EVALUATING THE COMPETITIVENESS OF QINZHOU PORT ON THAILAND-GUANGXI ROUTE UNDER PAN-BEIBU GULF ECONOMIC COOPERATION

LIURONG QIN

A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Master of Science Degree in Logistics and Supply Chain
July 2017

Thesis entitled "Evaluating the Competitiveness of Qinzhou Port on Thailand-Guangxi Route under Pan-Beibu Gulf Economic Cooperation"

By Liurong Qin

has been approved by the Graduate School as partial fulfillment of the requirements for the Master of Science Degree in Logistics and Supply Chain of Naresuan University

Oral Defense Committee

.... Chair

(Assistant Professor Preda Pichayapan, Ph.D.)

.... Advisor

(Boonsub Panichakarn, Ph.D.)

.... Internal Examiner

(Assistant Professor Pupong Pongcharoen, Ph.D.)

Approved

....

(Panu Putthawong, Ph.D.)

Associate Dean for Administration and Planning

for Dean of the Graduate School

2 4 JUL 2017

ACKNOWLEDGEMENT

First of all, I would like to express my sincere gratitude to Dr.Boonsub Panichakarn and Professor Fan Fan, who provided me with the opportunity of being a scholarship student at the Naresuan University (NU). It is my pleasure.

Also, I really grateful to the company, Nakhonsawan Tungprasert (NTPS Group), which offered the two-year scholarship to help cover the tuition and a part of living expenses for me.

Next, I would like to express my deepest gratitude to my supervisor, Dr.Boonsub Panichakarn for his patience guidance and valuable advice during my study. Without his guidance, patience and support, this thesis would not be possible.

I would also like to thank the staffs in School of Logistics and Supply Chain, for their time and help during my studying and living.

Special thanks must go to my friends in NU, for their kindness, warmth and those happy times we were staying together. Especially my roommate Fahui Xie, who encourage me, support me and hold me accountable for my progress.

Last but not least, I want to express all my love to my family, especially my father Mao Qin and my mother Zhilan Fan. This thesis is dedicated to my loving parents, for their endless love, support and encouragement.

Liurong Qin

Title	EVALUATING THE COMPETITIVENESS OF QINZHOU PORT ON THAILAND-GUANGXI ROUTE UNDER PAN-BEIBU GULF ECONOMIC COOPERATION
Author	Liurong Qin
Advisor	Boonsub Panichakarn, Ph.D.
Academic Paper	Thesis M.S. in Logistics and Supply Chain, Naresuan University, 2016
Keywords	Qinzhou Port, Port Competitiveness, Data Envelopment Analysis

ABSTRACT

This thesis was aimed to, through Data Envelopment Analysis (DEA), analyze the efficiency and competitive position of Qinzhou Port, compared with the rest eight ports of containerization in Pan-Beibu Gulf Economic Cooperation (PBGEC) region. The research innovatively adopt the Charnes, Cooper and Rhodes (CCR) model-DEA, Banker, Charnes and Cooper (BCC) model-DEA to determine the overall efficiency, pure technical and scale efficiency, and then the Super Efficiency Model-DEA has been used to indicate the efficiency ranking of the nine ports in the PBGEC. The result implies that Qinzhou port exists input redundancy and insufficient output due to its scale efficiency. Also, Qinzhou port is posed in an inferior position in its competitiveness. Lastly, suggestions for overcoming such weakness and then enhance the competitiveness are presented accordingly.

LIST OF CONTENT

LIST OF CONTENT (CONT.)

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION

PBG	=	Pan-Beibu Gulf
PBGEC	=	Pan-Beibu Gulf Economic Cooperation
ASEAN	=	Association of Southeast Asia Nations
TEU	=	Twenty-foot Equivalent Unit
WEF	=	World Economic Forum
IMD	=	International Institute for Management Development
DEA	=	Data Envelopment Analysis
CCR	=	Charnes, Cooper and Rhodes Model
BCC	=	Banker, Charnes and Cooper Model
EMS	=	Efficiency Measurement System
DMU	=	Decision Making Units
RTS	=	Return to Scale
VRS	=	Variable Return to Scale
CRS	=	Constant Return to Scale
DRS	=	Decreasing Return to Scale
IRS	=	Increasing Return to Scale

CHARPTER I

INTRODUCTION

Background of the Research

As a new sub-regional cooperation project within the frame of China-Association of Southeast Asian Nations (ASEAN) free trade zone, Pan-Beibu Gulf Economic Cooperation (PBGEC) has been posed as a hot issue for both China and ASEAN. ASEAN is a political and economic organization to accelerate economic growth, social progress, and cultural development and to promote peace and security in Southeast Asia. There are ten Southeast Asian countries in ASEAN that contain Vietnam, Philippines, Malaysia, Singapore, Indonesia, Myanmar, Thailand, Cambodia, Laos and Brunei (Moon, 2016). The PBGEC is a new sub-regional cooperation within the frame of China- ASEAN free trade area, the economic cooperation region includes the coastal areas from the Beibu Gulf to the southern sea of China, consists of China (Chinese provinces Guangxi, Guangdong, Hainan, the Hong Kong and the Macao) and ASEAN countries. Among the Beibu Gulf and the rest of the South China Sea are important transportation ways between China and ASEAN, and the trade within this region is mainly conducted through the Pan-Beibu Gulf (Gu, 2011). In addition, With the rapid development of economic globalization and regional economic integration and much closer China- ASEAN and PBGEC strategic partnership, in 2013, the bilateral trade volume between Guangxi and ASEAN countries reached 491 million US dollars with a growth of 61.2% over that of the previous year in 2013. Among Thailand has been Guangxi's fifth major trade partner (Forum, 2015). Obviously, PBGEC and Thailand-Guangxi route have very practical significance for both Thailand and Guangxi. As an initiative to create the costal industrial areas making full advantages in maritime transport with neighboring countries, China takes Qinzhou port (see below Figure 1) as one of gateways for Thailand and Guangxi.

The evaluation of the competitiveness of Qinzhou port is critically important. From a nation's perspective, maritime transport becomes very important to the nation's integration. Over 90% of international trade is through transporting by sea, and over

60% China-ASEAN trade is through port logistics (Zou, 2012). In order to support trade oriented economic development, seaports have to improve port competitiveness by ensuring that seaport services are provided on an international competitive basis (Tongzon, 2001). Thus, a seaport with strong competitiveness is an important factor to a nation's international competitiveness. While, in terms of the significance of sea ports, Qinzhou Port, in particular, is the only foreign trade container port in Guangxi, the container hub in Beibu Gulf. From October, 2015, all of foreign trade container routes of other ports in Guangxi have been transferred to the Qinzhou port except fruit trade (Daily, 2016). In the past 2015, the throughput of Qinzhou port reached 6.51 million tons, of which the throughput of container is 0.942 million twenty-foot equivalent unit (TEU) (see Qinzhou port throughput in Figure 2). So Qinzhou port is the busiest container port in Guangxi (Bureau, 2016), which paves the way for the Beibu Gulf port into an international shipping hub in Southeast Asia.

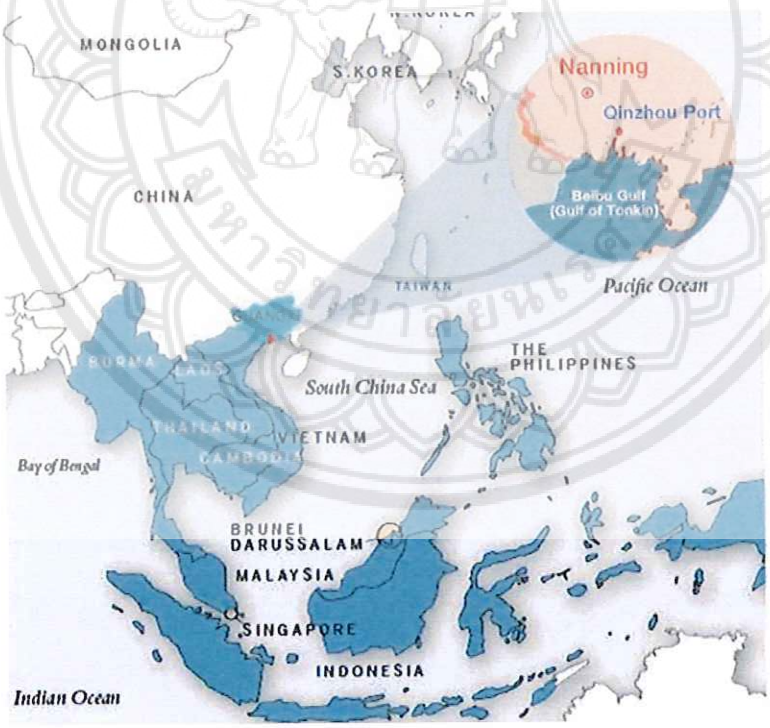

Figure 1 Qinzhou Port Location

Source: http://www.thaibizchina.com/thaibizchina/th/china-economic-business/result.php?SECTION_ID=461&ID=15108, 2016

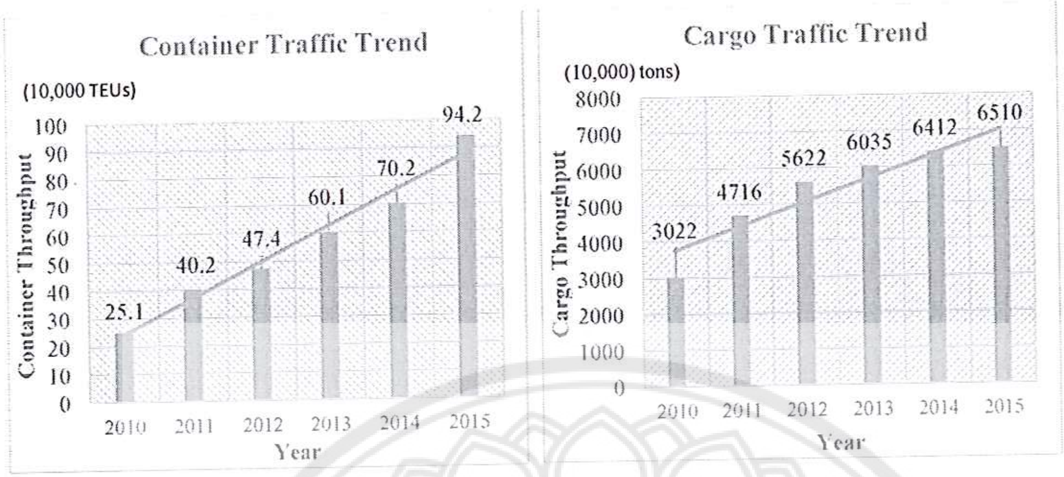

Figure 2 Qinzhou Port Throughput 2010-2015

Source: Guangxi Statistical Yearbook, 2011-2015

The Guangxi Zhuang Autonomous Region Bureau of Statistics, 2016

However, evaluation of the container port competitiveness is not an easy case. Competitiveness is rather flexible and can be used for numerous different purposes in basic economic units (company, sector, region, country, and macro-region) (Vuković, Jovanović, & Đukić, 2012). In order to evaluate the seaport competitiveness, one of the most important instruments to assess seaport competitiveness is the efficiency (Cruz, 2012; Van de Voorde & Winkelmans, 2002). Nevertheless, it should be pointed out that few studies have been less investigated the competitiveness of Qinzhou port. In particular, the studies that combined with Data Envelopment Analysis (DEA) method used in Qinzhou port cannot be found. Therefore, this research is to analyze the competitiveness of Qinzhou port in DEA method through efficiency. For such purpose, what are to be compared and analyzed are Qianzhou port and the rest eight ports, namely, Guangzhou port, Shenzhen port, Zhanjiang port, Zhuhai port within Guangdong province; Haikou port, Yangpu port within Hainan province; Hong Kong port and Thailand's Laem Chabang port.

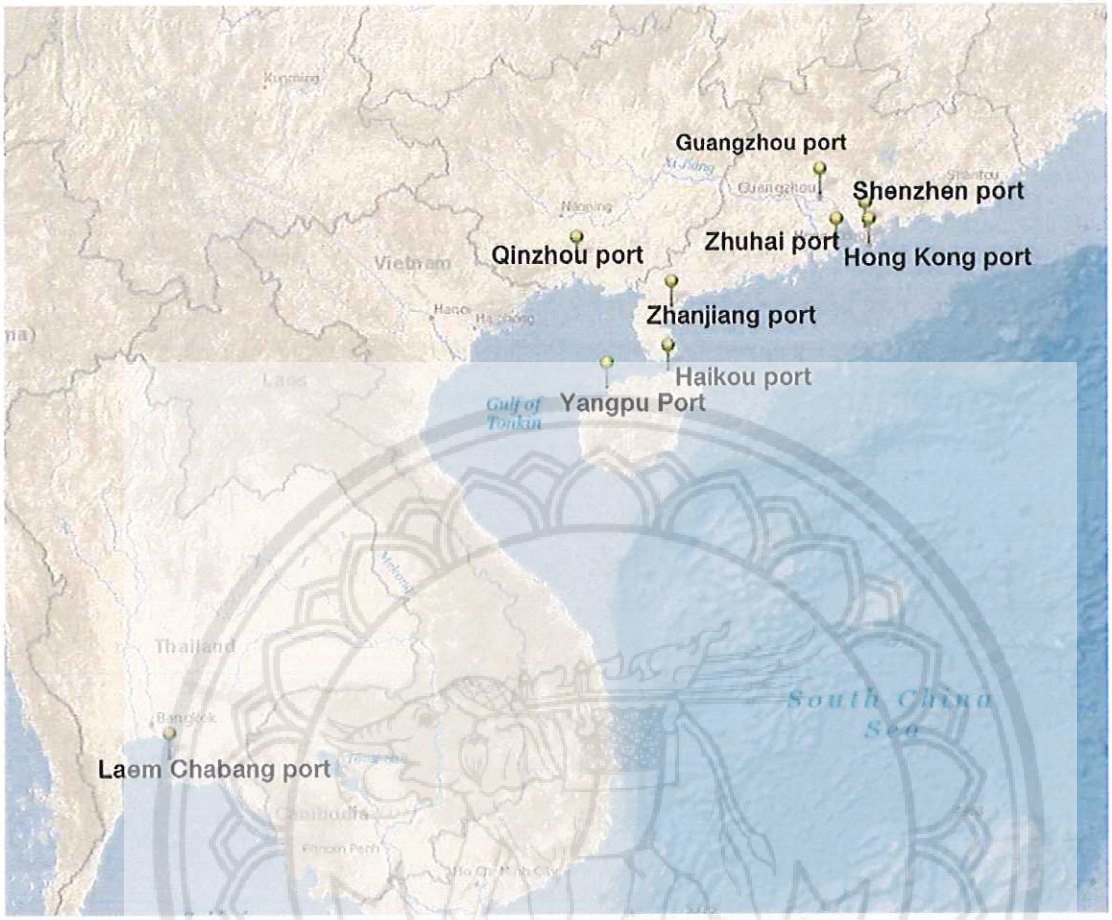

Figure 3 Location of the Nine Ports

Source: ArcGIS, 2016

Objectives

1. To analyse the efficiency and competitive position of Qinzhou port compared with the rest eight container ports on Thailand-China maritime route under PBGEC.

2. To propose suggestions to enhance Qinzhou port competitiveness based on DEA results.

Importance

With the fast growth of economic and trade cooperation between China and ASEAN, and increasing cooperation with PBGEC, Qinzhou port is becoming increasingly important. Therefore, there are many relevant articles about Qinzhou port have published and some researches and discussions on developing port logistics of Qinzhou port. However, few studies have been less investigated the competitiveness of Qinzhou port, especially the academic research that combined with analysis methods which used in the thesis are even no. Consequently, the research on the port competitiveness of Qinzhou port is very meaningful.

Moreover, research on the competitiveness of Qinzhou port can be one part to find the weakness of itself, and knows the gap between other ports, then the port can adopt a proper strategy to bridge the gaps and develop in a correct direction.

Research on the competitiveness of Qinzhou port can promote the structure optimization of the port's organization and improvement on strategizing to strengthen coordination, communication and control inside a port and promote efficiency and effectiveness of management.

Scope of Work

Area scope: analyzed from the title and objectives of the thesis, we know that the research focus on container ports between the maritime route of Thailand and China in PBGEC region. So the research area is focusing on Thailand, Hong Kong, Guangxi, Guangdong and Hainan provinces. In these areas, the major container ports of Thailand-China route in PBGEC region are caused to analyze.

Route and ports scope: the route scope includes maritime routes between Thailand and China under PBGEC. For this study, nine container ports located in the PBGEC area are compared and analyzed, namely, Hong Kong port, Guangxi's Qinzhou port, Thailand's Laem Chabang Port, Guangdong's Guangzhou port, Shenzhen port, Zhanjiang port, Zhuhai port and Hainan's Haikou port, Yangpu port.

Term Definition

Competitiveness : Competitiveness is a kind of ability, which at a superficial level is the ability to allocate and utilize the resource advantages that competitors cannot, and at a more fundamental level is the ability to integrate various resources organically, which are the elements of the enterprises(B. Liu & Liu, 2009).

Port competitiveness	:	Ports' (as independent economic entities) comparative ability against their rivals in occupying market share, creating value and maintaining healthy development, all these are carried out in process of configuring, creating and arranging resources to organically and properly in competing market environment (Sang, 2006).
Container	:	A reusable steel rectangular box for carrying cargo that first came into common use about 50 years ago. The sizes of containers are standardized so that they can easily be moved between specially adapted containers ships, trains and trucks. A container may be 20 feet, 40 feet, 45 feet, 48 feet or 53 feet in length, 8'0" or 8'6" in width, and 8'6" or 9'6" in height. (Administration, 2008; Council, 2016).
TEU	:	Twenty-foot Equivalent Unit (20 feet long, 8 feet wide, and 8 feet 6 inches high). A standard unit for measuring containers and describing a ship's cargo carrying capacity, or shipping terminal's cargo handling capacity (Council, 2016).

Research Framework

Here is the research framework as Figure 4 shows.

Chapter 2 is the literature review from the perspectives of competitiveness, Thailand-Guangxi logistics, PBGEC as well as the DEA.

Chapter 3 explains the methodology of this research, including research procedure, input and output variables, data collection, introduction of the DEA models, model calculation and DEA flow process.

Chapter 4, the data and results are presented through the DEA models.

Chapter 5 gives the suggestions for overcoming weakness and then enhance the port competitiveness. Thereafter, the conclusions and further research are also presented.

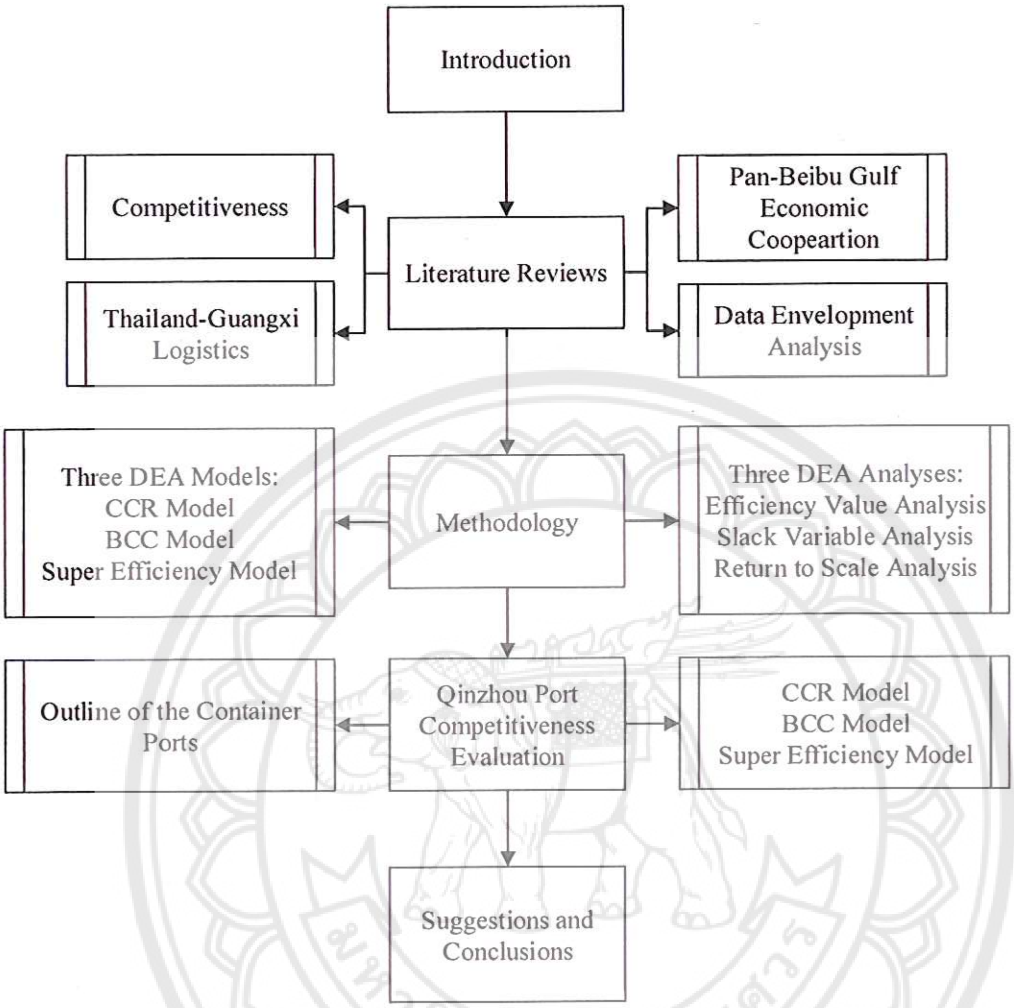

Figure 4 Research Framework

Notes: DEA: Data Envelopment Analysis; CCR: Charnes, Cooper and Rhodes; BCC: Banker, Charnes and Cooper

CHARPTER II

LITERATURE REVIEWS

The literature review is following an introduction. This chapter is divided into four sections. Firstly, some relevant concepts in competitiveness is presented. Secondly, it is a brief review of the current situation of Thailand-Guangxi logistics. Thereafter, an outline of PBGEC is presented. Finally, the last section will review on the assessment method applied in port competitiveness.

Competitiveness

In order to evaluate port competitiveness, the first was the question of what is the competitiveness. In the following section, we will first discuss the definition of competitiveness, then describe about port competitiveness.

1. Definition of Competitiveness

The term "competitiveness" has been discussed during the past decades. There appears to be no agreement on what competitiveness means. In practice, different definitions can be envisaged depending on the focus of interest (Begg, 1999).

For the region, Atkinson (2013) considered the competitiveness as "the ability of a region to export more in value added terms than it imports".

For a country, nowadays there are mainly three competitiveness research have been recognized: Michael Porter's competitiveness theory, World Economic Forum (WEF)'s Global Competitiveness Report and International Institute for Management Development (IMD)'s World Competitiveness Yearbook. Similarly, competitiveness was defined as productivity. The WEF's Global Competitiveness Report defined competitiveness as "the set of institutions, policies, and factors that determine the level of productivity of a country" (Porter, 1990). The WEF's Global Competitiveness Report defined competitiveness as "the set of institutions, policies, and factors that determine the level of productivity of a country" (Schwab & Sala-i-Martin, 2010). IMD's World Competitiveness Yearbook defined competitiveness as "the ability of a nation to create and maintain an environment that sustains more value creation for its enterprises and more prosperity for its people" (IMD, 2012).

For the enterprise, the United Kingdom government defined competitiveness as: "the ability to produce the right goods and services of the right quality, at the right price, at the right time. It means meeting customers' needs more efficiently and more effectively than other firms" (DTI, 1995).

Sang' s master thesis defined industrial competitiveness as: "enterprises' (as independent economic entities) comparative ability against their rivals in occupying market share, creating value and maintaining healthy development, all these are carried out in the process of configuring, creating and arranging resources organically and properly in a competing market environment" (Sang, 2006).

B. Liu and Liu (2009) considered the competitiveness as " a kind of ability, which at a superficial level is the ability to allocate and utilize the resource advantages that competitors cannot, and at a more fundamental level is the ability to integrate various resources organically, which are the elements of the enterprises".

Besides the above definition, Castillo-Manzano, Castro-Nuño, Laxe, López-Valpuesta, and Teresa Arévalo-Quijada (2009) considered that competitiveness as " based on the capacity of a port to create added value, generate a nucleus of business, and produce productive or industrial activity in the surrounding area".

However, there were also a standard definition of competitiveness were offered from European Commission: "competitiveness is the ability of companies, industries, regions, nations and supra-national regional units to produce with simultaneous exposure to international competition, relatively high income and high levels of employment" (Commision, 1999).

Through the above review, it shows that competitiveness is rather flexible and can be used for numerous different purposes in basic economic units (company, region, country) (Vuković et al., 2012). On this issue, this thesis tends to definition of B. Liu and Liu (2009), "competitiveness is a kind of ability, which at a superficial level is the ability to allocate and utilize the resource advantages that competitors cannot, and at a more fundamental level is the ability to integrate various resources organically, which are the elements of the enterprises".

2. Port Competitiveness

Similar to definition of competitiveness, there appears to be no agreement on what port competitiveness means.

Gu-Tae Yeo and Song (2006) considered that "port competitiveness provides ship owners, operators and shippers with a significant basis in selecting a calling-port, port operators can utilize the competitive advantage as a parameter for counter measures by grasping the advantages and disadvantages of the ports and be a prime factor of opportunities and threats of the ports. Also, port competition is a term commonly used to reflect the current status of the industry; all ports in the world make their respective efforts to secure and/or maintain a certain level of cargo flow".

W.-C. Huang, Teng, Huang, and Kou (2003) defined port competitiveness as "the ability of a port and its vicinity in the creation of value-added".

Dai and Chen (2006) considered that ports competition can be referred to "the competitive advantage and capability compared to other ports, in market occupancy, value creation, and maintaining continuous development, through the elements assembling, optimizing and interacting with exterior environment".

Sang (2006) gave a definition of port competitiveness that, "ports' (as independent economic entities) comparative ability against their rivals in occupying market share, creating value and maintaining healthy development, all these are carried out in process of configuring, creating and arranging resources to organically and properly in competing market environment".

B. Liu and Liu (2009) defined Port competitiveness as "the ability and opportunity that a port enterprise has to provide high-quality and low-price service for relative enterprises and industries in the competitive market environment, so as to achieve the maximum value of port enterprises".

It is shown that port competitiveness is a complicated concept through above review. In this thesis, the author agrees with the point of Sang (2006), port competitiveness as "ports' (as independent economic entities) comparative ability against their rivals in occupying market share, creating value and maintaining healthy development, all these are carried out in process of configuring, creating and arranging resources to organically and properly in competing market environment".

Thailand-Guangxi Logistics

With the China-ASEAN and PBG cooperation has made progress in recent years, Thailand and Guangxi logistics has been developed. In 2013, the bilateral trade volume between Guangxi and ASEAN countries reached 491 million US dollars with a growth of 61.2% over that of the previous year. Thailand ranks fifth in Guangxi-ASEAN trade (Forum, 2015).

The Guangxi government pays high attention to the relationship with ASEAN countries. Guangxi plays a very active role at promoting PBGEC, the Greater Mekong Sub-regional Cooperation, etc. In order to promote the economy and trade development, the culture and education exchange with ASEAN countries, the Guangxi government perfects the transportation infrastructure construction and logistics supporting actively. Below are some conditions of the logistics between Guangxi and Thailand.

Road: China and Thailand agreed to enhance road transport, especially on the Route 9 Highway linking Mukdahan province, Laos, Vietnam and Southern China, and the Route 12 Highway linking Nakhon Phanom, Laos, Vietnam and Southern China (Deparment, 2015). China is ready to facilitate transport of Thai farm exports like fruits and rice on the two highways (Review, 2009). At the same time, building another Nanning-Bangkok route has been discussed among the countries of Vietnam, Laos, Thailand and China. It will be another more convenient land route about 1600kms from Nanning-Youyi Guan-Hanoi-Muzhou (No. 6 highway)-Sam Nuua (Laos)-Xieng Khouang-Vientiane-Nong Khai-Khon Kaen-Bangkok (Hu, n.d.). The route connectivity as shown in the Figure 5.

Railway: as shown in Figure 6, all the ASEAN countries reached a consensus to build the Trans-Asian Railway on the ASEAN-Mekong Basin Develop Cooperation Ministerial Conference, and hope it will be accomplished before 2020 (Hu, n.d.).

Air: Guangxi is actively expending the ASEAN airway transport. Meanwhile, until the end of 2016, the direct flights and connecting flights from Guangxi's Nanning Wuxu, Guilin Liangjiang and Beihai Fucheng International Airports to Thailand's Suvarnabhumi, Chiang Mai, Chiang Rai, Samui, Krabi, Phuket, U-Tapao and Don Mueang International Airports have been opened, of which Nanning Wuxu – Suarnabhumi, Nanning Wuxu – U-Tabao, Nanning Wuxu – Don Mueang, Nanning Wuxu – Phuket, Guilin Liangjiang – Suvarnabhumi, and Beihai Fucheng – Suarnabhumi International Airports are direct flights (Airport, n.d.; Hu, n.d.; Y. Huang, 2015; Qunar, 2017). The direct flights map as shown in Figure 7.

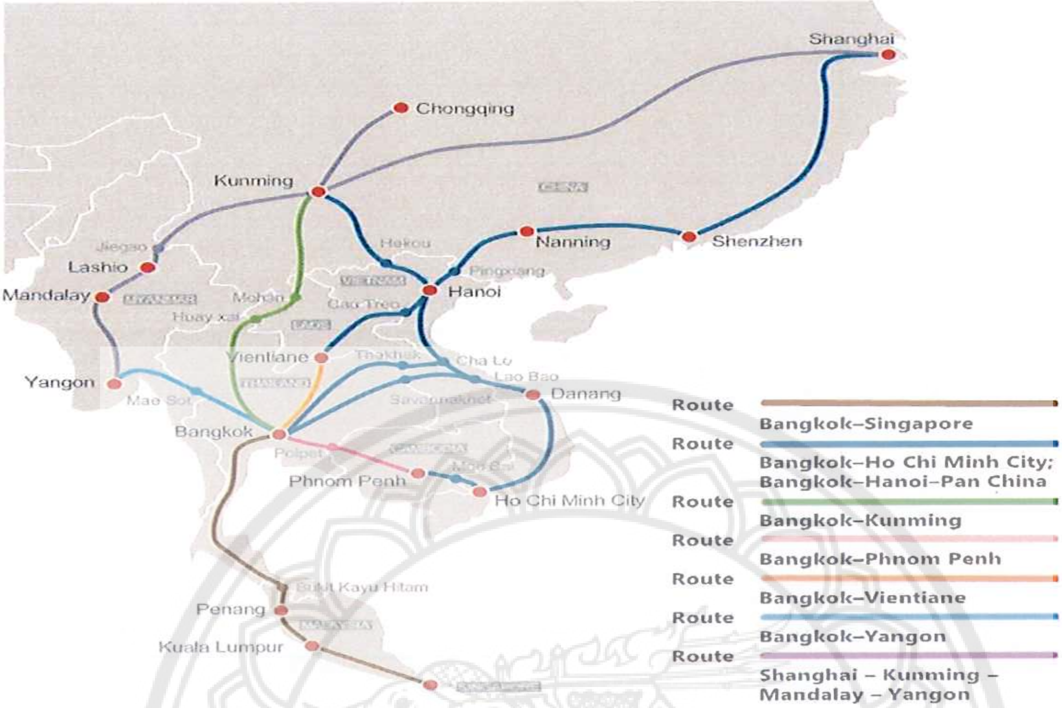

Figure 5 Road Connectivity

Source: Kerry Logistics, 2015

Figure 6 Trans-Asia Railway

Source: http://www.greenenergyinvestors.com/index.php?showtopic=19569, 2016

Figure 7 Direct Flights Map

Notes: Green line: Beihai Fucheng – Suvarnabhumi International Airports;
Pink line: Guilin Liangjiang – Suvarnabhumi International Airports;
Blue lines: Nanning Wuxu – Suvarnabhumi, Nanning Wuxu – U-Tabao, Nanning Wuxu – Don Mueang, Nanning Wuxu – Phuket International Airports

Source: Guilin Liangjiang International Airport, 2017
Qunar.Com, 2017

Sea: Guangxi has built the maritime trade relationship with Thailand. The container liner transport is already available through Beibu Gulf to Thailand (Hu, n.d.). The international services routes as shown in Figure 8. In April, 2015, Fangcheng port of Guangxi was approved as an appointed fruit port import by the General Administration of Quality Supervision, Inspection and Quarantine, becoming the first appointed fruit port in Guangxi (Chinanews, 2015). In May, 2016, Qinzhou port also was approved as an appointed fruit port (Pang & Chen, 2016).

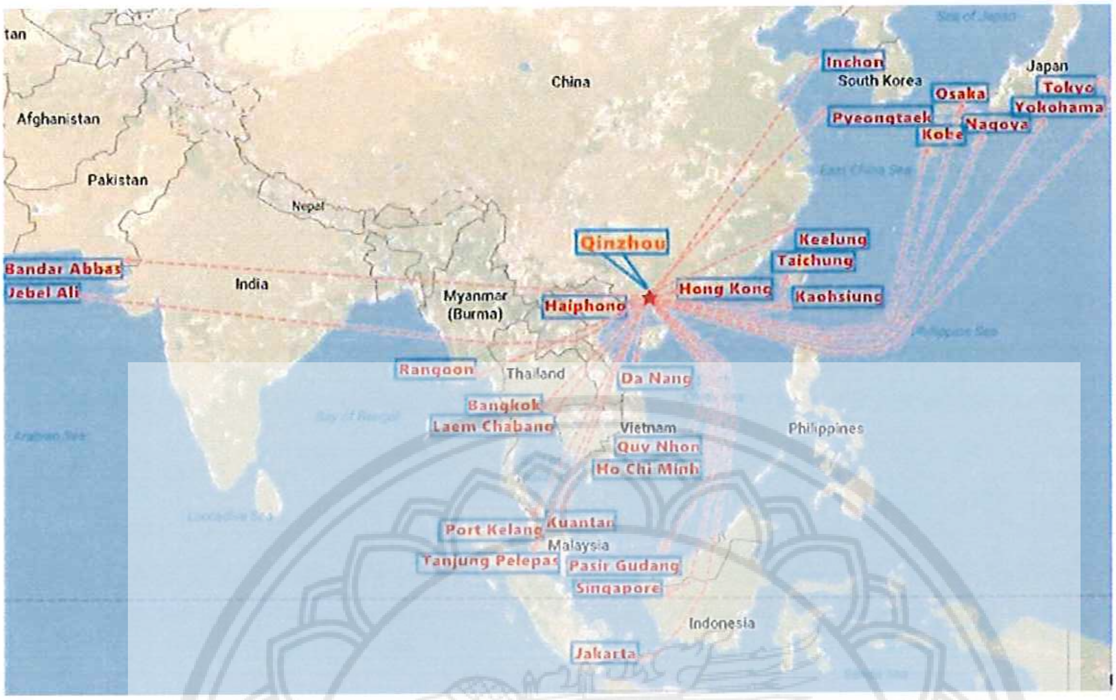

Figure 8 Beibu Gulf International Service

Source: Qinzhou Port Group Corporation Limited, 2016

In recent years, with the development of economic globalization, market internationalization and the information network, the Thailand-Guangxi logistics has achieved rapid development. But compared with the international advanced ports and logistics, there is still a big gap. Thailand and Guangxi should work together, grasp the opportunities and move forward port logistics and business cooperation, bilateral relations and friendship.

Pan-Beibu Gulf Economic Cooperation (PBGEC)

In order to better understand the PBGEC, let's first learn about the Beibu Gulf.

Beibu Gulf also known as the Gulf of Tonkin (see Figure 9) , is water surrounded by coastal area of the Guangxi Zhuang Autonomous Region (Guangxi), Peninsular of Leizhou, West of Hainan Island and coastal area of northeast of Vietnam, with the total area of around 130000 km² (Hosokawa, 2009).

Figure 9 Beibu Gulf (Gulf of Tonkin)

Source: http://www.grandesbatallas.es/batalla%20de%20saigon.html, 2016

Pan-Beibu Gulf is a new sub-regional cooperation area within the frame of China- ASEAN free trade area, the economic cooperation in Beibu Gulf includes the coastal areas from the Beibu Gulf to the southern sea of China, including China (Chinese provinces Guangxi, Guangdong, Hainan, the Hong Kong and the Macao), Vietnam, Philippines, Malaysia, Singapore, Indonesia, Brunei, Thailand, Myanmar, Laos and Cambodia (see Figure 10). The PBGEC centers on maritime cooperation, covers a large region, and has enormous potential.

PBGEC area has a lot of ports, there are more than 100 various ports of ASEAN countries. The sea center connected by Beibu Gulf and South China Sea, of which Vietnam's Haiphongt, Hozhi Ming, Jin Pu; Malaysia's Klang, Bintulu, Johore, Penang; Indonesia's Dan Rong Purico, Philippines Manila, Singapore port are all largest ports with more than 10 million ton annual throughput, of which Singapore port is one of the world class ports (Fan, 2014).

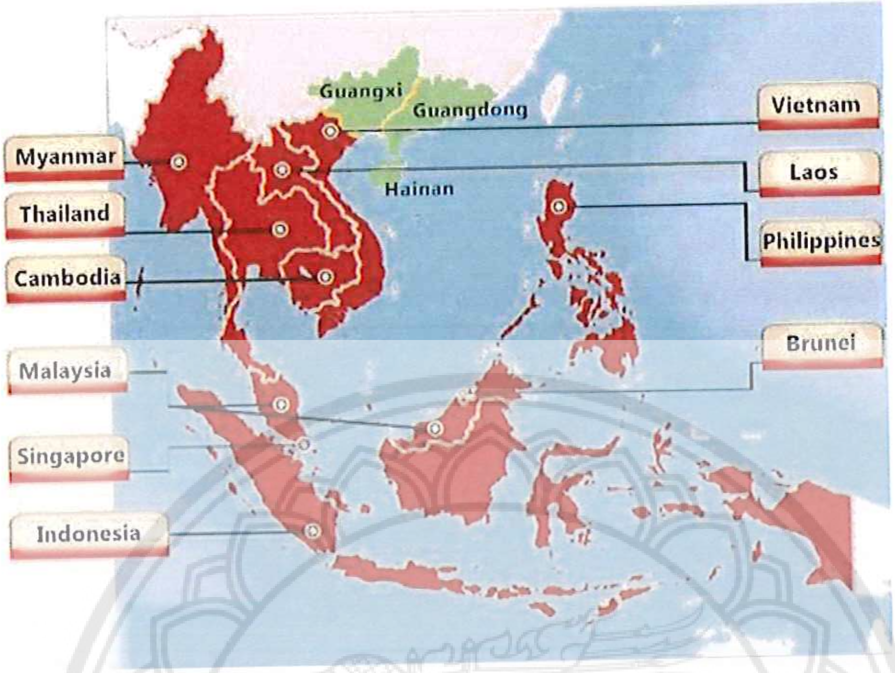

Figure 10 Pan-Beibu Gulf Economic Cooperation Region

Source: http://news.hsdhw.com/124260, 2016

PBGEC's Chinese area involves provinces Guangxi, Guangdong, Hainan, the Hong Kong and the Macao, including Guangxi's Fangcheng port, Qinzhou port, Beihai port; Guangdong's Guangzhou port, Shenzhen port, Zhuhai port, Zhanjiang port, Hainan's Haikou port, Yangpu port, Bapu port, Hong Kong port, etc. Hongkong port is the most important port in the area.

With the expansion and deepening of PBGEC in recent years, Thailand and Guangxi jointly promoted the port logistics and the other important areas in deep cooperation, completed special planning about port logistics, transportation construction and other important areas, strengthened the land transportation construction from Nanning to Bangkok, put forward the development goals, key projects and security measures for Thailand-Guangxi port cooperation. All this has laid an important foundation for closer cooperation in Thailand and Guangxi (Portal, 2014).

Data Envelopment Analysis (DEA)

1. Concepts of DEA

DEA is a non-parametric performance assessment methodology originally designed by Charnes, Cooper and Rhodes (1978) to measure the relative efficiencies of organizational or decision making units (DMUs). The DEA approach applies linear programming techniques to observe inputs consumed and outputs produced by decision-making units and constructs an efficient production frontier based on best practices. Each DMU's efficiency is then measured relative to this frontier. In other words, DEA assesses the efficiency of each DMU relative to all the DMUs in the sample, including itself. This relative efficiency is calculated by obtaining the ratio of the weighted sum of all outputs and the weighted sum of all inputs (Sheth, 1999).

The DEA method helps to identify inefficient DMUs as well as the sources and amounts of inefficiency of inputs and /or outputs. The DEA formulation can incorporate both input and output orientations as well as constant and variable returns to scale, of which CCR (Charnes, Cooper and Rhodes) and BCC (Banker, Charnes and Cooper) model are widely studied and applied. The first DEA model, CCR allows input and output orientations and assumes constant returns to scale was introduced by Charnes, Cooper, & Rhodes (1978). While the BCC model allows input and output orientations and assumes variable returns to scale was introduced by Banker et al. (1984). According to Gollani and Roll (1989), the CCR model identifies overall technical efficiency (pure technical efficiency and scale efficiency), while the BCC, pure technical efficiency only.

2. Term Definition of DEA Efficiency

Scale efficiency can be simply defined as the efficiency of the current size (input level) for the given input mix (Q. Liu, 2010).

Technical efficiency: the efficiency of a firm's production by comparing the industry optimal production for the given input mix and the given input level. Technical efficiency has been decomposed into the product of measures of scale efficiency and pure technical efficiency (Gollani and Roll, 1989; Fare, Grosskopf, & Lovell, 1994).

Pure technical efficiency can be described as managerial skills, assuming overall technical efficiency is due to managerial skills and scale effects. A ratio of the overall technical efficiency scores to pure technical efficiency scores provides a scale efficiency measurement (Barros, 2006).

Returns to scale, can be described to changes in output resulting from a proportional change in all inputs (where all inputs increase by a constant factor). If output increases by that same proportional change then there are constant returns to scale (CRS). If output increases by less than that proportional change, there are decreasing returns to scale (DRS). If output increases by more than that proportional change, there are increasing returns to scale (IRS) (Lu & Wang, 2016).

3. The DEA Applied in Ports

In recent years, DEA has been increasingly used to analyze port production. Compared with traditional approaches, DEA has the advantage that it can cater for multiple inputs to and outputs from the production process. This accords with the characteristics of port production, so that there exists, therefore, the capability of providing an overall summary evaluation of port performance (Lu & Wang, 2016). This study summaries the DEA method used in ports in recent 10 years in the Appendix A. Then the statistics of DEA method used in ports are shown in Figure 11.

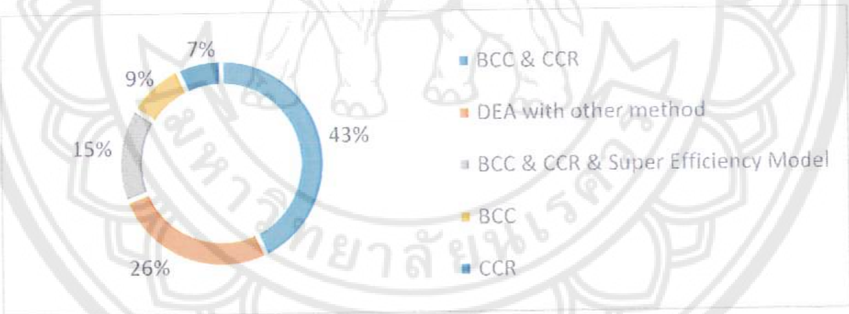

Figure 11 Statistics of the DEA Method used in Ports in Recent 10 Years

As indicated in the Appendix A and Figure 10. There have been many empirical studies on measuring port efficiency by using DEA in the literature. The models mostly used to apply the DEA method are the CCR model and BCC model.

With regards to the CCR and BCC model, 20 papers (43%) are published adopted with these two models in the port efficiency evaluation. Among Lu and Wang (2012) used both CCR and BCC models to analyze the efficiency of 14 China and 17 Korea container terminals. The results indicate that the terminals under the study exist substantial waste the scale and the leading container terminals are not saturated.

For BCC model only, there are four papers were through the BCC model to investigate the port efficiency, in which B.-L. Liu, Liu and Cheng (2008) used the BCC model to measure the efficiency of 45 container terminals in mainland China. The results shown that the productivity of China's container terminals are improved during the 3 years (2001-2006). The study also find that the Sino-foreign Joint Ventures perform better than Domestic Companies, and the terminals handling the containers of international shipping lines are more efficient than those engaged in domestic shipping lines.

With respect to the CCR model only, three papers were studied. Among Almawsheki and Shah (2015) evaluated the 19 container terminals in the Middle Eastern region through CCR model. The results shown that the Jebel Ali, Salalah and Beirut container terminal are the most efficient terminals in the region.

For CCR, BCC and super efficiency model, seven papers (approximately 15%) were applied these models to analyze the port efficiency, in which Munisamy and Singh (2011) applied these models to assess the performance of the 69 major Asian container ports. The findings of the paper is the overall technical inefficiencies of Asian container ports are primarily due to pure technical inefficiencies rather than to scale inefficiencies. Finally the suggestion also presented accordingly.

Moreover, there are 12 papers also adopted DEA models with other method to assess the port performance. Such as Jang, Park and Kim (2016) applied the DEA with Shannon's Entropy to measure the performance of 21 container terminals in Asia. This is the first work was applied Shannon's Entropy the in the port context.

Through the above review, there have been many empirical studies on measuring port efficiency by using DEA in the literature. The models mostly used to apply the DEA method are the CCR model and BCC model. However, it should be pointed out that few studies have been less investigated the competitiveness of Qinzhou port. In particular, the studies that combined with DEA method used in Qinzhou port cannot be found.

CHAPTER III

RESEARCH MATHODOLOGY

Here's the methodology will present the research procedure first (see Figure 12), and then will explain research methodology following the research procedure.

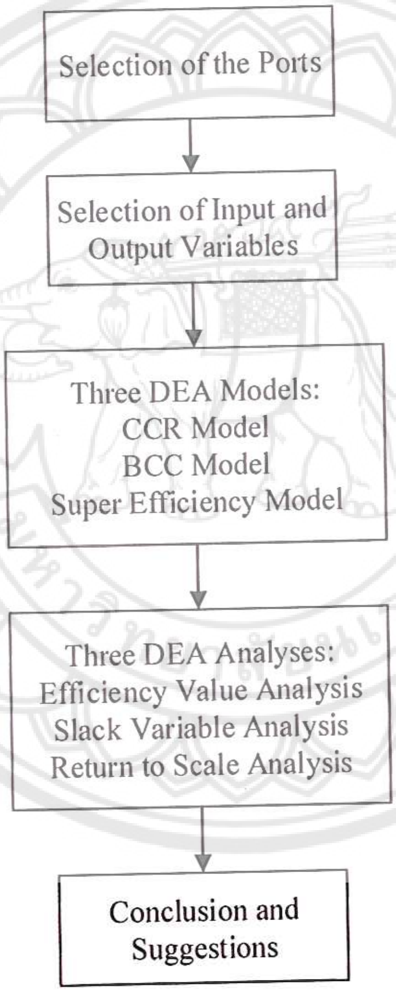

Figure 12 Research Procedure

Notes: DEA: Data Envelopment Analysis; CCR: Charnes, Cooper and Rhodes;
BCC: Banker, Charnes and Cooper

Selection of the Ports

The ports adopted in the thesis are nine container ports on Thailand-China route under PBGEC, namely, Qinzhou port, Laem Chabang port, Guangzhou port, Shenzhen port, Zhanjiang port, Zhuhai port, Haikou port, Yangpu port and Hong Kong port.

Input and Output Variables

1. Selection of Input and Output Variables

DEA can evaluate a DMU's performance with multiple inputs and multiple outputs. However, DEA also has the limitation. In order to avoid having too many DMUs with efficiency value being equal to 1, which would lower the discriminatory power of DEA, Norman and Stoker (1989) proposed that the number of DMUs should be at least twice the sum of input and output variables. So, considering the thesis had nine ports, adopting this suggestion would mean that the sum of input and output variables could not be more than four (Golany & Roll, 1989).

There have been many empirical studies on measuring port efficiency by using DEA in the literature. The input and output variables used in these studies in recent 10 years are presented in Appendix A. Thereafter, Table 1 counts for various variable occurrences in these studies. Table 1 tells us berth length, terminal area and number of berth are the three most frequently adopted input variables and the most frequently adopted output variable is container throughput in the previous studies. Accordingly, in this study, to take into account the previous research and ports situation, the number of berths, berth length (meter), and terminal area (hectare) are considered as input variables, and container throughput (TEU) is used as the output variables. The summary of input and output variables used in this research as shown in Table 2.

Table 1 The Frequency of Various Variables Adopted in the Previous Studies

Variables	Frequency (times)	Variables	Frequency (times)
Input Variables:			
Berth length (or quay length)	38	Terminal area	24
Number of berths	14	Quay crane	10
Yard area (or storage yard area)	10	Warehouse area (or storage area)	5

Table 1 (cont.)

Variables	Frequency (times)	Variables	Frequency (times)
Input Variables:			
Straddle carrier	5	Number of cranes	5
labor	5	Total yard equipment	5
Container cranes	4	Max draft	4
Terminal length	3	Terminal crane	3
Number of yard gantry	3	Number of yard crane	3
gantry	3	Quayside gantry	3
Cargo handling equipment	3	Number of pieces equipment	3
Yard tractor	3	Quayside cranes	3
Land size	3	Quay depth	2
Yard gantry crane	2	Water depth	2
Quay crane index	2	Yard stacking index	2
Handling equipment	2	Number of yard tractor	2
Reefer points	2	Operational expense	2
Rubber-tyred gantry crane	1	Fixed asset	1
Turnover	1	Ships handled	1
Reach stackers	1	Capital expenses	1
Port aggregate investment	1	Cargo gear number	1
Traveling bridge number	1	Working hours	1
Trucks and vehicles	1	Container handling trucks	1
Vehicles	1	Gates	1
Gate lanes	1	Quay equipment	1
Sophisticated equipment	1	General equipment (forklifts and yard tractor)	1
Import / export by customs	1	GDP by regions	1
Size of parking lot for incoming trucks/ parking lot	1	Storage capacity (total storage of all terminals in TEU)	1
Output Variables:			
Container throughput	36	Cargo throughput	10
Ship traffic	3	Vessel calls (gross tons)	2
Container handling trucks	1	Average total turnaround time (days)	1
Average output per ship berth day (tones)	1	Number of loaded shipments per year	1
Dry bulks / solid bulks	1	Liquid bulks	1
Co_2 emission	1	passengers	1

Table 2 Input and Output Variables Used in the DEA Models

Variables		Description	Measurement Unit
Input 1	Number of berths	Total container berths in container terminals of port	Number
Input 2	Berth length	Total container berth length of container terminals in port	Meter
Input 3	Terminal area	Total area of container terminals in port	Hectare
Output	Container throughput	Total container throughput in TEU	10, 000 TEU/year

2. Data Collection

Necessary information and data on input and output variables of DEA were collected and available through statistical yearbook, websites from the port, terminal, port authority and the other specialized websites.

3. Method of Data Analyzing

After obtaining the data, then we can apply these data into model through software. In this thesis, to analyze data through the CCR and BCC models with application MaxDEA software first, and then apply the super efficiency model to the EMS1.3 software according to the data.

The DEA Models and Analyses

1. Model Specification

DEA models are classifiable according to the type of envelopment surface and the orientation (input or output). There are two basic types of envelopment surface in DEA known as constant returns to scale and variable returns to scale. The first DEA model, CCR (Charnes, Cooper and Rhodes) was introduced by Charnes, Cooper, & Rhodes (1978) (Charnes, Cooper, & Rhodes, 1978). The CCR model identifies overall technical efficiency (pure technical efficiency and scale efficiencies) based on constant returns to scale. While the BCC (Banker, Charnes and Cooper) model introduced by Banker et al. (1984) and identifies pure technical efficiency only (based on variable returns to scale).

With respect to the model orientation, the input-oriented model focuses on how much inputs can be reduced while maintaining the same level of output, while the output-oriented model focuses on how much can output(s) increase while remaining the level of inputs the same. The input-oriented model is closely related to operational and managerial issues, and the output-oriented model is more related to planning and strategies (Cullinane, Song, Ji, & Wang, 2004). In this thesis, BCC and CCR models, input and output oriented are both to be used.

Because the above models are given a value of 1 for all efficient DMUs, it is unable to establish any further distinctions among the efficiency DMUs. Therefore, the DEA-Super Efficiency Model is to be used to rank the ports. This model removes an efficient DMU, and then estimates the production frontier again; this provides a new efficiency value for the efficient DMU that had previously been removed. The new efficiency value can thus be greater than 1. However, if an inefficient DMU is removed, the original production frontier does not change (Lu & Wang, 2016).

1.1 CCR model

Assuming that there are n DMUs, where each DMU_j (j=1, $\cdots$, n) produces s output $y_{rj}(r = 1, \cdots, s)$ by utilizing m inputs x_{ij}(i= 1,$\cdots$, m).

Then the CCR model is formulated in the following form:

$$\text{Max } h_j = \frac{\sum_{r=1}^{s} U_r y_{rj}}{\sum_{i=1}^{m} V_i x_{ij}} \tag{1}$$

$$\text{Subject to: } \frac{\sum_{r=1}^{s} U_r y_{rj}}{\sum_{i=1}^{m} V_i x_{ij}} \leq 1;\ j=1,2,\cdots,n$$

$$U_r, V_r > 0;\ r=1,2,\cdots,s;\ i=1,2,\cdots,m;$$

Where: h_k is the relative efficiency of the jth DMU;

y_{rj} is rth outputs of the jth DMU;

x_{ij} is *i*th inputs of the *j*th DMU;

U_r is a weight of *r*th DMU;

V_i is a weight of *i*th input.

Because formula (1) is a linear fractional programming problem, it is difficult to calculate. So it can be transformed to the linear programming dual that easy to calculate as follows:

$$\text{Min } \theta - \varepsilon\left[\sum_{r=1}^{s} s_r^+ + \sum_{i=1}^{m} s_i^-\right] \tag{2}$$

Subject to: $\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{ij}$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{rj}$$

$$\lambda_j \geq 0, s_r^+, s_i^- \geq \varepsilon \geq 0.$$

Where: ε is a small positive number;

λ_{j_i} is a weight of *j*th DMU;

s_r^+ is a slack variable of *r*th output;

s_i^- is a slack variable of *i*th input.

If and only if s_r^+ =0, s_i^- =1, θ =1, DMU is efficient.

1.2. BCC Model

The BCC model adds the convexity restriction ($\sum_{j=1}^{s} \lambda_j = 1$) based on formula (2). The linear programming dual of BCC model can be presented as follows:

$$\text{Min } \theta - \varepsilon\left[\sum_{r=1}^{s} s_r^+ + \sum_{r=1}^{m} s_i^-\right] \tag{3}$$

Subject to: $\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{ij}$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{rj}$$

$$\sum_{j=1}^{s}\lambda_j = 1$$

$$\lambda_j, s_r^+, s_i^- \geq 0$$

If and only if $\theta = 1$, $\left[\sum_{r=1}^{s} s_r^+ + \sum_{r=1}^{m} s_i^-\right]$=0, DMU is efficient.

1.3. Super Efficiency Model

The Super Efficiency Model is formulated in the following form:

Min θ (4)

Subject to: $\sum_{j=1, j\neq j_0}^{n} \lambda_j x_j + s_i^- = \theta x_{ij}$

$$\sum_{j=1, j\neq j_0}^{n} \lambda_j y_j - s_r^+ = y_{rj}$$

$$\lambda_j, s_r^+, s_i^- \geq 0$$

2. Flow Process of DEA

In this thesis, the process of DEA models and analyses are shown in the Figure 13. With respect to the CCR and BCC models, when the efficiency value is equal to 1, the meaning is the DMU is efficient. When the efficiency value is less than 1, the main cause of the inefficiency has to be judged based on the comparison from scale efficiency and pure technical efficiency. After confirming the main cause of inefficiency, the improvement of inefficient DMUs can be analyzed from the slack variable analysis. Then, using the return to scale analysis, it is possible to designate the return to scale for each DMU as increasing, decreasing, or constant (Lin & Tseng, 2007). Finally, the super efficiency model was adopted to rank the DMUs when the CCR and BBC models are given a value of 1 for all efficient DMUs. The new value of super efficiency model can be greater than 1. The description of detailed process is presented as follows:

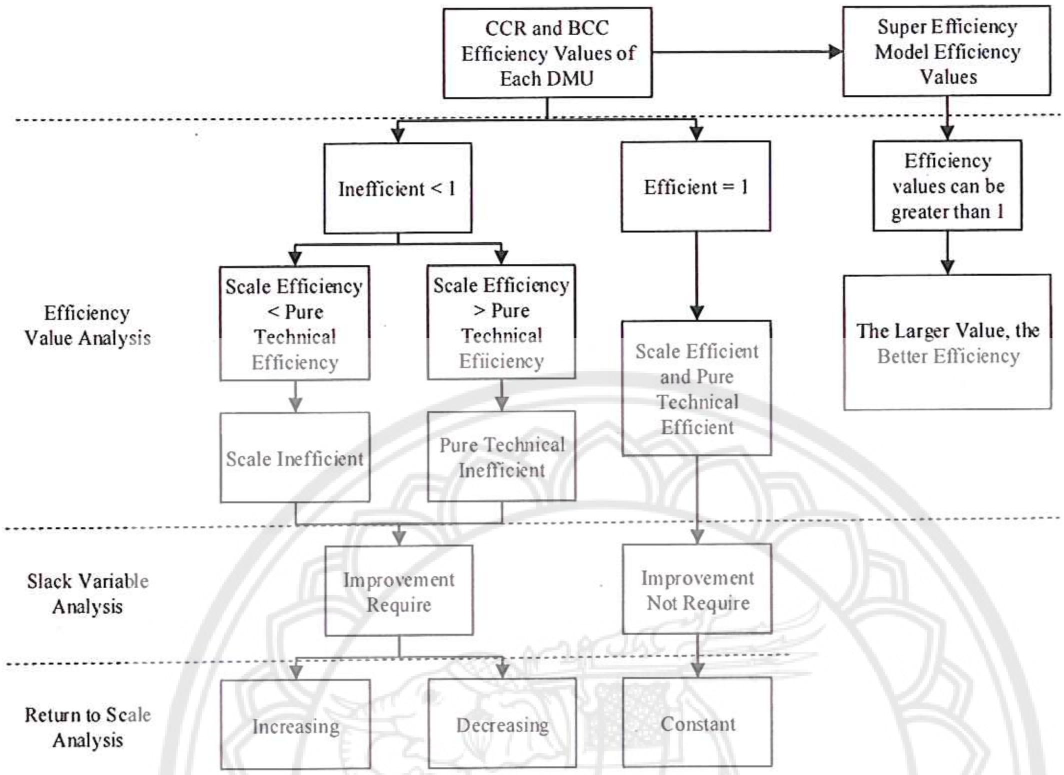

Figure 13 Flow Process of DEA

Notes: CCR: Charnes, Cooper and Rhodes Model; BCC: Banker, Charnes and Cooper Model

Source: modified from Lin and Tseng, 2007

1. For CCR and BCC Model

1.1 To Calculate the Efficiency Value Through Software MaxDEA

To run the model through the software MaxDEA, the relative efficiency score is obtained as shown in Table 3. The port is efficient when the efficiency score is equal to 1. While the port is inefficiency when the efficiency score is less than 1. At the same time, the software gives the proportionate movement value, slack movement value and projection value to inefficient port as supplements. The proportionate movement represents input redundancy value and slack movement indicates the insufficient output value and projection denotes the efficient target value (projection=original + proportionate movement + slack movement). These values can be one part to help the inefficient port knows the gap between other ports and improves by adjusting the input/output.

Table 3 Sample of Results of CCR and BCC Models with Application Software MaxDEA

DMU		Input 1			Input 2			Input 3	Output
Port	Score	Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection	...	...
Qinzhou port	--	--	--	--	--	--	--	--	--
Hong Kong port	--	--	--	--	--	--	--	--	--
⋮	--	--	--	--	--	--	--	--	--

1.2 To Calculate the Scale Efficiency with Application Software MaxDEA

In the previous step, the technical efficiency (the efficiency value from the CCR model) and pure technical efficiency (the efficiency value from the BCC model) were obtained, then scale efficiency value also can be calculated through software MaxDEA. To through the software MaxDEA, the scale efficiency and return to scale value is presented. According to compare the scale efficiency and pure technical efficiency value, it is possible to judge the main cause of port inefficient. With respect to the return to scale, from the result of software, it is possible to know that each port as increasing, decreasing or constant.

2. For Super Efficiency Model

Because the CCR and BBC models are given a value of 1 for all efficient DMUs so the super efficiency model was adopted to rank the DMUs. To run the model through software EMS, and then the ports ranking score is obtained. The ranking result shows the port's competitive position in the sample ports.

CHAPTER IV

QINZHOU PORT COMPETITIVENESS EVALUATION

This chapter aims to analyze the efficiency and competitive position of Qinzhou port, compared with the rest eight ports of containerization in Pan-Beibu Gulf Economic Cooperation (PBGEC) region through Data Envelopment Analysis (DEA) as mentioned in chapter three. What comes first is an outline of the nine container ports which are analysis in this thesis. After the description of ports, the data used in DEA method are presented. Thereafter, the DEA results and analysis are to be presented.

Outline of the Nine Container Ports

1. Qinzhou Port

Qinzhou port is located in the south of Guangxi Province, the north of Beibu Gulf, the south west of the coast line of China, and it serves as the main sea passage for the Great Southwest China to connect the Asian area and the world. In 2015, the throughput of Qinzhou port reaches 6.51 million tons, of which container is 0.942 million TEUs (Bureau, 2016).

The container business of Qinzhou port mainly operated by Guangxi Qin Zhou International Container Terminal Co., Ltd and Beibu Gulf –PSA International Container Terminal Co., Ltd. By the end of 2015, there are four container berths with 2.33 million TEU handling capacity. Facilities of container terminals in Qinzhou port are shown in Table 4. Qinzhou port has cover Southeast Asia and Northeast Asia in foreign trade container lines, the international liner routes to Vietnam, Myanmar, Thailand, Malaysia, Singapore, Indonesia, Japan and South Korea and other main ports are opened (Group, 2016).

Table 4 Facilities of Container Terminals in Qinzhou Port (Year 2015)

Terminals	Total area (hectare)	Berth (number)	Berth length (meter)	Terminal Operator
GQICT	76	2	767	Guangxi Qin Zhou International Container Terminal Co., Ltd (GQICT)
BPCT	82	2	1533	Beibu Gulf –PSA International Container Terminal Co., Ltd (BPCT)
Total	158	4	2300	

Source: Guangxi Statistical Yearbook 2016;
Guangxi Qin Zhou International Container Terminal Co., Ltd, 2016;
Beibu Gulf –PSA International Container Terminal Co., Ltd, 2016;
Statistical Communiqué of Qinzhou on the 2015 National Economic and Social Development, 2016

2. Hong Kong Port

Hong Kong port is one of the busiest and most efficient international container ports in the world. It provided about 340 container liner services every week, connecting about 470 destinations around the world. In the 2015, the container throughput of Hong Kong port reached 20.1 million TEU.

There are nine container terminals in Hong Kong port. They are cover 279 h and provide 24 container berths (see Table 5). Currently, the nine terminals are operated by Hongkong International Terminals Limited, Modern Terminals Limited, COSCO-HIT Terminals (Hong Kong) Limited, Asia Container Terminals Limited and Goodman DP World (Board, n.d.).

Table 5 Facilities of Container Terminals in Hong Kong Port (Year 2015)

Facilities	Unit
Container terminals (number)	9
Berths (number)	24
Berth length (meter)	7694
Quay crane (number)	99
Yard area (hectare)	279
Draft (meter)	17.5
Handling capacity (million TEU)	Over 20

Source: Hong Kong Maritime and Port Board, 2016;
Port of Hong Kong in Figures, 2016

3. Laem Chabang Port

Laem Chabang port located in the north part of the gulf of Thailand. It is the largest port in Thailand with 2572 acres. It handled 6.794 million TEU in 2015, Laem Chabang port is directly subordinate to the Port Authority of Thailand. However, the 11 container terminals are operated by seven different operators, namely, LCMT Company LTD, HPT (Hutchson Ports (Thailand) Limited), LCB Container Terminal 1 LTD, Eastern Sea Laem Chabang Terminal Co Ltd, TIPS Container Terminal No. B4, Laem Chabang Port, Thailand and Laem Chabang International Terminal Co., Ltd. (see Table 6) (Port, 2016).

Table 6 Facilities of Container Terminals in Laem Chabang Port (Year 2015)

Terminals	Total Area (hectares)	Berth (number)	Berth Length (meter)	Terminal Operator
A0	16.80	1	400	LCMT Company LTD.
A2	17	1	400	Hutchson Ports (Thailand) Limited
A3	13.70	1	350	Hutchson Ports (Thailand) Limited

Table 6 (cont.)

Terminals	Total Area (hectares)	Berth (number)	Berth Length (meter)	Terminal Operator
B1	18.50	1	359	LCB container terminal 1 LTD.
B2	10.50	1	300	Evergreen container terminal (Thailand) LTD.
B3	10.50	1	300	Eastern Sea Laem Chabang Terminal Co Ltd.
B4	10.50	1	300	TIPS Co., Ltd.
B5	82.01	1	400	Laem Chabang International Terminal Co., Ltd.
C1&C2	54	2	1200	Hutchson Ports (Thailand) Limited
C3	23.17	1	500	Laem Chabang International Terminal Co., Ltd.
Total	253.68	11	4640	

Source: LCMT Company LTD., 2016; Hutchson Ports (Thailand) Limited, 2016; LCB Container Terminal 1 LTD., 2016; Evergreen Container Terminal (Thailand) LTD., 2016 Eastern Sea Laem Chabang Terminal Co Ltd., 2016; TIPS Co., Ltd., 2016; Laem Chabang International Terminal Co., Ltd., 2016

4. Guangzhou Port

Guangzhou port is located at the center of the Pearl River Delta of China, is the original port of the Maritime Silk Road, and one of the most important foreign trade ports in China. In 2015, Guangzhou port handled 17.6249 million TEU of containers, ranked fourth in the China and ranked sixth in the world respectively (China, 2016). The operators of the major container terminals are shown in Table 7).

Table 7 Facilities of Container Terminals in Guangzhou Port (Year 2015)

Terminals	Berth (number)	Berth Length (meter)	Terminal area (hectare)	Terminal Operator
GNICT	4	1400	182	Nansha Stevedoring Co., Ltd.
GOCT	6	2100	223	Guangzhou South China Oceangate Container Terminal Co., Ltd. (GOCT)
NICT	6	418	270	Nansha International Container Terminal Co., Ltd. (NICT)
GCT	4	810	65	Guangzhou Container Terminal Co., Ltd. (GCT)
Huangpu	16	2858	99	Huangpu Stevedoring Co., Ltd.
Longsha	2	420	15.38	Guangdong CCCC Longsha Logistics Co., LTD.
Guangjun	2	362	5.30	Guangdong CCCC Longsha Logistics Co., LTD.
Xinsha	3	640	40	Xinsha Stevedoring Co., LTD.
Total	68	13241	899.86	

Source: China Ports Year Book 2016; Nansha Stevedoring Co., Ltd., 2016;
Guangzhou South China Oceangate Container Terminal Co., Ltd., 2016;
Nansha International Container Terminal Co., Ltd., 2016;
Guangzhou Container Terminal Co., Ltd., 2016;
Huangpu Stevedoring Co., Ltd., 2016;
Guangdong CCCC Longsha Logistics Co., LTD., 2016;
Xinsha Stevedoring Co., LTD., 2016

5. Shenzhen Port

Shenzhen port is located in the southern part of Pearl River Delta in Guangdong Province and border on Hong Kong.

Shenzhen port achieved 24.2045 million TEU in 2015. Shenzhen port began in 2013, surpass Hong Kong port among the world's top three container port, and then has been maintain the third largest container port in the world for three consecutive years (China, 2016).

There are four container terminals in Shenzhen port and operated by Hutchisonports (Yantian) International Container Terminals, Chiwan Container Terminal Ltd., Shekou Container Terminals Ltd. and DaChan Bay Terminals Ltd. respectively (see Table 8).

Table 8 Facilities of Container Terminals in Shenzhen Port (Year 2015)

Terminals	Berth (number)	Berth length (meter)	Terminal area (hectare)	Terminal Operator
YICT	16	7885	417	Yantian International Container Terminals Ltd. (YICT)
Chiwan	9	3100	125	Chiwan Container terminal Co., Ltd.
Shekou	9	4090	112	Shekou Container Terminals Ltd.
DaChan Bay	5	1830	138	DaChan Bay Terminals Co., Ltd.
Total	39	16943	792	

Source: China Ports Year Book 2016; Yantian International Container Terminals Ltd., 2016; Chiwan Container Terminal Co., Ltd., 2016; Shekou Container Terminals Ltd., 2016; DaChan Bay Terminals Co., Ltd., 2016

6. Zhanjiang Port

Zhanjiang port is situated in Leizhou Peninsula of Guangdong province in southern China, where it is bordered by South China Sea to the east, Hainan Island to the south and Beibu Gulf to the west. It is one of the important container ports in PBGEC region and the goal is to become the container hub port in PBGEC region. It handled 0.6012 million TEU in 2015 (China, 2016). Baoman container terminal Phase 1 is the main container terminal in Zhanjiang port and is operated by Zhanjiang Port

International Container Terminal Company. Terminal facility details are shown in Table 9.

Table 9 Facilities of Container Terminal in Zhanjiang Port (Year 2015)

Terminal	Berth (number)	Berth length (meter)	Total area (hectare)	Terminal operator
Baoman Phase 1	2	678	67.8	Zhanjiang Port International Container Terminal Co., Ltd.

Source: Zhanjiang Port International Container Terminal Co., Ltd., 2016

7. Zhuhai Port

Zhuhai port is adjacent to South China Sea, in southern Guangdong province, and is one of the major coastal ports in China. By the end of 2015, there are 58 container shipping lines in the Zhuhai port, linking to Thailand, Vietnam, and Japan, Hong Kong, Taiwan and other countries and regions. It achieved 1.3377 million TEU in 2015 (China, 2016). The container business of Zhuhai port main operated by Zhuhai International Container Terminals (Gaolan) Limited, Zhuhai International Container Terminals (Hongwan) Limited, Zhuhai Port Gaolan Stevedoring Co., Limited and Zhuhai Port Hongwan Stevedoring Co., Limited. The facility information are summaries in the Table 10.

Table 10 Facilities of Container Terminals in Zhuhai Port (Year 2015)

Terminals	Berth (number)	Berth Length (meter)	Total area (hectare)	Terminal Operator
ZICT (G) (Phase 1&2&3)	8	3060	150.6	Zhuhai International Container Terminals (Gaolan) Limited

Table 10 (cont.)

Terminals	Berth (number)	Berth Length (meter)	Total area (hectare)	Terminal Operator
ZICT (H)	8	540	21	Zhuhai International Container Terminals (Hongwan) Limited
Gaolan Stevedoring terminal	5	880	39	Zhuhai Port Gaolan Stevedoring Co., Limited
Hongwan Stevedoring terminal	3	598	18	Zhuhai Port Hongwan Stevedoring Co., Limited
Total	24	5078	228.6	

Source: Zhuhai International Container Terminals (Gaolan) Limited, 2016; Zhuhai Port Holdings Group Co., Ltd., 2016

8. Haikou Port

Haikou port in the north of Hainan Island of China, is an international container line port of Hainan province and a main hub port in China. By the end of 2015, Haikou port achieved 1.2713 million TEU of container (China, 2016). Haikou port mainly conducts container business in Xiuying terminal. The terminal covers about 30 hectare area and container business is operated by Haikou Harbor Container Terminal Co., Ltd. (Table 11).

Table 11 Facilities of Container Terminal in Haikou Port (Year 2015)

Terminal	Berth (number)	Berth length (meter)	Total area (hectare)	Terminal operator
Xiuying	3	786	30	Haikou Harbor Container Terminal Co., Ltd.

Source: Hainan Harbor & Shipping Holding Co., LTD., 2016

9. Yangpu Port

Yangpu port in Hainan province the same area as Haikou port, between the Haikou port and Basuo port. The first container terminal of Hainan province was born in Yangpu port and the terminal is managed by SDIC Yangpu Port Limited (Table 12). In the 2015, the Yangpu port achieved 0.2716 million TEU of container (China, 2016).

Table 12 Facilities of Container Terminal in Yangpu Port (Year 2015)

Terminal	Berth (number)	Berth length (meter)	Total area (hectare)	Terminal operator
Yangpu	9	1696	23.15	SDIC Yangpu Port Limited

Source: SDIC Yangpu Port Limited, 2016

Data Summary

Through above container ports description, combined with the input and output variables used in DEA method, the data used in DEA method for this study can be summarized in Table 13.

Table 13 Data for Data Envelopment Analysis Method in 2015

DMU	Input 1	Input 2	Input 3	Output
Ports	Number of berths (number)	Berth length (meter)	Terminal area (hectare)	Container throughput (10,000 TEU)
Qinzhou Port	4	2300	158	94.20
Shenzhen Port	39	16943	792	2420.45
Guangzhou Port	68	13241	899.86	1762.49
Zhanjiang Port	2	678	67.80	60.12
Zhuhai Port	24	5078	228.60	133.77

Table 13 (cont.)

DMU	Input 1	Input 2	Input 3	Output
Ports	Number of berths (number)	Berth length (meter)	Terminal area (hectare)	Container throughput (10,000 TEU)
Haikou Port	3	786	30	127.13
Yangpu Port	9	1696	23.14	27.16
Hong Kong Port	24	7694	279	2011.40
Laem Chabang Port	11	4640	256.68	679.40

Qinzhou Port Competitiveness Evaluation Based on Data Envelopment Analysis

After obtaining the data, then we can run the model through software. The CCR model and BCC model were adopted to analyze the efficiency of the container ports, both input and output oriented. And then the super efficiency model was used to rank the ports. Both the CCR and BCC models were applied to the MaxDEA software. The super efficiency model was applied to the EMS1.3 software (all running result details are presented in Appendix B and C).

1. Efficiency Analysis based on CCR Model

1.1 Input-oriented CCR Model

After importing data and running the model through MaxDEA software, the relative efficiency results will be received. Figure 14 shows the port efficiency value ranking first, and then the efficiency value detail is shown in Table 14.

The Figure 14 shows the relative efficiency ranking of nine ports under input oriented CCR model. Hong Kong port's efficiency performs the best (the score is 1), other port efficiency value are less than 0.8, and Zhuhai port performs the worst (0.101). Such score of the Qinzhou port is 0.281. For more information on the port efficiency value, the analysis is presented thereafter under Table 14.

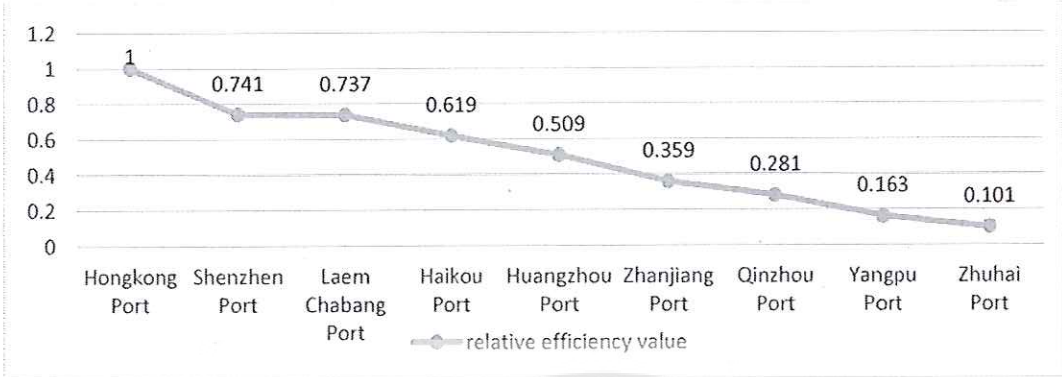

Figure 14 Input-oriented CCR Model Relative Efficiency Scores

As Table 12 shows, under the input oriented CCR model, Hong Kong port is efficient (efficiency value=1). In the table, proportionate movement represents input redundancy value and slack movement indicates the insufficient output value and projection denotes the efficient target value (projection=original + proportionate movement + slack movement). The projection value provides a performance improvement target for inefficient ports. That is, Qinzhou port should achieve 0.94 million TEU with 1 berth, 360 meters berth length and 13 hectares terminal area. Other inefficient ports can be analyzed like this.

Hong Kong port relative efficiency value is 1, projection value (target value) and original value (original data) is the same, and it has advantages in the PBGEC. In order to analyze the inefficient port problem in terms of input, Table 15 makes a percentage difference in comparison with the projection value and original value.

There is a large gap between the projection value and original value. This shows that the efficiency of inputs being used is not appropriate, a serious input crowding in the port on the given level of input. A relatively large percentage difference in the ports except Shenzhen port, Laem Chabang port and Haikou port. The degree of input crowing is more than 25%. Yangpu port is the highest crowding degree port with berth input crowding value is 96.4%. It is obvious that degree of resource waste is serious.

Table 14 Relative Efficiency Scores under Input-oriented CCR Model

Port	Score	Number of berths (number)			Berth length (meter)			Terminal area (hectare)			Container throughput (10,000TEU)		
		Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection
Hong Kong	1	0	0	24	0	0	7694	0	0	279	0	0	2011.400
Shenzhen	0.741	-10.119	0	28.881	-4396.153	-3288.151	9258.697	-205.498	-250.763	335.739	0	0	2420.450
Laem Chabang	0.737	-2.893	0	8.107	-1220.492	-820.670	2598.838	-67.515	-94.921	94.239	0	0	679.400
Haikou	0.619	-1.144	-0.339	1.517	-299.703	0	486.297	-11.439	-0.927	17.634	0	0	127.130
Guangzhou	0.509	-33.377	-13.593	21.030	-6499.130	0	6741.870	-441.682	-213.704	244.474	0	0	1762.490
Zhanjiang	0.359	-1.283	0	0.717	-434.818	-13.211	229.971	-43.482	-15.979	8.339	0	0	60.120
Qinzhou	0.281	-2.876	0	1.124	-1653.704	-285.963	360.333	-113.602	-31.331	13.066	0	0	94.200
Yangpu	0.163	-7.535	-1.141	0.324	-1419.934	-172.174	103.892	-19.377	0	3.767	0	0	27.160
Zhuhai	0.101	-21.582	-0.822	1.596	-4566.303	0	511.697	-205.565	-4.480	18.555	0	0	133.770

Notes: Proportionate movement: It is the radial part of improvement of inputs/outputs, the proportional decrease of inputs or the proportional increase of outputs. Positive values mean increase, and negative values mean decrease. Slack movement: it is s^- (input slack) or s^+ (output slack) in the linear programming equations. Projection: the efficient target value (projection=original + proportionate movement + slack movement)

Table 15 The Percentage Difference Comparison between Target and Actual Value under Input-oriented CCR Model

Variables	Value	Shenzhen Port	Laem Chabang Port	Haikou Port	Guangzhou Port	Zhanjiang Port	Qinzhou Port	Yangpu Port	Zhuhai Port
Number of berth (number)	Projection	28.881	8.107	1.517	21.030	0.717	1.124	0.324	1.596
	Original	39	11	3	68	2	4	9	24
	Percentage Difference	25.946%	26.300%	49.433%	69.074%	64.150%	71.900%	96.400%	93.350%
Berth length (meter)	Projection	9258.697	2598.838	486.297	6741.870	229.971	360.333	103.892	511.697
	Original	16943	4640	786	13241	678	2300	1696	5078
	Percentage Difference	45.354%	43.991%	38.130%	49.083%	66.081%	84.333%	93.874%	89.923%
Terminal area (hectare)	Projection	335.739	94.239	17.634	244.474	8.339	13.066	3.767	18.555
	Original	792	256.676	30	899.860	67.800	158	23.145	228.600
	Percentage Difference	57.609%	63.285%	41.220%	72.832%	87.701%	91.730%	83.724%	91.883%

Note: percentage difference value $= \frac{\text{original value} - \text{projection value}}{\text{original value}} \%$

1.2 Output-oriented CCR Model

From the running results of MaxDEA software, it is found that the relative efficiency ranking scores of input-oriented CCR and output-oriented CCR are the same, but output-oriented CCR gives the target value (projection value) of output (container throughput). Therefore, it is necessary to show the calculating results of output-oriented CCR model.

Table 16 Relative Efficiency Results under Output-oriented CCR Model

Ports	(Input 1) Slack movement (number)	(Input 2) Slack movement (meter)	(input 3) Slack movement (input 3) (hectare)	(output) Proportionate movement (output) (10,000TEU)	(output) Projection (10,000TEU)
Hong Kong	0	0	0	0	2011.4
Shenzhen	0	-4440.250	-338.625	848.075	3268.525
Laem Chabang	0	-113.583	-128.801	242.492	921.892
Haikou	-0.548	0	-1.498	78.350	205.480
Guangzhou	-26.697	0	-419.715	1699.032	3461.522
Zhanjiang	0	-36.833	-44.550	107.497	167.617
Qinzhou	0	-1017.667	-111.500	241.033	335.233
Yangpu	-7.009	-1057.743	0	139.696	166.856
Zhuhai	-8.160	0	-44.461	1193.744	1327.514

Note: The proportionate movement value of input and slack movement value of the output is 0. Here will not be listed.

In the Table16, the results give the optimized resource allocation target value to ports, such as Qinzhou port should reduce 1017.667 meters berth length (input 2), 111.5 hectare terminal area (input 3) to increase 24.1033 million TEU (proportionate movement value of output) and then achieve 335.233 thousand TEU (projection movement value of output). Other inefficient port can be analyzed similarly. Also, the efficient target value and original data are to be compared in Table 17. Apparently, the inefficient ports can achieve a large output at the current level of input. For instance, Qinzhou port can realize DEA efficient when it enlarges 71.9% container throughput at the current level.

2. Efficiency Analysis Based on BCC Model

2.1 Input-oriented BCC Model

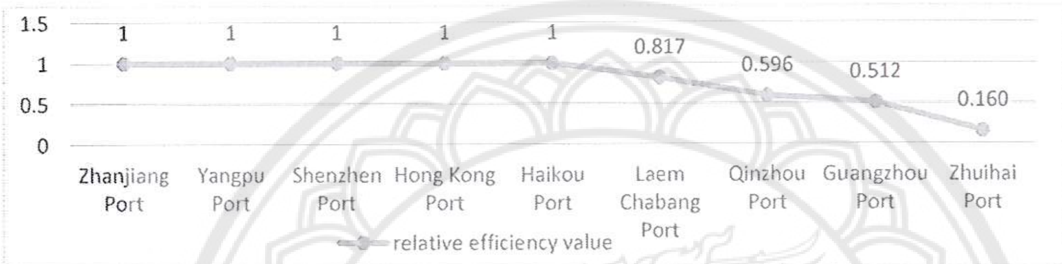

Figure 15 Input-oriented BCC Model Relative Efficiency Scores

The CCR model assumes constant returns to scale. While the characteristic of port industry is not constant returns to scale. Therefore, efficiency evaluation should be considered variable returns to scale. After applying input-oriented BBC model, the port efficiency scores ranking as shown in Figure 15. Through contrast Figure 14 and Figure 15, relative efficiency value under output-oriented BCC have a big change. There are 5 ports are DEA efficient: Zhanjiang, Yangpu, Shenzhen, Hong Kong and Haikou ports. The inefficient ports' relative efficiency value are generally higher, only Zhuhai port's relative efficiency value below 0.5. For analyzing the port efficiency value, the summary of the inefficient port efficiency value in the details is presented in the Table 18.

In the Table 18, proportionate movement and slack movement value is very small compared to the value of CCR model. Compared the port ranking of CCR model (consider constant returns to scale), Laem Chabang port and Guangzhou port drop sharply in ranking under the BCC (variable returns to scale), we hold that these two ports are not achieving DEA efficient the reason is the scale of ports is expanding rapidly but a good integration of resources is not done yet. On the other hand, the Laem Chabang port and Guangzhou port have a huge potential.

Table 17 The Percentage Difference Comparison between Target and Actual Value under Output-oriented CCR Model

Variables	Value	Shenzhen Port	Laem Chabang Port	Haikou Port	Guangzhou Port	Zhanjiang Port	Qinzhou Port	Yangpu Port	Zhuhai Port
Output (10,000TEU)	Original	2420.450	679.400	127.130	1762.490	60.120	94.200	27.160	133.770
	Projection	3268.525	921.892	205.480	3461.522	167.617	335.233	166.856	1327.514
	Percentage Difference	25.947%	26.304%	38.130%	49.083%	64.133%	71.900%	83.722%	89.923%

Note: percentage difference value = $\frac{\text{projection value} - \text{original value}}{\text{projection value}}\%$

Table 18 The Relative Efficiency Results of Inefficient Ports under Input-oriented BCC Model

DMU		Input 1 (number)			Input 2 (meter)			Input 3 (hectare)		
Port	Score	Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection	Proportionate movement	Slack movement	Projection
Laem Chabang	0.817	-2.018	0	8.982	-851.159	-884.165	2904.676	-47.084	-74.762	134.829
Qinzhou	0.596	-1.616	0	0.384	-929.062	-570.400	800.538	-63.823	-22.689	71.489
Guangzhou	0.512	-33.173	-13.601	21.226	-6459.539	0	6781.461	-438.991	-214.762	246.107
Zhuhai	0.160	-20.170	-0.756	3.074	-4267.657	0	810.343	-192.120	-5.602	30.877

2.2 Output-oriented BCC Model

The Figure 16 is the relative efficiency ranking under output-oriented BCC model. The relative efficiency scores with small gaps compared to the scores of input-oriented BCC. The relative efficiency value is between 0.1-0.8, Zhuhai port is the smallest one with the score 0.103.

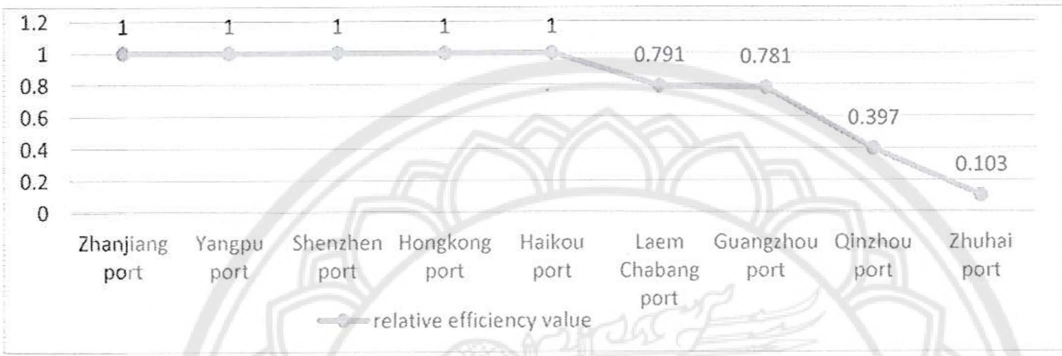

Figure 16 Output-Oriented BCC Model Efficiency Scores

To analyze the gap between the original data and the target value (projection value) which the port achieve DEA efficient is required. From Table 19, it is found that there are large gaps between the original data and the target value. The target value of Qinzhou port is 2.5 times than the original value. The target value of Zhuhai port even up to 9.7 times. It is worthy of pointing out that if Guangzhou port achieves DEA efficient, its output will have greatly increased, thus enhancing its competitiveness.

Table 19 Relative Efficiency Results under Output-oriented BCC Model

Port	Score	Input 1 (number)	Input 2 (meter)	Input 3 (hectare)	Output (10,000TEU)		
		Slack movement	Slack movement	Slack movement	Original	Proportionate movement	Projection
Zhanjiang	1	0	0	0	60.120	0	60.120

Table 19 (cont.)

Port	Score	Input 1 (number)	Input 2 (meter)	Input 3 (hectare)	Output (10,000TEU)		
		Slack movement	Slack movement	Slack movement	Original	Proportionate movement	Projection
Yangpu	1	0	0	0	27.160	0	27.160
Shenzhen	1	0	0	0	2420.450	0	2420.450
Hongkong	1	0	0	0	2011.400	0	2011.400
Haikou	1	0	0	0	127.130	0	127.130
Laem Chabang	0.791	0	-1091.818	-102.476	679.400	178.971	858.371
Guangzhou	0.781	-35.004	0	-313.193	1762.490	494.234	2256.724
Qinzhou	0.397	0	-984.182	-71	94.200	143.309	237.509
Zhuhai	0.103	-7.953	0	-43.894	133.770	1164.073	1297.843

3. Technical Efficiency and Scale Efficiency

To calculate and analysis the ports' aggregate efficiency (technical efficiency), pure technical efficiency and scale efficiency and obtain the results are shown in the Table 20.

The Hong Kong port has the efficiency advantage in the competition (pure technical efficiency and scale efficiency are achieved DMU efficient).

Shenzhen, Haikou, Zhanjiang and Yangpu ports' pure technical efficiency value are 1, scale efficiency value is between 0.3-0.8. But besides Shenzhen port shows decreasing return to scale, the other ports exhibit increasing return to scale. It is indicated that Haikou, Zhanjiang and Yangpu ports enlarge the operational scale will have returns to scale increasing effect, and then competitiveness will be strengthened. Conversely, Shenzhen port should reduce the scale of operation.

Laem Chabang port, Guangzhou port and Zhuhai port's pure technical efficiency value below their scale efficiency, indicating that the major cause of inefficiency is pure technical inefficient. That is, there is no corresponding output at the current level of input.

Relatively, Qinzhou port's pure technical efficiency value higher than scale efficiency value means that the major cause of inefficiency is scale efficiency. A large throughput need the large scale to support. Qinzhou port should pay attention to the production scale.

Table 20 Technical Efficiency Value and Scale Efficiency Value

Port	Technical Efficiency (CRS)	Pure Technical Efficiency (VRS)	Scale Efficiency	RTS
Hong Kong Port	1	1	1	Constant
Guangzhou Port	0.509	0.512	0.994	Increasing
Laem Chabang Port	0.737	0.817	0.902	Increasing
Shenzhen Port	0.741	1	0.741	Decreasing
Zhuhai Port	0.101	0.160	0.631	Increasing
Haikou Port	0.619	1	0.619	Increasing
Qinzhou Port	0.281	0.596	0.471	Increasing
Zhanjiang Port	0.359	1	0.359	Increasing
Yangpu Port	0.163	1	0.163	Increasing

Notes: CRS: to calculate technical efficiency based on constant return to scale;
VRS: to calculate pure technical efficiency based on variable return to scale;
Scale efficiency: scale efficiency=CRS/VRS;
RTS: returns to scale (increasing, decreasing and constant)

4. Super Efficiency

With respect to the relative efficiency ranking, the BCC model has five efficient ports, but it is not possible to differentiate the five ports since the ports efficiency score is 1. Therefore, it is necessary to use super efficiency model to rank the ports.

The ports ranking based on constant returns to scale and variable returns to scale are shown in Table 21. Shenzhen port's super efficiency value shows as Big based on variable returns to scale. It means that Shenzhen port is DEA efficient, whether to increase input or decrease output. However, it is relative in the sample ports.

The ranking under variable returns to scale has changed. Shenzhen port ranks first, follow by Hong Kong port. Zhanjaing port move up two places to No. 4 and Yangpu port move 3 places to No. 5 respectively, shows the strong competitiveness. On the contrary, Laem Chabang port and Guangzhou port dropped 3 places to No. 6 and No. 8 respectively. Qinzhou port ranking does not change. Zhuhai port is ranked in the bottom shows the weak competitiveness. High concentration of super efficiency value illustrates the intense competition level of ports of PBGEC.

Table 21 Super Efficiency Model Results

Port	VRS-SE value	Ranking	CRS-SE value	Ranking
Shenzhen	Big	1	0.741	2
Hong Kong	2.352	2	1.843	1
Haikou	1.935	3	0.619	4
Zhanjiang	1.500	4	0.359	6
Yangpu	1.296	5	0.163	8
Laem Chabang	0.817	6	0.737	3
Qinzhou	0.596	7	0.281	7
Guangzhou	0.512	8	0.509	5
Zhuhai	0.160	9	0.101	9

Notes: VRS-SE value: to calculate super efficiency value from a variable return to scale;

CRS-SE value: to calculate super efficiency value from a constant return to scale

Conclusion of the Results

The results of input and output oriented CCR model show that Qinzhou port efficiency score is 0.281, and the results of input and output oriented BCC model indicate that Qinzhou port efficiency scores are 0.596 and 0.397 respectively, both of which reveal that Qinzhou port exists input redundancy and insufficient output in the sample ports. In addition, the pure technical efficiency and technical efficiency comparison results also imply that the main cause of Qinzhou port inefficiency relies on scale efficiency. Moreover, the ranking of the super efficiency model indicates that Qinzhou port performs with weak competitiveness. Therefore, Qinzhou port should overcome such weakness and then enhance competitiveness.

CHAPTER V

SUGGESTIONS AND CONCLUSIONS

This chapter, based on the results and analysis of the last chapter, suggestions are made to enhance Qinzhou port competitiveness. A conclusion is presented thereafter. And the end of this chapter, limitations and recommendation are also presented.

Suggestions for Qinzhou Port Competitiveness Improvement

The DEA analysis results reveal that Qinzhou port exists input redundancy and insufficiency output due to its scale efficiency and is posed in an inferior position in the PBGEC ports cluster. In order to overcome these weaknesses and then enhance the competitiveness, some suggestion for Qinzhou port are presented as follows:

With regards to input redundancy and insufficiency output, Qinzhou port should achieve the output maximization in the current level of input. Consequently, Qinzhou port should make effective use of available resource, to make the most the existing resources for maximum economic and technical efficiency in an effective way. In addition, in order to improve the output, Qinzhou port should expand shipping line network and shipping calls. If Qinzhou port continues to consolidate and container shipping lines and calls, its cargo sources will likely increase, which will build a sound foundation for the Qinzhou port into the international shipping hub in Southeast Asia.

For scale efficiency, it can be improved by adjusting the input level in order to obtain the optimal scale. Besides, the DEA result shows the increasing returns to scale of Qinzhou port, it is indicated that if Qinzhou port enlarges the operational scale will have returns to scale increasing effect, and then competitiveness will be strengthened. Therefore, there is still much room for improvement of Qinzhou port. Port managers or terminal operators should make a reasonable development plan to gradually enlarge operation scale, such as increase the number of berth and facilities, expand the yard area, etc. Furthermore, as port construction, significant amounts of funding will be consumed. With the port construction development and sustainable development needed, the port requires large-scale investment of fund. Qinzhou port has to develop more financing channels, such as adopting the more open shipping policies (to relax restrictions on business operation from foreign shipping companies and agents and so on) to attract foreign investment.

Moreover, ports and terminals of the 21st century should be customer oriented ports and provide reliable and efficient service. In order to maintain and enhance their competitive position, port managers need the scientific management, high quality employees and higher informationization level. Talent is the first productivity, competition in any industry is a talent competition after all. Scientific management and high quality employees are indispensable to the port competitiveness improvement. Port managers and terminal operators should attach great importance to absorb and cultivate senior managers, technicians and other related professional talents. Then Scientific and technological progress and innovations are the port development important attributes. Qinzhou port should apply positively information and network technology into port and terminal management, and thus to improve operational efficiency and quality of container terminals.

In general, port managers should identify and promote their core competencies. It can be achieved by consolidating the ports facility and resources into competencies that enhance the ports flexibility and enable them to strengthen their weaknesses and change their threats into opportunities.

Conclusions

There are two objectives for this thesis. Firstly, to evaluate the competitiveness of Qinzhou port, compared with other eight ports of containerization in PBGEC region. Secondly, to make some suggestions for Qinzhou port competitiveness improvement based on the competitiveness comparison results of nine ports.

In order to finalize the targets in this thesis, the relative efficiency and competitive position of Qinzhou port, the maritime route between Thailand and China, are researched through the comparison with the rest eight ports under PBGEC. The CCR-DEA, BCC-DEA and Super Efficiency-DEA models are to be adopted for the research. The results of CCR model show that Qinzhou port efficiency score is 0.281, and the results of BCC model indicate that Qinzhou port efficiency scores are 0.596 and

0.397 respectively, both of which reveal that Qinzhou port exists input redundancy and insufficient output in the sample ports. In addition, the pure technical efficiency and technical efficiency results also imply that the main cause of Qinzhou port inefficiency relies on scale efficiency. Moreover, the ranking of the Super Efficiency Model indicates that Qinzhou port is posed in an inferior position in its competitiveness. Finally, this research offers some suggestions on competitiveness improvement according to such weakness respectively.

Further Research

There are some limitations of this study in following aspects. Firstly, due to the data of sample ports were difficult to obtain, this study just considers the cross-sectional data of year 2015. Secondly, as DEA analysis calculates the relative efficiency based on the selected samples, in this study we concentrate on the nine container ports of PBGEC for the year 2015, so the DEA results probably would be different if the sample ports were different or new data of another year are included.

And the implication for further study could be summarized. Upcoming research should apply panel data to evaluate the efficiency of the sample ports with larger sample ports and variables. And various research objects should be widely applied. Additionally, container terminals comparison between two or more countries also should be applied to further research.

REFERENCES

REFERENCES

Administration, U. S. M. (Ed.). (2008). *Glossary of Shipping Terms*. SE Washington, DC: Maritime Administration Press.

Airport, G. L. I. (n.d.). *Air Route Network Map*. Retrieved May 20, 2017, from http://www.airport-gl.com.cn/aboutus/aboutus_b.htm

Akgül, E. F., Solak Fışkın, C., Düzalan, B., Erdoğan, T., & Karataş Çetin, Ç. (2015). Port competitiveness and efficiency: An analysis of Turkish container ports. In *European Conference on Shipping, Intermodalism and Ports (Econship 2015), Turkey* (pp. 24-27). Istanbul: Dogus University.

Al-Eraqi, A. S., Mustafa, A., Khader, A. T., & Barros, C. P. (2008). Efficiency of Middle Eastern and East African seaports: application of DEA using window analysis. *European Journal of Scientific Research, 23*(4), 597-612.

Almawsheki, E. S., & Shah, M. Z. (2015). Technical Efficiency Analysis of Container Terminals in the Middle Eastern Region. *The Asian Journal of Shipping and Logistics, 31*(4), 477-486.

Atkinson, R. D. (2013). Competitiveness, Innovation and Productivity. *The Information Technology & Innovation Foundation.–August*, 2-7.

Baran, J., & Górecka, A. (2015). Seaport efficiency and productivity based on Data Envelopment Analysis and Malmquist Productivity Index. *Logistics & Sustainable Transport, 6*(1), 25-33.

Barros, C. P. (2006). A benchmark analysis of Italian seaports using data envelopment analysis. *Maritime Economics & Logistics, 8*(4), 347-365.

Begg, I. (1999). Cities and competitiveness. *Urban studies, 36*(5-6), 795-809.

Bichou, K. (2013). An empirical study of the impacts of operating and market conditions on container-port efficiency and benchmarking. *Research in Transportation Economics, 42*(1), 28-37.

Bo, L., & Kyu, P. N. (2013). Sensitivity analysis for identifying the critical productivity factors of container terminals. *Strojniški vestnik-Journal of Mechanical Engineering, 59*(9), 536-546.

Board, H. K. M. a. P. (n.d.). *Port of Hong Kong*. Retrieved October 10, 2016, from http://www.hkmpb.gov.hk/sc/index.html

Bureau, Q. S. (2016). *Statistical Communiqué of Qinzhou on the 2015 National Economic and Social Development*. Retrieved May 20, 2016, from http://www.qinzhou.gov.cn/sjtj_277/tjgb/201607/t20160725_42994.html

Castillo-Manzano, J. I., Castro-Nuño, M., Laxe, F. G., López-Valpuesta, L., & Teresa Arévalo-Quijada, M. (2009). Low-cost port competitiveness index: Implementation in the Spanish port system. *Marine Policy, 33*(4), 591-598. doi: 10.1016/j.marpol.2008.12.008

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research, 2*(6), 429-444.

China, N. B. o. S. o. (2016). *China Statistical Yearbook*. Reteieved March 19, 2017, from http://www.stats.gov.cn/tjsj/ndsj/2016/indexch.htm

Chinanews. (2015). *Fangcheng Port was Approved as Appointed the First Fruit Port in Guangxi*. Retrieved June 20, 2016, from, http://www.chinanews.com/df/2015/04-23/7229391.shtml

Commision, E. (1999). *Six Periodic Report on the Social and Economic Sitiation of Regions in the EU*. Retrieved June 20, 2016, from http://aei.pitt.edu/5712/1/5712.pdf

Council, W. S. (2016). *Glossary of Industry Terms*. Reteieved April 15, 2017, from http://www.worldshipping.org/about-the-industry/glossary-of-industry-terms

Cruz, M. R. P. d. (2012). *Competitiveness and strategic positioning of seaports: the case of Iberian Seaports* (Doctoral dissertation). Portugal: University of Beira Interior.

Cullinane, K., Song, D.-W., Ji, P., & Wang, T.-F. (2004). An application of DEA windows analysis to container port production efficiency. *Review of network Economics, 3*(2), 1-23.

Cullinane, K., & Wang, T. (2010). The efficiency analysis of container port production using DEA panel data approaches. *OR spectrum, 32*(3), 717-738.

Da Cruz, M. R. P., & de Matos Ferreira, J. J. (2016). Evaluating Iberian seaport competitiveness using an alternative DEA approach. *European Transport Research Review, 8*(1), 1-9.

Dai, M.-h., & Chen, S.-x. (2006). *Port Competition Evaluation Model and Application in Northeast Asia Ports*. Retrieved May 21, 2016, from http://www.seiofbluem ountain.com/upload/product/201002/1265163834rjog4ol3.pdf

Daily, E. (2016). *Investigation on Route Diversion of Guangxi Beibu Gulf Port* [Press release]. Retrieved October 18, 2016, from http://news.xinhuanet.com/energy/ 2016-02/26/c_1118162410.htm

Demirel, B., Cullinane, K., & Haralambides, H. (2012). Container terminal efficiency and private sector participation. In *Blackwell companion to maritime economics* (pp. 571-598).UK: Wiley-Blackwell.

Deparment, T. G. P. R. (2015). *Thailand and Neighboring Countries Discuss Cross-Border Transport Facilitation*. Retrieved July 20, 2016, from http://thailand.prd.go.th/ewt_news.php?nid=1763&filename=index

Dias, J. C. Q., Azevedo, S. G., Ferreira, J. M., & Palma, S. F. (2012). Seaport performance comparison using data envelopment analysis: the case of Iberian container terminals. *International Journal of Business Performance Management, 13*(3-4), 426-449.

Ding, Z.-Y., Jo, G.-S., Wang, Y., & Yeo, G.-T. (2015). The Relative Efficiency of Container Terminals in Small and Medium-Sized Ports in China. *The Asian Journal of Shipping and Logistics, 31*(2), 231-251.

DTI, U. (1995). *Competitiveness: Forging Ahead*. London: UK Department of Trade and Industry, Competitiveness Division.

Emrouznejad, A., Mustafa, A., & Al-Eraqi, A. (2010). Aggregating preference ranking with fuzzy data envelopment analysis. *Knowledge-Based Systems, 23*(6), 512-519.

Fan, F. (2014). *Research on Pan-Beibu-Gulf Lofistics Development and Cooperation.* Retrieved March 15, 2016, from http://www.slsc.nu.ac.th/th/

Fare, R., Grosskopf, S., & Lovell, C. K. (1994). *Production frontiers,* Cambridge: Cambridge University Press.

Forum, C.-A. S. (2015). *Thailand.* Retrieved May 16, 2016, from http://www.gxtj.gov.cn/ztlm/zgdmtjlt/gjjs/201509/t20150911_56237.html

Gao, H., Lv, L., & Liu, W. (2010). Efficiency measurement of Shenzhen port using data envelopment analysis. In *Emergency Management and Management*

Sciences (ICEMMS), 2010 IEEE International Conference on (pp. 206-209). America: IEEE.

Golany, B., & Roll, Y. (1989). An application procedure for DEA. *Omega, 17*(3), 237-250.

Grilo, J. D. C. (2013). *Performance evaluation using data envelopment analysis: the case of GENERAL CARGO TERMINALS*. Reteieved May 5, 2017, from https://fenix.tecnico.ulisboa.pt/downloadFile/395146463534/ Resumo_57267.pdf

Grosso, M., & Monteiro, F. (2009). Relevant strategic criteria when choosing a container port-the case of the port of Genoa. *Research in Transport and Logistics, 299*.

Group, B. G. P. (2016). *Qinzhou Port*. Reteieved March 3, 2017, from http://www.blackwhiteword.com/cms/category/216.dhtml#page_content

Gu, X. (2011). The Planning and Challenges of the Pan-Beibu Gulf Economic Cooperation. In *China-ASEAN Sub-Regional Cooperation: Progress, Problems and Prospect* (pp. 37-55). Singapore: World Scientific.

Hosokawa, D. (2009). Pan-Beibu Gulf Economic Cooperation. *China's New Initiative in Cooperation with ASEAN, 60*(2), 67-77.

Hu, H. (n.d.). Introduction of Guangxi Comprehensive Traffic Construction and Logistic Policy Facing China-ASEAN Free Trade Area. Reteieved July 28, 2016, from http://www.slsc.nu.ac.th/th/

Huang, W.-C., Teng, J.-Y., Huang, M.-J., & Kou, M.-S. (2003). Port competitiveness evaluation by fuzzy multicriteria grade classification model. *Journal of Marine Science and Technology, 11*(1), 53-60.

Huang, Y. (2015). The direct flight from Naning to Pattaya of Thailand has opened. One-way ticket only ￥99. *Nanning Evening*. Retrieved October 20, 2016, from http://www.nnnews.net/news/201509/t20150901_1427179.html

Hung, S.-W., Lu, W.-M., & Wang, T.-P. (2010). Benchmarking the operating efficiency of Asia container ports. *European journal of operational research, 203*(3), 706-713.

IMD, I. (2012). *World competitiveness yearbook*. Lausanne: International Institute for Management Development.

Infante, Z., & Gutiérrez, A. (2013). Port Efficiency in APEC. *México y la Cuenca del Pacífico, 2*(3), 41-73.

Jafari, H., Noshadi, E., & Khosheghbal, B. (2013). Ranking ports based on competitive indicators by using ORESTE method. *International Research Journal of Applied and Basic Sciences, 4*(6), 1492-1498.

Jang, H. M., Park, H., & Kim, S. Y. (2016). Efficiency Analysis of Major Container Ports in Asia: Using DEA and Shannon's Entropy. *International Journal of Supply Chain Management, 5*(2), 1-6.

Jiang, B., & Li, J. (2009). DEA-based Performance Measurement of Seaports in Northeast Asia: Radial and Non-radial Approach. *The Asian Journal of Shipping and Logistics, 25*(2), 219-236.

Kamble, S. S., Raoot, A. D., & Khanapuri, V. B. (2010). Improving port efficiency: a comparative study of selected ports in India. *International Journal of Shipping and Transport Logistics, 2*(4), 444-470.

Kim, D.-J. (2012). A comparison of efficiency with productivity criteria for European container ports. *The Asian Journal of Shipping and Logistics, 28*(2), 183-202.

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

Liu, B., & Liu, C. (2009). Research on the Competitiveness of China's Ports. In *ICCTP 2009: Critical Issues In Transportation Systems Planning, Development, and Management* (pp. 1-10). America: American Socity of Cibil Engineers.

Liu, Q. (2010). *Efficiency analysis of container ports and terminals.* London: University College London.

Lu, B., Park, N. K., & Huo, Y. (2015). The Evaluation of Operational Efficiency of the World's Leading Container Seaports. *Journal of Coastal Research, 73*(sp1), 248-254.

Lu, B., & Wang, S. (2016). *Container Port Production and Management*. Singapore: Springer.

Lu, B., & Wang, X. (2012). Application of DEA on the measurement of operating efficiencies for east-Asia major container terminals. *Journal of System and Management Sciences, 2*(1), 1-18.

Lu, B., & Wang, X. L. (2012). Comparative studies on efficiency evaluation of Chinese and Korean major container terminals. *Advances in Information Sciences and Service Sciences, 4*(23), 434.

Min, H., & Park, B.-I. (2008). A hybrid Data Envelopment Analysis and simulation methodology for measuring capacity utilisation and throughput efficiency of container terminals. *International journal of logistics systems and management, 4*(6), 650-672.

Mokhtar, K., & Shah, M. Z. (2013). Efficiency of Operations in Container Terminals: A Frontier Method. *European Journal of Business and Management, 5*(2), 91-106.

Moon, C.-i. (2016). Asean (International Organization). *Encyclopaedia Britannica.* Chicago: Encycloædia Britannica Australia Ltd.

Munisamy, S., & Danxia, W. (2013). Ranking efficiency of Asian container ports: a bootstrapped frontier approach. *International Journal of Shipping and Transport Logistics, 5*(6), 668-690.

Munisamy, S., & Jun, O. B. (2013). Efficiency of Latin American container seaports using DEA. *In Proceedings of 3rd Asia-Pacific Business Research Conference* (pp. 25-26). Australia: Asia Pacific Institute of Advanced Research.

Munisamy, S., & Singh, G. (2011). Benchmarking the efficiency of Asian container ports. *African journal of business management, 5*(4), 1397-1407.

Nguyen, H.-O., Nguyen, H.-V., Chang, Y.-T., Chin, A. T., & Tongzon, J. (2016). Measuring port efficiency using bootstrapped DEA: the case of Vietnamese ports. *Maritime Policy & Management, 43*(5), 644-659.

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

Nigra, S. M. O. (2010). *Efficiency of the Seaport Sector* (Doctoral dissertation). Retrieved March 10, 2017, from https://fenix.tecnico.ulisboa.pt/downloadFile/395142112150/Resumo.pdf

Olapoju, O. M., & Aloba, O. (2016). Some Measures of Input Underutilization in Lagos Seaports, Nigeria. *Ife Research Publications in Geography, 12*(1), 160-173.

Pang, G., & Chen, Y. (2016). Three Imported Fruit Ports in Guangxi were Approved. *People's Daily*. Retrieved March 12, 2017, from http://paper.people.com.cn/ rmrb/html/201605/16/nw.D110000renmrb_20160516_6-10.htm

Pillania, R. K., Jim Wu, Y.-C., & Lin, C.-W. (2008). National port competitiveness: implications for India. *Management Decision, 46*(10), 1482-1507.

Pjevčević, D., Radonjić, A., Hrle, Z., & Čolić, V. (2012). DEA window analysis for measuring port efficiencies in Serbia. *PROMET-Traffic&Transportation, 24*(1), 63-72.

Polyzos, S., & Niavis, S. (2013). Evaluating port efficiency in the Mediterranean. *International Journal of Data Analysis Techniques and Strategies 7, 5*(1), 84-100.

Port, L. C. (2016). *Information*. Retrieved March 20, 2017 from http://laemchabangport.com/index.php

Portal, D. o. C. o. G. Z. A. R. (2014). *Economic and Trade Cooperation between Guangxi and Thailand*. Retrieved July 20, 2016, from http://www.gxswt.gov.cn/zt/sdgc/gc5/detail/f180404a-260f-46b7-bddf-925f6e08b860

Porter, M. E. (1990). The competitive advantage of nations. *Harvard busness review, 68*(2), 73-93.

Qunar. (2017). *Qunar Flight*. Retrieved June 20, 2017, from https://flight.qunar.com/

Rajasekar, T., Ashraf, P. S., & Deo, P. M. (2014). Measurement of efficiency of major ports in India–a data envelopment analysis approach. *International Journal of Environmental Sciences, 4*(5), 926-936.

Review, C. E. (2009). *New air, sea links planned with Guangxi*. Retrieved May 21, 2016, from http://www.chinaeconomicreview.com/node/44014

Rudjanakanoknad, J., Suksirivoraboot, W., & Sukdanont, S. (2014). Evaluation of International Ports in Thailand through Trade Facilitation Indices from Freight Forwarders. *Procedia-Social and Behavioral Sciences, 111*, 1073-1082.

Sang, Y. (2006). *Comparative analysis of Lianyungang ports competitiveness based on calculation of principal component analysis.* (Masteral Dissertation). Swedens: World Maritime University.

Schøyen, H., & Odeck, J. (2013). The technical efficiency of Norwegian container ports: A comparison to some Nordic and UK container ports using Data Envelopment Analysis (DEA). *Maritime Economics & Logistics, 15*(2), 197-221.

Schøyen, H., & Odeck, J. (2017). Comparing the productivity of Norwegian and some Nordic and UK container ports-an application of Malmquist productivity index. *International Journal of Shipping and Transport Logistics, 9*(2), 234-256.

Schwab, K., & Sala-i-Martin, X. (2010). *The global competitiveness report 2010-2011.* Geneva: World Economic Forum.

Sharma, M. J., & Yu, S. J. (2009). Performance based stratification and clustering for benchmarking of container terminals. *Expert Systems with Applications, 36*(3), 5016-5022.

Sharma, M. J., & Yu, S. J. (2010). Benchmark optimization and attribute identification for improvement of container terminals. *European journal of operational research, 201*(2), 568-580.

Sheth, N. (1999). *Measuring and evaluating efficiency and effectivenes using Goal Programming and Data Envelopment Analysis in a fuzzy environment.* (Materal disseration). USA: Virgina Tech University.

Shin, C.-H., & Jeong, D.-H. (2013). Data Envelopment Analysis for Container Terminals Considering an Undesirable Output-Focus on Busan Port & Kwangyang Port. *Journal of Navigation and Port Research, 37*(2), 195-201.

Song, D.-W., & Yeo, K.-T. (2004). A competitive analysis of Chinese container ports using the analytic hierarchy process. *Maritime Economics & Logistics, 6*(1), 34-52.

Tongzon, J. (2001). Efficiency measurement of selected Australian and other international ports using data envelopment analysis. *Transportation Research Part A: Policy and Practice, 35*(2), 107-122.

Tongzon, J., & Heng, W. (2005). Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals). *Transportation Research Part A: Policy and Practice, 39*(5), 405-424.

Van de Voorde, E., & Winkelmans, W. (2002). A general introduction to port competition and management. *Port Competitiveness: An economic and legal analysis of the factors determining the competitiveness of seaports*, 1-16.

Van Dyck, G. K., & Ismael, H. M. (2015). Multi-Criteria Evaluation of Port Competitiveness in West Africa Using Analytic Hierarchy Process (AHP). *American Journal of Industrial and Business Management, 5*(06), 432-446.

Vuković, D., Jovanović, A., & Đukić, M. (2012). Defining competitiveness through the theories of new economic geography and regional economy. *Journal of the Geographical Institute" Jovan Cvijic", SASA, 62*(3), 49-64.

Wanke, P. F., Barbastefano, R. G., & Hijjar, M. F. (2011). Determinants of efficiency at major Brazilian port terminals. *Transport Reviews, 31*(5), 653-677.

Wu, J., Yan, H., & Liu, J. (2010). DEA models for identifying sensitive performance measures in container port evaluation. *Maritime Economics & Logistics, 12*(3), 215-236.

Wu, Y.-C. J., & Goh, M. (2010). Container port efficiency in emerging and more advanced markets. *Transportation Research Part E: Logistics and Transportation Review, 46*(6), 1030-1042.

Yeo, G.-T., Roe, M., & Dinwoodie, J. (2008). Evaluating the competitiveness of container ports in Korea and China. *Transportation Research Part A: Policy and Practice, 42*(6), 910-921.

Yeo, G.-T., & Song, D.-W. (2006). An application of the hierarchical fuzzy process to container port competition: policy and strategic implications. *Transportation, 33*(4), 409-422.

Yeo, K.-T., & Song, D.-W. (2003). An evaluation of container ports in china and Korea with the analytic hierarchy process. *Journal of the Eastern Asia Society for Transportation Studies, 5*(3), 726-741.

Yuen, A. C.-l., Zhang, A., & Cheung, W. (2013). Foreign participation and competition: A way to improve the container port efficiency in China? *Transportation Research Part A: Policy and Practice, 49*, 220-231.

Yuen, C.-l. A., Zhang, A., & Cheung, W. (2011, January). Port attributes related to container terminal efficiency in China and its neighboring countries: The DEA approach. *In International Forum on Shipping, Ports and Airports (IFSPA) 2010* (pp. 293-305). Hong Kong: Hong Kong Polytechnic University.

Yuen, C.-l. A., Zhang, A., & Cheung, W. (2012). Port competitiveness from the users' perspective: An analysis of major container ports in China and its neighboring countries. *Research in Transportation Economics, 35*(1), 34-40.

Zheng, X. B., & Park, N. K. (2016). A Study on the Efficiency of Container Terminals in Korea and China. *The Asian Journal of Shipping and Logistics, 32*(4), 213-220.

Zou, T. Y. (2012). *China - ASEAN Port Logistics Gradually Moving Towards "Standard Development" Era.* Retrieved August 10, 2016, from http://news.xinhuanet.com/fortune/2012-09/18/c_113120217.htm

APPENDIX

Appendix A Summary of the DEA Method Used in Ports

Author (year)	DMU	Method	Input variables	Output variables
Al-Eraqi, Mustafa, Khader, and Barros (2008)	22 seaports in the middle east and east African region	CCR, BCC	Berth length, storage area, handling equipment	Throughput (tons)
B.-L. Liu, Liu, and Cheng (2008)	45 container terminals in mainland China	BCC	Quay length, quayside gantry crane, rubber-tyred gantry crane	Throughput (TEU)
Min and Park (2008)	11 container terminals	BCC	Gantry cranes, terminal quay length, yard areas, size of labor force	Throughput (TEU), terminal capacity (TEU)
Pillania, Jim Wu, and Lin (2008)	21 leading ports from G7, BRIC and N-11 countries	CCR, BCC	Terminal area, total quay length, number of quayside gantries, number of straddle carries	Number of containers
Jiang and Li (2009)	12 seaports from China, Korea and Japan	DEA	Import/export by customs, GDP by regions, berth length, crane numbers	Throughput (TEU)
Sharma and Yu (2009)	70 container terminals	DEA	quay length (total quay length of a container terminal), terminal area, quay cranes, transfer cranes (yard cranes), straddle carriers, reach stackers	Container throughput
Y.-C. J. Wu and Goh (2010)	20 largest container ports	CCR, BCC	Terminal area, total quay length, number of pieces of equipment	Container throughput
Gao, Lv, and Liu (2010)	5 ports	DEA	Quay berth number, warehouse area, storage yard area, port aggregate investment, cargo gear number, traveling bridge number	Container throughput, cargo throughput
Cullinane and Wang (2010)	25 leading container ports	DEA	Quayside gantry (number), yard gantry (number), straddle carrier (number)	Container throughput, terminal length, terminal area

Appendix A (cont.)

Author (year)	DMU	Method	Input variables	Output variables
Emrouznejad, Mustafa, and Al-Eraqi (2010)	22 cargo seaports in the region of east Africa and middle east	BCC, CCR, Super efficiency	Berth length, terminal area, equipment units	Ships call, cargo throughput (tons)
Nigra (2010)	57 worldwide seaports (of which 21 Iberian ports0	BCC, Super efficiency	Capital expense, employees, operational expenses	General cargo, dry bulks/solid bulks, liquid bulks, passengers
Kamble, Raoot, and Khanapuri (2010)	12 major Indian seaports	BCC	Storage facilities, number of berth, number of cargo handling equipment	Average total turnaround time (days), average output per ship berths day (tons)
J. Wu, Yan, and Liu (2010)	77 terminals from 56 global container ports	CCR, BCC	Capacity of cargo handling equipment, number of berth, terminal area, storage capacity	Container throughput
Hung, Lu, and Wang (2010)	31 container ports in Asia-Pacific region	BCC, CCR	Terminal area, ship-shore container gantry crane, container berth, terminal length (the length of berths at which container ships anchor)	Container throughput
Munisamy and Singh (2011)	69 major Asian container ports	CCR, BCC, Super efficiency	Berth length, terminal area, total reefer points, total quayside cranes (and/or Mobile cranes), total yard equipment	Total throughput (TEU)
Wanke, Barbastefano, and Hijjar (2011)	25 major Brazilian port terminals	CCR, BCC	Terminal area, size of parking lot for incoming trucks/parking lot (in number of trucks), number of shipping berths	Aggregate throughput per year (in tons), number of loaded shipments per year
Chi-lok Andrewa Yuen, Zhang, and Cheung (2011)	23 container terminals	DEA	Number of berths, berth length, land size, quay crane, yard gantries	Throughput (TEU)

Appendix A (cont.)

Author (year)	DMU	Method	Input variables	Output variables
Demirel, Cullinane, and Haralambides (2012)	16 container terminals of Mediterranean	BCC, CCR	Quay length, terminal area, quay cranes (indclidng both ship-to-shore and the mobile quay cranes used mainly by small container terminals), yard equipment, maximum draft	Throughput (TEU)
Kim (2012)	19 European container ports	DEA	Length of berths, terminal area, number if cranes, working hours	Throughput (TEU)
Dias, Azevedo, Ferreira, and Palma (2012)	10 Iberian container terminals	BCC	Container cranes, terminal area, quay length	Container throughput
B. Lu and X. Wang (2012)	31 major container terminals	BCC, CCR, Super efficiency	Yard area, quay crane, yard crane, yard tractor, berth length	Container throughput
B. Lu and X. L. Wang (2012)	31 container terminals (14China ports an 17 Korea ports)	CCR, BCC	Yard area per berth, number of quayside cranes per berth, number of terminal cranes per berth, number of yard tractor per berth, berth length, water depth	Container throughput per berth
Niavis and Tsekeris (2012)	30 seaports in the wider region of south-eastern Europe	DEA, Super efficiency	Number of berth, length of quays, number of cranes used by each port for container handling	Total throughput (TEU)
Pjevčević, Radonjić, Hrle, and Čolić (2012)	5 Serbia river ports of Danube river	DEA	Total area of warehouses, quay length, number of cranes	Port throughput (tons)
Bichou (2013)	420 container terminals	CCR, BCC	Terminal area, max draft, length overall, quay crane index, yard-stacking	Throughput (TEU)

Appendix A (cont.)

Author (year)	DMU	Method	Input variables	Output variables
Infante and Gutiérrez (2013)	33 ports/terminals in the Asian Pacific region	CCR, BCC	Total number of gantry, terminal area, total berth length of the terminals	TEUs handled
Bo and Kyu (2013)	28 major East Asia container terminals	CCR	Yard area, quay crane, terminal crane, yard tractor, berth length	Throughput (TEU)
Mokhtar and Shah (2013)	6 major container terminals in Malaysia	CCR, BCC	Total terminal area, maximum draft in meter, berth length in meter, quay crane index, yard stacking index, vehicles, number of gate lanes	Throughput (TEU)
Munisamy and Danxia (2013)	69 major container ports in Asia	DEA	Berth length, terminal area, total reefer points, total quayside cranes, total yard equipment	Total throughput (TEU)
Munisamy and Jun (2013)	30 Latin America container seaports	BCC, CCR	Berth length, terminal area, quay equipment, yard gantry, sophisticated equipment (reach stackers, straddle carriers), general equipment 9forklifts and yard tractors)	Container throughput
Grilo (2013)	11 terminals of Portuguese ports	CCR, BCC	Total quay length, number of berths, quay depth, storage area, number of cranes	Cargo throughput (ton)
Polyzos and Niavis (2013)	30 Mediterranean ports	CCR, Super efficiency	Length of quays, number of ship to shore cranes	Number of TEUs that were moved
Shin and Jeong (2013)	8 terminals of south Korea	BCC, CCR	Quay length, number of container cranes, area of container yard	Container throughput and CO_2 emission
Schøyen and Odeck (2013)	24 container ports from Norway, all Nordic countries, United Kingdom	BCC, CCR	Berth length, terminal area, yard gantry cranes, straddle carriers	Container handling trucks, container throughput

Appendix A (cont.)

Author (year)	DMU	Method	Input variables	Output variables
A. C.-l. Yuen, Zhang, and Cheung (2013)	21 major container terminals in China, Busan, Singapore and Kaohsiung	DEA	Number of berths, total berth length, land size (port land area), number of quay cranes, yard gantries	Cargo throughput (TEU)
Rajasekar, Ashraf, and Deo (2014)	Major ports in India	CCR, BCC	Number of berth, berth length, number of equipments, number of employees	Container throughput)TEU), total traffic
Akgül, Solak Fışkın, Düzalan, Erdoğan, and Karataş Çetin (2015)	15 leading container ports in Turkey	CCR	Number of quay cranes, terminals area, storage capacity, quay length	Throughput (TEU)
Almawsheki and Shah (2015)	19 container terminals in the middle eastern region	CCR	Terminal area, quay length, quay crane, yard equipment, maximum draft	Throughput (TEU)
Baran and Górecka (2015)	18 leading container ports ranked in 2012	CCR, BCC	Number of berths, terminal area, storage capacity in TEU, quay length	Annual throughput (TEU)
Ding, Jo, Wang, and Yeo (2015)	21 coastal small and medium sized-port container terminals in China	CCR, BCC	Terminal length, handling equipment quantity, staff quantity	Container throughput
Lu, Park, and Huo (2015)	20 world's container ports	CCR, BCC, Super efficiency	Yard area, quay crane, terminal crane, yard tractor, berth length	Container throughput
Nguyen, Nguyen, Chang, Chin, and Tongzon (2016)	43 largest Vietnamese ports	DEA	Berth length, terminal areas, warehouse capacity, cargo handling equipment	Cargo throughput
da Cruz and de Matos Ferreira (2016)	10 Iberian seaport	CCR, BCC	Labor, fixed asset, turnover, ships handled	Cargo throughput

Appendix A (cont.)

Author (year)	DMU	Method	Input variables	Output variables
Jang, Park, and Kim (2016)	21 container ports in Asia	CCR, BCC, SBM	Number of berth, length of berth, terminal area, gantry crane	Cargo volume (TEU)
Olapoju and Aloba (2016)	Lagos seaports	DEA	Terminal area, berth number, berth length	Ship traffic, cargo throughput
Tetteh et al. (2016)	China and 5 west African countries	DEA	Number of berths, number of cranes, length of quay	Vessel calls(gross tons), port throughput (TEU)
Zheng and Park (2016)	30 major container terminals in Korea and China	CCR, BCC	Berth length, yard area, number of quay cranes, number of yard cranes	Throughput (TEU)
Schøyen and Odeck (2017)	6 largest Norwegian container ports against 14 similar small- and medium-sized ports in the Nordic countries and UK	DEA	Berth length, terminal areas, number of yard gantry cranes, straddle carries, container handling trucks	Container units (TEU)

Notes: CCR: Charnes, Cooper and Rhodes model; BCC: Banker, Charnes and Cooper model; DEA: Data Envelopment Analysis; G7: America, France, Italy, Canada, Germany, Japan, and the England; BRIC: Brazil, Russia, India, China; N11: South Korea, Indonesia, Vietnam, the Philippines, Pakistan, Bangladesh in Asia, Nigeria and Egypt in Africa, Mexico in North America, Iran in the Middle East, and Turkey

Appendix B Running Results of Software MaxDEA

Input-Oriented CCR Model's Result

NO	DMU	Score	Alpha	Benchmark (Lambda)	Times as a benchmark for another DMU	Proportionate Movement (input 1)	Slack Movement (input 1)	Projection (input 1)	Proportionate Movement (input 2)	Slack Movement (input 2)	Projection (input 2)
1	Guangzhou port	0.509166	0.490834	Hongkong port(0.876)	0	-33.377	-13.593	21.03	-6499.13	0	6741.87
2	Haikou port	0.618699	0.381301	Hongkong port(0.063)	0	-1.144	-0.339	1.517	-299.703	0	486.297
3	Hong kong port	1	0	Hongkong port(1.000)	8	0	0	24	0	0	7694
4	Laem Chabang port	0.736963	0.263037	Hongkong port(0.338)	0	-2.893	0	8.107	-1220.492	-820.67	2598.838
5	Qinzhou port	0.280998	0.719002	Hongkong port(0.047)	0	-2.876	0	1.124	-1653.704	-285.963	360.333
6	Shenzhen port	0.740533	0.259467	Hongkong port(1.203)	0	-10.119	0	28.881	-4396.153	-3288.151	9258.697
7	Yangpu port	0.162736	0.837264	Hongkong port(0.014)	0	-7.535	-1.141	0.324	-1419.999	-172.108	103.892
8	Zhanjiang port	0.358676	0.641324	Hongkong port(0.030)	0	-1.283	0	0.717	-434.818	-13.211	229.971
9	Zhuhai port	0.100767	0.899233	Hongkong port(0.067)	0	-21.582	-0.822	1.596	-4566.303	0	511.697

Input-Oriented CCR Model's Result (cont.)

NO	DMU	Score	Alpha	Benchmark (Lambda)	Times as a benchmark for another DMU	Proportionate Movement (input 3)	Slack Movement (input 3)	Projection (input 3)	Proportionate Movement (output)	Slack Movement (output)	Projection (output)
1	Guangzhou port	0.509166	0.490834	Hongkong port(0.876)	0	-441.682	-213.704	244.474	0	0	1762.49
2	Haikou port	0.618699	0.381301	Hongkong port(0.063)	0	-11.439	-0.927	17.634	0	0	127.13
3	Hong kong port	1	0	Hongkong port(1.000)	8	0	0	279	0	0	2011.4
4	Laem Chabang port	0.736963	0.263037	Hongkong port(0.338)	0	-67.516	-94.925	94.239	0	0	679.4
5	Qinzhou port	0.280998	0.719002	Hongkong port(0.047)	0	-113.602	-31.331	13.066	0	0	94.2
6	Shenzhen port	0.740533	0.259467	Hongkong port(1.203)	0	-205.498	-250.763	335.739	0	0	2420.45
7	Yangpu port	0.162736	0.837264	Hongkong port(0.014)	0	-19.383	0	3.767	0	0	27.16
8	Zhanjiang port	0.358676	0.641324	Hongkong port(0.030)	0	-43.482	-15.979	8.339	0	0	60.12
9	Zhuhai port	0.100767	0.899233	Hongkong port(0.067)	0	-205.565	-4.48	18.555	0	0	133.77

Notes: Benchmarks: for inefficient DMU: the reference DMUs with corresponding intensities (the "lambdas") in brackets; for efficient DMU: the number of inefficient DMUs which have chosen the DMU as Benchmark. Proportionate movement: Only available for radial models. It is the radial part of improvement of inputs/outputs, the proportional decrease of inputs or the proportional increase of outputs. Positive values mean increase, and negative values mean decrease. Slack movement: it is s^- (input slack) or s^+ (output slack) in the linear programming equations. Projection: it is the efficient target. For radial models, projection =original +radial movement +slack movement. Times as a benchmark for another DMU: It provides useful information for efficient DMUs (score = 1). If "Times as a benchmark for another DMU" is zero for an efficient DMU, it means that it is just efficient in default. There are no other DMUs take it as a benchmark, in other words, it is a lonely DMU with a special situation in terms of input and outputs. The more times of an efficient DMU as a benchmark for other DMUs, the more significant the benchmark

Output-Oriented CCR Model's Result

NO	DMU	Score	Beta	Benchmark (Lambda)	Times as a benchmark for another DMU	Proportionate Movement (input 1)	Slack Movement (input 1)	Projection (input 1)	Proportionate Movement (input 2)	Slack Movement (input 2)	Projection (input 2)
1	Guangzhou port	0.509166	0.963995	Hongkong port(1.721)	0	0	-26.697	41.303	0	0	13241
2	Haikou port	0.618699	0.616295	Hongkong port(0.102)	0	0	-0.548	2.452	0	0	786
3	Hong kong port	1	0	Hongkong port(1.000)	8	0	0	24	0	0	7694
4	Laem Chabang port	0.736963	0.35692	Hongkong port(0.458)	0	0	0	11	0	-1113.583	3526.417
5	Qinzhou port	0.280998	2.55874	Hongkong port(0.167)	0	0	0	4	0	-1017.667	1282.333
6	Shenzhen port	0.740533	0.350379	Hongkong port(1.625)	0	0	0	39	0	-4440.25	12502.75
7	Yangpu port	0.162736	5.144909	Hongkong port(0.083)	0	0	-7.009	1.991	0	-1057.591	638.409
8	Zhanjiang port	0.358676	1.788035	Hongkong port(0.083)	0	0	0	2	0	-36.833	641.167
9	Zhuhai port	0.100767	8.923851	Hongkong port(0.660)	0	0	-8.16	15.84	0	0	5078

Output-Oriented CCR Model's Result (cont.)

NO	DMU	Score	Beta	Benchmark (Lambda)	Times as a benchmark for another DMU	Proportionate Movement (input 3)	Slack Movement (input 3)	Projection (input 3)	Proportionate Movement (output)	Slack Movement (output)	Projection (output)
1	Guangzhou port	0.509166	0.963995	Hongkong port(1.721)	0	0	-419.715	480.145	1699.032	0	3461.522
2	Haikou port	0.618699	0.616295	Hongkong port(0.102)	0	0	-1.498	28.502	78.35	0	205.48
3	Hong kong port	1	0	Hongkong port(1.000)	8	0	0	279	0	0	2011.4
4	Laem Chabang port	0.736963	0.35692	Hongkong port(0.458)	0	0	-128.805	127.875	242.492	0	921.892
5	Qinzhou port	0.280998	2.55874	Hongkong port(0.167)	0	0	-111.5	46.5	241.033	0	335.233
6	Shenzhen port	0.740533	0.350379	Hongkong port(1.625)	0	0	-338.625	453.375	848.075	0	3268.525
7	Yangpu port	0.162736	5.144909	Hongkong port(0.083)	0	0	0	23.15	139.736	0	166.896
8	Zhanjiang port	0.358676	1.788035	Hongkong port(0.083)	0	0	-44.55	23.25	107.497	0	167.617
9	Zhuhai port	0.100767	8.923851	Hongkong port(0.660)	0	0	-44.461	184.139	1193.744	0	1327.514

Notes: Benchmarks: for inefficient DMU: the reference DMUs with corresponding intensities (the "lambdas") in brackets; for efficient DMU: the number of inefficient DMUs which have chosen the DMU as Benchmark. Proportionate movement: Only available for radial models. It is the radial part of improvement of inputs/outputs, the proportional decrease of inputs or the proportional increase of outputs. Positive values mean increase, and negative values mean decrease. Slack movement: it is s^- (input slack) or s^+ (output slack) in the linear programming equations. Projection: it is the efficient target. For radial models, projection =original +radial movement +slack movement. Times as a benchmark for another DMU: It provides useful information for efficient DMUs (score = 1). If "Times as a benchmark for another DMU" is zero for an efficient DMU, it means that it is just efficient in default. There are no other DMUs take it as a benchmark, in other words, it is a lonely DMU with a special situation in terms of input and outputs. The more times of an efficient DMU as a benchmark for other DMUs, the more significant the benchmark

Input-Oriented BCC Model's Result

NO	DMU	Score	Alpha	Benchmark(Lambda)	Times as a benchmark for another DMU	Proportionate Movement (input 1)	Slack Movement (input 1)	Projection (input 1)	Proportionate Movement (input 2)	Slack Movement (input 2)	Projection (input 2)
1	Guangzhou port	0.512156	0.487844	Haikou port(0.132); Hongkong port(0.868)	0	-33.173	-13.601	21.226	-6459.539	0	6781.461
2	Haikou port	1	0	Haikou port(1.000)	2	0	0	3	0	0	786
3	Hongkong port	1	0	Hongkong port(1.000)	4	0	0	24	0	0	7694
4	Laem Chabang port	0.816561	0.183439	Hongkong port(0.317); Zhanjiang port(0.683)	0	-2.018	0	8.982	-851.159	-884.165	2904.676
5	Qinzhou port	0.59606	0.40394	Hongkong port(0.017); Zhanjiang port(0.983)	0	-1.616	0	2.384	-929.062	-570.4	800.538
6	Shenzhen port	1	0	Shenzhen port(1.000)	0	0	0	39	0	0	16943
7	Yangpu port	1	0	Yangpu port(1.000)	0	0	0	9	0	0	1696
8	Zhanjiang port	1	0	Zhanjiang port(1.000)	2	0	0	2	0	0	678
9	Zhuhai port	0.159579	0.840421	Haikou port(0.996); Hongkong port(0.004)	0	-20.17	-0.756	3.074	-4267.657	0	810.343

Input-Oriented BCC Model's Result (cont.)

NO	DMU	Score	Beta	Benchmark (Lambda)	Times as a benchmark for another DMU	Proportionate Movement (input 3)	Slack Movement (input 3)	Projection (input 3)	Proportionate Movement (output)	Slack Movement (output)	Projection (output)
1	Guangzhou port	0.512156	0.487844	Haikou port(0.132); Hongkong port(0.868)	0	-214.762	246.107	0	0	1762.49	-214.762
2	Haikou port	1	0	Haikou port(1.000)	2	0	30	0	0	127.13	0
3	Hong kong port	1	0	Hongkong port(1.000)	4	0	279	0	0	2011.4	0
4	Laem Chabang port	0.816561	0.183439	Hongkong port(0.317); Zhanjiang port(0.683)	0	-74.766	134.829	0	0	679.4	-74.766
5	Qinzhou port	0.59606	0.40394	Hongkong port(0.017); Zhanjiang port(0.983)	0	-22.689	71.489	0	0	94.2	-22.689
6	Shenzhen port	1	0	Shenzhen port(1.000)	0	0	792	0	0	2420.45	0
7	Yangpu port	1	0	Yangpu port(1.000)	0	0	23.15	0	0	27.16	0
8	Zhanjiang port	1	0	Zhanjiang port(1.000)	2	0	67.8	0	0	60.12	0
9	Zhuhai port	0.159579	0.840421	Haikou port(0.996); Hongkong port(0.004)	0	-5.602	30.877	0	0	133.77	-5.602

Notes: Benchmarks: for inefficient DMU: the reference DMUs with corresponding intensities (the "lambdas") in brackets; for efficient DMU: the number of inefficient DMUs which have chosen the DMU as Benchmark. Proportionate movement: Only available for radial models. It is the radial part of improvement of inputs/outputs, the proportional decrease of inputs or the proportional increase of outputs. Positive values mean increase, and negative values mean decrease. Slack movement: it is s^- (input slack) or s^+ (output slack) in the linear programming equations. Projection: it is the efficient target. For radial models, projection =original +radial movement +slack movement. Times as a benchmark for another DMU: It provides useful information for efficient DMUs (score = 1). If "Times as a benchmark for another DMU" is zero for an efficient DMU, it means that it is just efficient in default. There are no other DMUs take it as a benchmark, in other words, it is a lonely DMU with a special situation in terms of input and outputs. The more times of an efficient DMU as a benchmark for other DMUs, the more significant the benchmark

Output-Oriented BCC Model's Result

NO	DMU	Score	Alpha	Benchmark(Lambda)	Times as a benchmark for another DMU	Proportionate Movement (input 1)	Slack Movement (input 1)	Projection (input 1)	Proportionate Movement (input 2)	Slack Movement (input 2)	Projection (input 2)
1	Guangzhou port	0.780995	0.280418	Hongkong port(0.400); Shenzhen port(0.600)	0	0	-35.004	32.996	0	0	13241
2	Haikou port	1	0	Haikou port(1.000)	1	0	0	3	0	0	786
3	Hongkong port	1	0	Hongkong port(1.000)	4	0	0	24	0	0	7694
4	Laem Chabang port	0.791499	0.263425	Hongkong port(0.409); Zhanjiang port(0.591)	0	0	0	11	0	-1091.818	3548.182
5	Qinzhou port	0.396616	1.521328	Hongkong port(0.091); Zhanjiang port(0.909)	0	0	0	4	0	-984.182	1315.818
6	Shenzhen port	1	0	Shenzhen port(1.000)	1	0	0	39	0	0	16943
7	Yangpu port	1	0	Yangpu port(1.000)	0	0	0	9	0	0	1696
8	Zhanjiang port	1	0	Zhanjiang port(1.000)	2	0	0	2	0	0	678
9	Zhuhai port	0.103071	8.70205	Haikou port(0.379); Hongkong port(0.621)	0	0	-7.953	16.047	0	0	5078

Output-Oriented BCC Model's Result (cont.)

NO	DMU	Score	Beta	Benchmark (Lambda)	Times as a benchmark for another DMU	Proportionate Movement (input 3)	Slack Movement (input 3)	Projection (input 3)	Proportionate Movement (output)	Slack Movement (output)	Projection (output)
1	Guangzhou port	0.780995	0.280418	Hongkong port(0.400); Shenzhen port(0.600)	0	0	-313.193	586.667	494.234	0	2256.724
2	Haikou port	1	0	Haikou port(1.000)	1	0	0	30	0	0	127.13
3	Hong kong port	1	0	Hongkong port(1.000)	4	0	0	279	0	0	2011.4
4	Laem Chabang port	0.791499	0.263425	Hongkong port(0.409); Zhanjiang port(0.591)	0	0	-102.48	154.2	178.971	0	858.371
5	Qinzhou port	0.396616	1.521328	Hongkong port(0.091); Zhanjiang port(0.909)	0	0	-71	87	143.309	0	237.509
6	Shenzhen port	1	0	Shenzhen port(1.000)	1	0	0	792	0	0	2420.45
7	Yangpu port	1	0	Yangpu port(1.000)	0	0	0	23.15	0	0	27.16
8	Zhanjiang port	1	0	Zhanjiang port(1.000)	2	0	0	67.8	0	0	60.12
9	Zhuhai port	0.103071	8.70205	Haikou port(0.379); Hongkong port(0.621)	0	0	-43.894	184.706	1164.073	0	1297.843

Notes: Benchmarks: for inefficient DMU: the reference DMUs with corresponding intensities (the "lambdas") in brackets; for efficient DMU: the number of inefficient DMUs which have chosen the DMU as Benchmark. Proportionate movement: Only available for radial models. It is the radial part of improvement of inputs/outputs, the proportional decrease of inputs or the proportional increase of outputs. Positive values mean increase, and negative values mean decrease. Slack movement: it is s^- (input slack) or s^+ (output slack) in the linear programming equations. Projection: it is the efficient target. For radial models, projection =original +radial movement +slack movement. Times as a benchmark for another DMU: It provides useful information for efficient DMUs (score = 1). If "Times as a benchmark for another DMU" is zero for an efficient DMU, it means that it is just efficient in default. There are no other DMUs take it as a benchmark, in other words, it is a lonely DMU with a special situation in terms of input and outputs. The more times of an efficient DMU as a benchmark for other DMUs, the more significant the benchmark

Result of Scale Efficiency (CRS and VRS)

NO	DMU	Technical Efficiency Score(CRS)	Pure Technical Efficiency Score(VRS)	Scale Efficiency Score	Return to Scale
1	Guangzhou port	0.509166	0.512156	0.994162	Increasing
2	Haikou port	0.618699	1	0.618699	Increasing
3	Hongkong port	1	1	1	Constant
4	Laem Chabang port	0.736963	0.816561	0.902521	Increasing
5	Qinzhou port	0.280998	0.59606	0.471426	Increasing
6	Shenzhen port	0.740533	1	0.740533	Decreasing
7	Yangpu port	0.162736	1	0.162736	Increasing
8	Zhanjiang port	0.358676	1	0.358676	Increasing
9	Zhuhai port	0.100767	0.159579	0.631457	Increasing

Notes: CRS: constant return to scale; VRS: variables return to scale

Appendix C Running Results of Software EMS (Efficiency Measurement System)

The Super Efficiency Model Results Based on Variable Return to Scale (input-oriented)

	DMU	Score	Number of berth*{I}	Berth length*{I}	Terminal area*{I}	Container throughput*{O}	Benchmarks	{S} Number of berth*{I}	{S} Berth length*{I}	{S} Terminal area*{I}	{S} Container throughput*{O}
1	Qinzhou port	59.61%	1.00	0.00	0.00	0.27	4(0.88) 8(0.02)	0.00	570.40	22.68	0.00
2	Shenzhen port	Big	0.88	0.08	0.06	4641.20	0				
3	Guangzhou port	51.22%	0.00	1.00	0.00	0.49	6(0.13) 8(0.87)	13.60	0.00	214.76	0.00
4	Zhanjiang port	150.00%	1.00	0.00	0.00	0.00	2				
5	Zhuhai port	15.96%	0.00	1.00	0.00	0.10	6(1.00) 8(0.00)	0.76	0.00	2.60	0.00
6	Haikou port	193.51%	0.36	0.00	0.64	0.17	2				
7	Yangpu port	129.62%	0.00	0.00	1.00	0.00	0				
8	Hong kong port	235.16%	0.00	0.00	1.00	2.40	4				
9	Laem Chabang port	81.66%	1.00	0.00	0.00	0.70	4(0.68) 8(0.32)	0.00	884.16	74.76	0.00

Notes: {I}: input; {O}: output; {S}: slacks; colored row: DMU is efficient.

Big: DMU remains efficient under arbitrary large increased inputs (input oriented).

Benchmarks: for inefficient DMU: the reference DMUs with corresponding intensities (the "lambdas") in brackets; for efficient DMU: the number of inefficient DMUs which have chosen the DMU as Benchmark.

BIOGRAPHY

BIOGRAPHY

Name –Surname	Liurong Qin
Date of Birth	June 20, 1991
Address	South Street, Qiaoxian Town, Shanglin County, Nanning City, Guangxi Zhuang Autonomous Region, P.R. China

Education Background

2014	B.B.A (Tourism Management), Guangxi University XingJian College of Science and Liberal Arts, China