesia	2800	14	158	39	5	126		1062
28	Khorfakkan	UAE	2270	16	77	22		33		818
29	Algeciras	Spain	2480	18	97	35	32	59	22	0
30	Jawaharlal Nehru	India	1992	14	135	27	11	87		468
32	Keihin	Japan	9310	20	356	73		135	9	1090
31	Manila	Philippines	3625	14	217	29		76		308

Rank 2016	Port	Country	Quay Length (m)	Max Depth (m)	Total Area (ha)	Gantry Cranes	Yard equipment			Dev. Distance (nm)
							RMG	RTG	S.C	
33	Jeddah	Saudi Arabia	4500	16	302	34		101		0
34	Gioia Tauro	Italy	3391	18	160	23			100	90
35	Piraeus	Greece	3300	19.5	79	37	42	22	22	224
37	Felixstowe	U.K.	3274	16	173	33		85		43
40	Salalah	Oman	2204	18	95	25		68		302
41	Port Said East	Egypt	2400	14.5	122	21		65		0
42	Marsaxlokk	Malta	2483	17	77	21		45		212
43	Tanger	Morocco	1600	18	80	16		49		28
45	Keelung	Taiwan	3703	15	32	30	9	12	12	739
47	Kobe	Japan	4800	15	160	31	53			583
48	Yokohama	Japan	3590	16	144	25	6	34		1220
49	Ambarli	Turkey	3200	16.5	80	16		63		961
50	Inchon	S. Korea	2448.5	16	138	23	30	31		496

Appendix 5-2

Study ports throughput from 2011 till 2016 representing DEA output data

Port	Country	Throughput in (000’)					
		2011	2012	2013	2015	2015	2016
Shanghai	China	31739	32528	33620	35285	36516	37132
Singapore	Singapore	29938	31649	32579	33869	30922	30904
Shenzhen	China	22570	22960	23280	24030	24142	23949
Ningbo	China	13220	16783	17330	19450	20636	21586
Hong Kong	China	24384	23118	22352	22226	20073	19813
Busan	S. Korea	16185	17023	17686	18683	19469	19245
Qingdao	China	13020	14609	15520	16624	17323	17998
Guangzhou	China	14260	14514	15505	16363	17097	18311
Jebel Ali	UAE	12618	13013	13632	15240	15585	15736
Tianjin	China	11588	12298	13012	14050	13881	14269
Port Kelang	Malaysia	9435	10001	10350	10946	11887	13201
Rotterdam	Netherlands	11877	11866	11621	12298	12235	12385
Kaohsiung	Taiwan	9636	9781	9938	10593	10264	10465
Antwerp	Belgium	8664	8635	8578	8978	9654	10037
Dalian	China	6400	8064	9910	10805	9591	9735
Xiamen	China	6461	7209	8008	8572	9215	9630

Hamburg	Germany	9014	8889	9257	9783	8821	8907
Tanjung Pelepas	Malaysia	7302	7494	7417	8232	8797	8013
Laem Chabang	Thailand	5068	5926	6041	6583	6780	7430
Saigon port	Vietnam	4426	4892	5112	6334	6556	6825
Saigon new port	Vietnam	3066	3515	3798	4750	5026	5987
Bremerhaven	Germany	5915	6115	5838	5777	5547	5518
Valencia,	Spain	4327	4470	4328	4442	4615	5222
Tanjung Priok	Indonesia	5618	6214	5466	5034	5154	4935
Khorfakkan	UAE	3230	3996	4000	4256	4414	4903
Algeciras	Spain	3601	4113	4343	4555	4516	4781
Jawaharlal Nehru	India	4321	4259	4162	4467	4492	4500
Keihin	Japan	4554	4235	4885	4917	4150	4251
Manila	Philippines	3465	3707	3779	3810	3976	4427
Jeddah	Saudi Arabia	4010	4738	4561	4184	4102	3957
Gioia Tauro	Italy	3307	3725	3652	3708	3512	3833
Piraeus	Greece	1681	2815	3199	3493	3360	3736
Felixstowe	U.K.	3249	3368	3434	4072	3676	3635
Salalah	Oman	3252	3630	3340	3030	2569	3325
Port Said East	Egypt	2864	2711	2947	3258	3036	3203

Marsaxlokk	Malta	2360	2538	2745	2869	3064	3079
Tanger	Morocco	2093	1826	2493	3078	2971	2964
Keelung	Taiwan	2403	2705	2642	2943	2666	2866
Kobe	Japan	2725	2564	2534	2617	2707	2801
Yokohama	Japan	2725	2564	2534	2617	2707	2801
Ambarli	Turkey	2122	2440	3318	3445	3062	2780
Inchon	S. Korea	1998	1982	2161	2335	2368	2679

Appendix 5-3

Sensitivity analysis of top container ports in the East- West trade route for the year (2012)

SN	Ports	DEA-CCR (2016)	Efficiency score after input deleted					
			Quay length	Max Depth (m)	Total Area (ha)	Gantry Cranes	Yard equipment	Dev. Dist. (nm)
1	Saigon port	100%	100%	100%	100%	100%	100%	100%
2	Shanghai	100%	100%	100%	100%	100%	100%	100%
3	khorfakkan	100%	100%	100%	100%	100%	94%	100%
4	Qingdao	100%	100%	100%	90%	100%	100%	100%
5	Hong Kong	100%	100%	100%	90%	100%	100%	100%
6	Guangzhou	100%	100%	100%	100%	83%	100%	100%
7	Singapore	100%	100%	100%	100%	100%	100%	81%
8	Algeciras	100%	100%	100%	100%	100%	100%	73%
9	Busan	100%	100%	100%	100%	100%	100%	73%
10	Keelung	100%	100%	100%	69%	100%	100%	100%
11	Tianjin	100%	100%	100%	100%	63%	100%	100%
12	Tanjung Pelepas	100%	100%	100%	88%	98%	100%	63%
13	Saigon new port	92%	92%	92%	92%	76%	89%	92%
14	Port Kelang	93%	78%	93%	93%	93%	93%	57%
15	Bremerhaven	88%	88%	88%	88%	84%	72%	56%
16	Ningbo	80%	80%	80%	80%	79%	80%	78%
17	Port Said East	83%	83%	83%	83%	76%	83%	59%
18	Dalian	82%	81%	82%	82%	67%	75%	82%
19	Kaohsiung	80%	80%	80%	80%	65%	80%	67%
20	Jawaharlal Nehru	76%	66%	76%	72%	76%	76%	76%
21	Laem Chabang	76%	67%	76%	72%	76%	76%	76%
22	Tanger	75%	75%	75%	73%	66%	75%	74%
23	Xiamen	72%	72%	72%	72%	65%	71%	60%

SN	Ports	DEA-CCR (2016)	Efficiency score after input deleted					
			Quay length	Max Depth (m)	Total Area (ha)	Gantry Cranes	Yard equipment	Dev. Dist. (nm)
24	Hamburg	73%	73%	73%	68%	70%	73%	47%
25	Shenzhen	66%	66%	64%	66%	66%	66%	66%
26	Gioia Tauro	67%	67%	67%	67%	60%	62%	67%
27	Jebel Ali	66%	66%	65%	66%	66%	63%	66%
28	Ambarli	69%	69%	69%	59%	46%	69%	69%
29	Marsaxlokk	63%	63%	63%	60%	60%	62%	63%
30	Tanjung Priok	61%	52%	61%	57%	61%	61%	61%
31	Jeddah	63%	63%	63%	63%	53%	63%	43%
32	Manila	59%	58%	59%	59%	45%	55%	59%
33	Salalah	57%	56%	57%	51%	56%	57%	57%
34	Valencia	56%	56%	56%	53%	46%	56%	56%
35	Piraeus	55%	55%	55%	41%	55%	54%	55%
36	Antwerp	54%	54%	54%	54%	54%	40%	52%
37	Yokohama	49%	49%	49%	49%	48%	43%	49%
38	Inchon	45%	45%	45%	44%	38%	45%	45%
39	Felixstowe	44%	44%	44%	43%	39%	44%	44%
40	Rotterdam	42%	42%	42%	42%	29%	42%	40%
41	Kobe	38%	38%	38%	38%	35%	36%	38%
42	Keihin	24%	24%	24%	24%	24%	24%	24%
No. of ports affected by input elimination			7	2	16	24	11	15

Appendix 5-4

Comparison between the input and output oriented results using the DEA- CCR slack variable analysis

port	Score		Quay Length		Max Depth		Total Area		Gantry Cranes		Yard equipment		Dev. Dist.		Throughput	
	input	output	input	output	input	output	input	output	input	output	input	output	input	output	input	output
Algeciras	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Busan	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guangzhou	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hong Kong	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keelung	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Qingdao	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Singapore	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saigon port	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shanghai	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tianjin	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0

port	Score		Quay Length		Max Depth		Total Area		Gantry Cranes		Yard equipment		Dev. Dist.		Throughput	
	input	output	input	output	input	output	input	output	input	output	input	output	input	output	input	output
khorfakkan	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanjung Pelepas	99.7	99.68	-10	-9.7	-5.3	-5.3	-0.3	0	-0.3	0	-20	-20.2	0	0	0	0.3
Port Kelang	93.1	93.16	-6.9	0	-6.9	0	-25	-19.1	-19	-13.2	-19	-13.1	0	0	0	7.3
Saigon new port	92.2	92.17	-12	-4.9	-75	-72.9	-7.8	0	-7.8	0	-7.8	0	-76	-74.3	0	8.5
Bremerhaven	88.1	88.58	-35	-26	-79	-75.8	-54	-48.3	-12	0	-12	0	0	0	0	12.9
Port Said East	83.4	83.69	-25	-9.7	-79	-74.3	-17	0	-17	0	-22	-6.3	0	0	0	19.5
Dalian	81.9	81.92	-18	0	-59	-50.2	-44	-32.1	-18	0	-18	0	-75	-70	0	22.1
Ningbo	80.3	82.5	-20	0	-49	-40	-48	-39.6	-20	0	-48	-35.7	0	0	0	21.2
Kaohsiung	80.1	82.63	-35	-16	-59	-46.7	-34	-14.8	-20	0	-36	-16.1	0	0	0	21

port	Score		Quay Length		Max Depth		Total Area		Gantry Cranes		Yard equipment		Dev. Dist.		Throughput	
	input	output	input	output	input	output	input	output	input	output	input	output	input	output	input	output
Jawaharlal Nehru	76.1	76.11	-24	0	-68	-58.2	-24	0	-35	-14	-55	-40.2	-90	-87.4	0	31.4
Laem Chabang	75.8	75.82	-24	0	-72	-63.5	-24	0	-33	-11.9	-47	-30.1	-95	-93	0	31.9
Tanger	75.2	75.42	-36	-15.5	-87	-84.4	-25	0	-25	0	-43	-28.2	0	0	0	32.6
Hamburg	73	73.18	-31	-5.3	-27	0	-27	0	-27	0	-32	-7.2	0	0	0	36.6
Xiamen	71.5	77.22	-39	-13.9	-62	-48.8	-66	-53.3	-29	0	-29	0	0	0	0	29.5
Ambarli	69.2	69.15	-68	-53.1	-78	-68	-31	0	-31	0	-45	-20.3	-93	-89.4	0	44.6
Gioia Tauro	67.4	67.36	-45	-18.8	-88	-81.6	-47	-21.7	-33	0	-33	0	-32	0	0	48.4
Shenzhen	66.4	72.05	-43	-8.9	-34	0	-45	-17.5	-36	0	-55	-28.4	-11	0	0	38.8
Jebel Ali	65.9	65.92	-42	-12.4	-34	0	-58	-36	-35	-1.3	-34	0	-86	-78.5	0	51.7
Jeddah	63.4	63.74	-50	-21	-77	-64.1	-58	-33.6	-37	0	-38	-1.9	0	0	0	56.9

port	Score		Quay Length		Max Depth		Total Area		Gantry Cranes		Yard equipment		Dev. Dist.		Throughput	
	input	output	input	output	input	output	input	output	input	output	input	output	input	output	input	output
Marsaxlokk	63	62.98	-51	-22.8	-80	-67.8	-37	0	-37	0	-37	0	-40	-5.1	0	58.8
Tanjung Priok	61	61	-39	0	-78	-63.7	-39	0	-48	-14.6	-68	-47	-97	-95.3	0	63.9
Manila	58.9	58.9	-41	0	-71	-50.8	-49	-12.9	-41	0	-41	0	-72	-51.6	0	69.8
Salalah	56.5	56.47	-44	0	-88	-78.3	-44	0	-44	0	-53	-17.4	-84	-72.2	0	77.1
Valencia	55.6	56.11	-56	-24.7	-68	-56.5	-44	0	-44	0	-46	-16.6	0	0	0	78.2
Piraeus	54.9	55.53	-45	-11	-73	-63.5	-45	0	-52	-16.3	-45	0	-7.9	0	0	80.1
Antwerp	53.5	61.81	-70	-41.9	-71	-52.5	-89	-80.1	-59	-22.6	-47	0	0	0	0	61.8
Yokohama	49.2	49.24	-67	-32.4	-59	-15.9	-68	-35.1	-51	0	-51	0	-74	-46.5	0	103.1
Inchon	45.1	45.13	-63	-17.8	-81	-57.6	-55	0	-55	0	-55	0	-93	-84.1	0	121.6
Felixstowe	44.1	45.77	-61	-12.8	-79	-74.2	-56	-4	-56	0	-57	-20.2	0	0	0	118.5
Rotterdam	41.7	48.11	-72	-24.8	-69	-11.2	-90	-73.8	-58	0	-75	-25.5	0	0	0	107.9

port	Score		Quay Length		Max Depth		Total Area		Gantry Cranes		Yard equipment		Dev. Dist.		Throughput	
	input	output	input	output	input	output	input	output	input	output	input	output	input	output	input	output
Kobe	38.1	38.1	-79	-45.4	-88	-69.5	-69	-17.5	-62	0	-62	0	-94	-83.2	0	162.5
Keihin	24.4	24.44	-84	-33.9	-90	-58.8	-78	-10.8	-76	0	-76	0	-98	-92.2	0	309.2
total efficient inputs			11	19	11	15	11	25	11	35	11	25	25	28	42	11
total improvement need improvement			31	23	31	27	31	17	31	7	31	17	17	14	0	31

Appendix 6-1

The difference of efficiency (CCR-CRS, output oriented) scores between 6 and 3 inputs

Rank	Unit name	6 inputs	3 inputs	%Change (output oriented)	Rank	Unit name	6 inputs	3 inputs	%Change (output oriented)
1	Ambarli	100%	100%	0%	23	Shenzhen	91%	89%	1%
2	Keelung	100%	100%	0%	24	Busan	100%	79%	21%
3	Qingdao	100%	100%	0%	31	Kobe	92%	87%	4%
4	Saigon port	100%	100%	0%	15	Salalah	92%	86%	5%
5	Shanghai	100%	100%	0%	27	Jebel Ali	88%	88%	0%
6	Tanger	100%	100%	0%	33	Tanjung Pelepas	100%	76%	24%
7	Tianjin	100%	100%	0%	39	Bremerhaven	100%	73%	27%
8	khorfakkan	100%	100%	0%	35	Port Kelang	96%	75%	20%
9	Hong Kong	100%	100%	0%	36	Xiamen	92%	78%	13%

Rank	Unit name	6 inputs	3 inputs	%Change (output oriented)	Rank	Unit name	6 inputs	3 inputs	%Change (output oriented)
13	Port Said East	100%	100%	0%	22	Laem Chabang	86%	84%	2%
10	Guangzhou	100%	99%	1%	29	Kaohsiung	92%	77%	14%
14	Jawaharlal Nehru	100%	96%	4%	34	Felixstowe	86%	82%	3%
11	Marsaxlokk	100%	94%	6%	37	Jeddah	91%	75%	15%
12	Saigon new port	100%	92%	8%	32	Valencia	85%	81%	3%
16	Singapore	100%	91%	9%	30	Piraeus	87%	75%	10%
25	Tanjung Priok	93%	93%	0%	40	Antwerp	84%	74%	8%
21	Yokohama	96%	88%	7%	26	Dalian	83%	74%	7%
17	Inchon	93%	90%	2%	28	Ningbo	82%	73%	7%
19	Algeciras	100%	83%	17%	41	Rotterdam	71%	65%	4%
18	Gioia Tauro	100%	82%	18%	42	Keihin	61%	60%	1%

Rank	Unit name	6 inputs	3 inputs	%Change (output oriented)	Rank	Unit name	6 inputs	3 inputs	%Change (output oriented)
38	Hamburg	100%	81%	19%					
20	Manila	92%	87%	5%					