ASSESSING SEAPORT OPERATIONAL EFFICIENCY: THE CASE OF SOUTH AFRICAN SEAPORTS

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LIST OF ABBREVIATIONS AND ACRONYMS

BSC	Balanced Scorecard
DEA	Data Envelopment Analysis
DMU	Decision-Making Units
GDP	Gross Domestic Product
LSCI	Liner Shipping Connectivity Index
MPI	Malmquist Productive Index
PCA	Principal Component Analysis
PEC	Pure Technical Efficiency Change
POPIA	Protection of Personal Information Act
PTE	Pure Technical Efficiency
RS	Return to Scale
SE	Scale Efficiency
SEA	Seaport Efficiency Assessment
SEC	Scale Efficiency Change
SFA	Stochastic Production Frontier
SSA	Sub-Saharan Africa
TC	Technology Change
TE	Technical Efficiency
TEC	Technical Efficiency Change
TLTPF	Transnet Long-Term Planning Framework
TNPA	Transnet National Ports Authority
TPT	Transnet Port Terminals
UNCTAD	United Nations Conference on Trade and Development
WREC	Wits Research Ethics Committee

ABSTRACT

Along with the economic globalization development, the volume of international trade has increased tremendously. The seaport is vital in coordinating and integrating global trade activities and supply chains. This study sought to assess the efficiency of the four major South African seaports from 2016 to 2021. Along with the influencing factors and challenges analysis, appropriate recommendations were given to policymakers and port users to enhance seaport efficiency. In this study, a three-stage approach was undertaken. Firstly, the relative efficiency among the selected South African seaports was observed based on the output-oriented Data Envelopment Analysis (DEA) approach. Secondly, the Malmquist Productive Index (MPI) was used to indicate the efficiency changes from 2016 to 2021. Thirdly, a combined analysis of the survey and Tobit regression was performed to analyse the factors that influence the seaport efficiency of South Africa. Both secondary data and primary data were collected and analysed. In other words, a mixed method of qualitative and quantitative analysis was adapted in this study. Among all the four seaports, the port of Cape Town turned out to be a relatively more efficient seaport during the studied period. The trend of the efficiency changes of all the selected seaports was first increasing, then decreasing and then increasing, among which Port Elizabeth reached optimal efficiency in 2019. The decline in seaport efficiency was mainly concentrated between 2019 and 2020, apparently due to the impact of COVID-19. The Port of Cape Town was deemed the most efficient seaport, followed by the Port of Ngqura and Port Elizabeth, while the Port of Durban was deemed the least efficient. The scale of the seaport and advanced technology impacted the four ports differently. The Port of Durban is in relatively high demand for upgraded technology. Education level, registered capital, shipping routes, designed capacity, throughput and the economy of the port city positively affect seaport efficiency, while the population of the port city affects seaport efficiency negatively. It emerged that South African seaports' main challenges are coastal congestion, sustainability development, and balancing investment and revenue. Technical development and external competition also challenge improving seaport efficiency. One of the areas of further research could be how technology improves a specific South African seaport efficiency.

Keywords: *DEA, South Africa, seaport efficiency, influencing factors*

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

The study aimed to assess the seaport efficiency focusing on South African seaports. Along with the economic globalization development, the volume of international trade has increased tremendously. The seaport is vital in coordinating and integrating global trade activities and supply chains (Sirimanne, 2019). And it has even become the main operating base of the world's logistics service industry. The port economy has a huge stimulating effect on the national economy. In times of rapid economic growth, especially during periods of rapid international trade growth, seaport efficiency is one of the bottlenecks restricting cargo transportation (Li et al., 2018). It is essential to assess the seaport's efficiency to enhance market competitiveness.

To achieve the aim, this study took a three-stage approach. Firstly, the relative efficiency among the selected South African seaports was observed based on the output-oriented Data Envelopment Analysis (DEA) approach. Secondly, the Malmquist Productive Index (MPI) was used to indicate the efficiency changes from 2016 to 2021. Thirdly, Tobit regression was performed to identify the factors that influence the seaport efficiency of South Africa. The typical four seaports operated by Transnet Port Terminals (TPT) were investigated. Cross-sectional and panel data (2016-2021) were analysed to answer the specific research questions, assessing static and dynamic seaport efficiency. This study established the factors affecting seaport efficiency and ascertained the challenges in improving the efficiency of South African seaports. Consequently, appropriate recommendations for policymakers and port users were concluded.

1.2 Background to the Study

With the development of economic globalization, the volume of international trade has increased tremendously. International maritime transport, known as the backbone of international trade (Sirimanne, 2019), plays a vital role in global supply chains due to the advantages of its lower cost and a worldwide network. According to United Nations Conference on Trade and Development (UNCTAD), over 80% of world merchandise trade by volume was carried by sea in 2018 (Sirimanne et al., 2019). Maritime transportation, especially container transportation, quickly occupied the transportation market with its advantages of high efficiency but low cost. Therefore, as the starting point and endpoint of container transportation and the main node of multimodal transportation, the seaport plays a vital role in coordinating and integrating global trade activities and supply chains and has even become the main operating base of the world's logistics service industry (Havenga et al., 2017; Ma et al., 2021). The port economy greatly stimulates the national economy (Munim & Schramm, 2018). In times of rapid economic growth, especially during rapid international trade growth, port efficiency is one of the bottlenecks restricting cargo transportation. Each port can continuously improve its facilities and equipment to increase efficiency according to its advantages to take the lead in the fierce competition (Lu et al., 2015) of ports at home and abroad. Therefore, the evaluation method of port efficiency has been a research hotspot of port development theory for a long period.

As for the situation of African countries, according to UNCTAD's statistics on the world economic growth rate from 2018 to 2021, Africa's annual economic growth rate is higher than the world average rate from 2018 to 2019 but lower than that of developing countries (Table 1). Africa’s container ports accounted for a modest share of about 4% of global containerized trade volume (UNCTAD, 2020), showing Africa's great economic potential and development space. Thus, it is critical to improving its market competitiveness. Although one-third of Africa's countries are landlocked, almost 90% of the continent's international trade is carried out by sea. Therefore, promoting economic development in Africa relies heavily on improving port efficiency.

From the perspective of logistics, the routes for cargo in and out of Africa, especially the central part of Africa, are mainly through Tanzania in the east, South Africa in the south, Namibia and Angola in the west, and other coastal countries forming a two-way logistics transportation pattern, which can be described as a combination of sea transportation in the Indian Ocean and the Atlantic Ocean and land transportation in Africa. With the development of African logistics and transportation markets, represented by countries with relatively perfect infrastructure construction, such as Tanzania, South Africa, Namibia, and Angola, cities with ports such as Dar es Salaam, Durban, Whale Bay, and Luanda have become important hubs for the import and export of goods in Africa.

Table 1: 2019 Container Port Traffic

Country or Region	Million TEUs	Percentage
World	795.95	-
Middle East & North Africa	61.50	0.08 (world)
Sub-Saharan Africa	17.38	0.02 (world)
South Africa	4.77	0.27 (SSA)
Togo	1.50	-
Nigeria	1.48	-
Kenya	1.43	-
Ghana	1.10	-

Source: World Bank (2021)

Located at the southernmost tip of the African continent South Africa is at the shipping hub of the Indian Ocean and the Atlantic Ocean. Its excellent geographical location makes it an important shipping centre connecting itself and other landlocked African countries to Asia, Oceania, America, and Europe. South Africa has become an international dry bulk cargo; container transport power, iron ore, coal, cars, grain, and other bulk goods are rising. According to Table 1, sourced from the World Bank, in 2019, 795.95 million TEUs were handled worldwide, and the Middle East & North Africa and Sub-Saharan Africa (SSA) shared 8% and 2% of world container traffic. South African handled the most containers among African countries with several 4.77 million TEUs, accounting for 27% of port container traffic of the SSA region. The top 5 African countries handling the most containers in 2019 are South Africa, Togo, Nigeria, Kenya, and Ghana, of which the throughputs are 4.77 million TEUs,1.50 million TEUs, 1.48 million TEUs, 1.43 million TEUs, 1.10 million TEUs, respectively. Although the throughput of South Africa is much higher than the second-ranking country Togo, it is much lower than the ones of the top 50 countries/regions. Osundiran et al. (2020) state that seaport efficiency significantly contributes to a country's international competitiveness. Many countries consider assessing the overall efficiency of seaports when conducting microeconomic reform programs. By Assessing of relative efficiency of container seaports in the context of South Africa, we can get insights into the productivity and performance of different seaports (Seth & Feng, 2020) as well as the sources of inefficiency. Moreover, selecting the researched seaports of the same country makes data more comparable as they face the same regulations and environmental factors (Tovar & Wall, 2019).

The main seaports of South Africa are owned and operated by the two operating divisions of the state-owned company named Transnet. One of the operating divisions is Transnet National Ports Authority (TNPA), which plays the role of the landlord by providing port infrastructure and maritime services at the eight commercial ports. The other Transnet division related to South African seaports is Transnet Port Terminals (TPT), which focuses on the operational sector. In the eight main commercial ports of South Africa, TPT handles containers, mineral bulk, breakbulk, agricultural bulk and the Roro sector of seven seaports excluding Mossel Bay (Transnet, 2021). Figure 1 shows the locations and the cargo types handled at each seaport.

Figure 1: Ports with TPT Operated Terminals

Source: (Transnet, 2020c)

Table 2 shows the seven seaports operated by TPT, namely Richards Bay, Port of Durban, Port of Elizabeth, Port of East London, Port of Ngqura, Port of Cape Town and Saldanha Bay.

Table 2: Transnet Port Terminals (TPT) Operated Terminals

Ports	Terminal	Cargo
Richards Bay	Richards Bay Terminal	Bulk & Break Bulk
Port of Durban	Durban Container Terminal Pier 1	Container
	Durban Container Terminal Pier 2	Container
	Ro-Ro Terminal	Vehicle, high & heavy cargo, Container (niche) Break Bulk
	Maydon Wharf Terminal	Break Bulk & Agricultural Bulk
Port of Elizabeth	Port Elizabeth Container Terminal	Container
	Break Bulk Terminal	Bulk & Break Bulk
	Ro-Ro Terminal	Vehicle
Port of East London	Motor Vehicle Terminal	Vehicle
	East London Terminal	Break Bulk, Agri-Bulk, Vehicles, Container
Port of Ngqura	Ngqura Container Terminal	Container
Port of Cape Town	Cape Town Container Terminal	Container
	Cape Town Multipurpose Terminal	Container, Agri-bulk, Break Bulk
Saldanha Bay	Saldanha Iron Ore Terminal	Iron Ore
	Saldanha Multipurpose Terminal	Bulk & Break Bulk

Source: T(Transnet, 2013)

1.3 Research Problem

1.3.1 Fierce global competition and COVID-19 impact

With the rapid development of the global economy and international trade, fierce competition has emerged in container and intermodal transport worldwide. To meet the increasing technology utilized in all fields, the technology of ships and ports must be developed urgently (Okeudo, 2013). In the context of fierce competition among the coastal seaports, improving the throughput, striving to become a hub port, and closely connecting to the neighbouring has become an important issue for most major seaports. Simultaneously, the growth momentum of the world's major container ports failed to continue in 2019. The outbreak of the worldwide spread COVID-19 pandemic became a global challenge that followed with substantial consequences.

Unfortunately, this "black swan" incident greatly affected the port and shipping industry. The negative impact of COVID-19 on Africa, especially in the field of maritime transport, is indicated by several figures. For instance, as of mid-2020, the number of ship calls in Sub-Saharan Africa dropped to -9.7%, while the drop in container ship calls stood at -12.7% (UNCTAD, 2020). Surviving and occupying the main advantage in the competition is crucial to South African seaports. Thus, the urgency and necessity of conducting relevant research on seaport efficiency assessment have been further strengthened. Even though there have been some studies on port efficiency conducted around the world, there have not been so many in the context of South Africa, especially using the Data envelopment analysis (DEA) and, more so, under the impact of COVID-19 pandemic.

1.3.2 Mismatch of demand and capacity

Africa's foreign maritime trade is mainly characterized by the export of energy and raw materials and the import of industrial products and consumer goods. However, many coastal seaports are located along the African continent's coastline, such as the Port of Durban in South Africa, the Port of Walvis Bay in Namibia, the Port of Luanda in Angola, the Port of Dar es Salaam in Tanzania, etc. The scales of the seaports are relatively small. The throughput capacity of the seaports is mainly less than 1 million TEU except for the port of Said in Egypt and the port of Durban in South Africa (Notteboom et al., 2020). In terms of subregions, in East Africa, the ports of Mombasa and Dar es Salaam mainly serve the trade between Kenya and Tanzania. Although Nigeria and other countries support the port cargo volume in central West Africa, the infrastructure construction is lagging, leading to serious congestion in the port area. Although the contradiction between demand and supply capacity is not obvious in North Africa, the container capacity of the ports of Casablanca and Algiers needs to be improved urgently. In South Africa, the port of Durban has a designed annual handling capacity of 3.6 million TEUs (Transnet, 2020a). In 2020, it handled 2.60 million TEUs of containers (Lloyd’s List, 2021). Although the port can handle more containers, structural contradictions exist, such as deep-water shorelines. With regional economic and trade development, the increasingly connected network and the demand for port construction will become more obvious. The lack of container port capacity may be one of the reasons for the growing frustration of African seaports.

1.3.3 Low seaport efficiency and high cost

African ports have been generally perceived to be inefficient, and transport costs have been rated among the highest in the world. Sakyi and Immurana (2021) computed the average seaport efficiency rate for all regions of the world based on the Liner Shipping Connectivity Index (LSCI) data from UNCTADSTAT from 2010 to 2017, which showed Africa had the lowest seaport efficiency growth rates. The survey of logistics costs among developing countries conducted by Pohit et al. (2019) showed that the 2016 global logistics costs as a percentage of Gross Domestic Product (GDP) ranged from 8% to 16%, and the rate of Africa was 15.7%, ranking second highest just after Russia. The GDP of South Africa in 2019 was 351.432 trillion (WorldBank, 2021b), while the logistics cost in South Africa amounted to 39.1 billion U.S. dollars in 2019 (Statista, 2021), occupying 11.13% of the GDP. Even though the rate decreased, the cost is still relatively high. In addition to the imbalance of import and export goods at African ports (80% of imported heavy containers are transported in empty containers), the main reason is the insufficient infrastructure capacity and the lack of real hub ports in Africa. Due to the less-developed infrastructure conditions and severe port congestion in Africa, a large number of goods are transported to Africa through the hub ports in Europe, Southeast Asia, and the Middle East by loading on small and medium-sized vessels, which not only increases the transportation time but also fails to achieve scale effect and directly increases the shipping cost. African ports, which call on small and medium-sized vessels, become more congested, thus trapped in a non-virtuous circle. According to UNCTAD (2020), Africa's relatively high labour costs, which are calculated by a proportion of gross revenue, are another reason for the high logistic cost in Africa.

To enforce the competitiveness of South African seaports, it is thus important to identify whether the seaports are operating efficiently in the utilization of resources.

1.4 Research Objectives

The study's primary purpose was to assess the seaport efficiency focusing on South African seaports. The specific objectives of the study were as follows:

i. To assess and rank the seaport efficiency of the selected South African major seaports.
ii. To analyse the changes in seaport efficiency of the selected South African major seaports from 2016 to 2021.
iii. To establish the factors affecting South African seaport efficiency.
iv. To ascertain the challenges in improving South African seaport efficiency.
v. To give appropriate recommendations to policymakers and port users to enhance seaport efficiency.

1.5 Research Questions

i. What's the operational efficiency of South African seaports between 2016 and 2021?
ii. How does the operational efficiency of South African seaports change between 2016 and 2021?
iii. What are the factors that affect South African seaport efficiency?
iv. What are the main challenges to improving South African seaport efficiency?
v. What recommendations can be made to the policymakers and port users for enhancing seaport efficiency?

1.6 Rationale of the Study

With the increasingly fierce competition among seaports, seaport efficiency has become a significant indicator to measure seaport competitiveness. Instead of simply judging by experience, this study seeks more objective approaches for seaport efficiency assessment based on a systematic literature review. By adopting appropriate well-developed models and analysis calculation results, this study helped policymakers and port users make efficiency comparisons and suggested enhancing seaport efficiency and competitiveness.

Existing research has carried out many practices and explorations in evaluating port efficiency, and various methods and theories are relatively mature in their application. Other studies have been more specialised, for instance, focusing on efficiency in terms of handling dangerous cargo in African seaports (Saruchera, 2020), specializing in the efficiency of dry African ports (Abdoulkarim et al., 2019), and green port efficiency evaluation based on 18 ports of China in the light of the current global environmental degradation and energy consumption demands (Wang et al., 2020). However, there are relatively few studies on the efficiency of African seaports compared to other regions in the world, especially in using DEA models. Few studies focused on the assessment of the seaport efficiency of West and East Africa (Al-Eraqi et al., 2008; Gamassa & Chen, 2017; Kalgora, 2019; Kalgora et al., 2019; Konstantinidis, 2016; Trujillo et al., 2020; van Dyck, 2015), SSA (Carine, 2015; Osundiran et al., 2020) and combination of other seaports around the world (Gamassa & Chen, 2017; Tetteh et al., 2016). However, a few studies have been conducted to determine the relative efficiency of seaports in the context of South Africa. According to the Container Port Performance Index (CPPI) (2020), South African ports came in at the bottom of the list of 351 ports, which showed the worst port performance among the compared countries (Worldbank, 2021a). Therefore, this study aimed to empirically assess the efficiencies of seaports based on the DEA method to assess the seaport efficiency and analyse the influencing factors in the context of South Africa specifically, which differed from the worldwide CPPI conducted by World Bank. Also, by collecting and analysing the primary data from the operational sections of selected seaports, this study filled the gap of relying on secondary data only, which made the findings more accurate and reliable.

Much research mentioned that to get an accurate outcome of DEA, the general rule of making the number of Decision Making Units (DMU) twice greater than the sum of inputs and outputs (Cavaignac & Petiot, 2017; da Cruz & de Matos Ferreira, 2016). In this case, the number of seaports is four and not great enough if simply taking each port as a DMU. The port of different years is treated as an independent DMU. Thus, the requirement of the minimum number of DMUs was achieved and enhanced the validity of the study.

1.7 Delimitations

This study focused on seaport efficiency in South Africa. Considering the comparability, homogeneity, and availability of data, the Port of Durban, Port of Ngqura, Port of Elizabeth, and Port of Cape Town were finally selected. TPT operates all these four seaports, specifically with dedicated container terminals. In other words, the study was focused on the container terminals of the four primary seaports operated by TPT. The two container terminals, Pier 1 and Pier 2 of Durban Port, were considered as one to represent Durban Port. The assessment was conducted based on the data from 2016 to 2021. As the data for 2017 was not presented on the website, total data for 2016,2018,2019,2020 and 2021 was collected. Thus, a total of 20 observations were obtained.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature reviews on seaport efficiency assessment, aiming to obtain a specific research framework based on relevant studies. This chapter explores related concepts and studies by integrating relevant knowledge in this field. The first sector of this part introduces the definitions of several key terms. The second sector of this part is the literature review of seaport efficiency assessment. The third sector of this part studies five approaches to efficiency evaluation. The fourth sector explores the factors affecting seaport efficiency generally. The fifth sector discussed the challenges to improving seaport efficiency, and the last sector is the theoretical and conceptual framework generated for this study.

2.2 Definition of key terms

2.2.1 Seaports and Container Terminals

A port normally refers to a place where ships can dock. A seaport, by its name, is a port located along the coast where people and goods can leave or enter a country by sea. Thus, a seaport interfaces land and maritime transport (Carine, 2015). The modern port has become a distributing centre and hub for global logistics and a distribution centre for industrial and agricultural products and international trade import and export materials by connecting sea transportation with inland transportation (Montwiłł, 2016).

Nyandu (2020) summarized three main functions of a port: transferring people and goods, promoting employment, and increasing benefits. With the development of the modern economy and technology, ports have undergone multiple generations of evolution. Ports have not only existed as berthing, loading, unloading, supplementary supplies, storage, and transportation centres. They are rapidly transforming into resource allocation sites and logistics centres. With the continuous acceleration of the global economic integration process, ports' functions have gradually expanded, and ports have become the most critical module in the modern logistics system, which has a significant driving effect on the economic development of the hinterland.

With the crucial role of seaports in commercial activities, the construction of seaport infrastructure, the utilization of human resources, as well as capital input and output occupy an important position in improving the efficiency of the logistics economy. Nowadays, the economic development of various countries is to a large extent. Depending on the size of each country’s ports, large cities with obvious internationalization are likely to develop into global economic centres (Sidenko, 2022). This development model has created a fiercely competitive atmosphere throughout the world’s seaports in the global logistics and transportation chain.

A terminal is a facility dedicated to mooring ships or ferries by the sea and rivers, allowing passengers to get on and off and load and unload goods (Gaythwaite, 2016). It is usually found in commercial cities with developed water and land transportation. A container terminal is a place where the entire loading and unloading process of containerized cargo can be completed (Martin & Thomas, 2001). The water area mainly includes harbour basins, anchorages, berths, and access channels, and the land area mainly includes storage yards, terminal fronts, office areas, and freight yards. According to the classification of terminals, container terminals can be divided into dedicated and multi-purpose terminals (Medda & Liu, 2013). Among them, the multi-purpose terminal has a wide range of applicability and is suitable for ports with small container throughput, while the dedicated terminal has a single function but has a very powerful ability to handle container loading and unloading. Therefore, it is suitable for ports with large container throughput, especially international containers.

Port and terminal have similar meanings most of the time. In some studies, the terminal has also been extended to represent a port (Périco & Ribeiro da Silva, 2020; van Dyck, 2015). The difference between a port and a terminal is that the port is the whole integration, and the terminal is the part of it, of course, an all-important part. A port can be understood as a collection of terminals with a higher level than a terminal. In this study, the efficiency assessment undertaken on South African seaports was especially based on the seaports with container terminals.

2.2.2 Seaport Efficiency

Fundamentally speaking, seaport efficiency is the recourse allocation optimization rate reflecting the input and output at the seaport operation and management stage, and it represents the relative efficiency. From the macroscopic point of view, seaport efficiency refers to the seaport's radiation efficiency and driving ability to the hinterland economy, reflecting the contribution rate of the seaport to the economy (Cong et al.,2020; He et al.,2019). Seaport efficiency not only reflects the situation of resource allocation but also reflects the port input and output capacity, operation and management level, and comprehensive competitiveness. Improving the seaport's efficiency is of great significance to promoting the effective development of the seaport and the rapid growth of the hinterland and regional economy (Olukoju,2020).

Many scholars have tried to utilize different indicators and various models to conduct research to measure seaport efficiency. The following four concepts will be introduced - technical efficiency, scale efficiency, pure technical efficiency, and return to scale.

2.2.3 Technical Efficiency (TE)

Technical efficiency refers to the relationship between resources (capital and labour) and outcome (Palmer & Torgerson, 1999). If the outcome is maximally improved with certain inputs, we then agree that technical efficiency is achieved. Conversely, we judge the intervention as technically inefficient when the outcome remains the same or even gets greater if certain input is removed. In other words, technical efficiency measures how the given recourses are fully used. Fare et al. (1994) decomposed technical efficiency into scale efficiency and pure technical efficiency, so in some studies, technical efficiency is also stated as overall technical efficiency (da Cruz & de

Matos Ferreira, 2016; Estache et al., 2004; Pjevčević et al., 2012).

2.2.4 Scale Efficiency (SE)

da Cruz and de Matos Ferreira (2016) stated that Farrell first introduced the concept of scale efficiency in the 1950s. It addresses the issue that when the enterprise increases the input resources equally, whether the added value of output is greater than the added value of the input. As can be seen, it represents the relationship between the added value of the input and the output (da Cruz & de Matos Ferreira, 2016). Therefore, when the output-increasing ratio is greater than the input-increasing ratio, the scale efficiency increases, verse vera (Wanke & Barros, 2015). From the perspective of seaport efficiency evaluation, scale efficiency measures the impact of changing seaport production scale on seaport output during production and operation. It shows the distance between the current port scale to the optimized seaport scale (Carine, 2015; Duong et al., 2019). Generally, the scale of a seaport can be improved by adding seaport investigation, building more facilities, hiring more people, etc. (Gamassa & Chen, 2017; Pérez et al., 2016). Assessing how a seaport scale meets the current operation situation contributes to avoiding the waste of unreasonable or unnecessary seaport expansion.

2.2.5 Pure Technical Efficiency (PTE)

As mentioned, pure technical equals technical efficiency and subtracts scale efficiency. It refers to the ability of the ports to use the resources (Carine, 2015). Barros (2006) described pure technical efficiency as managerial skills. Pure technical efficiency is directly related to seaport production technology and management level (da Cruz & de Matos Ferreira, 2016). Hence, more advanced facilities and a higher management level led to increased pure technical efficiency. In the view of seaport operation, pure technical efficiency refers to the operational capacity of the seaport infrastructure and management ability.

2.2.6 Returns to Scale

Elsner et al. (2015) defined returns to scale as the proportionality of output changes following changes in all input factors, and they are derived from production technologies. When returns to scale increase, logistics efficiency improves due to increased logistics resource input and optimization. When returns decline, it means the integration of logistic resources and scale extension is necessary, as the increase in output is less than the increase in input combinations (Deng et al., 2020).

2.3 Assessing Seaport Efficiency

Wiegmans and Witte (2017) posit that efficiency analysis can be explained by input, process, and output. For instance, if the input is the number of workers in a factory, the process is the consumed working hours. The output is the number of products produced during working hours. The factory efficiency can then be measured by comparing the number of products (output) with the time spent producing them and the number of workers who produce them (input). The less hour spent, the fewer workers worked, and the more products produced, the better. Likewise, seaport efficiency can be explained the same way. By selecting land (space), capital (facility), and labour (employee) (Dowd & Leschine, 1990) as the inputs, throughput as output, the seaport operation, and management as the process, seaport efficiency can be explained by comparing the throughput with space area/facility number/employee number and handling time. In most research, port efficiency is a relative efficiency. And how to choose the inputs and outputs is a complex issue that varies from study to study, which will be discussed in Chapter Three.

Port efficiency assessing methods can be summarized into two types, namely, the parametric approach and the non-parametric approach. The parametric method is represented by Stochastic Production Frontier (SFA) and Linear Regression. Non-parametric methods are mostly the BP Neural Network Method, Balanced Score Card, and Data Envelopment Analysis (DEA). This study takes a brief introduction of SFA and a comprehensive literature review of DEA.

2.3.1 Parametric approach

(1) Stochastic Frontier Analysis (SFA)

The Stochastic Frontier Analysis (SFA) is widely used in assessing seaport efficiency as it considers the influence of random errors in the analysis process. Based on the SFA model, Pérez et al. (2016) analysed the data from 40 container terminals in Latin America and the Caribbean from 2000 to 2010. The results showed that although the economic crisis affected the seaport's efficiency, it was still actively developing. At the same time, the efficiency of transhipment seaports was lower than that of other seaports, and the decision-makers were advised to consider promoting and strengthening inter-port competition.

Wiegmans and Witte (2017) conducted a study of 127 European container terminals based on SFA and DEA models, and by comparing the different combinations of inputs and output based on SFA, they found that when defining throughput as the output and capacity as one of the inputs, the highest efficiencies are achieved. And different combination analyses lead to very different best and worst performers.

(2) Linear Regression

Linear regression is a statistical analysis method that uses regression analysis in mathematical statistics to determine the quantitative relationship between two or more variables. Tongzon and Heng (2005) used the linear regression model combined with the Principal Component Analysis (PCA) to examine the effects of identified key factors on port competitiveness.

2.3.2 Non-parametric approach

(1) BP Neural Network Method

BP Neural Network is a valuable method of training Artificial Neural Networks based on the error backpropagation (BP algorithm) to the multi-layer neural network. Researchers used this model in some studies to predict the port’s throughput (Chen & Chen, 2009; Ding et al., 2019; Liu & Zhang, 2007; Ping & Fei, 2013).

(2) Balanced Score Card

The term balanced scorecard (BSC) refers to a strategic management performance metric used to identify and improve various internal business functions and their resulting external outcomes. David P. Norton and Robert S. Kaplan put forward the theoretical concept of BSC in 1996. Hamid (2018) measured the competitive advantages of the infrastructure of the ports in Indonesia. Yuhling et al. (2003) compared three ports in Taiwan based on BSC and fuzzy set theory and suggested operation strategies.

(3) Data envelopment analysis (DEA)

Data envelopment analysis (DEA) was first introduced in the 1970s and has been widely used for efficiency evaluation in different areas. It measures multiple observations with multiple inputs and outputs. A comprehensive study is unfolded in the next section of DEA studies.

Among all the five approaches above, Linear Regression does not consider the complex nonlinear relationship caused by the interaction effect of various factors in practice. Therefore, when too many factors exist, the model cannot satisfy the empirical analysis of port efficiency. The SFA method has a variety of evaluation models according to different error selections, which leads to too many alternative methods.

BP neural network has fast data processing ability but is limited when it falls into the local extreme value. The BSC system is complex, and the number of index evaluations is too large, which leads to some difficulties in index quantification and weight allocation. Meanwhile, BSC also requires enterprises to have certain management abilities and clear strategies, which is difficult for general enterprises to implement. One of the advantages of the DEA model is that even though it's based on multiple inputs and outputs, all these indexes are independent, which excludes certain subjective factors so that the evaluation conclusion has strong objectivity. Therefore, more and more scholars tend to choose data envelopment analysis to study port efficiency.

2.3.3 DEA studies

In the 1970s, Charnes et al. (1978) first came up with the idea of Data envelopment analysis (DEA), a non-parametric approach based on linear programming for measuring the productive efficiency of Decision-Making Units (DMUs). Simply saying, the efficiency of a DMU can be considered as its ability to transform inputs into desired outputs (Okeudo, 2013). The standard DEA-CCR model was broadly used (Bessent & Bessent, 1979; Bessent & Bessent, 1980; Maschler et al., 1979). Banker et al. (1984) developed the DEA-CCR model into the DEA-BCC model by measuring the variable return to scale instead of the constant return to scale. In terms of port efficiency evaluation, the first application of DEA can date back to the 1990s; Roll and Hayuth (1993) compared 20 ports based on the DEA-CCR model.

It has been proved that DEA is the most effective method to evaluate the relative efficiency of the DMUs with multiple inputs and outputs by substantial research conducted by scholars all around the world. Akbari et al. (2020) emphasized that no prior assumption on the relationships between inputs and outputs is required. With its advantage that measuring efficiency with multiple indicators (inputs and outputs), the analysis based on DEA is more reliable and reflects the actual reality more closely. Moreover, it does not need to assign relative weights to indicators, so it can maximally eliminate subjective factors and achieve more objective outcomes. Numerous empirical studies of seaport efficiency based on DEA testified to the reliability and accuracy of DEA.

The research undertaken by Cavaignac and Petiot (2017), which analysed 461 articles of DEA studies in the transport field between 1989-2016, revealed that the research of DEA adopted on the transport sector increased from 2000 and accelerated since 2008.

In the recent 30 years, DEA-CCR and DEA-BCC have been widely applied in various areas. Many researchers contribute to developing the approaches according to a different context, observations, objectives, etc., by exploring approaches such as the PCA-DEA model (Faed et al., 2016), DEA-super efficiency model (Kutin et al., 2017), DEA-Tobit model (Sağlam, 2018), DEA-Malmquist model (Ding et al., 2015; Duong et al., 2019; Osundiran et al., 2020; Tovar & Wall, 2019), DEA-Windows model (Birafane & El Abdi, 2019; Seth & Feng, 2020; Vlontzos & Pardalos, 2017), Analytic Hierarchy Process (AHP) - DEA model, DEA-Slacks-Based Measure (SBM) model (Chang et al., 2018), PCA-DEA-Tobit (Deng et al., 2020) and so on. Of course, there are much more research and models related, and as we can see, the models can be developed by assembling different approaches.

According to the characteristic of the DMUs, the DEA approaches to seaport efficiency can be grouped into two categories: The first category is the evaluation of the whole port. That is, do not distinguish containerized cargo from all the other kinds of cargo handled in the port, such as dry bulk, liquid bulk, break-bulk, rolling stock, etc. The cumulative inputs of all shoreland resources and operation resources are used, and comprehensive data such as throughput are used as an output to obtain the overall technical efficiency, pure technical efficiency, and scale efficiency of the port. However, due to the significant differences in operation modes and requirements when handling different types of cargo, it isn't easy to truly reflect the efficiency of each type of cargo. Therefore, this leads to an unpredictable deviation between the DEA outcome and the true situation. The second category is the efficiency assessment based on container ports. In this case, as the container cargo is the only subject to be considered, the data collected is homogeneous, which is more representative and comparative. Thus, this study selected the main seaports with dedicated container terminals as the research objects.

As mentioned, the DEA model has been combined with different approaches in different contexts. The application of DEA on seaport efficiency assessment gradually advances from static to dynamic, from single stage to multiple stages, and from radial to non-radial.

As mentioned, Banker et al. (1984) explored the DEA-BCC model based on the DEA-CCR model, which addressed the limitation of the assumption that constant returns to scale and analysis of technical efficiency and scale efficiency only. The EDA-BCC model assumes the variable returns to scale and calculates the value of pure technical efficiency by the overall technical efficiency value obtained from the DEA-CCR model divided by the scale efficiency value.

Sometimes when running the DEA model, more than one DMUs achieve efficiency. In other words, the value equals 1. Then, the relative efficiency cannot be distinguished. To address this issue, the Super-efficiency model is utilized. For example, Kutin et al. (2017) ranked the 50 ASEN container ports and terminals by adopting the DEA + Super-Efficiency model.

When the numbers of inputs and outputs increase to a certain extent, the reliability and accuracy of the outcome of DEA will be limited. In this case, some researchers explore a component of Principal Component Analysis (PCA) and DEA. Firstly, reduce the number of inputs and outputs by running PCA, then adapt the extracted inputs and outputs into the DEA model. For example, Faed et al. (2016) and Deng et al. (2020) adjusted the indicators with the PCA approach before they commenced the DEA analysis.

DEA-CCR and DEA-BCC measure the relative efficiency of the sampled DMUs. However, the factors that affect efficiency cannot be identified. A two-stage DEA and Tobit regression model was developed to determine the influent factors and their effects on efficiency. Sağlam (2018) researched 95 wind farms using the DEA + Tobit approach and indicated the positive and negative wind farm operational efficiency indicators.

Considering that different ports' environment variables and random errors may influence port efficiency, a three-stage DEA model is adopted to address this issue. Deng et al. (2020) investigated the carbon emission constraints level of 30 provinces/municipalities in China in 2016 by employing a three-stage approach, which consisted of PCA for indicator confirmation, a Slacks-Based Measure-Data

Envelopment Analysis (SBM-DEA) for performance assessment, and Tobit regression for identifying the driving factors.

The traditional DEA-CCR and DEA-BCC model generally reflect the efficiency of a certain time with cross-sectional data collected. To observe how the efficiency changes over time, panel data is selected. Several approaches have been employed to achieve the dynamic efficiency analysis, such as DEA + Malmquist Productive Index (MPI) and DEA-Window analysis. Osundiran et al. (2020) studied the efficiency of 19 Sub-Saharan African ports over time from 2008-2015 with the application of the DEA-MPI model. Their empirical study provides further evidence of the advantage of the DEA-MPI model in identifying the performance level and the weakness in the supply chain area. Another approach for analysis of dynamic efficiency is DEA Window Analysis. DEA Window Analysis is based on the panel data of the sampled ports for a period considering one port of different times as an independent DMU, divides the data into several windows with some overlaps by setting the length of the window. The dynamic changes of the port are evaluated by comparing the window data. One of the latest applications of DEA Window Analysis is the research of 15 US container ports with data since 2000 conducted by Seth and Feng (2020). They set a window length of 4 years and identified the investment direction towards the port that would affect the trade and income.

Many other approaches developed upon DEA, such as the AHP-DEA combining quantitative and quantitative methodologies, balancing subjective and objective affections, SBM-DEA, Fuzzy Sets Theory-Based DEA, etc.

Given the model orientation, input and output-oriented DEA models are widely applied in different areas. Generally speaking, the input-oriented method minimises the inputs under a given output, while the output-oriented method maximises the output with a given input. Thus, if the input indicator is adjustable, the input-orientation approach can be employed, like the productive activities of an enterprise. Conversely, if the output indicator is adjustable, the output-orientation approach is more likely to be chosen. It is an interesting argument that both input-oriented and out-oriented approaches can be applied perfectly. From the long-term perspective (Nguyen et al., 2016), for example, the 30-year Transnet Long Term Planning Framework (TLTPF), the construction of a seaport is ongoing to meet increasing demand as globalization grows, which means that the inputs such as land, capital, labour, etc. (the selection of inputs and outputs will be discussed in Chapter Three), turn out to be more adjustable, the output like annual throughput relatively becomes stable. Hence, the input-oriented approach can be used.

On the other hand, from the short-term perspective, say three to five years, even though port expansion is continuous, it takes a certain time to get the proposal approved and then build. Until the new facilities are used, it probably is much longer than three to five years. In this case, the inputs generally are considered of few changes. Moreover, before investing more, it is important to know whether the current resources are fully used. Thus, the output-oriented approach is a better choice. The literature review undertaken by the author also proved that most seaport efficiency studies are output-oriented. In this study, the DEA model is output-oriented as well.

2.4 Efficiency Evaluation Models

2.4.1 DEA-CCR Model

Because the DEA model is a well-developed model, the framework and theory of DEA are illustrated in detail and are proved to be reliable. Based on a substantial literature review, the author uses the fundamental equation as follows(Kalgora et al., 2019):

Consider n DMUs, when each DMU j (j = 1, …, n) uses m inputs Xj = (X1j, X2j, ..., Xmj) > 0 for producing s outputs Yj = (Y1j, Y2j, ..., Ysj) > 0.

$$E_j = \frac{u^T y_i}{v^T x_i} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{k=1}^{m} v_i x_{ij}}, j = 1,2, \ldots, n \qquad (1)$$

$$u_{r,\dots,}u_s > 0 \; and \; v_i, \dots, v_m \geq 0; r = 1, \dots, s; i = 1. \dots, m$$

Where:

x_{ij} = amount of input i produced by DMUj

y_{rj} = amount of output r produced by DMUj

n = the total number of DMUs

s = the total number of outputs

m= the total number of inputs

u_r = weight given to output r

v_i = weight given to input i

When evaluating the 0 th DMU, then the efficiency rate is E_0, the input x_{r0}, output y_{j0}, and translated the formulation (1) into a linear program, getting the Equation (2):

$$max \sum_{r=1}^{s} u_r y_{ro}$$

$$s.t. \sum_{i=1}^{m} v_i \, x_{i0} = 1 \qquad (2)$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, j = 1, \dots, n,$$

$$u_{r,\dots,}u_s \geq \varepsilon \; and \; v_i, \dots, v_m \geq \varepsilon; r = 1, \dots, s; i = 1. \dots, m$$

Where ε is defined as an infinitesimal constant, to express the input-oriented CCR approach, Equation (3) can be transformed as follows:

$$min \, \theta$$

$$s.t. \sum_{j=1}^{n} x_{ij}\lambda_j - \theta x_{i0} \leq 0, i = 1, \dots, m \qquad (3)$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - y_{r0} \geq 0, r = 1, \dots, s$$

$$\lambda \geq 0, j = 1, \dots, n$$

2.4.2 DEA-BCC Model

As discussed, the differences between CCR and BCC models can be summarized in the assumption and the outcome. For a DEA-BCC model, the assumption is variable returns to scale, while the assumption of a DEA-CCR model is constant returns to scale(Lu et al., 2015). The CCR model identifies overall technical efficiency (pure technical efficiency and scale efficiencies), while the BCC, pure technical efficiency only (da Cruz & de Matos Ferreira, 2016).

The DEA-BCC Model adds below (Equation 4) to the CCR model:

$$\sum_{j=1}^{n} \lambda_j \qquad (4)$$

2.4.3 DEA Windows

Charnes et al. (1985) proposed the so-called ‘window analysis’ technique to capture the efficiency variations over time. Window analysis assesses the performance of a DMU over time by treating it as a different entity in each time section, thus allowing tracking of the performance of a unit/process. Based on the panel data, the port at different times is regarded as an independent DMU, assuming the length of the window is w, the period is t, then the data of a seaport will be grouped into t-w+1 windows, which will be used as DMUs for analysing the dynamic efficiency of this seaport. Using the Window Analysis, the trend of efficiency of the same port in different periods is compared, and the seaport efficiency of different seaports within the same window is evaluated. It reflects the continuity of time and the cause of the efficiency changes.

2.4.4 Malmquist Productive Index (MPI)

As discussed in previous DEA studies, Malmquist Productive Index (MPI) is frequently used with DEA to assess port efficiency over time (Duong et al., 2019; Estache et al., 2004; Osundiran et al., 2020; Tovar & Wall, 2019). Technology change (TC) and technical efficiency change (TEC) make up the MPI (Duong et al., 2019). The equation (Equation 5) below shows how MPI would be calculated.

$$MPI = \left[\frac{d^t(x^{t+1}, y^{t+1})}{d^t(x^t, y^t)} X \frac{d^{t+1}(x^{t+1}, y^{t+1})}{d^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}}$$

$$= \frac{d^t(x^{t+1}, y^{t+1})}{d^t(x^t, y^t)} X \left[\frac{d^t(x^{t+!}, y^{t+!})}{d^{t+1}(x^{t+1}, y^{t+1})} X \frac{d^t(x^t, y^t)}{d^{t+1}(x^t, y^t)}\right] \frac{1}{2} \quad (5)$$

$$= TC \; X \; TEC$$

Where:

x^t and x^{t+1} = input factors of DUM at time t and t+1

y^t and y^{t+1} = corresponding output factors at time t and t+1

d^t and d^{t+1} =distance function concerning production technology at t and t+1

MPI measures the productivity change between period t and t+1. If MPI<1, productivity declined; if MPI>1, productivity increased.

TEC represents the change in technical efficiency between period t and t+1. If TEC<1, technical efficiency change declined; if TEC>1, technical efficiency improved.

TC represents the change in technology frontier between period t and t+1. If TC>1, technology progressed; if TC<1, technology regressed.

2.4.5 Tobit Regression

As discussed in the DEA studies section, Tobit regression has been conducted in several previous studies to identify the influencing factors as a supplement to DEA efficiency approaches (Deng et al., 2020; Nikolaou & Dimitriou, 2021; Sağlam, 2018; Wang et al., 2020). Tobit regression indicates the effects of independent variables on the dependent variable. The Tobit model can be shown as the equation (Equation 6) below:

$$Y_i^* = \alpha_0 + \alpha_i X_i + \varepsilon_i$$

$$Y_i = \begin{cases} Y_i^*, \; Y_i^* > 0 \\ 0, \; Y_i^* \leq 0 \end{cases} \quad (6)$$

Where:

Y_i^*= the latent variable

Y_i= the actually explained variable

X_i= explanatory variable

α_0= constant

α_i= random variable reflecting the relationship between Y_i and X_i

ε_i= random error term

2.5 Factors Affecting Seaports Efficiency

Previous studies have widely analysed the factors affecting seaport efficiency, which might be divided into internal and external aspects. In view of the internal factors, the factors such as terminal size, terminal techniques, labour, operational time, berth occupancy, handling speeds of cranes, terminal management and so on can be considered. In the views of the external factors, political influences, national policies, the development of the hinterland, GDP, population and so on can be considered (Almawsheki & Shah, 2015; Liu et al., 2021). Nyandu (2020) believed that congestion, labour practices, environmental issues, low property costs, quality of life and market access also includes internal and external factors.

2.5.1 Internal Factors

The internal factors affecting seaport efficiency are complex. Many researchers analysed these factors in different contexts. Almawsheki and Shah (2015) undertook an efficient evaluation of 19 container terminals in the Middle Eastern region and found that most medium-sized terminals are more efficient than the larger ones. By investigating six of China's ports of Pilot Free Trade Zones (PFTZ), Liu et al. (2021) discerned ownership structure's impacts vary with the types of port efficiency while human capital and the operation scale of ports have significantly positive effects. Ding et al. (2015) evaluated the efficiency change in 21 coastal small and medium sized-port container terminals in China and indicated that factors such as workforce structure, shareholding, registered capital, and shipping routes positively affect the efficiency, while the factor such as the number of terminal operators negatively affects the efficiency.

2.5.2 External Factors

Despite the abovementioned factors, researchers concluded that factors such as political environment, national policies, economic development, and so on strongly impact seaport efficiency.

The container terminal efficiency study conducted by Almawsheki and Shah (2015) of 12 countries in the Middle Eastern region also revealed that the Arab Spring revolutions in some countries in the region affected the economy, investments, security, shipping lines and internal policy, and consequently the efficiency of container terminals in the region. Based on their PFTZ ports study, Liu et al. (2021) indicated that establishing PFTZ accelerates port efficiency improvement, and the development of the hinterland has a positive effect on improving port efficiency while the population has a negative effect. With the study of the handling efficiency of high-risk cargo (HRC) at Namibian seaports, Saruchera (2020) found that internal and external factors affect improved HRC handling efficiency. Regarding external factors, the knowledge of relevant procedures, appropriate training and development and human elements are crucial.

2.6 Challenges in Improving Seaport Efficiency

2.6.1 Port Congestion

Port congestion is considered one of the main challenges in enhancing seaport efficiency in many previous studies (Bray et al., 2015; Carine, 2015; Nyandu, 2020; Nze & Onyemechi, 2018). Nze and Onyemechi (2018) explained that port congestion is related to delays, cargo dwell time, operational dwell time, storage dwells time and transactional dwell time; they further reveal the port capacity, regulation, efficiency, cargo throughput and berth occupancy rate are significantly affecting the port congestion.

Based on an empirical study of Lagos seaports, Ojadi and Walters (2015) concluded that the following six factors are the main challenges in improving efficiency, which are corruption, trade fraud, inadequate transport, infrastructure, lack of supply chain culture and deficiencies of the government agencies and private organisations at the port.

2.6.2 Technical Developments

The extensive use of containerized cargo has caused technological changes in the maritime industry and port modernization (Pérez et al., 2016). To observe how port modernization impacts port efficiency, Pérez et al. (2016) analysed the evolution of the efficiency of the main container terminals in Latin America and the Caribbean and indicated that the ports with more terminals are more efficient, and transhipment ports are less efficient. Trujillo et al. (2013) argued that port reform is crucial to modernising Africa's ports.

2.6.3 External Competition

Cullinane et al. (2006) concluded the challenges regarding the port's operation and external competition. The number of agents involved, the complex process between different service objects, and the increasingly competitive commercial environment lead to challenges. Inoue (2018) discussed port challenges by investigating Kobe-Osaka port and found that increasing competition with ports of East Asian counties put much pressure on port efficiency.

2.6.4 Lack of Sustainability Competences

Ashrafi et al. (2019) analysed the strategy and practice of sustainable port development by studying the sustainable development of port enterprises in Canada and the United States. They concluded that most ports believe sustainable development is important and have adopted many sustainable development strategies and practices. Still, most ports' strategic decision-making processes and operations do not fully consider this point. Their study also showed the key challenges/barriers include costs associated with sustainability initiatives, lack of sustainability competencies within organizations, limited client interest in more sustainability services, and difficulties in implementing sustainability practices. Lim et al. (2019) conducted a comprehensive and critical assessment of the sustainability of port operations by employing a systematic literature review. Their research concluded that the successful performance measurement of sustainable port development depends on establishing accurate indicators as the basis for measurement. At the same time, how to measure sustainability and achieve consistency among ports is a major challenge in improving port operations and prioritizing activities.

2.6.5 Loss of Revenue

Adabere et al. (2021) found one of the major challenges against Tema Ports' operation is the loss of revenue. Their study showed that this challenge negatively impacted the port operation efficiency regarding diversifying some shipping lines.

2.7 Theoretical and Conceptual Framework

2.7.1 Theoretical Framework

Four key types of efficiency, namely, Technical Efficiency (TE), Scale Efficiency (SE), Pure Technical Efficiency (PTE) and Return to Scale (RS), are introduced into Seaport Efficiency Assessment (SEA) theory aiming to understand the relationships existing in SEA. The study of SEA is complex and multi-dimensioned; no single theory can comprehensively reflect seaport efficiency. In unpacking TE, the study was guided by the relationship between resources (capital and labour) and outcome (Palmer & Torgerson, 1999). It measures how the given recourses have been fully used. In terms of SE, the study was guided by da Cruz and de Matos Ferreira (2016), who note that SE represents the relationship between the added value of the input and the output. It measures the impact of changing seaport production scale on seaport output during production and operation. Hence, the waste of unreasonable or unnecessary seaport expansion could be avoided. PTE refers to the seaports' ability to use resources (Carine, 2015), sometimes described as managerial skills (Barros, 2006). It reflects the relationship between seaport production technology, management level and seaport efficiency (da Cruz & de Matos Ferreira, 2016). RS refers to the relationship between the seaport efficiency and the change of inputs by indicating whether RS is increased or decreased. By integrating all these theories into the study, this study assessed seaport efficiency from a more comprehensive perspective.

2.7.2 Conceptual Framework and Hypotheses

Based on an integration of the above theories, the influencing factors of seaport efficiency can be analysed from the following seven points: education level, registered capital, shipping routes, designed capacity, throughput, the economy of the port city and population of the port city. Figure 2 below illustrates the proposed conceptual framework of this study from which hypothesis seven hypotheses were drawn.

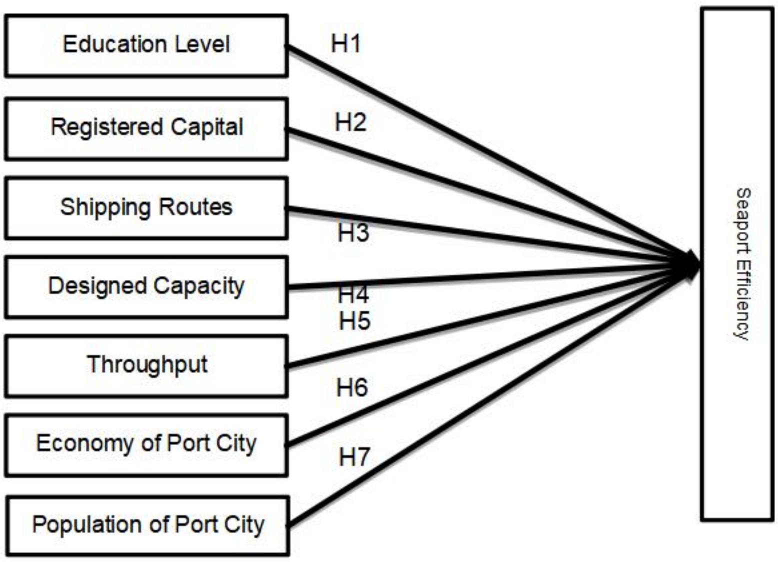

Figure 2: Conceptual framework for the study

Figure 2 illustrates the above hypotheses of this study. The following specific hypotheses are proposed:

H1: Education level has a positive effect on Seaport Efficiency.

H2: Registered Capital has a positive effect on Seaport Efficiency.

H3: Shipping routes have a positive effect on Seaport Efficiency.

H4: Designed capacity has a positive effect on Seaport Efficiency.

H5: Throughput has a positive effect on Seaport Efficiency.

H6: The economy of the port city has a positive effect on Seaport Efficiency.

H7: The population of the port city has of positive effect on Seaport Efficiency.

2.8 The overall framework of the study

This study followed a three-stage approach to assess seaport efficiency and answer the five research questions. Firstly, the relative efficiency among the selected South African seaports was observed based on the output-oriented DEA-CCR/BCC approach. Secondly, MPI indicated the efficiency changes from 2016 to 2021. Thirdly, Tobit regression was performed to identify the factors that influence the seaport efficiency of South Africa. According to the literature review in chapter two, the main influencing factors can be summarized as manpower, register capital, shipping routes, operation scale, hinterland economy, and hinterland population, based on an online survey. Figure 3 shows the framework of this study.

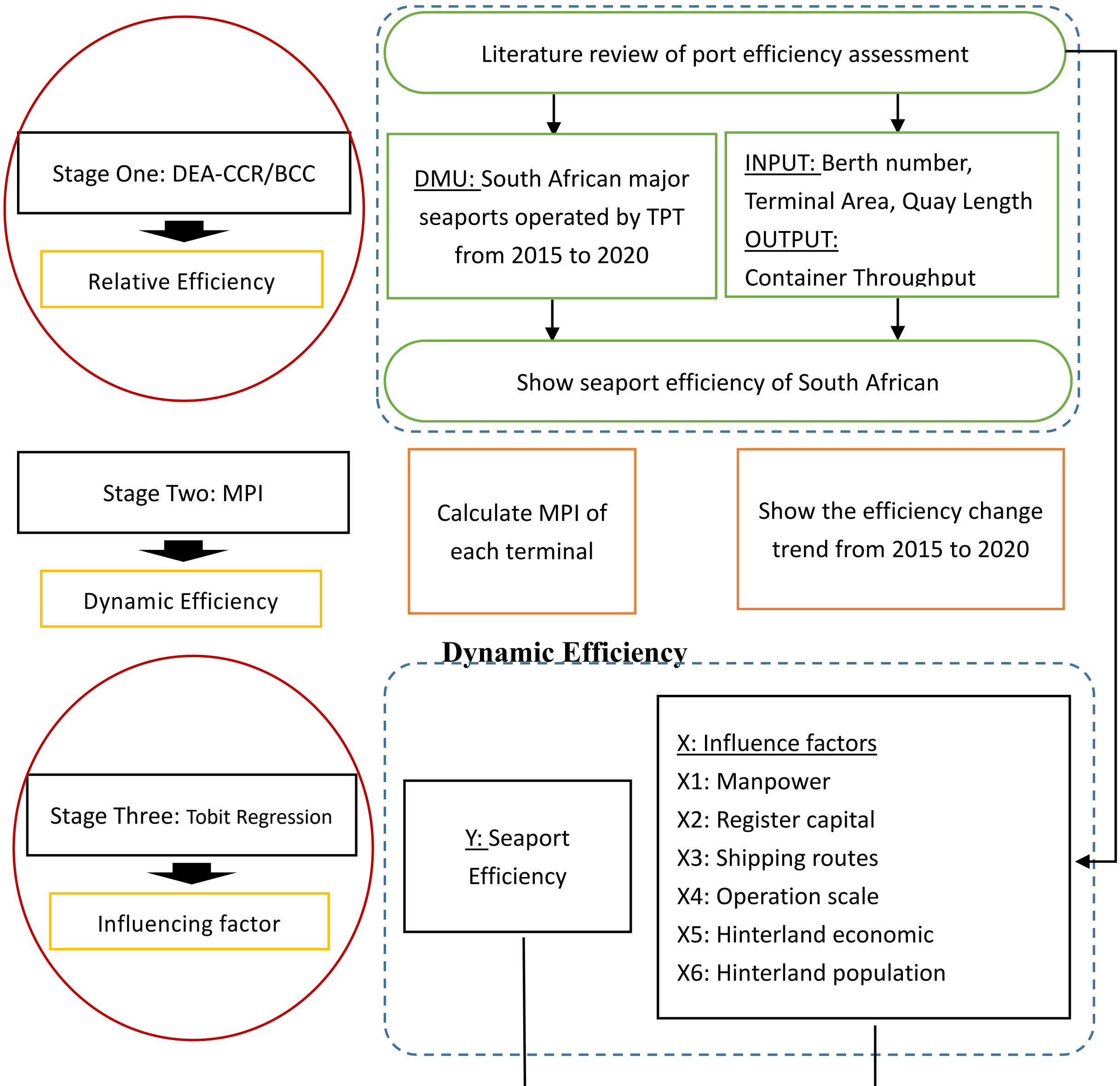

Figure 3: Overall Framework of the study

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discussed the methodologies used in this study and illustrated the reason for choosing these approaches with their advantages and the applicability and limitations to this study.

3.2 Research Purpose

Research means a systematic investigation; it contributes to generalizing knowledge (Health & Services, 2009). The word "systematic investigation" can explain how research is conducted. The process, in general, can be described as forming the hypothesis, designing the research methods, collecting and analysing data, and concluding research results. Thus, knowing why and what to do before starting a study, in another word, knowing the goal of a study, is the foundation of the whole study. And that is the so-called research purpose. Generally, there are three main research purposes: exploratory, descriptive and explanatory (DiscoverPhDs, 2020). The main purpose of this study was to assess the efficiency of South African Seaports; it is a combination of the three types of research purpose as it is the first one to study the seaport efficiency within the context of South Africa based on DEA models, it described the efficiency with several indicators (e.g. throughput), and it identified the relationships between inputs and outputs of the DEA models.

3.3 Research Philosophy

The research philosophy answers the question of 'Why research?', which then impacts 'What to research?' and 'How to research' (Holden & Lynch, 2004). Research philosophy is the belief that data about a phenomenon should be collected, analysed, and used. It enables researchers to examine the underlying assumptions about reality. There are two main philosophical assumptions: ontological assumptions (reality) and epistemological assumptions (knowledge) (Bell et al., 2018), which are linked to ontology and epistemology, respectively. According to the opinions of Bell, Bryman and Harley, the former refers to theories about the nature of reality or our understanding of what reality is. And the latter refers to the theories about what is known or what can be known or our understanding of how we can know reality.

As Kamil (2011) noted, there are two common dimensions to distinguish research philosophies objectivism and subjectivism. In the objective views of ontology, social and natural reality is independent of human cognition, while in the subjectivist view of ontology, reality is an outcome based on our experiences. On the other hand, in the objectivist view of epistemology, he mentioned that many researchers believe knowledge is independent of human activities. However, in the subjectivist view of epistemology, he stated that researchers believe that there is no ultimate true knowledge, the real or objective knowledge we believe is the socially constructed versions of reality based on language games, discourses, interests, traditions, or world views (Kamil, 2011). Meanwhile, Kamil (2011) also indicated that the descriptions of objectivism and subjectivism varied in different literature. Objectivism is also called positivism, sometimes called phenomenology or interpretivism. This study relies on objectivism in terms of ontological paradigm and positivism in epistemology. The study aimed to find out the South African seaport efficiency and analyse the factor that affects the seaport efficiency and challenges that South African seaports face objectively.

3.4 Research Approach

Kovács and Spens (2005) and Mitchell (2018a) discussed the different applications of three research approaches in logistics: deductive, inductive and abductive. The deductive approaches are deductive reasoning from the more general to more specific based on-premises or hypothesis, while the inductive approaches are inductive reasoning starting from specific observations to broader generalizations and theories based on particular observations. The abductive approaches combine deductive and inductive approaches by rendering a surprising observation or unusual phenomenon in reality and generalising from the interactions between the specific and the general

(Gregory & Muntermann, 2011; Mitchell, 2018b).

Three typically used approaches are quantitative (deductive), qualitative (inductive) (Soiferman, 2010), and mixed method approaches (McCusker & Gunaydin, 2015; Mitchell, 2018b). Qualitative approaches generally aim to answer questions about a phenomenon's ‘what’, ‘how’ or ‘why’ while quantitative approaches aim to answer questions like ‘how many’ or ‘how much’ (McCusker & Gunaydin, 2015). To increase the breadth and depth of research, a combination of quantitative and qualitative approaches is employed (Wisdom et al., 2012). This study tended to adapt the mixed method approach from the perspective of deductive reasoning. Firstly, the qualitative approach was used by conducting substantial literature reviews on seaport efficiency areas.

Consequently, the specific model DEA was selected to use in the study. Meanwhile, by combining the literature and the research context, the indicators of inputs and outputs of the selected model were identified. The adoption of DEA aimed to achieve research objectives (i) and (ii). Secondly, a quantitative approach was conducted. At this stage, primary data were collected to achieve the research objectives. The efficiency score of each sampled seaport and other outcomes were achieved, which led to achieving the research objective (v).

3.5 Research Design

The research design can be described as the bridge between research questions and the implementation of research (Durrheim, 2006). The research design is the blueprint of all research processes (Dulock, 1993). This study aimed to assess the efficiency of South African seaports as well as influencing factors and challenges. Thus, several research questions associated with this objective were put forward. To answer these questions, several processes commenced, starting with an abundant literature review of key concepts and related studies, the author established the conceptual and theoretical framework. By interpreting the outcomes, the research questions were answered. In terms of time frame, cross-sectional and longitudinal data (panel data) were collected. Generally, there were three steps to answer all the research questions. To answer the research questions (i) and (ii), this study focused on DEA approaches based on secondary data, including cross-sectional and panel data collected from the Transnet, World Bank and other open published platforms when necessary. To answer research questions (iii) and (iv), the primary data were collected by an online survey among port employees with Wits Qualtrics and Statistical Package for the Social Sciences version 28 (SPSS v.28) was used to run related analysis, and Eviews Student Version Lite v12 was used to run the Tobit regression. The outcomes from the first two steps indicated the answers to the research question (v). Table 3 summarises the justification for using multiple data collection methods for this study.

Table 3: Justification for using multiple data collection methods for this study

Purpose/sub-problems	Data source
To appreciate the research problem and its background	Secondary data - e.g. Transnet reports and World Bank reports
To develop the methodology of this study	Literature review
To assess the seaport efficiency of South Africa	Secondary data - e.g. Transnet reports and World Bank reports
To identify the influencing factors of South African seaport efficiency	Primary data - Online survey among South African seaport employees
To identify the challenges in improving South African seaport efficiency	Primary data - Online survey among South African seaport employees

3.6 Research population

The targeted research population of this study specifically refers to the online survey, which is the employees in operation sections of the four commercial seaports with container terminals in South Africa, namely Port of Durban, Port of Ngqura, Port of Elizabeth, and Port of Cape Town. According to the Transnet media presentation of 2020, the total number of employees is 56,414, and the population of targeted employees is roughly 3700 (Transnet, 2020b).

3.7 Sample and Sampling Technique

Out of the 3700 targeted employees, the study will sample 300 respondents, guided by

Adam (2020), whose table (Appendix 1) shows that when the population is 3000, the sample size between 249 and 341 was considered sufficient. Official permission will be obtained to achieve the expected sample size.

There are two main types of sampling techniques: probability or random sampling and non-probability or non-random sampling (Taherdoost, 2016). This study adopted simple random sampling so that all the container terminal employees had an equal chance to be included in this study.

3.8 Data sources and instruments: Questionnaire

The questionnaire (Appendix 2) consisted of five sections, table 4 shows the measurement scales and the sources:

1) Survey instruction: In this section, the survey background was introduced. Participants acknowledged that their participation in the study was voluntary and was aware that they may choose to terminate their participation at any time and for any reason before they agreed to start the survey.
2) Demographic data: In this section, six questions were asked to collect information on participants' gender, age, education level, working age and working area, which aimed to obtain the information for manpower structure analysis.
3) Influencing factors of seaport efficiency: In this section, participants were asked eight Likert scale questions to identify the factors of seaport efficiency. These factors were drawn from various literature sources. Both internal and external factors have been widely analysed in previous studies. In the views of internal factors, this questionnaire mainly focuses on the factors such as manpower (Ding et al., 2015; Nyandu, 2020), register capital (Almawsheki & Shah, 2015), shipping routes (Liu et al., 2021) and operation scale (Liu et al., 2021). In the views of the external factors, the view of influencing of hinterland economy (Almawsheki & Shah, 2015; Liu et al., 2021) and hinterland population (Liu et al., 2021) were collected.

4) Challenges: In this section, four questions around port congestion (Bray et al., 2015; Carine, 2015; Nyandu, 2020; Nze & Onyemechi, 2018), technical developments (Pérez et al., 2016; Trujillo et al., 2013) and operational procedures (Cullinane et al., 2006) were asked to obtain the views of the participants regarding the challenges in improving the South African seaport efficiency.
5) Suggestions: This section asked one open question regarding the respondents' suggestions to improve the South African seaport efficiency.

Table 4: Instrument measure scales and sources

Components	Measure Scale	Source
Influencing Factors	Manpower	Ding et al. (2015); Nyandu (2020)
	Shipping Routes	Liu et al. (2021)
	Operation Scale	Liu et al. (2021)
	Hinterland Economy	Almawsheki and Shah (2015); Liu et al. (2021)
	Hinterland Population	Liu et al. (2021)
Challenges	Port Congestion	Bray et al. (2015); Carine (2015); Nyandu (2020); Nze and Onyemechi (2018)
	Technical Developments	Pérez et al. (2016); Trujillo et al. (2013)
	Operational Procedures	Cullinane et al. (2006)

3.9 Inputs and Outputs Determination

Since this study was based on the application of DEA, determining inputs and outputs is crucial to achieving reasonable and accurate analysis (Afsharian et al., 2016). In terms of seaport efficiency evaluation, abundant studies have been conducted utilizing DEA and related approaches. The inputs and outputs in this study were determined based on the previous literature and the data availability of the actual context of South African seaports. Table 5 shows the inputs and outputs statistics of the DEA application for port efficiency assessment. This study focused on the most commonly used indicators, which were reasonable. Thus, the validity of inputs and outputs was secured.

Table 5: Taxonomy of Application of DEA in the Ports Industry

Author/year	Methods	Period	DMU	Port No.	Input	Output
Zarbi et al. (2019)	DEA windows	2012-2018	Iranian Ports	5	Length of quay wall Number of quay wall Size of yard area	Container Throughput
Osundiran et al. (2020)	DEA Malmquist	2008-2015	Sub-Saharan African Ports	19	Berth Number Crane Number Tugs Number Quay Length	Container Throughput
van Dyck (2015)	DEA windows	2006-2012	West Africa Ports	6	Quay Length Quayside Cranes Number Yard Gantry Cranes Number Reach Stackers Number	Container Throughput
Tetteh et al. (2016)	DEA	2008-2013	Chinese ports, West Africa Ports	6	Quay Length Crane Number Berth Number	Ship Calls Throughputs
Tongzon (2001)	DEA CCR	1996	Australian and other international container ports	16	Crane Number Berth Number Tug Number Terminal Area Delay Time Labour	Total number of containers loaded and unloaded ship working rate
Wiegmans and Witte (2017)	SFA DEA	2016	European inland waterway terminals	44	Working hours Terminal area Stacking Yard Quay Length Draught Cranes Number Reach Stackers Number Handling Capacity	Handling Capacity Throughput
Lu et al. (2015)	DEA-CCR DEA-BCC DEA-Super-Efficiency	2009	World's Leading Container Seaports	20	Yard Area Per Berth Quay Crane Number Yard Crane Yard Tractor Per Berth Berth Length	Throughput
Le and Nguyen (2020)	Double-bootstrap DEA Univariate and Multivariate analyses	2015-2016	Vietnamese seaports	41	Terminal Area Warehouse Area Equipment Number Berth Length	Throughput
Okeudo (2013)	DEA	2001-2010	Ports of Onne and Rivers	2	Total Ships Traffic Berth Occupancy Turn Around Time Personnel Strength	Cargo Throughput
Kalgora et al. (2019)	DEA-CCR DEA-BCC Windows I-C	2005-2016	Commercial ports in West Africa	5	Quay Length Terminal Area Quayside Cranes Yard Gantry Cranes Reach Stackers Draught	Container Throughput
Bergantino et al. (2013)	DEA-BCC SFA Three stages	1995–2009	Ports across countries	30	Dimension Of Quay Terminal Number Handling Area Cargo Handling Equipment (Cranes, Lifters, Link-Belt)	Throughput (total tonnes of cargo handled and the total number of TEUs)

3.10 Data Collection Procedures

Data collection is a key step in answering the research questions. Data collection methods can be divided into two categories: secondary and primary methods of data collection (Hox & Boeije, 2005). From the perspective of secondary data collection, according to the literature review, the DEA approaches in terms of seaport efficiency assessment, secondary data is widely selected. Islam (2020) described that secondary data is published in books, newspapers, magazines, journals, and online portals. Therefore, secondary data sources are abundant, and employing second data under certain criteria in the study improves research validity and reliability. The use criteria to be considered as the date of publication, author credentials, source reliability, quality of discussions, depth of analyses etc., add value to the validity and reliability (Islam, 2020). In this study, another part of secondary data collection focused on literature review, drawing the common challenges and influencing factors based on abundant research with the secondary research approach (Largan & Morris, 2019). From the perspective of primary data collection, the data was collected through a web survey (Qualtrics). Firstly, the participants' emails were obtained via the HR managers of the selected seaports. Secondly, the survey link was sent to each participant's email. The study's validity was ensured by relying on trustable secondary and primary data from experienced port operators. Cronbach's Alpha was used to test reliability. Table 6 shows the data collected in this study and the collection methods.

Table 6: Data to collect and collection method

Data to Collect	Collection Method	Data to Collect	Collection Method
DEA		**Influencing Factors**	
Berth number	Secondary Data	**Manpower**	Primary Data/ Secondary Data
Terminal Area	Secondary Data	**Register capital**	Primary Data /Secondary Data
Quay Length	Secondary Data	**Shipping routes**	Primary Data /Secondary Data
Container Throughput	Secondary Data	**Operation scale**	Primary Data /Secondary Data
		Hinterland economic	Primary Data /Secondary Data
		Hinterland population	Primary Data /Secondary Data

3.11 Data Analysis

The data analysis of this study was made up of the DEA analysis and survey analysis. In the aspect of DEA and MPI analysis, both the findings based on cross-sectional data and longitudinal data (panel data) were analysed. The technical efficiency, scale efficiency, pure technical efficiency and returns to scale of each DMU were discussed from a different point of view, which aimed to answer the research question (i) and (ii), respectively. In the survey analysis, SPSS 28.0 were used to run the analysis. Cronbach's Alpha was used to test reliability. From 0 to 1, if the value of Cronbach's alpha is above 0.5, it refers to reliability. The sample characteristics were described using descriptive statistics like frequencies, mean, median and standard deviations. If a standard deviation is lower, the respondent's score is closer to the mean, showing the answers are more consistent among respondents. To check the distribution of the data, normality and outlier tests were conducted. The correlation and covariance matrix were conducted to check how the variables are correlated with each other. If the correlation coefficient value is above 0.5, it indicates a moderate correlation. Tobit regression analysis was conducted by Eviews to verify the influencing factors.

3.12 Research Ethics

İbrahimoğlu et al. (2014) indicated ethics deal with human behaviour, a framework that covers philosophy, moral philosophy, moral problems, and moral judgments. Chanzanagh and Nejat (2010) called work ethic culture because work beliefs and values should follow the general regulations of culture and society. Hayati and Caniago (2012) believed that work ethics reflect human attitudes towards various aspects of work, monetary and non-monetary rewards, and the desire for career promotion. From the research perspective, Smith (2003) defined research ethics as the system of moral principles that guide research procedure.

This study followed the rules in the Protection of Personal Information Act (POPIA) of South Africa in terms of data protection. Ethical clearance was obtained from Wits Research Ethics Committee (WREC). This study followed all the ethical research standards under the guidance of Wits University and was conducted after approval by the ethical board of Wits University. The secondary data was gathered from open published resources such as the authority websites and annual reports. All the data collected was used in this study and will not be shared without express authorization from Transnet. Prior written consent was sought before obtaining primary data, and participants' identities were maintained by anonymising the responses. All the participants participated in the study voluntarily with no risks, financial cost and benefits and the contacts of WREC, researcher and supervisor. The participants were advised to withdraw at any time for any reason and without any prejudice. The ownership of the original data was acknowledged, and the purpose of collecting the secondary data was not to directly answer the research questions but to conduct appropriate analysis. All the data was kept electronically and securely.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSION OF FINDINGS

4.1 Introduction

This chapter consists of three sectors; the first is data analysis based on the DEA model aiming to answer research questions i and ii. The second sector is the survey analysis, which was targeted to answer research questions iii and iv. Despite the primary data analysis of the influencing factors, Tobit Regression based on secondary data was adapted to get influencing factors analysed from another perspective. The last sector of this chapter is the discussion of findings.

4.2 DEA Analysis

In this part, basic DEA analysis was run to rank the seaport efficiency and the MPI analysis was run to show the dynamic changes in the seaport efficiency during the investigated years.

4.2.1 Assess and rank the seaport efficiency

Firstly, based on the collected secondary data and DEA model, the berth number, terminal area, and quay length were taken as input variables, and container throughput was taken as output variables.

As discussed in the literature review, technical efficiency is also stated as overall technical efficiency (da Cruz & de Matos Ferreira, 2016; Estache et al., 2004; Pjevčević et al., 2012). Therefore, the following analysis will be conducted from the four dimensions of Overall Technical Efficiency (OE), Pure Technical Efficiency (PTE), Scale Efficiency (SE) and Return to Scale (RS).

Table 7 shows the DEA summary of the Port of Durban, Port Ngqura, Port of Elizabeth, and Port of Cape Town from 2016 to 2021. In terms of OE, only Port Elizabeth in 2019 reached DEA optimization, and both scale efficiency and technology efficiency were reached simultaneously, indicating that the resources of

Port Elizabeth were fully utilized this year and the resource allocation reached the optimum. The other three ports and Port Elizabeth in the other four years did not reach DEA efficiency, among which the overall efficiency of Durban port and Port Elizabeth was relatively low, and the overall efficiency of Port Cape Town was generally higher than that of the other four ports, which was reflected in its pure technical efficiency and scale efficiency.

Table 7: DEA summary of four seaports in 2016,2018,2019,2020,2021

Efficiency Analysis						
DMU	**Pure Technical Efficiency (PTE)**	**Scale Efficiency (SE)**	**Overall Efficiency (OE)**	**Coefficient of Return to Scale (CRS)**	**Return to Scale (RS)**	**Efficiency**
Port of Durban-2016	0.408	0.353	0.144	0.353	↑	Non-DEA effective
Port of Durban-2018	0.408	0.529	0.216	0.529	↑	Non-DEA effective
Port of Durban-2019	0.408	0.471	0.192	0.471	↑	Non-DEA effective
Port of Durban-2020	0.408	0.294	0.120	0.294	↑	Non-DEA effective
Port of Durban-2021	0.408	0.412	0.168	0.412	↑	Non-DEA effective
Port of Ngqura-2016	0.75	0.647	0.485	0.647	↑	Non-DEA effective
Port of Ngqura-2018	0.75	0.882	0.662	0.882	↑	Non-DEA effective
Port of Ngqura-2019	0.75	0.765	0.574	0.765	↑	Non-DEA effective
Port of Ngqura-2020	0.75	0.588	0.441	0.588	↑	Non-DEA effective
Port of Ngqura-2021	0.75	0.706	0.529	0.706	↑	Non-DEA effective
Port of Elizabeth-2016	1	0.176	0.176	0.176	↑	Non-DEA effective
Port of Elizabeth-2018	1	0.235	0.235	0.235	↑	Non-DEA effective
Port of Elizabeth-2019	1	1	1	1	Constant	Strong DEA effective
Port of Elizabeth-2020	1	0.059	0.059	0.059	↑	Non-DEA effective
Port of Elizabeth-2021	1	0.118	0.118	0.118	↑	Non-DEA effective
Port of Cape Town-2016	1	0.945	0.945	1.176	↓	Non-DEA effective
Port of Cape Town-2018	0.935	0.961	0.898	1.118	↓	Non-DEA effective
Port of Cape Town-2019	0.869	0.979	0.851	1.059	↓	Non-DEA effective
Port of Cape Town-2020	0.804	0.824	0.662	0.824	↑	Non-DEA effective
Port of Cape Town-2021	0.804	0.941	0.756	0.941	↑	Non-DEA effective

In terms of pure technical efficiency, in the past five years, the pure technical efficiency of Port Elizabeth has reached the optimum, and the main factor affecting its port efficiency is scale efficiency, which can be expanded to improve its port efficiency. The Port of Cape Town, the Port of Ngqura, and the Port of Durban, in turn, still have room to improve technical efficiency.

Regarding scale efficiency, only Port Elizabeth achieved optimal allocation in 2019. Among the different seaports in the remaining years, the scale efficiency of Cape Town and Port of Ngqura is relatively high, while that of Port Elizabeth and Durban is relatively low. The scale efficiencies of all four seaports showed a trend of rising first, then falling, and then rising again (Figure 4). The nodes of decline were mainly concentrated in 2019 and 2020, indicating that the change of scale efficiency was greatly affected by the COVID-19 pandemic.

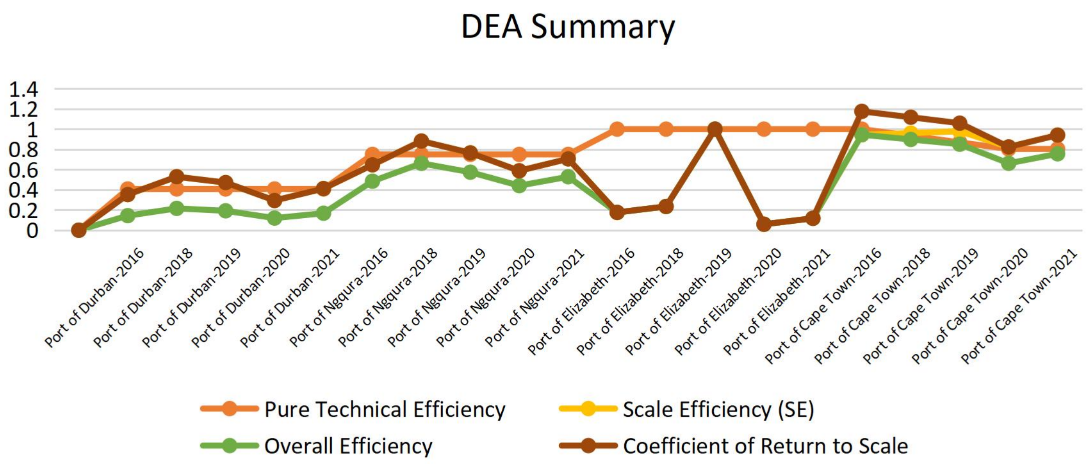

Figure 4: DEA Summary

From the scale efficiency coefficient perspective, the scale return coefficient of Port Elizabeth in 2019 equals 1, and the return to scale remains unchanged, reaching the optimal state. In terms of Cape Town Port from 2016 to 2019, the coefficient of return to scale is less than 1, indicating that the return to scale is increasing, which means that the current scale is too small; it should be expanded to increase efficiency. The coefficients of returns to scale of the remaining research objects in their respective years are greater than 1, and the returns to scale are diminishing, indicating that scale reduction can contribute to increasing efficiency.

Table 8 shows the slack variable S-, meaning "how much input should be reduced to achieve the target efficiency" (Chang et al., 2018). Input Redundancy Rate refers to the ratio of redundant input to current input; the higher the value, the more redundancy. Port Elizabeth does not need to reduce the input of Berth Number, Terminal Area, and Quay Length to achieve the optimal allocation of resources. The Port of Cape Town and the Port of Durban can achieve the desired efficiency by reducing the inputs of Berth Number and Terminal Area. The Port of Ngqura has reached the target efficiency by reducing the Terminal Area Quay Length input. Cape Town Port has the highest redundancy in the Terminal Area.

Table 8: Slack Analysis of four seaports in 2016,2018,2019,2020,2021

Input Redundancy Analysis							
	Slack Variable S- Analysis				Input Redundancy Rate		
Ports	Berth Number	Terminal Area	Quay Length	Summary	Berth Number	Terminal Area	Quay Length
Port of Durban-2016	0.092	15.566	0	15.658	0.012	0.096	0
Port of Durban-2018	0.138	23.349	0	23.487	0.017	0.144	0
Port of Durban-2019	0.123	20.755	0	20.878	0.015	0.128	0
Port of Durban-2020	0.077	12.972	0	13.048	0.010	0.080	0
Port of Durban-2021	0.108	18.160	0	18.268	0.013	0.112	0
Port of Ngqura-2016	0	21.143	32.353	53.496	0	0.29	0.025
Port of Ngqura-2018	0	28.831	44.118	72.949	0	0.395	0.034
Port of Ngqura-2019	0	24.987	38.235	63.222	0	0.343	0.029
Port of Ngqura-2020	0	19.221	29.412	48.632	0	0.264	0.023
Port of Ngqura-2021	0	23.065	35.294	58.359	0	0.316	0.027
Port of Elizabeth-2016	0	0	0	0	0	0	0
Port of Elizabeth-2018	0	0	0	0	0	0	0
Port of Elizabeth-2019	0	0	0	0	0	0	0
Port of Elizabeth-2020	0	0	0	0	0	0	0
Port of Elizabeth-2021	0	0	0	0	0	0	0
Port of Cape Town-2016	0.252	213.321	0	213.574	0.063	0.843	0
Port of Cape Town-2018	0.240	202.655	0	202.895	0.060	0.801	0
Port of Cape Town-2019	0.227	191.989	0	192.216	0.057	0.759	0
Port of Cape Town-2020	0.177	149.325	0	149.502	0.044	0.590	0
Port of Cape Town-2021	0.202	170.657	0	170.859	0.050	0.675	0

4.2.2 Analyse the changes in seaport efficiency from 2016 to 2021

Table 9: Malmquist Results (2016-2018)

Malmquist Result (2016 -> 2018)					
DMU	TEC	TC	PEC	SEC	MPI
Port of Cape Town	1	0.95	1	1	0.95
Port of Durban	1.1619	1.291	1.0815	1.0744	1.5
Port of Elizabeth	0.9778	1.3636	1	0.9778	1.3333
Port of Ngqura	1	1.3636	1	1	1.3636

Note: TEC=Technical Efficiency Change

TC=Technology Change

PEC=Pure Technical Efficiency Change

SEC=Scale Efficiency Change

Table 9 shows that the MPI of Port Cape Town presents a declining trend of 5% from 2016 to 2018. Since TEC, PEC, and SEC all equal 1, it reflects that the MPI decrease is due to the technology change. The MPI of the Port of Durban, Port of Elizabeth and Port of Ngqura is greater than 1 and shows an increasing trend, in which Durban port has a relatively large increase of 50%, caused by the joint increase of TEC, TC, PEC and SEC. The increase in technology is the main factor contributing to the increase in the MPI of Port Elizabeth and Port of Ngqura.

Table 10: Malmquist Results (2018-2019)

Malmquist Result (2018 -> 2019)					
DMU	**TEC**	**TC**	**PEC**	**SEC**	**MPI**
Port of Cape Town	0.8509	1.1133	1	0.8509	0.9474
Port of Durban	0.5807	1.5308	0.8865	0.655	0.8889
Port of Elizabeth	1.1317	3.7555	1	1.1317	4.25
Port of Ngqura	0.5735	1.5111	0.75	0.7647	0.8667

Table 10 shows that the MPI of Port of Elizabeth increased significantly during 2018-2019, mainly due to the combination of large TC growth and small SEC growth. The MPI of the other three seaports all showed a downward trend, among which the MPI decline of the Port of Cape Town was caused by the decline of SEC, while the MPI decrease of the Port of Durban and Port of Ngqura was caused by the common changes of PEC, SEC and TC, in which the decrease range of PEC and SEC is greater than the increased range of TC.

Table 11: Malmquist Results (2019-2020)

Malmquist Result (2019 -> 2020)					
DMU	**TEC**	**TC**	**PEC**	**SEC**	**MPI**
Port of Cape Town	1.1752	0.6618	1	1.1752	0.7778
Port of Durban	1.4159	0.4414	1.1169	1.2677	0.625
Port of Elizabeth	0.3314	0.1775	1	0.3314	0.0588
Port of Ngqura	1.7436	0.4412	1.3333	1.3077	0.7692

Table 11 shows that from 2019 to 2020, the MPI of all four ports is less than 1, indicating a downward trend, and the Port of Elizabeth has the largest decline of about 94%, mainly caused by the sharp decline of TC and SEC. TC of the other three seaports all decreased by different degrees, while SEC increased by different degrees, and the increasing range was smaller than the decreasing range of TC.

Table 12: Malmquist Results (2020-2021)

Malmquist Result (2020 -> 2021)					
DMU	**TEC**	**TC**	**PEC**	**SEC**	**MPI**
Port of Cape Town	1	1.1429	1	1	1.1429
Port of Durban	1.1745	1.1919	1.0256	1.1452	1.4
Port of Elizabeth	1.6667	1.2	1	1.6667	2
Port of Ngqura	1	1.2	1	1	1.2

Table 12 shows that from 2020 to 2021, the MPI of all four seaports is greater than 1, showing an increasing trend, and Port of Elizabeth has the largest increase of about 100%, mainly caused by the joint increase of TC and SEC. The MPI increase of Durban Port is caused by the joint increase of TC, PEC, and SEC. The increase in TC mainly affected the MPI increase at the Port of Cape Town and the Port of Ngqura.

4.3 Survey Analysis

Regarding the primary data collection, the sample population and size were discussed in Chapters 3.6 and 3.7. A total of 281 respondents were received, 257 of which turned out to be valid. And Cronbach's Alpha was 0.504, referring to reliability.

4.3.1 Demographic Data

Among all the responses, there were 203 males and 77 females, accounting for 72.2% and 27.4% of the total, respectively. People under the age of 40 accounted for 74% of the total. Among all the port staff who responded to the questionnaire, 70.8% have worked there for over 2 years, so they deeply understand the port operation efficiency and its influencing factors. Regarding the location where the respondents work, 37.5% were based in Durban, 18.2% at Port Elizabeth, 14.6% at Port of Ngqura, 16.4% at Cape Town and the remaining 13.2% unspecified seaports. Regarding seaport efficiency, 25% agreed that the port operation was inefficient, 18.9% of people were not very clear about the efficiency of their port, and 55.2% agreed on inefficiency. Table 13 shows the Frequency of demographic data.

Table 13: Frequency of Demographic Data

Gender		Frequency	Percent	Valid Percent
Valid	Male	203	72.2	72.5
	Female	77	27.4	27.5
	Total	280	99.6	100
Missing	System	1	0.4	
Total	281	100		
Age		**Frequency**	**Percent**	**Valid Percent**
Valid	18-30	106	37.7	40.2
	31-40	102	36.3	38.6
	41-50	44	15.7	16.7
	50+	12	4.3	4.5
	Total	264	94	100

Missing	System	17	6	
Total	281	100		

Working Period		**Frequency**	**Percent**	**Valid Percent**
Valid	1-2 years	58	20.6	21.6
	2-5 years	82	29.2	30.5
	5-8 years	44	15.7	16.4
	9-12 years	52	18.5	19.3
	13-15 years	24	8.5	8.9
	16+ years	9	3.2	3.3
	Total	269	95.7	100
Missing	System	12	4.3	
Total	281	100		

Location		**Frequency**	**Percent**	**Valid Percent**
Valid	Port of Durban	105	37.4	37.5
	Port of Port Elizabeth	51	18.1	18.2
	Port of Ngqura	41	14.6	14.6
	Port of Cape Town	46	16.4	16.4
	None of above	37	13.2	13.2
	Total	280	99.6	100
Missing	System	1	0.4	
Total	281	100		

Efficiency		**Frequency**	**Percent**	**Valid Percent**
Valid	Strongly disagree	28	10	10
	Somewhat disagree	44	15.7	15.7
	Neither agree nor disagree	53	18.9	18.9
	Somewhat agree	87	31	31.1
	Strongly agree	68	24.2	24.3
	Total	280	99.6	100
Missing	System	1	0.4	
Total	281	100		

4.3.2 Descriptive Statistics

Table 14 shows the descriptive statistics of the sample. INF_Education, INF_Capital, INF_Routes, INF_Capacity, INF_Throughput, INF_Economy and INF_Population, represent the influence factors of education, registered capital, shipping routes, designed capacity, throughput, hinterland economy and population, respectively. CHA_Congestion, CHA_Technology, CHA_Competition, CHA_Sustainability and CHA_Revenue represent the discussed challenges: port congestion, technology development, external competition, lack of sustainability competencies and loss of revenue. The values of each variable ranged from one to five, representing strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree and strongly agree, respectively.

Table 14: Descriptive Statistics

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
INF_Education	280	1	5	4.05	.832
INF_Capital	280	2	5	3.74	1.070
INF_Routes	280	1	5	3.79	1.069
INF_Capacity	280	2	5	4.21	.797
INF_Throughput	280	2	5	3.68	1.146
INF_Economy	280	1	5	4.10	.843
INF_Population	280	1	5	3.45	1.436
CHA_Congestion	280	3	5	4.82	.431
CHA_Technology	280	2	5	4.27	.765
CHA_Competition	280	2	5	4.14	.810
CHA_Sustainability	280	2	5	4.10	.819
CHA_Revenue	280	2	5	4.19	.784
Valid N (listwise)	280				

4.3.3 Influencing Factors Analysis

To answer research question iii, both primary and secondary data were used to run the analysis. Firstly, according to the feedback from the questionnaire, Table 15 shows the frequency of the answers to the questions concerning influencing factors. The percentages of the respondents that held the opinion that the education level, registered capital, shipping routes, designed capacity, throughput, and hinterland economy had positive effects on seaport efficiency were 71.4%, 60.3%, 60.3%, 78.2%, 56.4% and 71.4%, respectively, which showed strong support to the hypotheses H0 to H6 from another perspective. As has been studied in the literature review, the port city's population negatively impacts seaport efficiency. Even though the rate of 55.3% is above 50%, it was relatively lower than other variables; what’s more, considering the deviation that might be caused by subjectivity and the current quantity of respondents, the port city's population affect the port efficiency negatively.

Table 15: Frequency of Influencing Factors

	Valid Percent						
	A	**B**	**C**	**D**	**E**	**F**	**G**
Strongly disagree	0.7	0	0.7	0	0	0.4	15.4
Somewhat disagree	0	16.8	13.2	0.7	21.4	0.4	12.1
Neither agree nor disagree	27.9	22.9	25.7	21.1	22.1	27.9	17.1
Somewhat agree	36.4	29.6	27.1	34.3	23.2	32.1	23.2
Strongly agree	35	30.7	33.2	43.9	33.2	39.3	32.1
Total	100	100	100	100	100	100	100

NOTE: A=INF_Education, B=INF_Capital, C=INF_Routes, D=INF_Capacity, E=INF_Throughput,

F=INF_Economy,G=INF_Population

Secondly, to avoid the influence of subjective factors on the analysis, Tobit Regression based on the secondary data was tested by taking the DEA outcome as the dependent variable and the data of manpower, registered capital, throughput, hinterland economy and population as independent variables. Due to the limitation of data collection and to minimize the influence of the COVID-19 pandemic, the data for 2018 and 2019 were chosen to be analysed. The number of employees at each container terminal represented the manpower. The Quay Length represented the registered capital, the throughput represented the operation scale, and the GDP represented the hinterland economy. Figure 5 shows the outcome of the Tobit Regression in terms of influencing factors of seaport efficiency. All five factors were significant; manpower and registered capital positively affect the seaport efficiency. However, the throughput, hinterland economy and population negatively affect the seaport efficiency. This was inconsistent with the results of survey analysis and literature studies. The main reasons that caused the discrepancy might be as follows: firstly, the sample size of the Tobit Regression was not big enough; in this research, to avoid the pandemic influence, only data from 2018 to 2019 were chosen. Secondly, the data used to represent each variable has room for improvement. For example, despite simply using the number of employees, the education lever and working experience can also represent manpower.

Dependent Variable: OVERALL EFFICIENCY OE
Method: ML - Censored Normal (TOBIT) (Newton-Raphson / Marquardt steps)
Date: 02/27/23 Time: 04:24
Sample: 1 8
Included observations: 8
Left censoring (indicator) is always zero
Convergence achieved after 5 iterations
Coefficient covariance computed using observed Hessian

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MANPOWER	2.738724	0.310546	8.819061	0.0000
REGISTED CAPITAL	0.021083	0.002204	9.565743	0.0000
THROUGHPUT	-1.28E-05	1.33E-06	-9.585546	0.0000
GDP	-0.005771	0.000655	-8.812496	0.0000
POPULATION	-0.000646	7.33E-05	-8.821450	0.0000
C	5149.631	584.0595	8.816962	0.0000
Error Distribution				
SCALE:C(7)	0.053905	0.013476	4.000000	0.0001

Mean dependent var	0.578500	S.D. dependent var	0.329452
Akaike info criterion	-1.253186	Schwarz criterion	-1.183675
Log likelihood	12.01275	Hannan-Quinn criter.	-1.722012
Avg. log likelihood	1.501593		

Left censored obs	0	Right censored obs	0
Uncensored obs	8	Total obs	8

Figure 5: Tobit Regression: Influencing Factors

4.3.4 Challenge Analysis

Figuring out the challenges to improve seaport efficiency is a complicated issue, as it varies from different contexts such as regions, seaport scales, operational procedures, policies and so on. Five main challenges were concluded through the literature review in chapter two: port congestion, technology development, external competition, lack of sustainable competencies and loss of revenue. Table 21 shows the frequency of answers to the questions of challenges that improve seaport efficiency. Most people agreed that the port congestion was a great challenge to improving the seaport efficiency with a high rate of 98.2%. The percentages of people who firmly believed that the above factors challenged improving the seaport efficiency were 45.7%, 39.6%, 38.2%, and 41.8%, respectively. While only 1.8% of the respondents neither agreed nor disagreed that port congestion was one of the challenges seaports faced, 17.1% to 26.8% didn't hold the same opinions on technology development, external competition, or lack of sustainable competencies and loss of revenue.

Table 16: Frequency of Challenges

	Valid Percent				
	A	**B**	**C**	**D**	**E**
Strongly disagree	0	0	0	0	0
Somewhat disagree	0	0.7	0.7	0.7	0.4
Neither agree nor disagree	1.8	17.1	24.6	26.8	21.8
Somewhat agree	14.6	36.4	35	34.3	36.1
Strongly agree	83.6	45.7	39.6	38.2	41.8
Total	100	100	100	100	100

NOTE: A= CHA_Congestion , B= CHA_Technology, C= CHA_Competition, D= CHA_Sustainability, E= CHA_Revenue

4.3.5 Hypotheses Test Results

As stated in chapter two, seven hypotheses were extracted from the conceptual framework. These hypotheses were tested to show the relationship between each influencing factor and seaport efficiency by the Pearson Chi-Square test. Table 17 shows the hypotheses test result. When $p< 0.05$, the hypothesis was significant and supported; otherwise, the hypothesis was rejected or not supported. The test results showed that hypotheses H1-H6 were significant. Thus, education level, registered capital, shipping routes, designed capacity, throughput and the economy of the port city affect the seaport efficiency positively. Hypothesis H7 was rejected; thus, the port city's population negatively affects the seaport efficiency.

Table 17: Hypothesis tests results

Hypothesis	p	Remarks
H1: Education level has a positive effect on Seaport Efficiency.	***	Supported
H2: Registered Capital has a positive effect on Seaport Efficiency.	0.023*	Supported
H3: Shipping routes have a positive effect on Seaport Efficiency.	0.035*	Supported
H4: Designed capacity has a positive effect on Seaport Efficiency.	0.004**	Supported
H5: Throughput has a positive effect on Seaport Efficiency.	***	Supported
H6: The economy of the port city has a positive effect on Seaport Efficiency.	0.043*	Supported
H7: The population of the port city has of positive effect on Seaport Efficiency.	0.205	Not Supported

***,p = signifcant at p < 0.05; **, p = signifcant at p < 0.005; ***, p = signifcant at p < 0.001.**

4.4 Discussion of Findings

This study aimed to study the efficiency of African ports and their influencing factors.

This section mainly discusses the previous content's correlation between empirical results and literature reviews.

4.4.1 Assessing and ranking the seaport efficiency of South African major seaports

DEA model was used to assess and rank the seaport efficiency of the Port of Durban, Port Ngqura, Port of Elizabeth, and Port of Cape Town from 2016 to 2021. Four dimensions of Overall Technical Efficiency (OE), Pure Technical Efficiency (PTE), Scale Efficiency (SE) and Return to Scale (RS) were used to analyse the relative efficiency (da Cruz & de Matos Ferreira, 2016; Estache et al., 2004; Pjevčević et al., 2012). The DEA model has been well-tested in the application of assessing port efficiency. Researchers such as Pérez et al. (2016), Kutin et al. (2017), Osundiran et al. (2020) and so on studied port efficiency based on the DEA model. Their empirical study provides further evidence of the advantage of the DEA-MPI model in identifying the performance level and the weakness in the supply chain area.

In terms of OE, only Port Elizabeth in 2019 reached DEA optimization, and both scale efficiency and technology efficiency were reached simultaneously, indicating that the resources of Port Elizabeth were fully utilized this year and the resource allocation reached the optimum. The other three ports and Port Elizabeth in the other four years did not reach DEA efficiency, among which the overall efficiency of Durban port and Port Elizabeth was relatively low, and the overall efficiency of Port Cape Town was generally higher than that of the other four ports, which was reflected in its pure technical efficiency and scale efficiency.

In terms of PTE, in the past five years, the pure technical efficiency of Port Elizabeth has reached the optimum, and the main factor affecting its port efficiency is scale efficiency, which can be expanded to improve its port efficiency. The Port of Cape Town, the Port of Ngqura, and the Port of Durban, in turn, still have room to improve technical efficiency.

In terms of SE, only Port Elizabeth achieved optimal allocation in 2019. Among the different seaports in the remaining years, the scale efficiency of Cape Town and Port of Ngqura is relatively high, while that of Port Elizabeth and Durban is relatively low. The scale efficiencies of all four seaports showed a trend of rising first, then falling, and then rising again (Figure 4). The nodes of decline were mainly concentrated in 2019 and 2020, indicating that the change of scale efficiency was greatly affected by the COVID-19 pandemic.

In terms of RS, the scale return coefficient of Port Elizabeth in 2019 is equal to 1, and the return to scale remains unchanged, reaching the optimal state. In terms of Cape Town Port from 2016 to 2019, the coefficient of return to scale is less than 1, indicating that the return to scale is increasing, which means that the current scale is too small; it should be expanded to increase efficiency. The coefficients of returns to scale of the remaining research objects in their respective years are greater than 1, and the returns to scale are diminishing, indicating that scale reduction can contribute to increasing efficiency.

4.4.2 Changes in seaport efficiency of South African major seaports from 2016 to 2021.

The traditional DEA-CCR and DEA-BCC model generally reflect the efficiency of a certain time with cross-sectional data collected. To observe how the efficiency changes over a certain period, panel data is selected, and several approaches have been employed to achieve the dynamic efficiency analysis, such as DEA + Malmquist Productive Index (MPI) and DEA-Window analysis. Osundiran et al. (2020) studied the efficiency of 19 Sub-Saharan African ports over time from 2008-2015 with the application of the DEA-MPI model. Their empirical study provides further evidence of the advantage of the DEA-MPI model in identifying the performance level and the weakness in the supply chain area. This study calculated the MPI of the four major ports of 2016-2018 2018-2019,2019-2020,2020-2021, respectively. The four indices, TC, TEC, PEC, and SEC, were used for analysis guided by the previous studies

(Ding et al., 2015; Duong et al., 2019; Osundiran et al., 2020; Tovar & Wall, 2019).

4.4.3 The influencing factors affecting seaport efficiency

The hypothesis test results showed that the education level, registered capital, shipping routes, designed capacity, throughput and the economy of the port city affect the seaport efficiency positively. In comparison, the port city's population negatively affected the seaport's efficiency. These findings are in line with the studies of Almawsheki and Shah (2015), Liu et al. (2021), and Ding et al. (2015) such as manpower structure, shareholding, registered capital, and shipping routes positively affect efficiency, while the factor such as the number of terminal operators, the population of the port city negatively affects the efficiency.

4.4.3 The challenges improving seaport efficiency

With regard to the challenges of improving seaport efficiency, this study found that port congestion was a great challenge to improving seaport efficiency with a high rate of 98.2%. The percentages of people who firmly believed that the above factors challenged improving the seaport efficiency were 45.7%, 39.6%, 38.2%, and 41.8%, respectively. While only 1.8% of the respondents neither agreed nor disagreed that port congestion was one of the challenges seaports faced, 17.1% to 26.8% did not hold the same opinions on technology development, external competition, or lack of sustainable competencies and loss of revenue. Port congestion is considered one of the main challenges in enhancing seaport efficiency in many previous studies (Bray et al., 2015; Carine, 2015; Nyandu, 2020; Nze & Onyemechi, 2018). Nze and Onyemechi (2018) explained that port congestion is related to delays, cargo, operational, storage and transactional dwell times; and that port capacity, regulations, efficiency, cargo throughput and berth occupancy rate significantly affect port congestion.

Pérez et al. (2016) and Trujillo et al. (2013) supported that technology development is crucial to improving seaport efficiency. Cullinane et al. (2006) concluded the challenges regarding the port's operation and external competition. Inoue (2018) investigated Kobe-Osaka port and found that increasing competition with ports of

East Asian counties put much pressure on port efficiency.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In this chapter, the analysis of this study was summarized, and some recommendations for policymakers and future research were given.

5.2 Conclusions

5.2.1 South African seaport efficiency assessment

This study concluded that the Port of Cape Town was the most efficient seaport in these years, followed by the Port of Ngqura and Port Elizabeth, while the Port of Durban was the least efficient. Through Malmquist's analysis of the dynamic change trend of seaport efficiency, the trend of the efficiency changes of all the selected seaports was first increasing, then decreasing and then increasing, among which Port Elizabeth reached optimal efficiency in 2019. The decline in seaport efficiency was mainly concentrated between 2019 and 2020, apparently due to the impact of COVID-19. The main reason for the decline in the efficiency of Cape Town Port in previous years was the mismatch between the change in scale efficiency and the technology change. The change in the efficiency of Durban Port is mainly caused by the change of technology, the change of pure technology efficiency and the change of scale efficiency, among which the change of technology and scale efficiency weigh more, which shows that from 2018 to 2019, scale efficiency cannot keep up with the progress of technology, and from 2019 to 2020, technology cannot keep up with the growth of scale efficiency. Port Elizabeth has seen significant efficiency gains in 2018-2019, in line with the planned maintenance in 2017. The efficiency change of Port of Ngqura was similar to that of Cape Town, except that it showed an upward trend from 2016 to 2018.

5.2.2 Influencing factors of South African seaport efficiency

This study concluded that education level, registered capital, shipping routes, designed capacity, throughput and the economy of the port city affect the seaport efficiency positively, which was also supported by the research of Almawsheki and Shah (2015)， Ding et al. (2015) and Liu et al. (2021). At the same time, the population of the port city affect the seaport efficiency negatively, which is consistent with the research of Liu et al. (2021).

5.2.3 Challenges in improving South African seaport efficiency

This study concluded that port congestion is a great challenge in improving seaport efficiency, whilst technology development, external competition, lack of sustainable competencies and loss of revenue are of great importance challenges during the pursuit of seaport efficiency improvement.

5.3 Recommendations

5.3.1 Appropriate seaport expansion

Generally, the scale of a seaport can be improved by adding seaport investment, building more facilities, hiring more people, etc. (Gamassa & Chen, 2017; Pérez et al., 2016). Assessing how a seaport scale meets the current operation situation contributes to avoiding the waste of unreasonable or unnecessary seaport expansion. According to the figures of the four seaports in 2021, the seaport efficiency of the Port of Cape Town ranked relatively high, and the Port of Durban ranked last. The Port of Durban should be the priority when considering improving the seaport scale.

5.3.2 Advanced seaport technology

As discussed previously, Pure technical efficiency is directly related to seaport production technology and management level (da Cruz & de Matos Ferreira, 2016). Hence, more advanced facilities and a higher management level led to increased pure technical efficiency. In the view of seaport operation, pure technical efficiency refers to the operational capacity of the seaport infrastructure and management ability. As per the latest figures studied of the four seaports, more advanced seaport technology contributes to achieving resource optimization, among which the port of Durban has a greater demand to upgrade technology.

5.3.3 Seaport registered capital

According to the literature review in chapter two, the main influencing factors can be summarized as manpower, register capital, shipping routes, operation scale, hinterland economy, and hinterland population. Even though the survey respondents were insufficient, the analysis showed that the registered capital negatively impacted the seaport efficiency. Thus, it is prudent for seaport owners or investors to add seaport capital.

5.3.4 Recommendations for future research

Even though the outcome of the data analysis went in line with the literature review, the research still has room to improve to get more accurate conclusions. Due to the impact of COVID-19 and port strike issues, the number of respondents collected was insufficient to run Tobit Regression based on the primary data. When running the Tobit Regression based on the secondary data. The indexes that represent the variables can be modified. For example, instead of the number of employees, the education level can be considered to represent the manpower. Considering the COVID-19 impact, only 2018 and 2019 were collected to run the Tobit Regression in this study; in subsequent studies, more data from different years can be expanded to get more accurate and systematic results. On the other hand, more accurate primary data can be obtained by improving the content of questionnaires and combining questionnaires with interviews to draw the most accurate conclusions.

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APPENDIX 1: SAMPLE SIZE TABLE

Table for determining minimum returned sample size for a given population size for continuous and categorical data

Population size	Sample size					
	Categorical data (margin of error=.05), ρ=2			Continuous data (margin of error=.03), ρ=4		
	90% confidence Level $t = 1.645$	95% confidence Level $t = 1.96$	99% confidence Level $t = 2.58$	90% confidence Level $t = 1.645$	95% confidence Level $t = 1.96$	99% confidence Level $t = 2.58$
450	169	208	269	133	168	229
500	176	218	286	137	174	241
600	187	235	316	144	185	262
700	196	249	342	149	194	279
800	203	260	364	153	201	293
900	209	270	383	156	206	306
1000	213	278	400	159	211	317
1200	221	292	429	163	219	334
1500	230	306	462	167	227	354
2000	239	323	500	172	236	376
3000	249	341	545	177	245	401
5000	257	357	588	182	254	424
8000	262	367	615	184	259	437
10000	264	370	625	185	260	442
20000	267	377	645	187	264	452
50000	270	382	657	188	266	459
100000	270	383	662	188	267	461
150000	271	384	663	188	267	461
200000	271	384	664	188	267	462
>1000000	271	385	666	188	267	463

Source: Adam (2020)

APPENDIX 2: QUESTIONNAIRE

Start of Block: SURVEY INSTRUCTION

My name is Hao Gong, and I am a Master of Management Student at Wits Business School in Johannesburg. As part of my studies, I must undertake research assessing South African seaport efficiency. Therefore, you are invited to participate in this research study. The information required from this questionnaire will be used solely for academic purposes.

Your participation in the study is very important to us. You will not receive any financial benefit from this study; however, your participation will contribute to a wealth of academic knowledge in the country. The study results will be used for academic purposes only and may be published in an academic journal. All your responses will be kept confidential.

The survey should take you around **10 to 15 minutes** to complete. Your participation in this research is voluntary. You have the right to withdraw at any point during the study, for any reason, and without any prejudice.

By clicking the button below, you acknowledge that your participation in the study is voluntary, you are 18 years of age, and you are aware that you may choose to terminate your participation at any time and for any reason.
Please note that this survey will best display on a laptop or desktop. Some features may be less compatible for use on a mobile device.

○ I consent, begin the study

○ I do not consent, and I do not wish to participate

End of Block: SURVEY INSTRUCTION

Start of Block: DEMOGRAPHIC DATA

Q2.1 What is your gender?

○ Male

○ Female

Q2.2 What is your age?

- 18-30
- 31-40
- 41-50
- 50 or older

Q2.3 What is your level of education?

- Less than high school
- High school graduate
- Some college
- 2-year Degree
- 4-year Degree
- Professional Degree
- Doctorate

Q2.4 How many years you've been working at Transnet?

- Less than 2 year
- 2-5 years (including 5 years)
- 5-8 years (including 8 years)
- 9-12 years (including 12 years)
- 13-15 years (including 15 years)
- More than 15 years

Q2.5 Which port are you working at?

- ○ Port of Durban
- ○ Port of Port Elizabeth
- ○ Port of Ngqura
- ○ Port of Cape Town
- ○ None of above

Q2.6 Our seaport operations are efficient.

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

End of Block: DEMOGRAPHIC DATA

Start of Block: INFLUENCING FACTORS OF SEAPORT EFFICIENCY

Q3.1 The education levels of the employees positively affect seaport efficiency.

- ○ Strongly disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Strongly agree

Q3.2 The seaports with higher registered capital have higher operational efficiency.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q3.3 The seaports with more shipping routes have higher operational efficiency.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q3.4 The seaports with more designed capacity have higher operational efficiency.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q3.5 The seaports with higher throughput have higher operational efficiency.

- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Neither agree nor disagree
- ◯ Somewhat agree
- ◯ Strongly agree

Q3.6 The economy of the port city positively affects seaport efficiency.

- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Neither agree nor disagree
- ◯ Somewhat agree
- ◯ Strongly agree

Q3.7 The population of the port city positively affect seaport efficiency.

- ◯ Strongly disagree
- ◯ Somewhat disagree
- ◯ Neither agree nor disagree
- ◯ Somewhat agree
- ◯ Strongly agree

Q3.8 What else do you think affects the seaport efficiency of South Africa?

____

End of Block: INFLUENCING FACTORS OF SEAPORT EFFICIENCY

Start of Block: CHALLENGES

Q4.1 To what extent do you think the followings are challenges to port efficiency?

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Port Congestion	○	○	○	○	○
Technical Developments	○	○	○	○	○
External Competition	○	○	○	○	○
Lack of Sustainability Competences	○	○	○	○	○
Loss of Revenue	○	○	○	○	○

Q4.2 What else do you think challenges improving the seaport efficiency of South Africa?

____

End of Block: CHALLENGES

Start of Block: SUGGESTIONS

Q5.1 What are your suggestions for improving the South African seaport efficiency?

____

End of Block: SUGGESTIONS

APPENDIX 3: ETHICS CLEARANCE

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Gong

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H21/11/15**
PROJECT TITLE	Assessing seaport operational efficiency: A case of South African Seaports
INVESTIGATOR(S)	Miss H Gong
SCHOOL/DEPARTMENT	Wits Business School/
DATE CONSIDERED	19 November 2021
DECISION OF THE COMMITTEE	Approved Risk Level: Minimal
EXPIRY DATE	15 February 2025
DATE 06 June 2022	**CHAIRPERSON** ____________________ (Professor J Watermeyer)

cc: Supervisor : Professor F Saruchera

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to submit an amendment of the protocol to the Committee. **I agree to completion of a regular progress report. For Minimal and Low studies, this is due annually on 31 December. For Medium and High Risk studies, this is due twice annually on 30 June and 31 December.**

Signature ____________________ **Date** ______/______/______

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

APPENDIX 4: LANGUAGE EDITING MEMORANDUM

EDITING CONFIRMATION

To whom it may concern:

This memo serves to confirm that the manuscript/research project detailed below has been language-edited and/or proof-read.

Regards,

-SM001-

S. Mpunz *(Cert. Lang. Ed.)*
Language Editor

****

Manuscript Title:

ASSESSING SEAPORT OPERATIONAL EFFICIENCY: THE CASE OF SOUTH AFRICAN SEAPORTS

Author:

HAO GONG

Issued on:

28/02/2023

Disclaimer:
The editor/proofreader makes no claim as to the accuracy of the manuscript contents nor the objectives of the author. While all possible efforts have been made to ensure the text as edited is readable and grammatically correct, the author(s) have the option to accept or reject suggestions and trackable changes made to the document before submission.

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sarchcot@gmail.com