The Technical Efficiency of SACU Ports: A Data Envelopment Analysis Approach

By

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DECLARATION

In accordance with Rule G4.6., I hereby declare that the above-mentioned treatise is my own work and has not been previously submitted for assessment to another university or for another qualification.

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ABSTRACT

There ever growing international trade and increasing congestion of ports led to an increased focus attention on technical efficiency. Seaports are a central and necessary component in facilitating international trade. Yet, there is only limited comprehensive information available on the technical efficiency of African ports. The study investigated the technical efficiency of the SACU ports during the period 2014-2019 using DEA model. The DEA model is effective in resolving the measurement of port efficiency since the calculations are nonparametric and do not need definition or knowledge of a priori weights for the inputs or outputs, as is necessary for estimate of efficiency using production functions. To identify the roots of the technical inefficiency of the SACU ports, the study subdivided technical efficiency into pure technical and scale efficiency. The model used cargo handled, container throughput, ship calls as output variables. Whilst, quay cranes, number of tugboats, draft, quay length and number of quays were used as input variables. The study used the scores of DEA-BCC model as explanatory variables in Tobit model. The results showed that quay cranes and quay length are the cause of technical inefficiencies in the ports.

DEDICATION

To my parents Nosakhele Bekebu and Malothana Bekebu

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"5Trust in the LORD with all your heart,
And lean not on your own understanding;
6 In all your ways acknowledge Him,
And He shall direct your paths."
Proverbs 3:5-6 (NKJV)

After three arduous years, I can confidently state that my thesis would not have been a success if I had not placed entire confidence in God. It is because of Him that I have been able to connect with credible and prominent persons both within and outside of my field. Their knowledge and counsel surely influenced both my thesis and my personal development.

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LIST OF ABBREVIATIONS

AAGR	Average Annual Growth Rate
AGVs	Automated Guided Vehicles
ALVs	Automatic Lifting Vehicles
APEC	Asia-Pacific Economic Zone
BAP	Berth Allocation Problem
BCC	Banker Cooper and Charnes
CBD	Central Business District
CCR	Charnes Cooper and Rhodes
CD	Chart Datum
CDA	Car Distributors Assembly
COLS	Corrected Ordinary Least Squares
CRS	Constant Returns to Scale
DBT	Dry Bulk Terminal
DCT	Durban Container Terminal
DEA	Data Envelopment Analysis
DWT	Deadweight Tonnage
DMU	Decision Making Unit
DRC	Democratic Republic of Congo
DRS	Decreasing Returns to Scale
GA	Genetic Algorithm
GDP	Gross Domestic Product
GT	Gross Tonnage
IDZ	Industrial Development Zone
IFO	Intermediate Fuel Oil
IRS	Increasing Returns to Scale
ISPIS	International Ship and Port Facility Security Code
KPI	Key Performance Indicators
KZN	Kwa-Zulu Natal
M	Metre
MGO	Marine Gas Oil

MIP	Mixed-Integer Programming
MPT	Multi-Purpose Terminal
MSC	Mediterranean Shipping Company
MT	Metric Tonnes
MTE	Mean Technical Efficiency
MPI	Malmquist Productivity Index
MSC	Mediterranean Shipping Company
N-2	National Route 2
N. MILE	Nautical Mile
NAMPORT	Namibian Port Authority
NPA	National Port Authority
OLS	Ordinary Least Squares
OTE	Ordinary Technical Efficiency
PDE	Panel Data Estimation
PTE	Pure Technical Efficiency
PWB	Port of Walvis Bay
QC	Quay Crane
QCAP	Quay Crane Allocation Problem
QCSP	Quay Crane Scheduling Problem
RBCT	Richards Bay Coal Terminal
RMGC	Rail-Mounted Gantry Cranes
RR	Required Revenue
RTGCs	Rubber-Tired Gantry Cranes
SADC	Southern African Development Community
SACU	Southern African Customs Union
SAMAD	South Africa Motor Assemblers and Distributors
SATS	South Africa Transport Services
SC	Straddle Carrier
SFA	Stochastic Frontier Analysis
SAMSA	South African Maritime Safety Authority
SE	Scale efficiency
SEZ	Special Economic Zone
SIDA	Swedish International Development Cooperation Agency
SMP	Small Medium Ports

SOE	State-Owned Enterprises
SPM	Single Point Mooring
STS	Ship To Shore
SWL	Safe Working Load
TEU	Twenty-foot Equivalent Unit
TNPA	Transnet National Port Authority
TPT	Transnet Port Terminals
UNSCR	United Nations Security Council Resolution
VEM	Vector Error Model
TPT	Transnet Port Terminals
UNCTAD	United Nations Conference on Trade and Development
V&A	Victoria and Alfred
VLBC	Very Large Bulk Carrier
VLCC	Very Large Crude Carrier
VOC	Dutch East India Company
VRS	Variable Returns to Scale
VTS	Vessel Tracking Service System
YC	Yard Cranes
YCS	Yard Crane Scheduling

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CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.1 Introduction

This study introduces the topic "The Technical Efficiency of SACU Ports: A DEA Approach" The study will be focusing on coastal Southern Africa Customs Union (SACU) countries which include Namibia and South Africa. To state the question, the study begins with an introduction followed by the background of the study and the SACU countries in question. It gives a brief overview of the research focus by explaining the problem statement of the research then continues to explain research questions and what the research aims to achieve. In its explanation, it also comprises objectives of the research and significance of the study. It further, explains the literature review and methodology. Ethical consideration follows by explaining what ethical issues will be taken into consideration. The chapter then ends with the organisation of the study.

1.2 Background

Port is a coastal place where ships can dock and move people or cargo from and to land (Dwarakish & Salim, 2015). Begum (2003) notes that a port's efficiency is important for international trade because a country's seaports are the place of foreign trade. Port is the compulsory movement point of the bulk of trade, allowing the import of goods that the country does not have and export goods that contribute to the growth of its economy (Begum, 2003). Begum (2003) stated that in Bangladesh there was a rejuvenation of ports which resulted in port efficiency increasing and trade.

Ports performance has become an ever more important topic. Port terminals are vital to the efficiency of the entire chain, as they provide linkages across the global logistics chain between various modes of transport (Kutin, Nguyen and Vallee, 2017). In addition to its crucial position in the global trading network, the productivity of container ports and terminals is also a core concern for operators as a worldwide port and terminal competition intensifies (Kutin, Nguyen and Vallee, 2017). The port efficiency level significantly affects a country's productivity and competitiveness due to its position within the logistics chain (Wu and Goh, 2010).

Efficiency analysis provides port operators/authorities with the means to make more informed port planning or operating decisions while providing port users (particularly shipping lines) with the means to assess the relative competitiveness of ports in decision-making on informed port use (van Dyck, 2015). For several years, productivity studies have been used by ports in Western Europe, North America, and East Asia to boost operations by maximizing the use of processing resources, stimulating port development, and substantial port-related investment (van Dyck, 2015).

Ports are the backbone of global trade, shipping moves more than 90% of global trade (Bergantino, Musso, and Porcelli, 2013). That is inspired by global economic globalization. Current outlook and economies globalization demand higher output from all actors in the transport sector, especially ports, where there is significant public input in their production processes (Bergantino et al., 2013).

Seaport authorities have been under increasing pressure to boost performance by making sure facilities are provided globally on a sustainable basis. Ports ' performance is a measure of a country's economic growth (Liu, 2008), and thus the calculation and comparison of one port to another in terms of production has become an important part of the microeconomic reform programs of many countries (Jiang and Li, 2009).

Efficiency plays a key role in container port rivalry (Yuen et al., 2013, Luo et al., 2012, Tongzon and Heng, 2005), so the performance appraisal of the container port is necessary for the longevity and viability of the industry (Cullinane and Wang, 2006). Not only does such an overview provide a powerful container port operations management method in this context, but it also constitutes valuable information to inform container planning and operations at regional and national ports (Verhoeven, 2010).

One core aspect of their overall position as transport nodes is the capacity of ports to ensure efficient cargo transfers. Until containerization, as in the late nineteenth century, in a sense of increasing global trade, major ports were already competing in their attempt to provide quick transport between sea and land (Ducruet, Itoh, and Merk, 2014). These considerations are much more relevant today, as the port can only be used as part of value-driven supply chains (Robinson, 2002) or as a community of autonomous ports owned by multinational players (Olivier and Slack, 2006). Although it is possible to consider port efficiency as a whole from various points of view, its effect on trade facilitation (Clark et al., 2004) and regional growth (Saslavsky and Shepherd, 2012) has been emphasised.

Besides, efficiency is the performance in which a Decision-Making Unit (DMU) utilizes its inputs to produce outputs. In simple terms, efficiency can be defined simply as the output to input ratio. Farrel (1957) proposed that a DMU's performance would consist of two parts, technical efficiency, reflecting the capacity and willingness of a business to maximize its production from a given input set and allocative efficiency, reflecting the ability and willingness of the company to use the inputs in optimum proportions for the factor price. The sum of the technical and allocative efficiency defines economic efficiency or total efficiency.

1.3 Importance of Port Efficiency

The value and significance of optimum port productivity cut through the multiple stakeholders that use container port terminals from several different perspectives. Port efficiency is an essential measure for terminal operators to track and optimize terminal capacity, schedule capital expenditure, and recover project revenue while reducing business costs (UNCTAD, 1975). The operator's goal is to service vessels as quickly and efficiently as practicable by deploying sufficient facilities, making maximum use of the available manpower, making optimal use of the quay, and running the landside efficiently (Transnet National Port Authority (TNPA), 2013).

The goal of the carrier is for the terminal operator to transform the terminals or ports as quickly as possible and to invest in cranes at the lowest cost to be able to handle vessels of all sizes efficiently, manage costs by reducing labor, and preventing the dispute of various shipping lines between the docking of vessels (TNPA, 2013). The key goal of the port authority is to obtain maximum vessel calls and draw volumes of cargo, requiring higher technical efficiency levels. As regards technical efficiency standards, the port operator also plays an important oversight function for all port users. It is in their interest to optimize land usage to positively affect the degree of service quality that the port user will offer to the end-user. The viewpoints of the industry and the shippers are focused on technical efficiency, transit times over the entire supply chain, reliability, and cost consistency (TNPA, 2013).

1.4 Measures of port technical efficiency

The fundamental seaport technical efficiency measurement tools are classified into two categories: parametric approaches and non-parametric techniques (Trujllo and Tovar, 2007). The first category of methods approaches technical efficiency by measuring a theoretical function of output. The divergence from the function line is due in part to lack of efficiency and in part to the presence of error in measurement (Cullinane, Wang, Song and Ji, 2006). Stochastic Frontier Analysis (SFA), which Liu (1995) first employed in the port industry, is the most important parametric approach. Later, SFA was used by several researchers to evaluate port and terminal performance SFA (Coto-Millan et al., 2000; Notteboom, Coeck and Van Den Broeck, 2000; Tongzon and Heng, 2005).

The non-parametric methods are implemented because they are based on the use of empirical evidence without the implementation of any output function. In this example, the divergence from the efficiency limit is due to the inefficiency of each terminal. The most used non-parametric approach is Data Envelopment Analysis (DEA) (Cullinane et al., 2006; Wu and Goh, 2010). The DEA is a method for data processing to compare the technical efficiency of so-called decision making units (DMU). In general, DEA is a linear programming approach that uses the inputs and outputs of the efficient cycle to measure the relative efficiency of each DMU.

The components of the production chain, such as labour, land, and machinery, are the most commonly used inputs, while the outputs may be components, such as the production size, port economic outcomes, or other related indicators. Farrell (1957) first applied the technique, but it was improved by Charnes, Cooper and Rhodes (1978) and Banker (1984). The creation of the two basic DEA models called CCR and BCC models, from the initials of the founders, was the result of these improvements. In comparison to the DEA-BCC model, which assumes variable returns to scale, the DEA-CCR model assumes constant returns to scale.

1.5 Overview of the Southern African Customs Union (SACU) Ports

Southern Africa Customs Union (SACU) is a customs union with five members in Southern Africa: Botswana, Eswatini, Lesotho, Namibia, and South Africa. SACU was founded in 1910. Namibia joined the union in 1969 after winning independence from South Africa. The union aims to protect and sustain the free trade of goods between the five nations. It also offers a similar export tariff and joint excise tariff for this common customs zone.

Those with ports, including Namibia and South Africa, are the only SACU countries included in this study. Botswana, Eswatini, and Lesotho are landlocked countries. These land-locked nations use the ports of Namibia and South Africa to import and export their goods.

1.5.1 Namibia

The Namibian Ports Authority (Namport) is a government-owned corporation that operates Namibian ports, Port of Walvis Bay and Port of Lüderitz (Amakali, 2017) respectively. Southern African Development Community (SADC) landlocked countries cargo is handled by the Port of Walvis Bay these countries include Botswana, the Democratic Republic of Congo (DRC), Zambia, Zimbabwe, and neighbouring South Africa (Port Management 2014). At the Port of Walvis Bay, Namport (2017) registered an annual number of 4,000 vessel calls, carrying around 5 million tons of cargo. (Namport, 2017,). Nomakalu, Niishinda, Kadhila, Fillipus, Mukasa and Mushendami (2014) projected that break-bulk carriers and bulk carriers are around 60 percent of the ships heading to Walvis Bay. The port has a 24-hour to 48-hour turnaround.

1.5.2 South Africa

Currently, in South Africa, 90% of the country's trade is facilitated through ports. The South African ports play a significant role in achieving the government's social-economic goals (Ports Regulator, 2016). Looking at the patterns of international trade, maritime passages are located at global locations where trade volumes are high (Ports Regulator, 2016). For starters, Northern Europe and Pacific Asia are known for connecting the Circum-Equatorial Corridor via the Suez Canal. Some corridors, such as the Malacca Strait and the Panama Canal, are also used to link various trade routes. Many of these routes deal with trade in the East-West.

South Africa's geographic position is along the North-South and Transoceanic pendulum connectors (Ports Regulator, 2016). These routes supplement the Circum-Equatorial corridor and attract container traffic as alternative routes from the Circum-Equatorial route (Ports Regulator, 2016). Shipping companies have embarked on a journey of increasing economies of scale and reducing operating costs in their quest of achieving reducing costs and increasing profits, they have focused on increasing the size of vessels involved in international trade. Small vessels are being replaced by big vessels and the increase in the size of vessels has implications for ports (Port Terminals, 2017). Ports that do not expand or modernise their infrastructure and equipment that is needed to service large vessels have reduced port calls because they are not able to accommodate big vessels.

With a draft of 23 meters, the Port of Saldanha Bay is the deepest in Southern Africa. It handles about 67 million tons of cargo per year (National Ports Plan, 2017). The port can host big ships. The iron ore quay offers docking of two Very Large Bulk Carriers (VLBCs) in addition to one docking liquid bulk quay for Very Large Crude Carriers (VLCCs) for the import of crude oil (National Ports Plan, 2017). Also, the port has a multi-purpose terminal with four quays and offshore rig support facilities.

The Port of Cape Town is in the Western Cape Province. It offers services to the Western Cape for container vessels, bulk carriers, and general handling facilities. The port moves about 10 million tons of cargo a year. It also has ship repair facilities and accommodates local and overseas fishing boats, oil rigs, cruise-liners, and recreational users (National Ports Plan, 2017 and Transnet Port Terminals, 2017). The Port of Mossel Bay provides recreational boaters and is home to a fleet of local fishermen. Compared with other South African ports it handles small cargo. The port handles about 700 vessels per year, most of them small, about 120 m long vessels (Transnet Port Terminals, 2017).

Located in the Eastern Cape Province of South Africa, the Port of Port Elizabeth handles manganese coal, trucks, liquid bulk, and general dry and break-bulk cargo containers. The port handles nearly 8 million tons of cargo a year (National Ports Project, 2017 and Transnet Port Terminals, 2017). Meyiwa and Chasomeris (2016) assumes that if manganese and liquid bulk terminals were to be moved to the Port of Ngqura, the cargo handled at the Port of Port Elizabeth will be low. The port handles container cargo for the local neighbourhood and is located to handle the overflow of the Gauteng cargo should the Port of Durban handling capacity reach its capacity. Ngqura also handles cargo both for East and West African countries and also is a transhipment for internal cargo (Meyiwa and Chasomeris, 2016).

Port of East London specializes in the hinterland of the Eastern Cape and the cargo it handles is primarily manufacturing and agronomic cargo, with a significant focus on serving the local automobile industry (National Ports Plan, 2017; Port Terminals, 2017 and van der Molen and Moes, 2009). Annually, the port handles 1,1 million tons of cargo. However, the port is located at the mouth of a river, which has steep rocky banks and, as a result, is constrained in both breadth and depth. Such limitations limit the prospect of potential port expansion opportunities (National Ports Plan, 2017; Port Terminals, 2017 and van der Molen and Moes, 2009).

In addition, Nabee and Walters (2018) announced that the Port of Durban is a leading container port for KwaZulu-Natal province and Gauteng region, as well as the Southern Africa region, and is the main port handling containerised cargo. The port averagely handles 4,000 call vessels annually, with an annual cargo capacity of nearly 61 million tons, the largest amount in South Africa (Nabee and Walters, 2018). Richards Bay is the newest port in the eastern region and is the largest port for bulk cargo handling in South Africa, with its major hinterland containing KwaZulu-Natal, Gauteng, and Mpumalanga in the north (Nabee and Walters, 2018). In South Africa, the port is the largest by tonnage, handling almost 104 million tons of cargo per year, representing 41% of South Africa's overall port demand. Furthermore, Nabee and Walters (2018) said the port has a top-class coal terminal. In addition, other facilities provided by the terminal include bunkering, ship maintenance, and recreational boat support services.

1.6 Research focus

1.6.1 Research Problem

Facts show that SACU ports are characterized by inefficiency, weak infrastructure, high density of traffic, and long dwelling times in the port. Shipping dwell time refers to the time spent inside a port by a vessel (Kahyarara and Simon, 2018). Dwell time figures are an important commercial resource used to draw cargo and produce revenue. Cargo dwelling time in ports in Sub-Saharan Africa is abnormally long: more than two weeks on average compared to less than a week at major ports in Asia, Europe, and Latin America (Kahyarara and Simon, 2018).

Another peculiarity in SACU ports is the regular occurrence of very long dwelling periods, adversely affecting the efficiency of port operations and increasing congestion at a high cost to the economy in container terminals (Kahyarara and Simon, 2018). Cargo dwell times in sub-Saharan Africa often show an irregular distribution, with evidence that discretionary activities increase network inefficiencies and the overall cost of logistics (Scholvin and Plagemann, 2014).

The above situation also prevents coastal SACU countries from making greater use of their ports from establishing regional trade with surrounding countries and restricts surrounding countries. The Port of Walvis Bay faces infrastructure limitations and land shortages, leading to limits on accommodation for larger vessels and other large-scale operations (Amakali, 2017). Nonetheless, when Namport revealed in 2008 that expansion plans were underway that would eventually increase the size of the Port, it addressed this problem of space constraints. The standard of these ports is also low, rendering the regional and continental connectivity of these countries difficult with the wider economic field of the SACU.

Gumede and Chasomeris (2013) report, from the analysis of stakeholder comments, that ports in South Africa have congestion, low productivity, and inefficiency; incoherent and unfair product pricing; and weak service quality, among other issues. There are few quays and cranes in South African ports which cause traffic congestion (Van Der Molen and Moes, 2009). Some ports are not sufficiently deep to handle large vessels (Africa Ports and Ships, 2018). Van Der Molen and Moes, (2009), reported South African ports were among the costliest and unreliable in the world.

It is because of this that the study is carried out to respond to the gaps enumerated above and contribute to broadening the frontier of research on port technical efficiency.

1.6.2 RESEARCH OBJECTIVES

Research objectives have primary and secondary objectives. The primary objective of this study is to determine the technical efficiency of SACU ports. The secondary objectives are as follows:

- To present an overview of the SACU ports;
- To identify the impact of the technical efficiency of the ports;
- To provide an assessment of port operations; and
- To contribute to literature about this topic.

1.7 Justification

While in international trade, logistics, trade, and economic growth ports play a critical role, they are highly capital-intensive. Therefore, port technical efficiency assessment is important to port owners, investors, governments, and users as it helps track port performance and identify essential factors that improve port technical efficiency and competitiveness in trade (Nguyen, Nguyen, Chang, Chin, and Tongzon, 2015). Furthermore, there has not been a lot of research done on Southern African port's technical efficiency. This research may thus add to the literature available in South Africa and Namibia on ports' technical efficiency. Transnet Port Terminals (TPT) and the Namibian Port Authority (Namport) will also be briefed on the advantages of having technical efficient ports.

1.8 Assumptions

Variable	**Explanation**
Quay crane (QC)	**- If there are more quay cranes boats will be quickly loaded or offloaded and leave port quickly.** **- Less quay cranes increase dwell times which reduces productivity.**

Number of Tugboats	- **If there are more tugs, boats can enter a port quickly and leave port quickly which improves efficiency.** - **If there are less tugboats it will take time for a boat to enter a port which might contribute to congestion**
Number of Quays	- **If there are more quays available more boats can dock in at the same time, importing or exporting** - **If there are few quays, there will be congestion, increasing dwell time, reducing imports or exports by delaying on congestion/traffic.**
Quay Length	- **If the quay length is short, it can accommodate small vessels which are no longer fashionable or it cannot accommodate any cargo vessel.** - **Long quaysides are accommodating big cargo vessels that have large loads of cargo – imports or exports**

Draft (Depth of the Port)	- **Ports with deep draft are more accessible.** - **If a port has a shallow draft very few vessels can access it.**

1.9 Delimitations

The study will focus on 10 ports. 7 from South Africa (Cape Town, Durban, East London, Ngqura, Mossel Bay, Port Elizabeth, Richards Bay, and Saldanha Bay) and two from Namibia (Walvis Bay and Port of Lüderitz. The study uses the following variables: Quay Crane, Number of tug boats, Draft, Quay length and Number of Quays and as inputs and cargo handled, container throughput and ship calls as outputs. The researcher chose these variables because most of the previous studies used these variables and also they were the only variables with available data that would enable the author to run regressions.

1.10 Definitions of Concepts

- **Cargo handled**

Includes dry cargo – cars and minerals such as coal, manganese; liquid - petroleum and containers). Cargo handled in a port is equal to trade that has taken place in that port – it is imports and exports that have been processed in a port. Cargo handled is measured in cargo tons (Hlali, 2018).

- **Ship Call**

Ship call is an intermediate port where ships customarily stop for supplies, repairs, or transhipment of cargo.

- **Quay crane (QC)**

A QC is used to load and unload containerized cargo from the vessels at container terminals. In comparison to traditional hook-using cranes, QCs are fitted with a handling tool called a spreader; this is lowered to the top of a container and then locked into its four corner casts. During movements, QCs typically hold a single container; however, most modern QCs can move four TEUs at a time (four 20-foot containers or two40-foot) (van der Molen and Moes, 2009).

- **Number of Tugboats**

A tugboat is a boat or ship that manoeuvres cargo vessels by pushing or towing them inside a port. Cargo vessels cannot access a port without being pushed by a tugboat (Kahyarara and Simon, 2018).

- **Number of Quays**

A quay is a long platform by the sea or a river where boats can be tied and loaded or unloaded. Few quays cause traffic congestion because few cargo vessels can be loaded or offloaded at a time (van der Molen and Moes, 2009). The number of quays available means that a port will concurrently load or unload multiple vessels. An important performance metric is the number of quayside cranes, which directly influences the speed at which the cargo can be loaded or unloaded (more cranes can increase the amount of cargo handled per ship) and the turnaround period as well (Hlali, 2018).

- **Quay Length**

The length of the quay (meters) is a significant measure of the turn-around or dwelling period that can be accomplished by ports since it represents the scale of a ship that can be assigned to a quay at a given point in time (Kahyarara and Simon, 2018).

- **Draft**

Draft determines the minimum depth of water a ship can safely navigate.

1.11 Organisation of the Study

Chapter 1 presents an introduction to the study covering the background of the study. The chapter highlights the problem statement, objectives, and delimitations of the study. Chapter 2 gives an overview of SACU ports. Chapter 3 discusses theories that are related to the study and includes previous studies like the one being carried out now. In-depth, Chapter 4 presents the research methodology and analytical framework used in the conduct of the analysis. A debate on port operations is discussed in chapter 5.

The research findings and discussions are discussed in chapter 6. Next, it addresses the topic of outputs and inputs. Findings from the particular aims of the research are then introduced and debated. Descriptive as well as inferential statistics are used in doing so. Relevant literature discussed in chapter two is integrated into parallel to the discussions to allow comparative and pattern comparisons of key research results and provide a back-stop for the confirmation of study results. Finally, Chapter 7 outlines key outcomes, outlines important policy implications and recommendations, explores alternative research paths, and concludes the study.

1.12 Summary

This chapter presented the introduction and background of the study, including the objectives and the problem statement. Having presented this introductory chapter, the scene is set to present the background overview of the SACU ports. This is presented in the next chapter.

CHAPTER TWO

SACU PORTS OVERVIEW

2.1 Introduction

This section reviews SACU ports history, and marine craft. There are ten (10) SACU ports namely, Richards Bay, East London, Ngqura, Port Elizabeth, Mossel Bay, Cape Town, Saldanha Bay, Walvis Bay, and Lüderitz. Lastly, this section ends with a summary of this chapter.

2.2 SACU Ports Historical Overview

Throughout history, the industrial dynamism of many cities has been linked to their ports, which play vital roles as job hubs and trade exchanges with larger global business systems with significant economic impacts on local economies (Fujita and Mori, 1996). Ports occupy valuable land near other urban activities; they are a source of economic opportunity, but they can also be sources of conflict (Abdullah, Ahmad, Shah and Anor, 2012). Each port serves and competes for a share of the traffic generated in its hinterland and the broader market area, consisting of ports connecting to other ports around the world and their hinterlands (Dunford and Yeung, 2009).

Although globalization has differentially influenced ports around the world, the rise of containerization has also affected the function and location of ports and activities within them (Lee and Chao, 2009). These mechanisms have helped to contribute to a scenario in which infrastructural, socially, and institutionally, seaport gateways are gradually isolated from the city-regions that host them (Hall, 2007). The complexities of conventional ports and port societies have changed significantly owing to new port technologies (Tiesnese, 2012). This section of the study gives a history of the ports and towns or cities these ports are situated

2.2.1 Port of Richards Bay

The Port of Richards Bay was constructed by Transnet Port Terminals (TPT) (then Portnet) in the early 1970s, according to Fair and Jones (1991). The harbour included four clean- or general-cargo quays (the consolidated terminal) and two private bulk-coal quays when it was officially opened in 1976. It was dredged to handle ships in the 150,000 deadweight tonnage (DWT) range and was linked by a mostly purpose-built rail path of 525 km to the interior coalfields (Fair and Jones, 1991). There have also been many infrastructural additions, including the extension of the privately-owned Richards Bay Coal Terminal (RBCT), which now has four quays, and the addition to a private chemical terminal of four dry-bulk terminals that handle a number of minerals and fertilizers (Jones and the Fair, 1991). It is important to remember that much of the capital spending in the port of Richards Bay is committed to various types of goods (Hall, 2000). In comparison, the port's general cargo capacity is limited. For example, while the port can transfer containers from the general cargo terminal, there is no dedicated container handling facilities at the port (Hall, 2000).

2.2.2 Port of Durban

Maharaj and Mather (2014) stated that Natal became a British Colony in the 1840s and it became clear that the importation and sale of goods via the port of Port Natal in Durban (D'Urban as it was originally named) would be provided for the colony to prosper. The British Government intended to expand the Port Natal harbour, but this was stopped for some time by financial restrictions, the gross revenue from the colony was just £ 3100 in 1846 (Maharaj and Mather, 2014). Due to the sand bar and sandbanks at the estuary mouth, obtaining access to the protected estuary in which Port Natal port was located was limited. There was just 1,95 meter (m) of draught at high tide in March 1850 (Maharaj and Mather, 2014). Port engineers worked on the issues of the sand bar around the port entrance, which seriously restricted ship draught and the risk of maritime traffic, and many schemes were introduced from the 1850s to the early 1900s (Barnett, 1999) cited by Maharaj and Mather (2014).

Maharaj and Mather (2014) concluded that the "battle of the bar" had been fought by the late 1930s, and with dredgers still holding the entrance approach at a depth of 13 m, vessel width and size began to gather traction. The port and the community also expanded in the second half of the 19th century, unregulated by land limitations until the mid-20th century (Maharaj and Mather, 2014). Shelter from the winter storms was created by the massive natural estuary that created a natural bay surrounded by a large dune/bluff to the south. The port and town had now entered a situation where difficulties began to occur and harmed the other party (Maharaj and Mather, 2014). The structural arrangements in place worsened this situation.

The Port of Durban has always been part of a national department, and since its creation in the mid-1800s, the Borough and later the City of Durban has been under municipal jurisdiction (Maharaj and Mather, 2014). Not unexpectedly, both organisations have different priorities. The Port needed to increase cargo volumes through the quay while lowering prices, while the City wanted full economic gains for residents and the local sector while balancing transport flows and reducing congestion at the same time (Maharaj and Mather, 2014). The relationship between the City and the Port was at one time rather adversarial, largely based on the attitudes of the two biggest economic leaders in the Port and the City (Horwood, 1969). Each of these people were members of Scottish tribes that in the 16th and 17th centuries had waged war on each other. The "war" continued until these two personalities retired with few cooperative outcomes (Horwood, 1969).

The City and the Port began working together in the post-1990 period, but also had a difference of opinion on matters dependent on their mandates (Horwood, 1969). Within their territory, the port authorities also prepared thus missing the impacts beyond their land boundaries. This was attributed to the administrative hierarchy, the administration, and planning of the port at the national level, while the services rendered by the local government (water, power, highways, and electricity) strengthened the assumed dominance of the national departments when none could necessarily dominate over the other but should be seen as complementary and harmonized (Horwood, 1969).

2.2.3 The Port of East London and Port Elizabeth

The report prepared by Transnet Port Terminals (2020) for the Eastern Cape Transnet Port Authority reported that the mouth of the Kowie River in Port Alfred was established as a port and terminal site in 1825. This was discarded after the mouth of the river was discovered to be too shallow and vulnerable to silting. Construction began in 1872 on the main harbour, and construction on the breakwater began in 1873 (Transnet Port Terminals, 2020). Port Rex was the original name. Steve Biko's rare double-decker bridge (road over rail) crossing the Buffalo River was completed in 1935 and remains the only bridge of its kind in South Africa to this day. The grain elevator on the West Bank, established in the 1970s, was the largest in Africa (Transnet Port Terminals, 2020).

In 1825, the port was granted official port status, with the appointment of a harbourmaster and customs collector a year later (Inggs, 1986). The Korsten suburb is named after Hollander Frederick Korsten, who arrived in Algoa Bay in 1812 and quickly became the area's largest merchant and had a fleet of ships (Inggs, 986). A surfboat service was provided in 1836 for cargo and passenger handling, with the first quay completed in 1837. By 1877, the busiest South African port had been Port Elizabeth (Transnet Port Terminals, 2020). However, only in 1933 was the Charl Malan Quay (present container terminal) established, by which time Cape Town and Durban had taken away most of the traffic because of their superior facilities (Transnet Port Terminals, 2020). For Port Elizabeth, the records go back as far as 1799, with the building of Fort Frederick and the establishment of a British garrison to protect shipping operations in Algoa Bay (Transnet Port Terminals, 2020). The first recorded exports were in 1812 of sheep and butter to Mauritius.

The history of the port terminal in East London began in 1848, according to the Transnet Port Terminals report (2018), when the British military agreed to construct a port in King Williams Town to supply the garrison. Therefore, both ports trace their history back to the Border Wars and the procurement of military arms, provisions, and staff. The direct connections to the major trading routes of the time have opened up business opportunities. In the 1870s, the early Kimberly diamond rush depended on mining equipment transported from East London, while in the 1840s, Port Elizabeth witnessed a wool boom, the 1880s ostrich feather boom, and the early 1900s mohair boom (Transnet Port Terminals, 2020).

Port Elizabeth (then the 'Liverpool of the Cape') was the largest port in the country between 1820 and 1870, feeding an economy dominated by wool exports, and where inland travel relied on the ox-wagon (Transnet Port Terminals, 2020; Huisman, 1971). The historical relations between the terminals and the rest of the world and sub-region go far - the first gold and diamond shipments from South Africa were handled by the Port Elizabeth terminal (Transnet Port Terminals, 2020). There is still a tradition of being at the forefront of technology - the first ship-to-shore communications from the nation were exchanged between the port of Port Elizabeth and the Castle of Armadale in 1921. Today, Ngqura is Sub-Saharan Africa's most advanced deep-water port (Transnet Port Terminals, 2020).

2.5. Terminals and The Apartheid Struggle

It was mentioned in the Transnet Port Terminals (2020) report that a 300-year war of rebellion by the people of the Eastern Cape against colonial rule first and then against apartheid is also expressed in the history of the ports. The ports and terminals of Port Elizabeth and East London were both established to assist the British military during the Frontier Wars between 1779 and 1879. (Transnet Port Terminals, 2020).

During the Second Boer War, Port Elizabeth was also an important staging point for troops, horses, and supplies going to the front by train (Transnet Port Terminals, 2020). The ports and their terminals were widely marginalized during the apartheid period because of the heavy support for the region's struggle. When the Transkei and Ciskei homelands were established, East London became a contentious port (Transnet Port Terminals, 2020). The Transnet Port Terminals (2020) report claimed that greater control for nominally autonomous homelands would have been assured by providing access to the sea. Mkhonto Wesizwe soldiers held an enclave extending from East London to King Williams Area Town, fearing that the port would provide an entry point for the African National Congress (Transnet Port Terminals, 2020). The remaining legacy is the four-lane highway between the two, which was developed as a military route.

Due to foreign sanctions, volumes across the terminals in the two ports have also decreased, according to Hockly (1948), and their value as drivers of the local economy has decreased. Ford's decision to withdraw from South Africa and the eventual relocation of the Ford assembly plant in the mid-1980s had a lasting impact on the economy of Port Elizabeth (Hockly 1948). Cargo has relocated to Durban, meaning no investment has been made in the ports and the port. Port Elizabeth had only a single ship-to-shore container crane as early as the mid-1990s. Hockly (1948) noted that the terminals once again came into their own with the lifting of penalties in 1994. The volumes handled by the facilities and the decision to construct Ngqura, Africa's first deep-water port incorporated with a special economic zone, represent the rapid growth in South Africa's trade with the rest of the world (Transnet Port Terminals, 2020).

2.6. Terminals and The Motor Industry

Hockly (1948) postulates that the South African motor industry, which has its origins in the province, is inextricably connected with the legacy of the Eastern Cape and its terminals. For more than 90 years, Volkswagen South Africa, General Motors South Africa, and Ford South Africa have imported and exported through the Port Elizabeth terminal (Hockly 1948). Ford, which began manufacturing cars in 1923, was the largest. In 1926, General Motors South Africa produced brands such as Chevrolet, Oakland, GMC trucks, Buick, Pontiac, Oldsmobile, and Vauxhall (Transnet Port Terminals, 2020).

South Africa Motor Assemblers and Distributors (SAMAD) began assembling vehicles in Uitenhage in 1949, recorded by Transnet Port Terminals (2020). Two years later, the first Beetle (car) rolled off the line in August 1951. In 1956, Volkswagen South Africa purchased ownership of SAMAD (Transnet Port Terminals, 2020). Today, the Port Elizabeth car terminal is helping to pay thousands of workers in the Nelson Mandela Bay Metro, while the Port Elizabeth and Ngqura container terminals are responsible for importing and exporting car components (Africa Ports, 2020). The three suppliers sell a variety of car components to destinations around the world, including engines and catalytic converters (Transnet Port Terminals, 2020).

The East London Mercedes-Benz car assembly began in 1958 at what was then the Car Distributors Assembly (CDA). Mercedes-Benz secured a 76% interest in the manufacturing plant in 1992 and continues to manufacture award-winning Mercedes-Benz C-Class vehicles for export and local markets (Transnet Port Terminals, 2020). The plant is served by the first multi-level car terminal built for the region.

2.6.1. Manganese

The report by Transnet Port Terminals (2020) states that Manganese exports began in May 1963 via Port Elizabeth. It was agreed to construct the terminal because the increasing volumes could not be coped with by the rail line and the port of Durban. In the Postmasburg/ Hotazel sector, Port Elizabeth is even closer to the manganese mines by rail. Transnet Port Terminals is in the process of constructing a new facility in the Port of Ngqura, freeing up the area used by the current terminal, to compose a new chapter in the history of the Eastern Cape port terminals (Transnet Port Terminals, 2020).

2.2.4 Port of Ngqura

The construction of the port was approved by the South African parliament in 2002, according to Transnet Port Terminals (2018). It is the eighth port, after the ports of Durban, Richards Bay, East London, Port Elizabeth, Mossel Bay, Cape Town, and Saldanha Bay, to be served by Transnet Port Terminals. Caroline Ndevulana, the quay crane operator, made history in October 2009 when she unloaded the first container from the first commercial vessel at the Ngqura container terminal (Transnet Port Terminals, 2020).

The Port of Ngqura has an eastern breakwater of 2.7 kilometres (the longest in South Africa) and a secondary breakwater of 1.1 kilometres on the western side of the water (Africa Ports, 2020). It will have a total of 32 quays extending further up the Coega River valley and along the south-western coast when the Port of Ngqura is completely built (Africa Ports, 2020). Work has begun on new terminals for fuel and manganese to replace those in Port of Port of Elizabeth. The principal transhipment centre for the South African port system is Ngqura. In 2012/13, according to Drewry Consultants, Ngqura was the world's fastest-growing container terminal (Transnet Port Terminals, 2020).

The newest of the Eastern Cape ports, Ngqura, has become an important part of the province's rich maritime heritage (Transnet Port Terminals, 2020). After commercial shipping operations began in 2009, it has given Eastern Cape farmers and the agriculture sector with a new gateway to international markets. Positioned as the region's hub port, Ngqura has drawn the world's major shipping lines, connecting the region to all the world's major markets (Transnet Port Terminals, 2020). As a result, the citrus industry has been able to extend into new markets such as Canada, and parts from all over the world can be sourced by suppliers located in the Eastern Cape (Transnet Port Terminals, 2020).

2.2.5 Port of Mossel Bay

Mossel Bay became a rest stop after its discovery in 1488, where explorers and travellers would replenish their water and food supplies, giving rise to trade between the explorers and the Khoi inhabitants (Brand, 2014). On 8 July 1601, the town got its name when Paulus van Caerden could only find mussels at the point where his provisions were replenished). In 1733, the first evidence of European settlement, on the Hartenbosch estate, was recorded (Brand, 2014).

A permanent settlement was established, according to Muller (1981), where the central business district (CBD) is today in 1787 and Mossel Bay began to develop as a Southern Cape and Karoo port. Instead of the difficulties faced by local farmers transporting their grain to Cape Town, its residents were mostly fishermen, and granaries were built during the same year. The following year, the first shipment of wheat left the Port of Mossel Bay, but South Easter and Agulhas Bank put the wheat trade at risk and finally failed (Muller, 1981). Private business trading started in 1792 and fisheries were developed and the town began to develop economically with the removal of prohibitions on internal trade (Muller, 1981).

Mossel Bay developed from a traditional fishing community to an administrative centre, supplying local people and the nearby agricultural communities with services and goods (Mossel Bay Municipality, 2020). In 1852, Mossel Bay obtained municipal status and consisted of 30 houses, which expanded by 1865 to a population of 600. (Mossel Bay Municipality, 2020). In 1854, on the east side of the bay, the first stone quay was built, and in 1860, another wooded quay. Much of the stone houses were designed from 1870 to 1920. (Mossel Bay Municipality, 2020).

Mossel Bay has seen a seasonal influx of holidaymakers since the early 1900s, giving birth to seaside camping sites and caravan parks. The ostrich feather boom in 1905 led to increased development in the area, according to the Mossel Bay Municipality (2020), allowing the port to develop as well. This was also the year that the rail connection to Cape Town was opened and there were also rail connections to the north in 1907. Before the fall of trade in 1913, when exports of raw materials such as ochre became more dominant, Ostrich feather was the main export (Mossel Bay Municipality, 2020).

Only a few decades later, with steady growth, the Port of Mossel Bay was considered the fifth most important port in South Africa. In 1980, the exploration and development of offshore petroleum gas fields was a stimulus for the town of Mossel Bay to develop.

Steenkamp (2015) notes that the port was used for several maritime-related purposes during those early years. It was free to the public and the train used to travel to the station, centrally located in the port premises. An important occasion took place in 1988 when a festival that took place over 9 days marked the 500th anniversary of Diaz's arrival in Mossel Bay (Mossel Bay Municipality, 2020).

Furthermore, Mossel Bay has a special role in the maritime history of South Africa as this was the first recorded location used every day by European seafarers sailing down the South African coast to the East (Africa Ports, 2020). One of Mossel Bay's most famous attractions is the Post Office Tree, where seafarers from centuries ago posted home letters using a cleft in an ancient tree as a post-box. This was a result of ships calling every day for watering at the Port of Mossel Bay and other uses (Africa Ports, 2020).

The port of Mossel Bay, halfway between Cape Town and Port Elizabeth, is the smallest of the commercial ports along the coast of South Africa. The port is mainly used for the fishing industry (Africa Ports, 2020). To support the synthetic fuel industry, two offshore mooring points inside the port limits are used. A total area of 18 hectares is used by the port, of which the fishing industry is the main customer. Different plans were proposed in the past for the construction of the inland sector of the port but were discarded for many reasons (Africa Ports, 2020).

2.2.6 Port of Cape Town

The Port of Cape Town is referred to by Marshall (1940) as the Table Harbour, the Fairest Cape, the Cape of Hurricanes, the Mother Island, the Cape of High Hope, which he finds to be an indicator of what to expect from all these terms. Marshall (1940) argues that Cape Town competes as the most popular port in Africa with Alexandria for its prestige and is undeniably one of the most beautiful ports in the world with a majestic Table Mountain backdrop surrounded by the rough peninsula and the vast mountainous hinterland of Africa. The port is located on one of the busiest trading routes in the world and will, for that sole reason, therefore have geographical and economic importance (Marshall, 1940).

Marshall (1940) states that the Dutch founded Cape Town on their long voyages to and from the Dutch East Indies on 6 April 1652, when Jan van Riebeeck arrived in Table Bay to set up a victual station for ships of the Dutch East India Company (VOC). Slaves were brought from Madagascar and Indonesia when the new settlement was unable to provide enough labour to build the town (Marshall, 1940). Up until the British took over, the settlement was under intermittent Dutch control. The port has progressed gradually over the years and now consists of two 'docks'-the outer Ben Schoeman Dock on which the container terminal is located, and the older inner Duncan Dock with the multipurpose and fruit terminals, as well as a dry dock, repair dock, and tanker basin (Marshall, 1940).

During the Seven Years' Wars in the mid-1700s, British and French ships were often called to the port. British tourists have had started naming the city "Cape Town"(Marshall, 1940). For its strategic advantage, the British tried to capture the Port of Cape Town in 1781, however, a French fleet formed a garrison to support the Dutch defenders (Marshall, 1940). The port of Cape Town has undergone a surge of growth and renovation since the French arrived (Ports and Ships, 2020; Marshall, 1940).

The British seized possession of several Dutch colonies when the Netherlands was invaded after the French Revolution and the Napoleonic Wars, according to Worden (1994). The Port of Cape Town was taken over by Britain in 1795, but it was returned to the Netherlands in 1803. (Worden in 1994). In 1800, despite its development, the City of Cape Town had only 200 houses and it was named De Kaapa (The Cape). The British captured the town at the Battle of Bloubergstrand in 1806 and, with the Anglo-Dutch Alliance, assumed permanent rule in 1814. The new British Cape Colony rapidly expanded during the 1800s (Worden, 1994).

The World Port Source (2020) shows that in 1834 the slaves in the city were freed, but they had to work for four years as indentured servants. By 1840, about 20 thousand people lived in the town, and the municipality was established. Up until 1867, the City of Cape Town had a full city council. (in 1994, Worden). Since 1881, several new immigrants have settled in the local area. Roads have been improved, and an electric tramway has been put into operation. The need for fresh water supplies and waste disposal has continued to consolidate urban centres (Worden, 1994). The town of Greater Cape Town was founded in 1913.

Diamonds were found in Griqualand West in 1869, and gold was discovered in the Witwatersrand in 1886. (Worden in 1994). With these discoveries, many new immigrants were introduced to South Africa. At the turn of the century, the Second Boer War ended in a British victory and the possession of two former Boer republics (Worden, 1994). The British joined the Cape Town colony with the defeated republics and their Natal colony to create the Union of South Africa with the City of Cape Town becoming a capital (Worden, 1994). Worden (1994) indicates that significant growth was seen in Cape Town. The City of Cape Town was expanded in the central business district, new industrial sites were built and modern buildings appeared (Worden, 1994).

The 1948 elections brought to power the National Party and its policy of apartheid (racial segregation) was implemented in South Africa (Worden, 1994). Areas were classified by race, and areas that had been multi-racial were eliminated or razed. In District Six, a white-only town was declared and 60 thousand inhabitants were forced out before all the infrastructure was demolished. The Cape area is a "Coloured labour" location (Worden, 1994).

Worden (1994) states that Cape Town did not have extreme racial barriers for much of the 20th century, unlike other towns in South Africa. In 1972, under national law, voters protested the removal of non-whites from the voter rolls. In 1989, nearly 40 thousand residents entered a nonviolent protest against apartheid. (1994, Worden).

Many anti-apartheid protestors found their homes in Cape Town Harbour, and many political inmates were held in the neighbouring Robben Island jail (Worden, 1994). Nelson Mandela gave his first speech from Cape Town City Hall in 1990, just hours after being released from prison, starting a new period for South Africa (Worden, 1994).

South Africa's first democratic referendum was taken in 1994 and the future has changed forever. Since then, the Port of Cape Town economy has expanded dramatically, largely because of increased tourism and a boom in real estate (Cape Town History, 2020).

2.2.7 Port of Saldanha Bay

Saldanha Bay port is a commercial and bulk cargo provider in South Africa, northwest of Cape Town (Welman and La Ferreira, 2016). According to Welma and La Ferreira, the city of Saldanha Bay has a relatively large production sector and it is a well-known harbour area (2016). The region's economy depends on steel production, fishing, tourism, and the port industry. In 1976, the port was widened and deepened to accommodate bigger vessels. The construction of a multipurpose cargo terminal made it possible to import oil and export high-value iron-ore, lead, and copper oil during the 1980s (Dunford and Yeung, 2011).

Saldanha Bay was identified as one of the priority growth regions for the presidency in 2011 (Welman and La Ferreira, 2016) and was formally declared an industrial development zone (IDZ) in 2013. (Welman and La Ferreira in 2016). Operation Phakisa Strategy was initiated by the government of South Africa in July 2014 to unlock the economic potential of the ocean regions of South Africa (Welman and La Ferreira, 2016). The so-called 'blue economy' of which the Port of Saldanha Bay is considered to be part, seeks to build employment and alleviate poverty in the country's West Coast region.

2.2.8 Port of Walvis Bay

The Port of Walvis Bay (PWB), once known to be Namibia's only deep-water port, has a rich and long-standing tradition as far back as the 1800s. The colonial powers were of special interest, considering the strategic and geographical position of the port (Bergstrom, 2008). The Bay was annexed by the British on behalf of the Cape Colony in 1878, as it was historically known, according to a report prepared by SIDA (1990) cited by Amakali (2017). As part of the mandated territories of 1922, Walvis Bay was administered under the South West Africa Relations Act, No. 24 of 1922. (Amakali, 2017).

However, as part of the South African Cape Province, Walvis Bay was reintegrated in 1977, an initiative harshly condemned by the Security Council, which adopted resolutions (UNSCR 432) and (UNSCR 435) advocating the reintegration of the bay as part of Namibia's jurisdiction (Bergstrom, 2008). The PWB was run by South Africa Transport Services (SATS) before Namibia's independence (Bergstrom, 2008). SATS employees managed onshore assets, while private firms controlled and monitored stevedoring and a fraction of the storage facilities (Bergstrom, 2008).

Bergstrom (2008) further shows that South African ports, which was an autonomous business company under SATS, controlled the economic activities of the Port of Walvis Bay. The port was fully constructed with harbour craft, container handling cranes, and storage facilities.

2.2.9 Port of Lüderitz

Port of Lüderitz occupies the southern portion of the globe and has connections to markets in the South African province, Northern Cape (Africa Ports, 2020). The Port of Lüderitz is the second port of Namibia, named after a German merchant, Adolf Lüderitz, and was 'discovered' by Europeans in 1487 when the Portuguese explorer Bartolomeu Dias arrived on his 'epic discovery journey' (Africa Ports, 2020). The town of the same name was able to reinvent itself as a tourist attraction, taking full advantage of Germany's unique architecture and other colonial sights (Africa Ports, 2020). Africa Ports (2020) indicates that while tourists visiting other parts of Namibia may come to witness the extraordinary wildlife as part of a safari tour, there is often a very different agenda for those staying in Lüderitz. Many of those who come for a trip to this location come to enjoy this calm port zone's security. Since 1995, investments have improved port facilities and Lüderitz is now addressing new maritime traffic as well as the offshore industry's needs, including the diamond mining and fishing industries (Namport, 2019).

2.3 Namibian Maritime Industry

The Namibian Ports Authority ('Namport' or 'Authority') is a public company created by the 1994 Ports Authority Act of Namibia (Act 2 of 1994). Namport is referred to as 'Gang' along with its subsidiaries, Elgin Brown & Hamer Namibia (Pty) Ltd, Namport Land Holdings (Pty) Ltd, and Lüderitz Boatyard (Pty) Ltd and Namibia e-Trade Facilities (Pty) Ltd. (Namport, 2019). Namport manages the Port of Walvis Bay and Lüderitz from its headquarters in Walvis Bay. The Port of Walvis Bay is situated on the southwest coast of Africa and acts as a simple and fast transport route linking Southern Africa, Europe, Asia, and the Americas. Situated 254 nautical miles south of the Port of Walvis Bay, the Port of Lüderitz serves the southern regions of Namibia and offers access to South Africa's Northern Cape markets (Namport, 2019).

Walvis Bay is a natural gateway for foreign trade, strategically positioned halfway down the coast of Namibia, with easy access to main shipping routes (Figure 2.1 shows the Namibian trade routes for Namibia). The Port of Walvis Bay is Namibia's largest commercial port, handling approximately 5 million tonnes of cargo and receiving between 1,800 and 2,500 vessel calls each year. The Port of Walvis Bay is a port that is clean, productive, and world-class. Temperate weather patterns are observed during the year and no weather delays are induced. Its world-class infrastructure and facilities ensure efficient and safe handling of cargo (Africa Ports, 2019).

Figure 2.1 Namibian Trade Routes

Source: TNPA (2019)

Within the harbour, the deep-water anchorage is accessible and is secured by the natural bay and by Namport. The port complies with the Security Code of the International Ship and Port Facility Security Code (ISPS). Namport has gradually strengthened its cargo handling facilities to cope with even higher cargo throughput levels and remains committed to infrastructure growth, in line with its goal of delivering safe and reliable port and related services (Namport, 2019).

Container arrivals, exports, and transhipments as well as bulk and breakbulk quantities of different goods are handled by the Port of Walvis Bay. Namport covers a broad variety of markets, including the crude, salt, mining, and fishing industries. They export both bulks and bagged salt from the Port of Walvis Bay. In the southern regions of Namibia and north-western South Africa, the Port of Lüderitz serves mines with imports and exports of mining materials. It is also an important basis for the local fishing industry (Amakali, 2017).

2.4 South African Maritime Industry

In the South Atlantic and Indian Seas, trade routes serviced by the world's biggest shipping lines travel through the South African coastline. Approximately 96% of South Africa's exports are shipped by sea and the eight commercial ports are trading routes between South Africa and its South African allies, as well as catering facilities to and from Europe, Asia, the Americas, and Africa's eastern and western coasts (Transnet National Port Authority (TNPA), 2019). There are eight commercial ports in South Africa. The KwaZulu-Natal ports are the ports of Richards Bay and Durban; the East London, Port Elizabeth, and Ngqura are ports of the Eastern Cape province; and the Mossel Bay, Cape Town, and Saldanha Bay ports are ports of the Western Cape province (Southern African Ports can be seen in Figure 2.2) (TNPA, 2019).

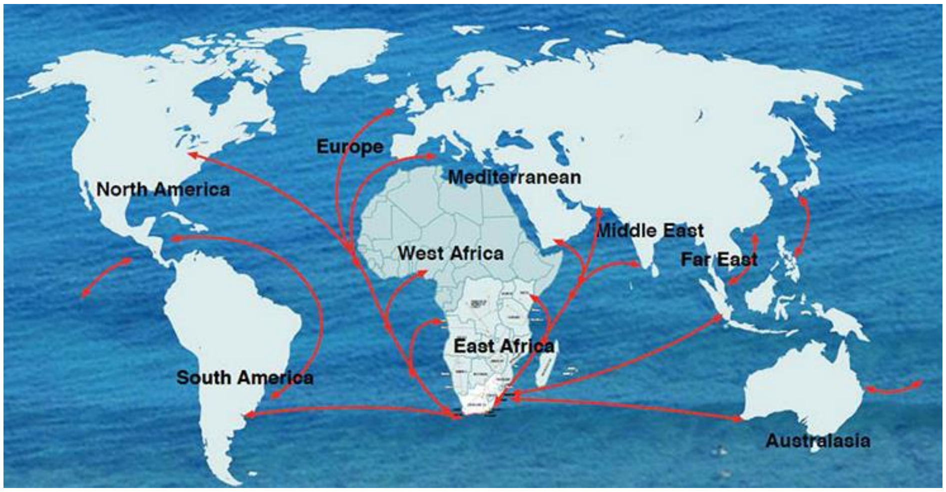
Figure 2.2 Southern African Ports

Source: Maritimesa (2020)

The South African State-owned Transnet National Ports Authority (TNPA) operates the ports as a landlord, while the South African State-owned Transnet Port Terminals (TPT) are the main provider and presence in the port chain (TNPA, 2019). Both container and RoRo terminals are operated and maintained by TPT, while the private sector, except for the Richards Bay Coal Terminal (RBCT) located in the Port of Richards Bay, is mainly involved in the service of multipurpose terminals (TNPA, 2019). The Port of Ngqura, South Africa's newest port, was completed in 2006 and is located in the Eastern Cape off the coast of Port Elizabeth (TNPA, 2019).

The strategic position of Transnet Port Terminals in the South African economy is to promote the productive movement of imports, exports, and transhipments through its cargo terminal operations (Motau, 2015). Port Terminals guarantees year-round connectivity between the South African economy and other key business partners in the country and the rest of the world through its strategic role in operating these key business centres (TNPA, 2019). As a primary trade facilitator for holistic industry innovation between South Africa and the global economy (Figure 2.3 shows international trade routes), TPT is continually seeking to increase the quality and reliability of its activities to minimize the cost of business (TNPA, 2019).

Figure 2.3 International Trade Routes



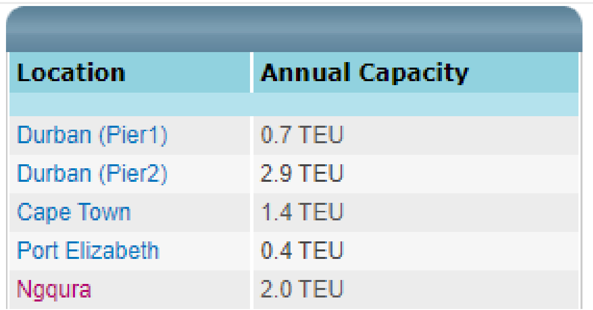
Source: TNPA (2019)

TPT offers container processing services, from rail lines, cargo forwarders, and cargo operators, to a wide variety of customers. Four main market divisions are categorized into activities, namely: containers, dry bulk, break-bulk, and automobile. The division runs 16 terminals with 68 quays in seven ports along the coasts of South Africa (SAMSA, 2018)

2.4.1 Container Terminals

Container terminals in the ports of Durban, Ngqura, Port Elizabeth, and Cape Town are run by TPT (TNPA, 2019). The total annual capacity of the division currently exceeds 6 million 20-foot equivalent units (TEUs) (Figure 2.4 shows container terminals capacity). The container terminals in Durban and Cape Town are running close to capacity, but proposals are in progress to expand capacity at these ports (TNPA, 2019).

Figure 2.4 Containers



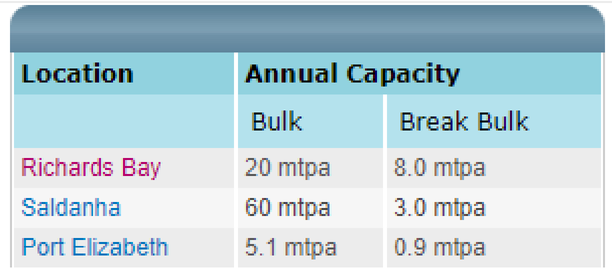
Location	Annual Capacity
Durban (Pier1)	0.7 TEU
Durban (Pier2)	2.9 TEU
Cape Town	1.4 TEU
Port Elizabeth	0.4 TEU
Ngqura	2.0 TEU

Source: TPT (2020)

2.4.2 Dry Bulk Terminals

Operations within the bulk sector are marked by the handling of dry bulk goods through a network of conveyor belts, tipplers, stackers, reclaimers, and ship loading and unloading devices (TNPA, 2019). Port Terminals handles mineral bulk commodities at ports in Richards Bay, Port Elizabeth, and Saldanha Bay (Figure 2.5 shows annual mineral bulk capacity) and handles agricultural bulk commodities at ports in Cape Town, Durban, and East London (Figure 2.6 shows annual agricultural bulk capacity) (TNPA, 2019).

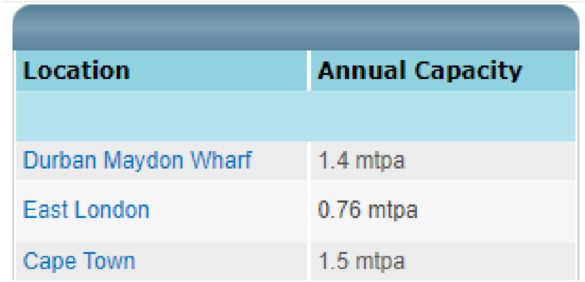
Figure 2.5 Mineral Bulk



Location	Annual Capacity	
	Bulk	Break Bulk
Richards Bay	20 mtpa	8.0 mtpa
Saldanha	60 mtpa	3.0 mtpa
Port Elizabeth	5.1 mtpa	0.9 mtpa

Source: TPT (2020)

Figure 2.6 Agricultural Bulk



Location	Annual Capacity
Durban Maydon Wharf	1.4 mtpa
East London	0.76 mtpa
Cape Town	1.5 mtpa

Source: TPT (2020)

2.4.3 Break-Bulk Terminal

Transnet Port Terminals, by its break-bulk activities in multi-purpose terminals in all seven ports, handles coal, lumber, granite, irregular and mission cargo, and other goods (TNPA, 2019). In some cases, conventional bulk cargo can be handled at break-bulk facilities using a skip process (Break-Bulk annual capacity as shown in Figure 2.7).

Figure 2.7 Break Bulk

Location	Annual Capacity
Durban Ro-Ro	0.4 mtpa
Durban Maydon Wharf	1.2 mtpa
East London	0.21 mtpa
Cape Town	1.5 mtpa
Saldanha	3.0 mtpa

Source: TNPA (2019)

2.4.4 Automotive Terminal

At the ports of Durban, East London, and Port Elizabeth, Port Terminals runs automobile terminals. These facilities accommodate several vehicles that are pushed on and off the ship (TNPA, 2019). Port Terminals has embarked on a 'Top Five in Five' campaign to ensure that the division by 2022 becomes one of the top five global operators of port terminals. This will be done by cultivating a community of high success which will be supported by a clear, unifying vision of extending the service of the division (TNPA, 2019).

2.5. SACU Port Terminals

SACU port terminals include container terminals, bulk terminals, automotive terminals, and passenger terminals.

2.5.1. Container Terminals

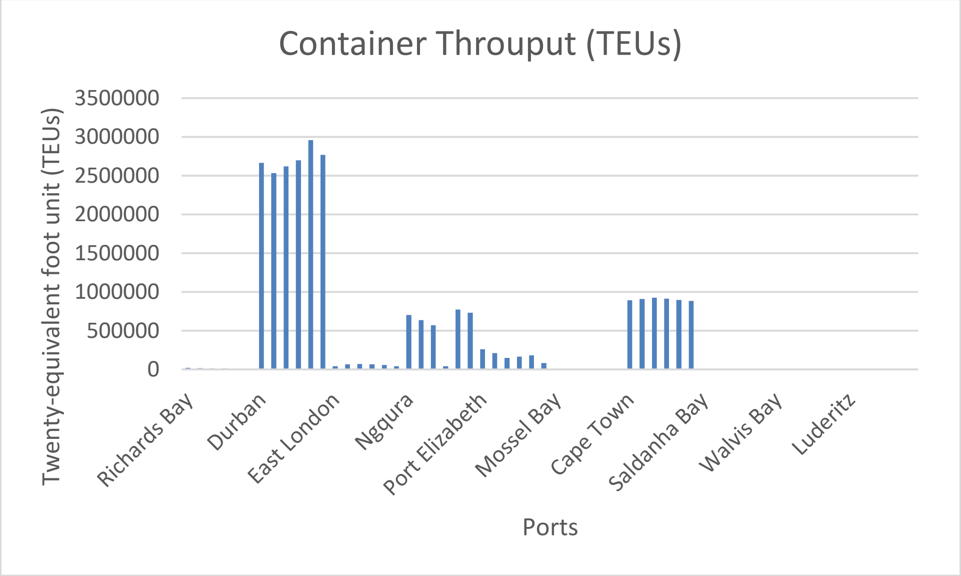
In South Africa, there are four major container ports, all built as a multiple gateway scheme, consisting of Durban (main port), Cape Town, Port Elizabeth, and Ngqura. The estimated capacity of the South African container ports is 7.4 million TEUs, with the total amount handled by containers reaching approximately 4.64 million TEUs in 2014, marking a rise of 5.4 percent from 4.4 million TEUs in 2013. (Motau, 2015). The Port of Durban handled 65 percent of the overall volume out of the total volume throughput, with Cape Town handling 19 percent and Port

Elizabeth/ Ngqura handling a combined 14 percent of the total volume. (Transnet Integrated Report, 2014; Motau, 2015). Also, the largest port in Namibia is the Port of Walvis Bay, which handles all of the container traffic in Namibia. Due to their position on the world trade routes, the Port of Walvis Bay and Ngqura are planned to be transhipment hubs (Transnet Integrated Report, 2014; Namport, 2017).

According to figure 7, the Durban Container Terminal (DCT) handles the most containers this corresponds with the port since it is the fourth-largest container terminal in the Southern Hemisphere. According to TNPA (2020), for the calendar year 2019, the Port of Durban handled 2,769 million TEUs of containers while in 2014 it handled 2.664 million TEUs of containers.

A total amount of 733 550 TEUs of containers, was handled by the Port of Ngqura in the 2019 calendar year, down considerably from the 7, 748 million TEUs reported in 2018. While some of this decline is attributable to the economic crisis affecting South Africa and also by the go-slow that took place in the port (Africa Ports, 2020). The competitor for this port, the Port of Walvis Bay handled 144 109 TEUs in 2018, a decline from 176 335 TEUs that was reported in 2018 (Africa Ports, 2020).

Figure 2.8 Container Throughput



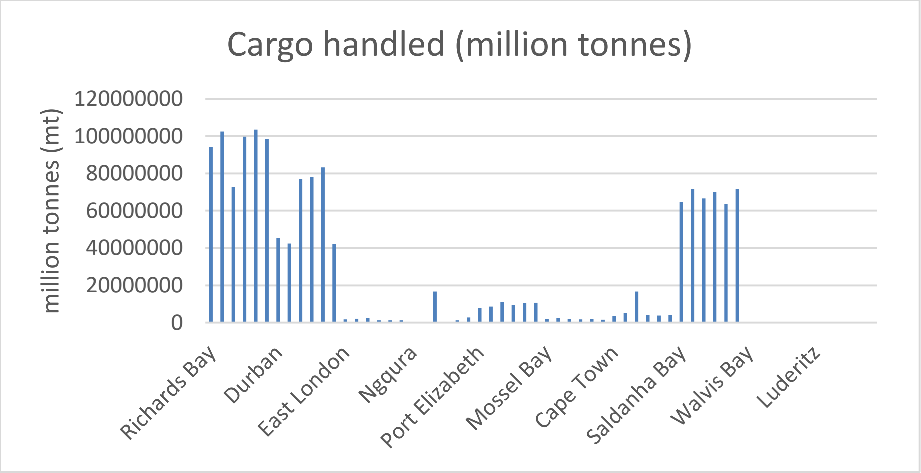
Source: own computation

2.5.2. Bulk Terminals

Via its break-bulk activities in multipurpose terminals at all seven ports, bulk terminals maintain coal, steel, iron ore, wood, granite, project cargo, irregular, and other commodities (TNPA, 2019). In certain cases, at break-bulk terminals using a skip service, conventional bulk cargo can be handled. The Port of Richards Bay (coal exports) and the Port of Saldanha Bay are ports that specialize in bulk cargo (iron ore for exports). However, Port of Durban, East London, Port Elizabeth, Cape Town, and Walvis Bay do handle bulk cargo, but they are more of multipurpose ports since they have other different terminals inside them such as container terminals or automotive terminals (TNPA, 2019).

From the graph below, the Port of Richards Bay handled 98,561 million metric tonnes of cargo in 2019, while in 2018 had handled 103 550 million metric tonnes of cargo. It corresponds with the port being the largest coal export facility in Africa. The other port that handles most of the bulk cargo, Port of Saldanha Bay handled 63 423 million metric tons of cargo in 2018, in 2019 the port handled 71 555 million metric tons of cargo, a slight increase from the previous year. Most of the cargo handled by the port was iron ore for export.

Figure 2.9 Cargo Handled



Source: own computation

2.5.3. Automotive/RO-RO Terminals

Automotive terminals are at the ports of Durban, East London, and Port Elizabeth. These facilities handle a variety of vehicles driven onto and off the vessel (TNPA, 2019. Besides, Port of Walvis Bay does handle automotive imports and exports, however, it does not have a terminal dedicated to automotive cargo (Amakali, 2017). The car terminal in Durban serves automobile companies such as Toyota and Ford while East London serves Daimler. The car terminal in Port Elizabeth serves Volkswagen and Isuzu (TNPA, 2019.

2.5.4. Passenger Terminals

The Ports that have passenger terminals are the ports of Durban, Cape Town, and Walvis Bay. However, the Port of Port Elizabeth does get ship calls from passenger vessels but it does not have a dedicated terminal.

The Port of Durban has a well-equipped passenger terminal at N-berth on the T-Jetty, for the convenience of cruise ships operating mostly during the summer months between November and May (Africa Ports, 2020). MSC Cruises runs a cruise ship to Mozambique and the Indian Ocean islands destination for full-summer cruising in Durban during the summer of each year (Africa Ports, 2020). The 'inhabitant' cruise ship is the MSC Ensemble for the 2019/20 season. Cruises, like the Pomene MSC cove, are offered between Durban and the Mozambique coast, as well as longer cruises to Reunion and Mauritius and to and from Cape Town (Africa Ports, 2020).

There is a rising number of other cruise companies that run cruises along the Southern African coast, including Phoenix Reisen and Aida Cruises, according to Africa Ports (2020). These and other cruise ships, if possible, will use one or two berths, and often the port will have as many as three cruise ships together at the port. Construction of the long-awaited new cruise terminal outside Point Waterfront at B Berth has started (Africa Ports, 2020).

Africa Ports (2020) believes that the Port of Cape Town is a vital destination for cruise ships, especially those engaged in sailing around the globe, and provides passengers arriving or departing from their cruise with excellent direct airline connections to most parts of the world. Many of the smaller and medium-sized passenger ships, with their added tourist attraction and atmosphere, no longer make use of the world-famous V&A Waterfront and have joined the larger ships that go to the main port along with its strong protection (Africa Ports, 2020).

In addition, Amakali (2017) notes that the rise in the number of cruise liners calling at Walvis Bay Port has contributed to an increase in the tourism industry. A dedicated quay for cruise ships was developed with the construction of the current container terminal. The quay that handles passenger's vessels has a length of up to 300 m, with a draught of -11 meters, according to Amakali (2017).

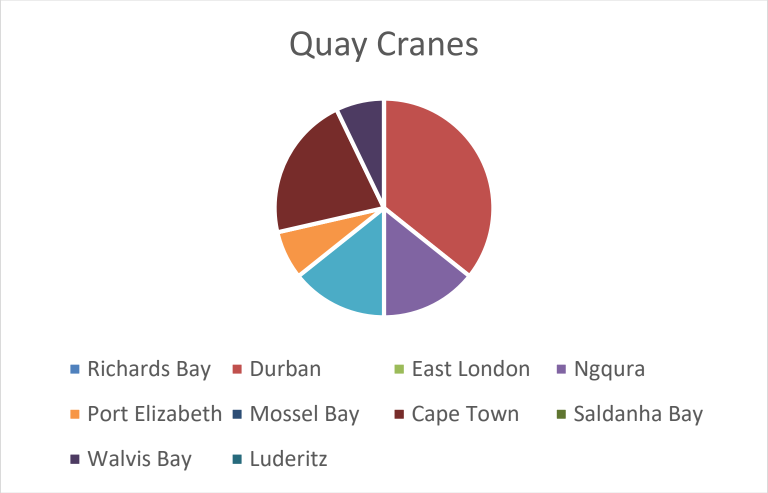
2.6 Port Infrastructure

Infrastructure is the fundamental physical and operational framework required for a community or corporation to work (Munim and Schramm, 2018). The infrastructure of the port is split into two: the basic port and the working port. A marine access channel, which corresponds to the physical capability of the site to handle ship movements, is the essential port infrastructure. Basic ports usually have a port entry, sea locks, defensive work (including breakwaters and shore protection) and can easily enter the port for inland shipping (Munim and Schramm, 2018). Inland port channels and port basins are the operating port facilities. Port service activities include highways, tunnels, bridges, and locks in the port city (Munim and Schramm, 2018). There are also quay walls, jetties, and finger piers for operational port facilities.

2.6.1 Quay Cranes

A quay crane is a type of large dockside portal crane for loading and unloading intermodal containers from container ships at container terminals (Motau, 2015). Quay cranes are a support system that can cross the length of a quay or yard on a rail network (Motau, 2015). Quay cranes are only found in container terminals. In the case of this study, they can be found in the ports of Durban, Ngqura, Port Elizabeth, Cape Town, and Walvis Bay.

Figure 2.10 Quay Cranes



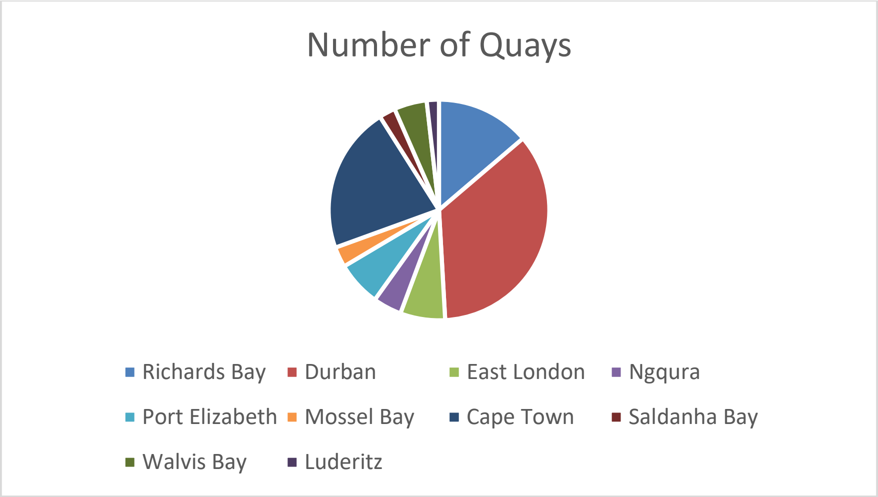
Source: own computation

From figure 10, the Port of Durban has the most quay cranes with 20 quay cranes, this is because the port has two container terminals and it is the fourth-largest container terminal in the Southern Hemisphere. While on the other hand, Richards Bay, East London, Saldanha Bay, and Lüderitz have minimum values of quay cranes of zero (0) this statistic corresponds with these ports because they are not designed to handle cargo that requires quay cranes, it is because there are no container vessels that use that port. Quay cranes are to load and offload containers. An alternative to quay cranes is reach-stackers, they are mostly used by the small ports to handle containers.

2.6.2 Number of Quays

A quay is a long platform beside the sea or a river where boats can be tied up and loaded or unloaded (Hlali, 2017). All ports have quays but they differ in size and functions. A port can have several different quays because they serve a different purpose. Some quays could be used by fishing vessels but they cannot be used by oil tankers or container vessels.

Figure 2.11 Number of Quays



Source: own computation

From figure 11, the Port of Durban has the most quays, it corresponds with the port being the biggest in the SADC region and also handling different types of cargo and The Port of Mossel Bay has the least number of quays.

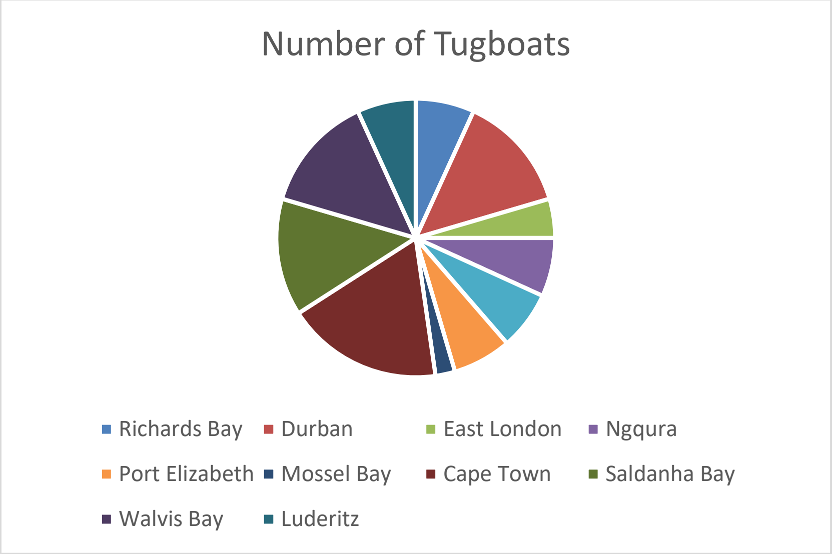
2.7 Port Fleet

Port fleet means ships that are owned by a port. Port fleet includes tugboats, dredger, feeder, barge, and pilot vessels

2.7.1 Tugboats

In a port, tugboats play a vital role in assisting a ship to moor or dock by either towing or moving a vessel into the port. Through forcing or tugging them into the dock, the tugboat eases the manoeuvring activity of boats. Mega vessels can never be maneuverer on their own. Also with the increased size of the boat, they need tug boats to carry some of their domains and tow them through narrow water channels.

Figure 2.12 Number of Tugboats



Source: own computation

From figure 12 the Port of Cape Town has the most tugboats, and is one of the busiest ports in South Africa, handling the greatest volume of fresh fruit, and second only to Durban as a container port, because of its location together with one of the world's busiest trading routes. A fleet of four Voith Schneider tugs is run by the Port of Cape Town (Africa Ports, 2020). They include PINOTAGE and MERLOT 43t bollard pulls tugs, built-in 1980, and ENSELENI and PALMIET, two former Durban 50t bollard pull tractor tugs built-in 2001. Each tug is held at class 8 SAMSA level and is prepared for firefighting and rescue purposes. The port also employs two workboats called Kestrel and Blue Jay, two female pilot boats designed by Red Bishop and Plover, four launches named Troupant, Koester, Kite, and Weaver, a Pelican pollution boat, plus an Inkunzi floating heavy-lift crane (Africa Ports, 2020).

According to figure 12, there is a minimum number of tugboats in the Port of Mossel Bay, since it caters to fishing vessels that often do not need a tugboat to reach the port. Mossel Bay has a workboat/tug with a 19t bollard pull called Arctic Tern (built-in 1998). The port also uses the Snipe mooring launch, which is also used as a pilot ship and for the movement of crew and other staff (Africa Ports).

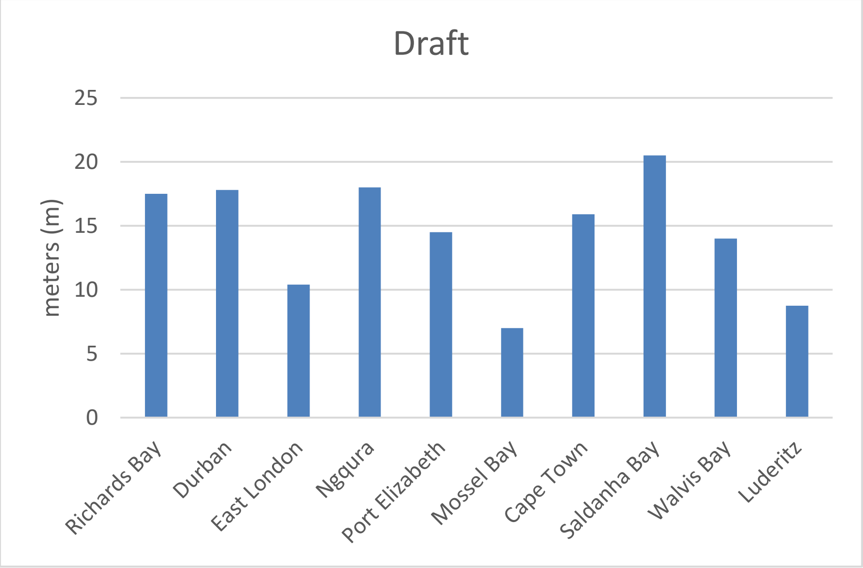
2.8. Port Limitations

Port limitations are a port restriction that prevents ships' connectivity to a port. Connection to a port can be constrained by the scale or nature of its entry. The emphasis will be on the draft in the case of this analysis.

2.8.1 Draft

The SACU ports consist of deep-water ports. Deepwater ports are ports whose draught (the mean drawn by the vertical distance from the surface of the water to the seafloor) reaches 13,72 m in both the entry channel and the terminal area. Deep-water ports include the ports of Richards Bay, Durban, Ngqura, Port Elizabeth, Cape Town, Saldanha Bay, and Walvis Bay. Saldanha Bay (draft is 23 m) and Ngqura are the ports with the deepest drafts (draft is 18m).

Figure 2.13 Draft



Source: own computation

According to figure 13, the port with the deepest was draft was Saldanha Bay with 23 meters, it corresponds with the port of Saldanha Bay because the port remains the largest and deepest natural port in the Southern Hemisphere able to accommodate vessels with a draft of up to 21.5 meters. The Port of Mossel Bay has the shallowest draft, referring to the port since the port is small and is an active port catering primarily for the fishing and oil and gas industries, which started with Messages in the late 1980s (TNPA, 2017). The port sees no other commercial activity and in the following years, there has not been any other substantial development.

2.9 Summary

History shows that these ports were built during colonialism except for the Port of Ngqura and also they have links with the discovery of minerals in their respective countries. SACU ports are strategically positioned next to trade routes. Most of the ports have world-class facilities to accommodate big vessels that ship cargo all over the world. Some of the ports have multipurpose terminals, some handle break-bulk cargo, agricultural bulk cargo, mineral bulk cargo, automotive cargo, containerized cargo, and fisheries. However, each port has a specialty, for instance, the port of Saldanha and Richards Bay are specializing in mineral bulk, whilst the port of Durban and Ngqura are known for containerized cargo. Port of Mossel Bay and Lüderitz are mainly for fisheries.

CHAPTER THREE

PORT OPERATIONS

3.1 Introduction

Ports compete with each other to attract users, accommodate more cargo and raise sales (Elfeijani, 2015). The main competitiveness approach, as predicted by port stakeholders, is to offer a good quality of service in less time and at less expense (Elfeijani, 2015). This will be achieved while a port is successfully executed. To better define the relevant structures, evaluating the port output literature gives more perspectives and understandings. Therefore, this chapter reviews the literature on port performance to define the most important factors impacting port performance, taking into account the performance of seaside, terminal and landside activities.

3.2 Container Port Performance, Productivity, and Efficiency

Performance is commonly interpreted as a business term for measuring an organization's progress in achieving any degree of its strategic goals (Feng, Mangan and Lalwani, 2012). Logistics efficiency can be described as the degree to which a company's objectives are accomplished (Elfeijani, 2015). Port efficiency parameters are also defined as determinants of port competitiveness or factors affecting port competitiveness (Tongzon and Heng 2005).

Performance is multi-dimensional and there is no adequate production metric (Bonney, 2014). Port performance can be calculated by service quality, port performance, seaside accessibility, land-side connectivity, storage facilities and power, cargo dwell time, port reliability, technology, transaction procedures, costs, ship turnover time, and the spectrum of services offered, as noted earlier (Haezendonck, van den Broeck and Jans, 2011).

Such variables can be classified into three categories or measures: viability of the port, the efficiency of the port, and service quality. Its productivity is one of the most important port success indicators (Elfeijani, 2015). To recognise prospects for growth and optimization, daily assessment of efficiency in ports is critical (Beškovnik, 2008). Productivity and effeciency are the two main principles of economic success (Liu, 2010). The efficiency term is generally defined as the ratio between the output volume measurement and the input volume measurement used (Chinda, 2010). Port owners and officials can only manage port facilities. Port productivity, however, consists only of the productivity of seaside and terminal activities. Landside productivity, though, requires soil transport productivity that is not under the control of the terminal. High productivity means that less input is necessary to produce more output, or more output is produced by the same amount of input for a given period (Chinda, 2010; Mangat, 2006).

In addition, because of improvements in efficiency and technological aspects, productivity growth is defined as the net production shift (Fried, Schmidt and Lovell., 1993). Productivity thus tests the efficiency with which inputs are converted into outputs by a processing activity (Kao, Chen, Wang, Kuo and Horng, 1995). Mangat (2006) adds that productivity is a comprehensive indicator of how organizations accomplish five goals successfully and efficiently: target accomplishment, time-calculated trend productivity, consistency of service, reliability and comparability with other companies.

There is also a close association between production and productivity, where efficiency is determined by productivity (Mangat, 2006. Efficiency is characterized as the output of every organization relative to the benchmark (Liu, 2010). This applies to improving production by internal coordination without the consumption of external inputs (Stuebs and Sun, 2010). Moreover, economic efficiency refers to the productivity (i.e. productivity) of goods and services from a given quantity of energy (i.e. cost);' labour efficiency is a measure of labour productivity per unit of labour cost' (Stuebs and Sun, 2010).

High port efficiency, using limited capital, from the meanings given above, means high performance in a shorter period. Port throughput, or crane throughput, or the number of containers handled per acre per year, or the number of ship calls or turnaround times, port sales, truck turnaround period, gate usage, container dwell time, equipment idle pace, service efficiency, customer loyalty or market share may be calculated (Elfeijani, 2015). Complete throughput estimates, such as cargo handled, number of ship calls, and twenty equal foot units (TEUs) per year, or TEUs per terminal area acre, are, however, generally used to calculate partial port productivity (Le Griffin and Murphy, 2006).

In addition, the most important metric for container terminal and port performance is container throughput, as it is closely linked to cargo handling facilities and services. Moreover, it is the main source for comparisons of container ports and terminals. It is also the most acceptable and analytically tractable performance metric in port manufacturing (Elfeijani, 2015). Therefore, as an output vector for calculating port efficiency, this analysis requires overall container throughput. Multiple subsystems which return to container port operations are composed of load-handling processes in marine container ports.

In comparison, all goods that are delivered in individual pieces rather than in bulk or crates are broken bulk or general cargo (Grote, Mazurek, Gräbsch, Zeilinger, Le Floch, Wahrendorf, and Höfer, 2016). There are several other types of bundled items, and what they have in common is that they are lifted in one piece, or bundle, on and off a ship. The general method at the breakbulk terminal is similar to those at the container terminal and dry bulk terminal, but the treated commodity is different: the transhipment of cargo from the sea by vessel to a truck, rail, or barge for delivery to the hinterland, and vice versa (Schott and van den Hoed, 2018). Therefore, cargo handled is used as an output variable because it accounts for general cargo.

The productive and good use of port capital as a single unit achieves an increase in port efficiency. Also, independently solving each subsystem's problems does not provide the entire system with an optimal solution. This switches the gear from one subsystem to another (Elfeijani, 2015).

Both facilities and port superstructure rely on the optimum management of seaside, dock, and land assets activities. These are the most powerful forces on port production due to their high costs (Coto-Millan et al., 2000). They are, in reality, the primary factors affecting port performance. This is because, in addition to their effect on port efficiency, they affect the quality of service provided by the port as well as the port production, which is calculated by time and cost, Ports thus need to be productive by achieving optimum results with minimal capital (Elfeijani, 2015 cited Beškovnik, 2008).

There is a need to look in-depth at the three major operating phases of terminal work to consider port efficiency, competitiveness, and quality. That includes seaside activities, landside operations, and operations at the port. The whole of port productivity is made up of these three independent, but intertwined and coordinated activities. The main focus of the study is on the first two operations: seaside operations and sea-land operations. However, the study will firstly describe container and dry bulk terminal layouts.

3.3 Terminals Layouts

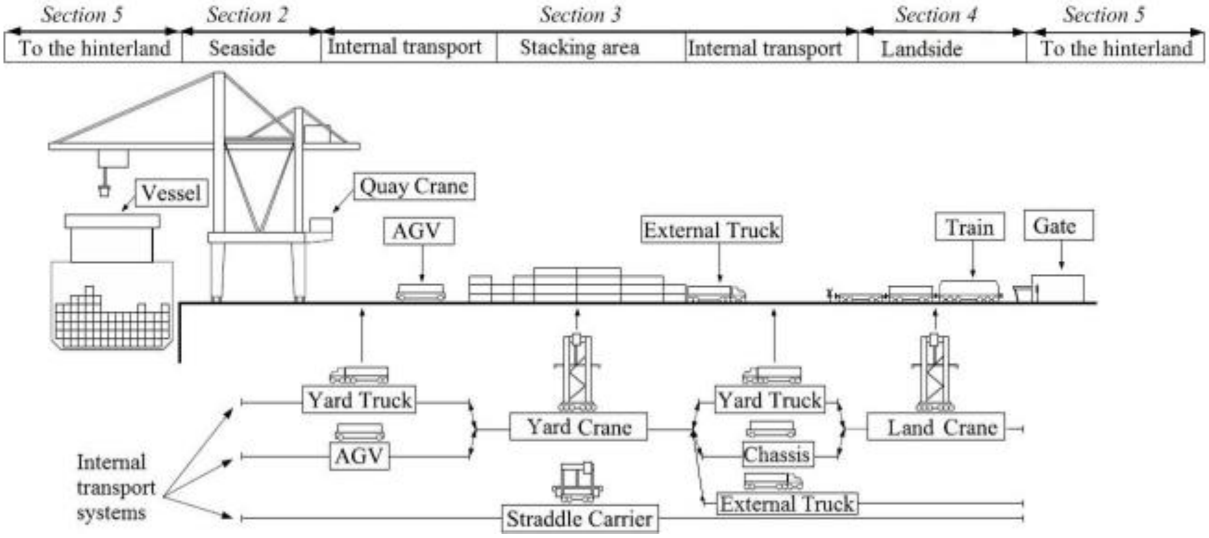
In global supply chains, containers and bulk terminals play an important part in the shipping of goods. The amount of cargo handled at ports has risen astronomically. There have been many improvements in their architecture to accommodate and cope with the growing volume of cargo entering and exiting ports (Meisel, 2009). New layouts require a smaller footprint and must ensure a quicker, cheaper, and more efficient shipping transition between land and sea. The analysis first discusses the container terminal layout configuration and then follows with the bulk terminal (Meisel, 2009).

3.3.1 Layout of a Container Terminal

A seaport container terminal architecture consists of numerous areas, each having a particular functional role (Meisel, 2009). The four key categories of area are the quay area for mooring cargo vessels, the container transport area inside the terminal, the container storage yard area, and the truck and rail area for servicing foreign trucks and trains (Meisel, 2009).

For terminal operations, various technical equipment is used. Cranes at the quay and in the yard are employed. The transport of containers between the terminal areas is carried out by yard trucks or automated driven vehicles (AGVs) (Meisel, 2009). Alternatively, the transport and stacking processes in the yard can be done by so-called straddle carriers (SCs) or Automatic Lifting Vehicles (ALVs) (Ligteringen, 1999). The operating areas and the facilities alternatives are sketched in Figure 3.1. A brief overview of the areas and the equipment is given below.

Figure 3.1 Schematic cross-sectional view of a container terminal



Source: Meisel (2009)

3.3.2 Quay Area and Quay Cranes

The quay, where ocean-going vessels, feeder boats, and barges moor, is the sea-side operating area of a container terminal (CT). Quay cranes (QCs) perform the loading and unloading processes of containers. To enable transhipment operations independently of the equipment provided at the port, some container vessels are self-equipped with cranes (Tozer and Penfold, 2001). Nowadays, however, vessel operators typically refrain from this choice because most terminals provide a decent standard of equipment. Depending on their size, up to six QCs will concurrently service vessels. Big vessels will have up to 22 side-by-side container stacks in a bay that require correctly dimensioned cranes with a 60-meter span (Tozer and Penfold, 2001). A professional crane driver is required to run a QC due to the difficulty of reaching the containers inside a vessel.

A QC's efficiency is determined by the number of movements per hour. For the efficiency of a terminal, this is a crucial predictor. A QC realizes about 30 movements every hour in practice (Chu and Huang, 2002). Technological developments, however, are directed at increasing crane efficiency. To ease the placement of containers inside the hold, vessels may be fitted with cell guides. With two trolleys, QCs can be fitted. The vessel is operated by one trolley and the other trolley serves the horizontal transport vehicles (Chu and Huang, 2002). Containers are moved from one trolley to the other on a frame between the uprights of the crane.

3.3.3 Transport Area and Transport Vehicles

Containers are transferred between the operating areas by the horizontal transport mechanism of a container terminal. Yard trucks and straddle carriers are the most commonly used equipment types (Meisel, 2009). Yard trucks are manned vehicles that lift containers from the chassis. They are unable to lift containers, so they need a loading and unloading crane (Meisel, 2009). This includes careful alignment of cranes and trucks to prevent waiting for the crane. Dual Trolley QCs can be used to minimize idle times because they allow the vessel and the trucks to temporarily decouple (un) loading operations (Meisel, 2009).

Straddle carriers also referred to as truck carriers, are an alternative to the use of yard trucks. They are also able to lift and stack containers next to moving containers. This helps QC operations and transport operations to be decoupled (Meisel, 2009). A QC can place an unloaded container on the quay and begin the service phase if straddle carriers are used. Which avoids crane sitting and increases the efficiency of cranes in terms of movements per hour.

Completely automatic replacements, including Automated Guided Vehicles (AGVs) and Automated Lifting Vehicles (ALVs), can be supplemented by yard trucks and straddle carriers. Induction coils mounted on the pavement direct the movement of automated vehicles. AGVs are capable of holding one to 40 containers or two to 20 containers. ALVs hold a single bag but can lift it like straddle carriers (Meisel, 2009). At present, automatic transport networks in CTs do not achieve high-efficiency standards for transport. One explanation is that a similarly low average speed is typically exhibited by autonomous vehicles. Another explanation is that an automatic vehicle failure will lead to the whole transport system's downtime (Meisel, 2009). However, reducing labour costs at the terminal and the efficient implementation of job plans arising from the absence of human failure are the promised benefits of autonomous vehicles. Because automation investment needs to pay off, it is extremely appealing for terminals with a high level of labour costs (Meisel, 2009).

3.3.4 Yard Area and Yard Cranes

For the intermediate handling of containers, the yard is used. Import containers are stored until the initiation of hinterland transport. Import containers are kept in the yard until the dedicated vessel arrives (Meisel, 2009). There are also areas for empty and reefer container collection. Typically, a yard is split into a series of yard blocks separated by traffic lanes. A block consists of several parallel rows of containers, each having many storage positions arranged lengthwise. At each location, several container levels can be stacked (Meisel, 2009).

Gantry cranes perform stacking and retrieving operations. Such cranes may be rail-mounted portal cranes (RMGCs) or rubber-tired gantry cranes (RTGCs). An RMGC spans up to 13 container rows, based on its design (Meisel, 2009). An RTGC covers only up to 8 container rows but can be repositioned in other blocks of the yard. Up to six levels high, all crane forms stack tanks. The uppermost tier of each stack is normally left empty to allow a crane with a container to move over the stack (Meisel, 2009). One row can be reserved for the transport vehicle service. Alternatively, vehicles are served at the front of a block, allowing for greater loading capacity but requiring increased movement of the gantry cranes.

Advanced technical solutions improve a crane-operated yard's transhipment capacity. Double Rail Mounted Gantry Cranes have two different-size cranes working within the same block (Meisel, 2009). The various sizes allow the cranes, allowing for more versatile operations, to move through each other. Gantry cranes can, to a large degree, be automated. The block arrangement is broken down by extra clearance between the container rows if straddle carriers are used for yard operations (Meisel, 2009). This helps straddle carriers to reach the desired storage location for each row and use it. Straddle carriers can stack containers up to four levels in height. Again, the top tier is typically left bare. Containers may be loaded on the transport chassis in the yard if yard vehicles are used at the container terminal (Meisel, 2009). Low investment and maintenance costs and direct access to each container are certainly feasible, but storage space is lost at the same time. A key efficiency metric for terminals where storage space is limited is storage capacity. Generally, if gantry cranes are employed, the best holding capacity is reached. The use of straddle carriers results in a smaller storage space, which, however, is also much greater than the capacity of holding chassis tanks (Meisel, 2009).

3.3.5 Truck and Train Area

The interface to the hinterland is provided by a seaport terminal servicing trains and external vehicles (Meisel, 2009). Gatehouses, where containers are checked and transport papers are stored, must be passed by vehicles. If straddle carriers are used in yard operations, to be served, trucks transfer to a parking area. To be served, trucks are sent directly to the dedicated yard blocks if gantry cranes are used. Truck self-service is possible if containers are stored in the yard on the chassis (Meisel, 2009). Railway tracks lead into the terminal to accommodate the trains. Trains are often served by gantry cranes if the yard is run by gantry cranes, where horizontal container transport is again needed. Straddle carriers or ALVs are otherwise used,

Either straddle carriers alone or a mixture of gantry cranes and yard trucks will work within a container terminal (Goedhart, 2002). Because each form of equipment displays its strengths and disadvantages, there is no better choice of equipment overall. The selection decision ultimately attempts to achieve a high transshipment potential and an economic equilibrium between the improvements to be made and the projected running costs (Goedhart, 2002). But a certain decision can also be imposed by local circumstances, such as room constraints or the standard of labour education. The basic collection of equipment carried out in a terminal forms a series of specifications for terminal operations management (Goedhart, 2002).

3.3.6 Layout of a Bulk Terminal

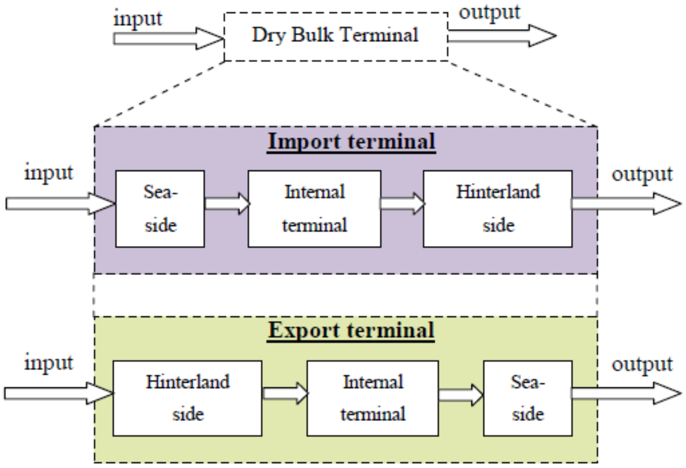
Terminals for dry bulk are mostly built and constructed for one particular category of cargo, whether iron ore, coal, or grain. Dry bulk cargo is divided into main bulks and small bulks (Xin, Negenborn, and Teus van Vianen, 2018; Ligteringen, 1999). Coal, iron ore, and grain constitute the largest dry bulk cargo. Iron, plastic pellets, wood chips, sugar, cement, and minerals compose the smaller dry bulk cargo. In most cases, there is a clear gap between the export terminal and the import terminal for the same material, considering the various transport processes needed for loading and unloading (Xin, et al., 2018). Figure 3.2 depicts the import and export terminals within a dry bulk terminal.

The loading of bulk carriers at the export terminal takes place using conveyor belts stretching right above the tanker, from which the material falls freely into the holds at steady and high capacity

(Lodewijks, Schott and Ottjes, 2007). The same cargo is unloaded at the import terminal through cranes, which must be able to travel about to catch all the stuff in the hold and to go from one hold to the other. As a result, the export terminal could be more similar to the tanker quay/platform arrangement, while the import terminal requires a heavy crane dock (Lodewijks, et al., 2007).

The storage portion of the terminal is the same on both sides of the water: depending on the form of cargo, the material is stacked in long piles in the open air or closed silo. The space for conveyor belts and the rails for the stacking/recovery equipment divide the stacks (Umang, Bierlaire and Vacca, 2011).

Figure 3.2 Dry Bulk Terminal for Imports and Exports



Source: Lodewijks, et al., (2007)

Transport hubs for shipping dry bulk goods are dry bulk terminals. Typical dry bulk materials are important for the manufacture of electrical energy and steel, such as coal and iron ore. There has been significant growth in dry bulk transport over the last few decades in the face of increased global demand for dry bulk materials (Xin, et al., 2018). In 2014, more than 30 percent of the international seaborne trade by volume accounted for major dry bulk materials. The efficiency of the transport of dry bulk materials needs to be improved to meet the increased demand for the transport of dry bulk materials (Xin, et al., 2018).

3.4 Seaside Operations

Seaside operations concern the approach, docking, and berthing of ships before the stage of cargo operations. For the efficiency of such activities, sufficient drafting, channel dimensions of approach, piloting services, and docking/berthing services and facilities are critical considerations. Port operators, especially those running large transhipment hubs, are often trying to enhance their services by ensuring a seamless process of berthing (Lee and Jin, 2013). The cost of shipping is calculated by the scale of a container, which decreases transport costs for bigger shipments (Clark, Dollar and Micco, 2004) and increases port throughput.

With the steady growth in port throughput and the trend of large-scale ships, the size of the port area is continually expanding and the number of incoming ships is also increasing, leading to higher demand for tugboat configuration in the port area (Wang, Zheng and Peng, 2018). The tugboat service is an integral part of the organizational framework of the growth of the port. Tugboat assistance is needed for berthing & leaving, doing a U-turn, and moving the mooring. It is important to accurately measure the number and horsepower of towing tugboats according to the tonnage and length of the vehicle (Wang, Zheng and Peng, 2018).

The primary four steps needed for a tugboat to work when a ship enters the port and exits the port (Wang, et al., 2018): Arrival process: The ship must be towed to the quay when the ship approaches the harbour channel for tugboat loading and unloading operations. Moving process: It is important to take out tugs at several terminals because there are several forms of loading and unloading cargo. Since the vessels do not travel on their own between various wharves, tugboat-assisted work is necessary (Wang, et al., 2018). The ship turned around: Depending on the setting of manoeuvring waters and quays in different port areas, some ships may need to turn their heads to complete their work when entering or leaving the port. In this case, tugboat-assisted It needs effort. Exit the port process: the ship has to leave the quay to reach the waterway with the aid of a tugboat after finishing the work at the port (Wang, et al., 2018).

Cullinane, Ji and Wang, likewise. (2005) to investigate the relationship between port competitiveness and privatisation, using the length of the quay (among other factors). Wu (2009) also uses the length of the quay to calculate the productivity of 28 container ports. The quay length was used by Tongzon (2001) and other factors to measure the efficiency of several Australian ports. Quay architecture can influence the efficiency of seaside operations and the number and specifications of the quay cranes (QCs) dedicated to such quays. In this sense, Nam, Kwak and Yu (2002) found that sharing QCs with neighbouring quays can boost productivity. An important comparative advantage impacting port preference decisions is the provision of docks on arrival quays (Chang, Lee and Tongzon, 2008).

Generally speaking, owing to the lack of adequate quays to accommodate inbound cargo ships, it may be said that difficulties with the distribution of quays exist (Elfeijani, 2015). This shortage of quays may be attributed to an inadequate number of productive QCs allocated to a certain quay. Inefficient QCs slow the overall QC handling rate due to technical or operating factors. As the crane is waiting for transport vehicles to pick up the off-loaded containers under the QC or to transport containers from a storage yard, this can also be due to long QC idle times (Elfeijani, 2015). This longer turnover period of the vehicle could be attributed to congestion or shortage of transport vehicles to service a particular ship or QC. It may also be attributed to the longer time taken by yard cranes (YCs) to recover outbound containers due to the vertical stacking caused by the lack of space (Elfeijani, 2015).

All this illustrates the integrity of port subsystems, where the process as a whole is impaired by any faults in any subsystem. The influence of quay allocation issues in a single port not only affects the performance of that port but can also extend to other ports (Ilmer, 2008). Efficiency performance in any port minimizes ships' turnover time, where time wasted immediately converts into higher costs (Elfeijani, 2015); thus, it has a positive effect on the performance of the next port of call for the same ship (Elfeijani, 2015).

The interruption of any ship induced by the previous port, on the other hand, could interrupt the preparations for the next port of call to be moored. This is backed by Ilmer (2008), who provides an analysis of the increase in port investment in containers in Northern Europe and of the projected balance of supply and demand for the region in 2010. He points out that failure to adhere to berthing windows, on the other hand, due to ship delays 55 caused by congestion in provirus ports and a last-minute notice of ship arrival time, the delay of any ship caused by the previous port could interrupt the next port's berthing plans. This is supported by Ilmer (2008), who provides an overview of the growth in container port investment in northern Europe and of the expected supply and demand balance in 2010 in that region. It reports that non-compliance with berthing windows creates increased pressure on terminal capacity at certain ports, more pressure on terminal capacity at certain ports due to shipping delays of 55 due to congestion at provirus ports, and a last-minute notice of ships' arrival time.

Also, terminal performance is influenced by ships' arrival times and productivity in cargo handling. Using this theory, Dai, Lin, Moorthy, and Teo (2008) researched quay allocation problems and suggested a local search algorithm to solve static quay allocation problems to improve the efficiency of quay use. Imai, Nishimura and Papadimitriou (2008), who presented a difference in the topic of quay distribution at multi-user terminals, offer another viewpoint. The research focused on busy container ports in developing countries. To minimize the average service time of container ships at the external terminals, a genetic algorithm-based heuristic was developed as those ships were required to surpass real waiting times at the assigned terminals (Elfeijani, 2015). The importance of port productivity in terms of water depth and quay length has been seen by this short literature review.

3.4.1 Trends in Maritime Transport and Handling Equipment

The use of containers has been on the rise since their arrival in 1956, and this demand has the strongest prospects for development in the industry. As a result, high-capacity ships were built. As the capability of the ship begins to grow and ports need to adapt to their size (Gallegos, 2009). On the other hand, maritime shipping of dry bulk products includes, in particular, iron ore, coal, corn, bauxite/aluminium oxide, and phosphates. Many shipping companies build panamax ships to measure cranes for loading and unloading bulk cargo, which lowers transport costs (Gallegos, 2009). Bulk cargo is the second largest category of maritime shipping, accounting for about one-fourth of the total cargo shipped annually (Gallegos, 2009). For instance, in terms of deadweight tonnage (DWT), Valemax is the largest class of bulk carriers. Valemax-class ships have a deadweight range ranging from 380,000 to 400,000 tonnes. They are also among the longest ships currently in service of any kind used for general cargo (Schott and van den Hoed, 2018; Elfeijani, 2015).

Further, a traditional way of classifying the size of ships is their ability to navigate through the Panama Canal, which enables ships to travel from the Atlantic to the Pacific Ocean and vice versa without having to round Cape Horn (Nidec Netherlands, 2020). Each type of ship belongs to a particular class: Panamax Ships have a transport capacity of between 50,000 and 79,000 tons and a maximum diameter of 32.2 metres, enabling them to transit across the Panama Canal. Container ships of this type will carry up to 4,000 containers in 13 rows (Nidec Netherlands, 2020).

Post-Panamax ships have a transport capability of between 80,000 and 110,000 tonnes. Their size forbids them from passing through the locks of the Panama Canal. Container ships of this type will transport up to 9,000 containers stacked in 18 rows. Super Post-Panamax ships have a transport capacity of more than 150,000 tonnes. Container ships of this type will carry up to 11,000 containers stowed in 24 rows (Nidec Netherlands, 2020).

Ship To Shore (STS) cranes (known as quay cranes) This is a type of large dockside gantry cranes used at container terminals for loading and unloading containers from container ships (Nidec Netherlands, 2020). STS container cranes are typically categorized according to their lifting capability and the size of the container ships they can load and unload. Panamax STS Crane can completely load and unload containers from a container ship that can move through the Panama Canal (Ships of 12 to 13 container rows wide) (Nidec Netherlands, 2020).

Post-Panamax STS Crane will completely load and unload containers from a container ship that is too big to move through the Panama Canal (about 18 rows wide) and Super-Post Panamax STS Crane. The main modern container cranes are known as "Super-Post Panamax" (for vessels of about 22 or more container rows wide) (Nidec Netherlands, 2020). A modern container crane capable of raising two containers of 20ft at once would typically have a rated lifting power of 65 tonnes below the spreader. Some new cranes have already been installed with a load capacity of 120 tonnes, allowing them to lift to four 20ft or two 40ft containers (Nidec Netherlands, 2020).

Moreover, Port accessibility is considered one of the most significant factors impacting port efficiency due to the drastic rise in ship size, as it controls the size of ships that can reach the port. Adequate water depth, adequate quay length, and a number of quays are therefore necessary to allow inbound ships to dock safely to start cargo operations (Elfeijani, 2015; Acosta, Coronado, and Cerban, 2007). These three port devices, the depth of water, the length of the quay, and the number of quays, have been the subject of various experiments. For example, Lin and Tseng (2007) use the terminal length and the number of deep-water piers to create a strategic strategy to improve the competitiveness of the port

3.5 Terminal Operations

Terminal operations are very important variables for port performance (Beškovnik, 2008). After the inbound container/cargo ship crosses the fairway channel that suits its draft and moors alongside a fitting quay, they launch. Both cargo handling activities include terminal operations, beginning with loading/off-loading and concluding with the transhipment of the cargo. The means devoted to handling the cargo inside the terminal or port provide these activities. The bulk of port cargo loss happens in the sea-land cargo operation. Security, including cargo loss and injury, is another significant factor affecting port performance (Gekara and Chhetri, 2013).

Storage yard capacity, which is a part of the port facilities, is one of the main aspects of port productivity and profitability. It specifies the volume of cargo storage and processing, storage mode, number, and type of handling equipment (Ioannou, Jula, Liu, Vukadinovic, Pourmohammadi and Dougherty, 2000). Advanced material handling: In agile ports, autonomous guided vehicles. A larger analysis of the key causes of unproductivity in the flow process of containers was undertaken by Chen (1999). The results revealed that organizational performance was affected by several influences and triggered movements that were not efficient.

It was also observed that higher container storage had a substantial influence on the number of unproductive motions and delivery activities. To absorb even more containers in a small storage yard, containers are stacked vertically. Unique and costly stacking equipment is required to execute this 58 mission. In certain situations, double handling is needed in a vertical stacking mode to recover lower containers, which improves running times and hence the efficiency of the container port (Alessandri, Sacone and Siri, 2007). The efficiency of QC and therefore the turnaround period for a ship can also be influenced (Steenken, Voß and Stahlbock, 2004).

In comparison, inside wider storage areas, more cargo may be transported and processed. In container ports, high stacking equipment does not need to be deployed. However, additional horizontal transport vehicles need to be deployed to speed up container travel and to prevent idle QC periods (Fried et al., 1993). Therefore, greater investment in cars is required, and running costs will also rise. Inputs in the port quality assessment are known to be these (Fried et al., 1993). Hence, the optimum amount of storage space is a very critical consideration for port success and productivity. For these purposes, the form and number of container handling devices are included in this study.

Yet another perspective is provided by Ioannou, Jula, Liu, Vukadinovic, Pourmohammadi, and Dougherty (2000). The research used the Los Angeles and Long Beach ports as case studies to analyse the effect of the costs of various technology and ideas on container port capacity, and the traffic network beyond the port. The most significant cost-function-related findings revealed that the average container handling costs were impacted by land prices and AGV prices. Moreover, the high cost of land forced the port to make use of new technology to increase its profitability. This showed that land and handling services are important factors to be taken into consideration when assessing the reliability of a container port.

In addition, the space of the storage yards is not only essential, but the architecture of the storage yard is also a crucial component of the efficiency of the container terminals. As the efficiency of stacking and retrieval of containers is regulated by block measurements and configuration, they ultimately influence the performance of service times of all handling equipment and ships. Concerning the viewpoint of yard layout development, Lee and Chao (2009) suggested a heuristic model create a movement approach to enhance the layout of an export container yard. They reported that the processing times for ships were reduced by the pre-marshalling of shipped containers, as it eliminated the longer time it took to collect containers while the ship was next door.

Therefore, to evaluate the disruptive factors that hinder optimal efficiency, frequent assessment of the performance of these services is important to take the required steps to avoid their influence (Beškovnik, 2008). It is therefore important to include the number of QCs, number, and length of quays, draft, tugboats, and storage yard area in this analysis to analyse port performance and quality.

3.6 Seaside Operation Problems

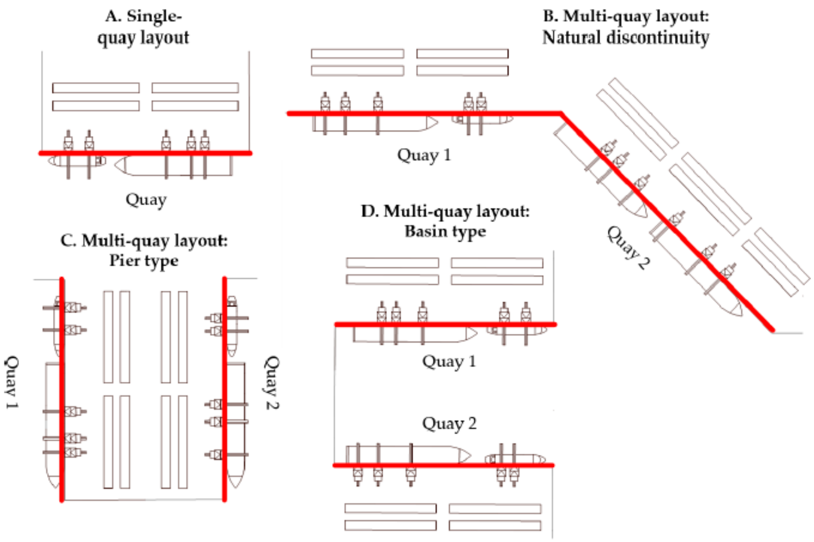
This section of the chapter discusses seaside operations problems in container and bulk terminals.

3.6.1 Quay Decisions in Container Terminals

The development of container shipping presents continuous challenges to ports not only for large but also for small and medium-size terminals (Ernst, Oguz, Singh and Taherkhani, 2017). The pressure becomes stronger as the vessel's size grows, and the shipping operators' requirements become higher concerning the quality of port services and service time. Many small and medium-sized ports have different terminal layouts than those of high-productivity port hubs or have displaced container handling facilities (Ernst, et al., 2017).

Instead of one long quay, a terminal with more discontinued quays may form different layouts (Ernst, et al., 2017). Quays may be constructed as a pier type, basin type, or natural type following the shoreline shape (Figure 3.3). Different layouts imply distinct approaches to solving basic seaside tactical logistic problems: the berth allocation problem (BAP), the quay crane allocation problem (QCAP), and the quay crane scheduling problem (QCSP) (Ursavas, 2015). Due to the seaside operations that are considered to be most important for shipping operators because of their high impact on vessels' service time in ports, the methods and models of optimization developed in the last few decades aim to improve and facilitate relevant decisions: namely, the decision of when the ship will be berthed, on which berth, how many quay cranes will be assigned to the vessel, and in which way the handling process will be shared between assigned cranes (Xiao and Hu, 2014).

Figure 3.3 Different Layouts of Quays



Source: Ernst, et al., (2017)

The quay area decision problems are critical and have a major impact on a container terminal's operational performance (Xiao and Hu, 2014). In the quay area, the corresponding decision problems include berth allocation, quay crane assignment, quay crane scheduling, and stowage planning. Stowage planning deals with how to assign the containers to empty slots in a vessel. We will not review the work on stowage planning (Xiao and Hu, 2014).

3.6.2 Berth Allocation Problem

A specific anchoring berth has to be allocated to a vessel by the container terminal planners before the vessel's arrival. The Berth Allocation Problem (BAP) deals with how to optimally allocate such vessels to the berths or quay locations (Guan and Cheung, 2004; Li et al. 1998). The berthing (handling) time and the berthing position along the quay length of a vessel have to be determined. The input data to be considered include the technical specifications of the vessels, QCs, data on the berth type (e.g., berth layout, number, length), projected vessel handling time, mooring time windows, priorities of the vessels, dedicated berth areas, (Guan and Cheung, 2004). The objectives of BAP include maximizing the productivity of the vessel handling, maximizing customer service levels, minimizing the total service time of vessels, and minimizing the costs (Guan and Cheung, 2004).

Hansen et al. (2008) solve the dynamic BAP problem by taking into account the service costs of ships depending on the berth they are assigned to in addition to the handling times. Hendriks, Lefeber, and Udding, (2013) study a robust BAP in which cyclically calling ships to have arrival time windows, instead of specific arrival times. They minimize the maximum amount of QC capacity required in different scenarios. In a later study, Hendriks et al. (2013) work on a similar problem in which cyclically calling ships have to be processed in different terminals of the same port. They minimize the amount of inter-terminal transport and balance the QC workload in different terminals and periods. Xu, Li and Leung (2012) study the BAP considering the water depth and tidal condition constraints. They model the problem in a static mode (all ships are available) and a dynamic mode (ships arrive over time). They develop efficient heuristics to solve problems.

3.6.3 Quay Crane Assignment Problem

After assigning the berths to the vessels, we now need to allocate the QCs to the vessels for loading/unloading operations which are done through the Quay Crane Assignment problem (QCAP). The QCAP is sometimes referred to as a crane split (Stahlbock and Voß 2008). It deals with the allocation of the QCs to the vessels and the vessels' bays. Given the vessels to be served and available QCs to be used, the QCAP has to ensure that the overall loading/unloading operations of vessels can be completed as quickly as possible. The QCAP is closely related to the BAP: The solution to the BAP serves as the input to the QCAP, while the solution from the QCAP will, in turn, affect the BAP (Stahlbock and Voß 2008).

Peterkofsky and Daganzo (1990) pointed out the importance of crane operational efficiency and developed a branch and bound solution to speed up a cargo ship's loading and unloading operations. Han, Gong, and Jo (2015) simultaneously addressed the berth and quay crane scheduling problems and took vessel arrival times and container handling uncertainty into consideration. A mixed-integer programming model was proposed and a simulation-based genetic algorithm procedure was employed to provide the proactive berth and quay crane schedules.

Giallombardo, Moccia, Salani, M. and Vacca (2010) combined the berth allocation and the quay crane assignment problems and developed a mixed-integer quadratic program which was subsequently reduced to a mixed-integer linear program. A heuristic that combined tabu search and mathematical programming techniques was developed to solve the problem.

3.6.4 Quay Crane Scheduling Problem

The QCAP allocates the available QCs to the vessel bays. The next decision is to decide the sequence of the loading/unloading tasks performed by these QCs, which is done by Quay Crane Scheduling (QCSP). The tasks to the QCs are the containers on the vessel to be unloaded and the containers on the prime movers (PMs) delivered from the yard area to be loaded (Zhang, Liu, Lee and Wang, 2018). A QCS model typically considers the following constraints: unloading tasks must precede any loading task, interference between neighbouring QCs, a QC can perform at most one task at a time, and the QC travel speed (Zhang, et al., 2018). The objective is usually to minimize the make span of all tasks.

Tavakkoli-Moghaddam, Makui, Salahi, Bazzazi and Taheri (2009) tried to solve the quay crane assignment(QCAP) and the quay crane scheduling (QCS) problems simultaneously. A mixed-integer programming (MIP) model and genetic algorithm (GA) were used to analyse real-sized problems and to optimize the total completion time of the vessels and the QCs. In comparison with the results for the MIP model provided by the LINGO optimization software package, it was found that the proposed GA was better in terms of the solution times.

A new model for the QCSP has been developed by Meisel (2011) concerning the time window constraint for the quay cranes. A mathematical formulation, a lower bound, and the unidirectional search heuristic were used to deal with the minimization of the total vessel handling time. Lu et al. (2012) studied the QCSP by considering multiple QCs which can process different operations (but not simultaneously) at a single bay (shared bay). A polynomial-time complexity heuristic approach was developed to find the optimal assignment and sequencing of containers to contiguous QCs.

3.6.5 Yard Area

Yard area operations are often a potential bottleneck in a CT (Li, Wu, Petering, Goh and de Souza, 2009). The performance of a CT depends heavily on the decisions made for yard area operations. In the yard area, the corresponding decision problems include assigning the yard blocks for the calling vessels, determining the storage locations for individual containers, yard marshalling, and Yard Crane Scheduling (YCS) (Xin, Negenborn, and Van Vianen, 2018). The YCS has two sub-problems. The first planning problem arises if the available number of YCs is lower than the number of blocks within the yard. In this case, cranes need to be moved to those blocks where stacking and retrieval operations have to be performed (Xin, et al., 2018). The deployment of cranes is planned on a horizon of several hours. For technical reasons, only one or two YCs can work within a block simultaneously. The objective pursued by the YC deployment is the minimization of an unfinished workload, which needs to be carried from one period to the next period (Cheung, Li, and Lin, 2002; Linn, and Zhang, 2003).

The scheduling of stacking and retrieval operations of containers in the yard has to take the QC operations into account (Cheung et al., 2002; Linn, and Zhang, 2003003). More precisely, a horizontal transport vehicle that has to receive or deliver a particular container at a yard block will arrive there at a certain point in time depending on the progress of QC operations. These arrival times of vehicles refer to ready times of stacking and retrieval operations in the YC scheduling. Further constraints arise if two YCs operate within a yard block (Cheung et al., 2002; Linn, and Zhang, 2003).

3.6.6 Quay Decisions in Bulk Terminals

Bulk terminal operations planning can be divided into two decision levels depending on the time frame of decisions: Tactical Level and Operational Level. Tactical level decisions involve medium to short-term decisions regarding resource allocation such as port equipment and labour, berth and yard management, storage policies (Robenek, Umang and Bierlaire, 2012). The operational level involves making daily and real-time decisions such as crane scheduling, yard equipment deployment, and last-minute changes in response to disruptions in the existing schedule (Robenek., 2012).

The tactical berth allocation problem refers to the problem of assigning a set of vessels to a given berthing layout within a given time horizon (Robenek., 2012). There could be several objectives such as minimization of the service times to vessels, minimization of port stay time, minimization of the number of rejected vessels, minimization of deviation between actual and planned berthing schedules (Robenek., 2012). There are several spatial and temporal constraints involved in the BAP, which lead to a multitude of BAP formulations. The temporal attributes include the vessel arrival process, the start of service, handling times of vessels, while the spatial attributes relate to the berth layout, draft restrictions, and others (Robenek., 2012).

In a container terminal, all cargo is packed into containers, and thus there is no need for any specialized equipment to handle any particular type of cargo. In contrast in bulk ports, depending on the vessel requirements and cargo properties, a wide variety of equipment is used for discharging or loading operations (Robenek., 2012). For example, liquid bulk is generally discharged using pipelines that are installed at only certain sections along the quay. Similarly, a vessel may require the conveyor facility to load cargo from a nearby factory outlet to the vessel. Thus, the cargo type on the vessel needs to be explicitly taken into consideration while modelling the berth allocation problem in bulk ports (Robenek., 2012).

The tactical yard assignment problem refers to decisions that concern the storage location and the routing of materials. This affects the travel distance between the assigned berth to the vessel and the storage location of the cargo type of the vessel on the yard and determines the storage efficiency of the yard (Robenek., 2012; Meisel, 2009). Thus, the problems of berth allocation and yard management are interrelated. The start times and end times of operations of vessels determine the workload distribution and deployment of yard equipment such as loading shovels, wheel loaders in the yard side. Moreover, berthing locations of vessels determine the storage locations of specific cargo types to specific yard locations, which minimize the total travel distance between the assigned berthing positions to the vessels and the yard locations storing the cargo type for the vessel (Robenek., 2012; Meisel, 2009).

3.7 Summary

Ports compete against each other for attracting users, handling more cargo, and increasing revenue. The key strategy of competition is to provide a good standard of service in less time and for less cost, as expected by port stakeholders. This chapter examined the influence of seaside operations and terminal operations on technical efficiency. Seaside operations show that the number of tugs, draft, and number, and length of a quay influence technical efficiency. On the other hand, quay cranes, yard storage, conveyancer belts, and yard cranes have an influence on how a port performs. The trends in maritime transport have resulted in the for ports to expand in order to accommodate big vessels. Also, seaside operations such as BAP, QCSP and QCAP have an impact on the efficiency of a port.

CHAPTER FOUR

LITERATURE REVIEW

4.1 Introduction

This chapter reviews existing systems of ideas intended to explain technical efficiency and further reviews empirical evidence of technical efficiency of ports in countries around the world and SACU countries. The chapter is divided into three sections, namely, theoretical, empirical literature, and summary of the chapter.

4.2 Theoretical Literature

The chapter begins with reviewing the Neoclassical theory of the firm, then the chapter defines and examines the theory of production, further explains the concept of technical efficiency, and lastly, analyses the x efficiency theory.

4.2.1 Neoclassical Theory of the Firm

The firm's neoclassical theory provides the basis for efficiency-related principles. The firm's neo-classical theory derives from the static structure of equilibrium, first formulated by Cournot in 1883 (Kraaijenbrink and Spender, 2011). The mainstream neoclassical theory regards the business as a black box that turns money into economically viable products (Kraaijenbrink and Spender, 2011).

A production function or production possibilities collection is defined by this transformation of inputs into outputs. The firm's traditional neoclassical theory suggests that the company exists in a completely open environment where both businesses aim to increase their benefit (Kraaijenbrink and Spender, 2011). This is achieved by bringing together a plan to increase sales and minimize expenditures. As a consequence, a competitive general balance is reached by equating the median replacement rates of any two economic factors (inputs or outputs) among both businesses (Cohen and Cyert, 1975).

The economic balance contributes to the earning of regular profits for both firms. In other words, firms are unable to raise more money than is required to offset their economic expenses (Kraaijenbrink and Spender, 2011). However, it is likely for certain individual businesses to make abnormal profits in the short term, and this effect would draw other firms to enter the market and compete with existing firms (Kraaijenbrink and Spender, 2011). Competition between firms would lower the stock price until both companies make a regular profit in the long term (Holmstrom and Tirole, 1987). If any firm is unable to generate regular revenues due to inefficient practices, so these inefficient firms would either be acquired by more profitable firms in the long term, or they will have to quit the business (Holmstrom and Tirole, 1987). Therefore, according to the company's traditional neoclassical theory, the production company that allocates capital to achieve the highest production amount for the input given will succeed and the inefficient company will leave the market (Kraaijenbrink and Spender, 2011).

Empirical analysis, however, shows that not all firms work on an efficiency frontier. A significant number of firms still do not manufacture at a time when long-term average costs are reduced, but still succeed in the market (Holmstrom and Tirole, 1987). The standard neoclassical theory thus struggles to understand why inefficient industries succeed on the market, and some new hypotheses have been established to support the company's conventional theory because of this (Kraaijenbrink and Spender, 2011).

Demsetz (1997) noted that the firm represents the imperatives of the pricing system in neoclassical philosophy. If the pricing system operates well, it allocates money well. The standard theory, however, is not well prepared to describe the firm's internal processes and does not include an overview of the decision-making process or a straightforward description of the factors determining market performance or loss. The company's neoclassical philosophy (Baumol, 1959; Marris, 1964), behavioural models (Simon 1959, Cyert and March 1963), and X-efficiency theory have also been challenged by alternatives such as management philosophies (Leibenstein, 1966; 1978). Since these ideas encompass a broad spectrum of literature, the fundamental concepts underlying each theory have been briefly outlined to explain why institutions do not always perform efficiently.

Beaudreau (2016) notes that it is believed that the organization generates optimizing flow in the neoclassical sense at its benefit:

$$\frac{\partial \Pi}{\partial q} = 0 \Leftrightarrow p(q) + p'(q)q = C'(q) \Leftrightarrow q^* = f(p), \qquad 3.1$$

Where p(q) + p′(q)q is marginal income, the optimum output flow of the business is C'(q) marginal cost, and q*. The basic drawbacks of the theory are, according to Beaudreau (2016), time is abstracted in the theory and therefore q* relies on a fixed price p. Beaudreau (2016) suggests that this is in contrast to the observable growth of businesses, market cycles, and bankruptcies of companies; the theory assumes that price determines the supply flow, but how the company approaches its new optimum after a price shift is not mathematically clarified in the theory (Beaudreau, 2016).

The static and the dynamic neoclassical theory obtained by dynamic optimization are contradictory with each other; the interactions between the development decisions of firms are not sufficiently taken into account in modelling the activity of a single organization and the theory does not clarify the reason for companies to improve their production technologies or the efficiency of their production technology (Beaudreau, 2016).

Moreover, the theory of the firm influences decision-making in a variety of areas, including resource allocation, production techniques, pricing adjustments, and the volume of production. Therefore, this theory explains how the ports make their decision and how they decide to allocate resources. Also, it tries to explain how these port authorities should determine their prices, but because the is no competitive market between the SACU ports prices are not determined by the market, ports in Namibia are owned and controlled by Namibian Port Authority (Namport) and in South Africa ports are owned and controlled by Transnet National Port Authorities (TNPA). The only competition that exists is between Namibian Ports and South African Ports.

They compete mainly for transhipments and do not have any impact on rates. For example, in South Africa, the Transnet National Ports Authority (TNPA) and the Ports Regulator of South Africa are both working in a monopoly market and are currently using the Appropriate Revenue

(RR) approach as a technique for deciding system-wide price changes for South Africa's ports. In South Africa, the reason for port pricing is to cover all port prices, recover all port expenses, and make a profit (Gumede and Chasomeris, 2015).

4.2.2 Theory of Production

The production theory is defined by Kurz and Salvadori (1997) as an attempt to understand the rules under which a firm determines how much of each product or service it provides (its "outputs" or "products") it can create and how much each type of labour, raw material, fixed capital goods, will be used (its "inputs" or "production factors. Any of the most basic concepts of economics are involved in the theory. Both include, on the one hand, the relationship between the prices of goods and the prices (or incomes or rents) of the productive factors used to produce them, and, on the other hand, the relationship between the prices of commodities and the productive factors and, on the other, the quantities of certain commodities and the productive factors produced or used (Kurz and Salvadori, 1997). In the case of this research, the principle would clarify how to port dues are measured and how many cranes are required to maximize the turnaround time of vessels in a port (Kurz and Salvadori, 1997).

Furthermore, entrepreneurship has also been added as an input and is measured by the managerial expertise and ability to manage the other factors of production (Shepherd, 2015) Anything that goes into the production process is an input. It might be a service or it might be good. Inputs are classified as fixed or variable depending on how their use can be changed in the production process. From an economic point of view, a fixed input is one whose short-term supply is inelastic, but from a technical point of view, a fixed input stays fixed at a certain output level (Shepherd, 2015). In the short term, a variable input is one whose supply is elastic. Technical, a variable input changes with changes in output (Fuss and McFadden, 2014; Ferguson, 2008). However, all inputs are variable in the long run. However, all inputs are variable in the long run. Output on the other hand is the result of the production process and could be a good or service that is derived from the production process (Fuss and McFadden, 2014; Ferguson, 2008).

The usage of a production function defines the technical relationship between inputs and outputs (Robinson, 1953). Inputs and outputs are expressed in quantitative forms. Therefore, the production function is the maximum amount of output that can be produced from a given set of inputs (Robinson, 1953). The role of output often reflects a firm's technology. In this case, technical efficiency is achieved when a port produces the maximum possible output from inputs used, subject to existing technology (Robinson, 1953). On the other hand, economic efficiency is accomplished when a firm achieves a given output at the lowest net cost (Färe, Grosskopf and Lovell, 2013).). Production function can be represented in a mathematical model:

$$Q = F(Ld, L, K, M, T, t) \qquad 3.2$$

Where: Ld = land and building, L = labour, K = capital, m = materials, T = technology, t = time. If the sum of inputs used is reduced into two: labour and capital, would have the function as:

$$Q = F(K, L) \qquad 3.3$$

L and K must be raised ceteris paribus for Q to rise. If the company will improve its output depends on the time, whether short-term or long-term. Output can be expressed as either the overall output, the marginal product, or the average product.

The philosophy of development is a misnomer, since the theory of economics is nothing more than simplistic and numerous associations, without any fundamental theory (Färe, Grosskopf and Lovell, 2013). Material systems are entirely orthogonal, as planned by economists and process engineers. In engineering or applied mechanics, ideas such as the marginal product of labour or capital have no counterparts (Färe, Grosskopf, and Lovell, 2013).

Beaudreau (2016), on the other hand, states that the principle of neoclassical development is logically and empirically false and a cause of structural irrelevance. The theory of neoclassical development contradicts the fundamental mechanical laws according to which only force/energy can be physically efficient (Beaudreau, 2016). Since labour is inherently supervisory in nature and capital is not an energy source, it is fair that the principles of labour productivity and capital productivity contradict fundamental physics (Beaudreau, 2016).

It is important to remember that there are two leading productivity principles related to a production system, among others: the one sometimes called 'technical efficiency' and the other called 'allocative efficiency' (Libenstein, 1978). Below, these two principles will be presented. The specification of the production function implies that technical efficiency and management problems have already been discussed and solved (Libenstein, 1978). This is why a production function is (correctly) defined as a relationship between the maximum feasible technical output and the inputs necessary to produce that output (Mishra, 2007). It is, however, vaguely defined as a technical relationship between output and inputs in many theoretical and most empirical studies, and the presumption that such output is maximal (and minimal inputs) is always tacit. Furthermore, while the relationship between output and inputs is essentially physical, production functions also use their monetary values (Mishra, 2007).

Several types of inputs that cannot be aggregated into physical units are used in the production process. It also generates many kinds of output calculated in various physical units (joint production). There is an extreme view that there are numerous outputs produced by all development processes (Faber, Proops, and Baumgärtner, 1996). One of the ways to resolve the multiple production situation is by applying market weights to them to combine different items. Through doing so, one abstracts from basic and intrinsic elements of processes of physical production, including error, entropy, or waste (Faber, et al., 1996). In addition, manufacturing functions typically do not model firm processes, missing the role of management, sunken cost assets, and the interaction between fixed overhead and variable costs (Faber, et al., 1996).

It was noted that while the idea of manufacturing role usually suggests that technical efficiency has been attained, in practice this is not valid. This issue was discussed by some economists and operations researchers (Farrel, 1957; Banker, 1984; Lovell and Schmidt, 1988) by what is known as 'Data Envelopment Analysis' or DEA. The benefits of DEA are: first of all, a mathematical form for the production function does not need to be specifically defined here; it is capable of managing multiple inputs and outputs and is used for every input/output calculation, and there is no assumption of performance at the technical/managerial level. The concealed associations and causes of inefficiency are valuable for investigating. Technically, as a tool of analysis, it employs linear programming. To evaluate the technical efficiency of SACU ports, the analysis will use DEA.

4.2.3 Concept of Technical Efficiency

Technical efficiency is a productive efficiency factor that stems from the function of production. It was first practically recognized by Farrell (1957) cited by (Alrashidi, 2016). Productive efficiency consists of technical efficiency and price efficiency of tasks or variables. Allocative (or price) productivity refers to the ability to optimally integrate inputs and outputs given the prevailing costs and is calculated in terms of the processing unit's behavioural target, such as observed vs. optimum cost or observed benefit vs. optimum profit (Farrell, 1957). Technical efficiency is calculated as the ratio of the observed output to the maximum output under the assumption of a fixed input or as the ratio of the observed input to the minimum output under the assumption of a fixed output (Porcelli, 2009).

The production frontier characterizes the minimum input bundles needed to generate a given output level or the highest potential output production level from a given input level, usually referred to as technical efficiency (Palmer and Torgerson, 1999). And if the terms of production efficiency and technical efficiency are quite similar, they are not the same. The best way to separate production and technical efficiency are by changing the mix of inputs to perceive productive efficiency in terms of cost minimization, while technical efficiency maximizes output from a given mix of inputs (Palmer and Torgerson, 1999). Technical efficiency clarifies a company's physical success and tests a port's relative capacity to get the highest potential output at a given input or input collection (Palmer and Torgerson, 1999). A producer's technical efficiency is a measure of the measured and desirable values of its outputs and inputs (Farrell, 1957). This applies to the opportunity to reduce waste either by processing as much output as technology and input use allows or by using as little input as technology and output production demands (Palmer and Torgerson, 1999). Technical efficient ports are those ports that run on the production boundary that represent the maximum output at each input level (Farrell, 1957). Technical inefficiency can be defined as the amount by which an organization is below its production boundary or gain frontier. The company is more inefficient when it is far away from the border (Farrell, 1957).

On the other hand, González-Páramo (1995) affirms that technical or competitive efficiency in a business is provided by its ability to transform inputs (labour, capital, and other factors) into outputs (goods or services) in the sense of a technology that can be summarized with a production function setting maximum value or the "borderline" of achievable output in multiple input combinations. Tello-Trillo (2013) suggests that the study of technical or competitive output focuses mainly on the use of human or capital resources in the production of one or more products and services. In other words, it focuses on the use of physical units, implying that the expense or quality of variables and the value of the income earned from output remain beyond review.

The definition of efficient production function implies that each organization assesses technical efficiency concerning the category of companies from which this function has been calculated (Infante, Ortiz and Gutierrez, 2013). As more firms are added to the study, they may lead to a reduction but not to an improvement in a particular firm's technical efficiency. The heterogeneity of variables would not be important as long as it is distributed equally for all firms. Technical efficiency in a company can demonstrate input-output and managerial efficiency when certain differences in company average quality (especially in quality distribution) occur (Infante, et al., 2013). When these variations in quality are physically observable, this effect may be minimized by identifying a large number of fairly homogeneous factors in the output.

However, in reality, it will never be possible to remove them entirely. For this reason, a firm's technical efficiency will, to some degree, reflect input quality; apart from its variables, it is difficult to calculate managerial efficiency (Farell, 1957). Technical efficiency is thus defined with a certain group of firms and to a certain group of factors that are specially calculated. Any change to those requirements would impact calculation (Farell, 1957).

Pure technical efficiency shows to what degree the evaluated productive unit fulfils the full utilization of the available physical resources (Banker, 2004). Additionally, scale efficiency is important when variable scale yields are present in production technology (Banker, 2004). This form of efficiency indicates whether the evaluated productive unit has reached the optimum point of size. Scale yields arise from that the quantity of all variables involved in the production process in equal measure (Banker, 2004). There are three types of scale yields, which are called Returns to Scale – increasing returns to scale, decreasing returns to scale, and constant returns (Banker, 2004).

4.2.1 Returns to Scale

The concepts economies of scale and return to scale are related but, in economics, mean very different things. Therefore, economies of scale apply to cost savings arising from increased output volume, returns on a scale are the difference or improvement in productivity resulting from a proportionate increase of all inputs (Simar and Wilson, 2002).

4.2.2 Increasing Returns to Scale

A condition where all output variables are increased and efficiency increases at a higher rate leads to increased output returns or decreasing costs (Simar and Wilson, 2002). This means that if all inputs are duplicated, the output would also increase at a more rapid pace than double. Accordingly, the returns to scale are increasing. This rise is due to several factors, such as the isolation from outside economies of scale.

4.2.3 Decreasing Returns to Scale

Decreasing returns or increasing costs refer to the production situation where the output increases in a smaller proportion of all the input factors are increased in a specified proportion (Snyder, et al., 2012) This would mean output would be less than multiplied when inputs are multiplied. If an increase of 20% in labour and capital is followed by an increase of 10% in revenue, this is an example of dropping returns on the scale (Simar and Wilson, 2002).

4.2.3 Constant Returns

The constant return to scale or constant cost refers to the situation of production in which output increases the same proportion in which production factors are increased. When input variables are duplicated output is often multiplied in simple terms (Simar and Wilson, 2002).

External and external economies in this situation are almost the same as internal and external disease economies (Jehle, 2002). This condition occurs when economies of scale are offset by diseconomies of scale after attaining a certain level of output. This is known as a homogeneous production function. A good example of this form is the Cobb-Douglas linear homogenous output function (Jehle, 2002).

Technical efficiency thus reflects the synthesis of pure technical as well as size efficiencies (Simar and Wilson, 2002). Technology is seen as a crucial factor in understanding the idea of technical efficiency. Companies face technical constraints, as only a few feasible factor combinations are required to get a certain amount of production (Infante, et al., 2013). Industries will instead confine themselves to implementing technically feasible development plans. Then the category of all combinations of variables and technically feasible goods is called the development category (Infante, et al., 2013).

Simar and Wilson (2002) state that it becomes important to calculate the maximum possible output corresponding to a certain number of factors if factors pose a cost to the company. It is what is known as the production group's borderline which measures the maximum value of output that can be obtained through many factors (Simar and Wilson, 2002). This refers to the isoquant definition, which is the total of all possible combinations of factors required to produce a certain amount of output (Jehle, 2002).

The study seeks to investigate the technical efficiency of SACU ports. The concept of technical efficiency helps to identify which ports are technically efficient and technically inefficient by using scale yields such as increasing returns, decreasing, and constant returns. If a port is experiencing constant returns to scale, it is believed to be technical efficient, and if a port is experiencing decreasing returns to scale or increasing returns to scale it is believed to be technical inefficient.

4.2.4 X- efficiency Theory of the Firm

X-efficiency theory combines behavioural theory with the theory of management utility and was developed in fast successions (Leibenstein, 1978). X-efficiency represents a company's overall efficiency (given the resources it uses and the latest available technologies) in converting inputs into outputs. Leibenstein (1978) argues that by criticizing the principle of neoclassical theory, businesses are not best placed to optimize revenue, and many of them maximize managerial utility instead (Stigler, 1976).

In addressing the neo-classical theory, Leibenstein (1978) describes two possible sources of inefficiency. The first cause is a disparity between price and marginal cost, better known as allocative inefficiency. The cause of this could be monopolies, tariffs, and other impediments to sustainable rates of production. The second factor is known as X-inefficiency, which results from the failure of firms to attain the lowest possible cost of making their goods, resulting in the loss of capital. Leibenstein (1978) states that inefficiencies in X-inefficiency are more significant than inefficiencies in allocative inefficiency.

Under the principle of X-efficiency, the principle of non-maximizing action was often known as the core idea of X-efficiency (Leibenstein, 1978) and an important cause of X-inefficiency is the issue of principal-agent relationships. In comparison, the latter may escape the repercussions of cost overruns and have less desire to hold costs down because of the function of incomplete contingent arrangements between principals and agents. In this scenario, businesses would be more X-inefficient,

The principle of x-efficiency has several distinct underlying principles (Huil, 2014). One of the key hypotheses is that, because of the focus of the work of top managers, poor productivity will occur. The primary concern of top management is on financial and corporate affairs rather than operating the factory and production effeciency (Leibenstein, 1966). This is a kind of agency problem. In other words, the type one agency issue is the likelihood of conflict of interest between the owners and the management of a company (Huil, 2014). One explanation for the presence of x-inefficiency may be a differentiation of interests. The units of study for this assumption are people that are also covered in the next assumption.

The second assumption is that Leibenstein (1975) sees citizens as the central unit of analysis, which is not the case, for instance, in neoclassical theory. The unit of study is the neoclassical theory of households and businesses. Through this distinction in the unit, Leibenstein (1975) wishes to make it clear that people have a significant effect on the success of organizations in both a negative and a positive way, and that the ultimate performance of an organization depends on the performance of the people working for the organization (Huil, 2014).

Now comes the third premise, which is the efficiency of motivation. Tomekovic (1962, quoted according to Leibenstein, 1996) provided four interesting results inside this stage. The first of the four is that smaller units of function are more efficient than larger ones to a certain extent. This may be that someone has to contribute to production within fewer working units and the potential is strong to eradicate so-called free rider. His second result is that there are more efficient work units made up of mates than non-friends. Friends help each other; this may be true for productivity as well.

The third result from Tomekovic (1962) is that units that are normally supervised are more successful than those that are closely supervised. In a given labour cycle, each person has a different labour effort and most people have different working styles with different efforts (Huil, 2014). One potential explanation for this may be that more confidence is enjoyed by broadly supervised units than by tightly supervised units. Without strain from being tightly watched, they will feel freer and may function however they would like. This is often illustrated by other books.

Efforts can be defined in two distinct ways, according to Leibenstein (1978), quoted by (Huil, 2014). On the one hand, there is a voluntary basis on which staff act. There is a beneficial utility involved with this form of job because workers do not have to work, but because they wish to and are strongly motivated, they do so. There is the kind of job on the other hand, where workers are tracked. Leibenstein (1978) quoted by Huil (2014) found that if it is sensitive to low output level data, a well-monitored structure could increase efficiency. But he stated the downside of tracking at the same time. There are financial losses on the one hand, and that could lower employee motivation on the other, so they get a sense of mistrust.

The technical efficiency definition is related to X-efficiency. X-inefficiency is said to exist where, due to the absence of competitive forces, an organization is not technically successful. For example, a monopoly uses unsustainable labour practices because it does not have an opportunity to minimize costs. In the case of the study, the SACU ports may be physically inefficient, e.g. in the case of South Africa, where the ports are operated and managed by TNPA, there is no rivalry between the ports, as though they were owned by separate firms. The only pressure could come from neighbouring countries' ports such as Mozambique or Namibia.

4.3 Empirical Literature

Empirical literature comprises of empirical literature of global countries and empirical of Namibia and South Africa.

4.3.1 Empirical Literature Review from Global Countries

Dappe, Jooste and Suárez-Alemán (2017) explored how a port's capability in Indian and Western Pacific Ocean countries is affected by maritime transport costs and trade. To test performance, DEA was adopted with the following input and output variables: number or scale of quays, gantry cranes and services, terminal yarding and labour force, port cranes, and some quay cranes. The study finds that being as competitive as the nation with the most profitable port sector would decrease its maritime transport average cost by up to 14% and raise its exports by up to 2.2%. The study suggested that future studies should apply the review to all developed countries to decide whether port output disparities clarify the discrepancy between the cost of maritime transport and exports through developing countries.

Wua and Goh (2010) assessed the port efficiency of containers in BRIC and the Next-11 countries using DEA for the 2005 period. The study applied DEA with the following variables of input and output: total tonnage throughput, service level, customer satisfaction, ship calls, total cargo moving through docks, revenue from port rental facilities, ship working time, number of containers, number of ships, total containers handled and total cargo handled. The findings indicate that none of the advanced market ports are role models for the business.

Pjevčević, Radonjić, Hrle, and Čolić (2012) conducted a study to analyse port efficiencies of Serbian ports for the period between 2001–2008. The study used DEA to determine the efficiency of Serbian ports. Variables used were total warehouse space, quay length, number of cranes, and port throughput. Port of Pančevo and port of Smederevo described by Pjevčević (2015) are efficient. The study reported that the lack of data unavailability has an influence on the number of ports studied as well as the number of inputs and outputs, and is likely to overshadow the reasons behind port effeciency. The work carried out here may thus be the beginning of one more complex study rather than the end of the same.

To evaluate regional port efficiency in Asia Pacific Economic Cooperation (APEC), Wu, Yuan, Goh and Lu (2016) applied SFA. They made use of three inputs, quay lengths, terminal area, capability, and one output-port traffic container. We concluded that the findings suggest that, first, the average capacity utilized by APEC members ' ports was only 65.7 percent during 2002–2011, which means that another 34.3 percent of the additional via put could be managed with the same resource levels.

Hlali (2018) evaluated the container ports ' performance of 26 major ports such as Shanghai and Singapore for the 2015 era using DEA and SFA. In these ports, the variables used to assess efficiency were: total quay length, port depth, total terminal area, and storage space. In 2015 the most efficient container ports are Shanghai, and with an undetectable gap, Shenzhen achieved a high technical performance benefit. Hlali (2015) suggested that future research would expand this report, and identify container ports according to their requirements. Furthermore, Hlali (2015) suggested that the separation of terminals into transhipment, getaway, and hybrid be a required step in port efficiency assessment, as ports are part of various strategies and serve varied functions within the regional port network.

Kammoun (2018) used both the DEA and SFA models to assess the technical efficiency of Tunisian ports for the period from 2007 to 2017. The variables selected were managed labour, stevedoring machinery, storage, and cargo. The empirical result shows that DEA-BCC (0.746) > SFA-CD (0.536)>DEA-CCR (0.334) was the total average of the operating performance scores from 2007 to 2017. Despite these tests, the Gabes port can be considered the best effecient port in the 3 models (DEA-BCC, DEA-CCR, and SFA-CD).

By applying both DEA and SFA, Barros, Chen and Wanke (2015) determined the efficiency of Chinese seaports between 2002 and 2012. The selected variables for the study were operational costs, wages, container port traffic, and the number of passengers. Findings suggest that there is considerable heterogeneity in China's seaports, affecting their cost efficiency estimation.

Wang, Huo, and Ortiz (2015) used both DEA and Panel Data Estimation (PDE) models to assess the energy efficiency of China's port operations. He concluded that advancing intelligent logistics and intelligent transport would boost fuel economy using remote sensing and Big Data Analytics

For the period 1999 to 2009, Serebrisky, Sarriera, Suárez-Alemán, Araya, Briceño-Garmendía and Schwartz (2016) used the SFA model to examine the Latin American and Caribbean port efficiency drivers. The model used a statistical number of ports, length of a quay, terminal area, mobile cranes, and gantry cranes as inputs and annual total production. Researchers found an improvement in the average technical efficiency of ports in the Latin American and Caribbean region from 52 percent to 64 percent between 1999 and 2009; the best-performing port achieved 88 percent technical efficiency at the border in 2009.

Suárez-Alemán, Sarriera, Serebrisky and Trujillo (2016) have recently employed the SFA model to find out if all developing regions are equal when it comes to container port capacity. The variables used were for some ports were the number of quays, annual throughput (TEU), length of a quay, terminal area, mobile cranes, and gantry cranes. Results showed that the results of the time series indicate an upward trend in port efficiency in developing regions, rising from 47 percent in 2000 to 57 percent in 2010. The study indicates that the involvement of the private sector, the reduction of public sector corruption and developments in linear connectivity, and the existence of multimodal links increase port efficiency rates in developing regions.

Jiang and LI (2009) used DEA to examine seaports' performance in Northeast Asia. The study's variables were imports, GDP, lengths of quays, number of cranes, and throughput. The results of measuring technical efficiency suggest that substantial potential exists to increase the technical efficiency of seaports and the variability in the technical efficiency of seaports in northeast Asia.

Yuen, Zhang and Cheung (2013) conducted a Theme-International Interaction and Competitiveness study: A Way to Increase Container Port Performance in China? The study made use of DEA-CCR in its analysis. The output and input variables were the number of quays, a total length of a quay, land size, number of quay cranes and yard gantries, and TEU. The results were that having some Chinese ownership could make a container terminal more efficient while a container terminal would be less efficient with the Chinese being the main shareholder.

Trujillo, González, and Jiménez (2013) gave an overview of the African ports reform process. Use Quays, Terminal Area, TEUs, Cranes, Index of Corruption, and Port Performance as variables. Form DEA was used to perform a summary. The study results show that not only are landlord ports the most productive but also the most respected ones.

Kennedy, Lin, Yang, Ruth (2011) applied the Stochastic Frontier Analysis (SFA) model to evaluate Five Asian Ports using the Stochastic Frontier Production Function Model for the period 2005 to 2010. The labour, port throughput in TEUs, quay capacity, terminal area, and a number of quay cranes used the following variables. Because of the quality of port facilities, storage, and cargo handling, they concluded that large seaports are more efficient than smaller ones.

Van Dyck (2012) analysed Port Efficiency in West Africa using Data Envelopment Analysis for the 2006–2012 period. Variables used in this study were container crossing (TEUs), total quay length, terminal area, number of quayside cranes, number of yard gantry cranes, and number of reach stackers. The study identified Port Tema in Ghana as the most productive port among the sample closely following suit with the Abidjan and Lome ports.

Ding, Jo, Wang and Yeo (2015) conducted a study to assess the relative efficiency of container terminals in China's small and medium-sized ports for the period 2008-2012. To determine the performance of these ports they applied DEA. The variables used were Employment, number of shareholders, terminal activity, Capital, and number of shipping routes. The results indicate Rizha port and Lianyungang port are the most efficient terminals. They further suggested that by coordinating hub ports, small and medium-sized ports (SMP) can boost their performance. Ding et al. (2015) proposed that future research would concentrate on the multi-dimensional concept of SMPs based on their differences from hub ports, e.g. bulk/container cargo length, storage size, network condition, and information structure.

Odeck and Brathen (2012) performed a meta-analysis study of 40 papers published in scientific journals focussing on the Mean Technical Efficiency (MTE) of DEA and SFA seaports. The research related MTE scores to different factors such as the methodology used, the form of data used, the number of observations, and the number of variables overall. The study further compared fixed-effects with the random-effect regression model, in which the latter assumes that the particular study's basic features matter, while the former assumes that all experiments have a general trend. The findings indicate that the experiments using nonparametric DEA models have higher MTE scores than those using parametric SFA models, and the outcome is important at a 10 percent significance level.

The year of study and the total number of variables used are the increasing variables that greatly explain the difference in TE scores across studies. This outcome indicates that recent studies yield lower MTE scores, that recorded MTE scores have declined over time, and that higher MTE scores are provided by studies that use a greater number of variables. Some important findings were also obtained by analysing the effects of research characteristics, represented by the dummy variables. Studies using only European data have been shown to produce lower MTE scores, whereas studies using Asian and the Middle East/Africa data do not generate substantially different MTE scores relative to studies using a world data cross-section. Finally, contrary to the use of cross-sectional data, the use of panel data generates considerably lower MTE scores.

Tovar and Wall (2015) analysed the technical efficiency of Spanish ports. They built their model using the following variables, container cargo, solid bulk cargo, liquid bulk cargo, general non-containerised cargo, passengers, infrastructure and buildings, deposit surface area, labour, and supplies. A parametric method, Stochastic Frontier Analysis was used in the methodology, unlike other studies that used DEA a nonparametric method. Among the port reports, the findings revealed signs of technical inefficiency. If the ports were working successfully, the results were that containerized cargo could be increased by more than 6.4 percent on average, with an equal drop in variable inputs. With a resulting decrease in vector inputs, solid bulk cargo and general non-containerized cargo will be raised by 4.1 percent and 6.1 percent, respectively. The findings showed that there is sufficient space for ports to specialize, with no rise in maintenance costs. This opens up the prospect of moving towards a management model focused on taking advantage of existing capacity rather than new projects, provided that major investments in infrastructure have been made in Spanish ports over the last decade.

Cheon, Dowall and Song (2010) assessed how, between 1991 and 2004, port structural changes affected productivity improvements. For 98 major world ports, they developed a panel of data for port ownership, organizational organization, and port inputs and outputs, and introduced the Malmquist Productivity Index (MPI) model. The MPI offered optimization mechanisms for input combinations, which made it possible to produce outputs in the face of administrative improvements, changes in ownership, major agent issues, technological advancement, productive growth of the size, and many other explanations for efficiency and lack thereof. The findings found that restructuring of ownership led to increases in overall factor efficiency. The restructuring resulted in an integrated container terminal operation, especially for large ports, as it allowed specialist private companies to focus on terminal operations and cargo handling services.

Polyzos and Niavis (2013) evaluated for deficiency in the Mediterranean for the year 2008. They used the ports' two-stage performance. For the classification of ports depending on the related quality, DEA was used. To examine the relationship between the output of each port and factors influencing the activity of ports, DEA results were further analysed on the Tobit model. The length of quays and the number of ships to shore cranes were used as inputs, whilst the number of TEUs moved from each port would be used as outputs for 2008. The results of the DEA study show the practical inefficiencies of the ports because not only the elegance of enormous container sizes but above all the qualitative, actual, and safe container transport is significant. All in all, ports have to be able to meet some spike in the cost of the move. This presupposes ideal places, flexible pricing practices, ample contact with the hinterland, and skilled personnel. Then, to make a port efficient, immediate structural changes in its structure are needed.

To analyse and measure the productivity of major container ports in Peninsular Malaysia. Mokhtar and Shah (2013) used Malmquist Productivity Index (MPI) the study used 6 container port terminals in peninsula Malaysia as DMU. They constructed panel data from 2003 to 2010 of container terminals in peninsula Malaysia. Total terminal area, maximum draft, quay length, quay cranes, yard stacking, vehicles, and number gate lanes were used as an input of the MPI model while container throughput was used as an output. The findings of Malmquist productivity reproduce the real productivity of container ports inside container terminals following the services and obtained throughput. The current expansion of container terminals by port operators is proved in line with future demand.

To assess dry port efficiency, Haralambides and Gujar (2016) applied the eco-DEA model, taking into account the CO2 emissions generated by the transport of containers from dry ports in the northern region of India to the various gateway ports. Equipment, workers, terminal area, distance, and emissions were added to the eco-DEA model as inputs and container throughput as output. The findings suggest that as environmental factors are factored into the model, performance assessments are dramatically changed. It is easy to move the approach suggested here to every other industrial field where environmental issues are becoming a challenge.

Niavis and Tsekeris (2012) conducted a study to benchmark measure and identify major determinants of the technical efficiency of container supports in the region of South-East Europe.

The study employs both non-parametric (standard and super-efficiency DEA) models and the Tobit model to provide a more holistic approach and useful insight into the given problem. The study included 30 seaports in the wider region of South-East Europe. The number and the lengths of quays, cranes were used as inputs and container throughput as an output. Area, population, GDP per capita, and distance from Suez Canal were used as explanatory variables in the Tobit model. Due to the implementation of the convex constraint in this model the DEA-BCC model resulted in indicators of more efficient ports. In the DEA-CCR model, the convex constraint does not exist and this restriction allows for more productive points at the output frontier. Active in 2003 were four American ports and two Asian ports. The other ports also usually had poor productivity rates. The productive ports in the Americas were, in general, the standard for benchmarking in the same region's ports. The model revealed that the terminal area and container throughput were strong relationship variables.

The operational reliability of seaports is crucial to the processing of goods in foreign supply chains and is known to have an impact on shipping and logistics that plays an important role in trade with other countries. The organizational efficiency of five agent seaports was assessed by Kennedy, Lin, Yang and Ruth (2011). The thesis used stochastic boundary analysis to analyse the operating efficiency of seaports and the Delphi methodology to obtain the opinion of the expert respondent on its characteristics. The vector used for SFA was the length of the quay, terminal area, number of cranes, and throughput of containers. The sample of experts for the Delphi technique included port employees, the number of employees represented, and the percentage of employees in all ports. Depending on the terminal, the findings obtained provide port administrators, owners, and market professionals with valuable implications. The findings demonstrate that the scale of the port and infrastructure, the role of the private sector, and the effeciency of both cargo handling and logistics services are significant determinants of performance.

4.3.2 Empirical Literature Review from Namibia and South Africa

Motau (2015) measured port efficiency at the container terminals in South Africa. Both quantitative and qualitative analyses were used in the analysis to collect enough data to better explain the patterns. The findings revealed that the operator of the port terminal produced production rates ranging from low-than-target gross crane movement per hour and ship operating time to a marginally higher-than-target performance over a few months. It was proposed that the condition of the cranes should be technically and physically sound at all times, along with their landside support facilities, for a container terminal to achieve better container crane performance.

Amakali (2017) researched the history and outcomes of port governance in Namibia: The Port of Walvis Bay case. To interpret both qualitative and quantitative findings, a composite approach of the approaches was used. The historical analysis was the purpose of the situation, so separate data sources (primary and secondary) were used for the study. The research found that within the area, the port is competitive but lags in powerful data processing systems. Collective actions can be attributed to the increase of Namport's sales year-on-year, with management delegating board decisions successfully and staff efficiency well.

Mienie, Sharp and Brettenny (2017) ranked selected African ports using DEA. The number of quays, quay lengths, terminal cranes, yard equipment, and TEUs were used as variables to determine efficiency. The findings show that, relative to several of their neighbours to the north, many South African container terminals will boost their operations. The findings also show that the Ghanaian port of Tema is completely efficient, although a bias correction resampling technique was used to define the scope for improvement.

4.4 Summary

This chapter highlighted the theoretical overview and review of the theory of frim, production theory, x-efficiency theory, and concepts of technical efficiency and highlighted the empirical literature review while indicating the various variables and their relationships. The results from the reviewed empirical literature vary depending on the methodology applied to identify the port efficiency or technical efficiency. Some empirical studies used Data Envelopment Analysis (DEA) or Stochastic Frontier Analysis (SFA) to analyse efficiency. Chapter four discusses port operations and how are the variables used for this study were chosen.

CHAPTER FIVE

METHODOLOGY

5.1 Introduction

Inferences drawn from chapter one, two, three and four, informed this study on the selection of research design and general methodology. The chapter describes the series of processes and methodologies implemented for this study, including information on how concepts have been utilized. In stage one (1), the DEA method is used to measure the technical efficiency of the SACU ports from 2014 to 2019 using input variables (number and length quays, draft, number of tugboats and quay cranes) and output variables (container throughput, cargo handled and ship calls). In stage two (2), the Tobit model is used to further the analysis by taking the results of the DEA as dependent variables while input variables from the DEA model are used as independent variables.

5.2 Key Performance Indicators (KPIs)

The technical efficiency of the port is evaluated by checking whether the real performance exceeds its optimum value (Vitsounis and Pallis, 2012). Four sections define port efficiency metrics:' Ship Operations, Cargo Handling, Warehousing and Inland Transport' (Vitsounis and Pallis, 2012). Due to inadequate facilities, the port's poor performance depends on the time spent staying, delaying surcharge, and ignorance from larger ships. Container terminals are the main factors in the operational technical efficiency of a port by-ship transit times and thus maximizing terminal performance (Pallis and Syriopoulos 2007). Yard operations in container ports are the busiest of all terminal operations in (Pallis and Syriopoulos 2007). Efficient handling of ships with shortened waiting times in port and optimal utilization of the quay infrastructure must be the main priority of a container yard operation (Ruto & Datche, 2015).

The most important port technical efficiency parameter is the capacity to handle more vessels in one quay (Yang, Wang and Li, 2012). Quay machinery and devices also add to the performance of the port by loading and unloading cargo from a truck to a quay or unloading a load from a ship to a truck or vice versa (Babounia El ImraniI, 2016).

In addition to the port, quays are also active in improving port terminal capacity. The number and length of the quay at a port is one of the most important factors influencing port performance and technical efficiency (Yang et al., 2012). Strong cargo handling practices and adequate infrastructure help to prevent congestion and are indicators of technical efficient port facilities which ultimately boost foreign trade and port connectivity (de Langen Nidjam and van der Horst, 2007).

Another important element, port dwell time refers to the time spent or its extension by the carriers inside the port (Liu, 2010 Cargo dwelling time is another significant influencing factor, described as "the period between the vessel's arrival and the cargo departure from the port facilities, and less the more efficient average dwelling period is the seaport" (Slack, Wiegmans and Witte, 2018). Since faster ship loading and unloading will improve ship calls, the pace of cargo handling is also very significant. Slow speed would allow the vessel to hold the quay longer, thereby slowing the call of the next vessel and making a bad perception since the number of terminals is fixed (Neysi, Jafari and Zangoui, 2013).

5.3 Measuring Port Technical Efficiency

The widely used techniques for estimating technical efficiency /productivity/analysis are Stochastic Frontier Analysis (SFA), Data Envelopment Analysis (DEA), Vector Error Model (VEM), Corrected Ordinary Least Squares (COLS), Ordinary Least Squares (OLS) (Barr, 2004). By covering data and line location modification, COLS uses average line projection regression techniques. It will then weigh the corrected line against the limit (Bates and Bates, 2007). The Original Least Squares (OLS) estimation approach effeciently utilizes a regression algorithm to adjust the average data line (Chun & Keleş, 2010).

Nonetheless, this analysis uses Rstudio to estimate technical efficiency (Barr, 2004). Via this approach, which is based on input and output information, the system maps a production frontier. The efficiency level is defined by the interval between the observation and the limit (Valentine and Gray, 2001). The vector throughputs are contrasted to test the efficiency of case ports on the output. DEA systems use input and output weights as the basis for measuring production, and these units can be divided into efficient and inefficient companies or businesses. Inefficient unit values reflect the amount of input or output variables required to be functional.

In this analysis, the input variables used are quay cranes, draft, quay length, and number quays and tugboats while the output variable is; cargo handled, ship calls, and throughput of containers. The variables were taken from secondary sources by scholars and shipping agencies, such as annual accounts of case ports and literature. The DEA framework was then used to define the performance of the case ports and then evaluate the factors affecting port technical efficiency using the Tobit model.

5.4 Data Envelopment Analysis (DEA)

Charnes et al (1978) developed the Data Envelopment Analysis (DEA), this approach is based on linear programming and transforms the input and output variable into a linearity technique to calculate performance, this conversion is based on the inputs and outputs of its decision-making units (DMU). Normal CCR tests the constant return to scale in the DEA model while normal BCC tests the variable return to scale efficiencies.

DEA framework can be divided into input-oriented and output-oriented applications. In the case of this study, it uses an output-oriented application. There are two models for radial and non-radial DEA calculation of efficiency (Mienie, Sharp, & Brettenny, 2017). Data Envelopment Analysis is a technique for determining performance based on the principle of mathematical programming. When extracting information from sample observation, DEA provides an alternative to classical statistics. DEA optimizes each observation to measure a discrete piece-wise frontier defined by the set of DMUs (Mienie, Sharp and Brettenny, 2017).

In other words, DEA focuses on individual effects as opposed to conventional statistical optimization methods that rely on parameter averages (Cooper, Seiford, and Zhu, 2011). DEA refers to each port in the present application as a DMU, in the sense that each port is responsible for translating inputs into outputs. DEA analysis can include multiple inputs and multiple outputs in their efficiency assessment (Cooper, Seiford, and Zhu, 2011). The current study does have multiple inputs (number and quay length, draft, number of tugboats, and quay cranes) and outputs (container throughput, cargo handled, and ship calls). Moreover, DEA has two models namely, DEA-CCR and DEA-BCC.

5.4.1 DEA models

5.4.1.1 Farrell model

Farrell (1957) proposed using the output frontier or so-called efficiency frontier to measure the consistency of input, using the "non-present production function" to replace the common "preset production function," taking all decision-making units (DMUs) as equal to one production function and using piece-wise to connect the most suitable DMU points to create an enveloping curve or efficiency frontier (the value of 1 indicates it is efficient, otherwise it is inefficient). There are three key theories in this theory: (1) the output boundary consists of the most effecient evaluation units and comparatively inefficient evaluation units that fall below the boundary; (2) the constant return to scale (CRS); (3) the convex root of the output boundary and the slope of each phase is not positive.

5.4.1.2 Charnes–Cooper–Rhodes (CCR) model

Charnes et al. (1978) extended Farrell's definition of multiple inputs and single output performance calculation to the concept of multiple inputs and multiple outputs, used linear combinations to translate them into single virtual input and output, determined the efficiency limit from the ratio of two linear combinations, and estimated the relative efficiency of each CRS DMU, which is between 0.

5.4.1.3 Banker–Charnes–Cooper (BCC) model

In both Farrell and CCR models, Banker et al. (1984) generalized the definition of the CCR model ratio and rate of operation; performance was supposed to be measured in CRS, but allocative effeciency, acceptable scale, and technical complexity could not be inefficient. BCC then changed CCR to the variable returns to scale (VRS) concept, broke down technical efficiency into pure technical efficiency and scale efficiency, and measured its efficiency and returns to scale.

Furthermore, the simple DEA models can be broken into CCR and BCC variants. "overall technical efficiency" is the efficiency value measured in the CCR, while "pure technical efficiency" is the efficiency value calculated by the BCC. "Scale Efficiency is the former divided by the latter". The distinction between the performance value of the scale and the pure technical value sheds light on the key cause of DMU inefficiency and can include technical issues relating to the quantity and combination of input and output variables or the whole operating scale. The scale return analysis would determine whether it is in the stage of increasing or decreasing returns to scale to assess the rise/decrease of the scale.

The following model was suggested by Charnes, et al. (2001) as an explanation of how the relative efficiency score of DMU is obtained:

$$max\frac{\sum_{k=1}^{s}u_k y_{kp}}{\sum_{j=1}^{m}v_i x_{ip}} \tag{5.1}$$

$$S.t\frac{\sum_{k=1}^{s}u_k y_{ki}}{\sum_{j=1}^{m}v_j x_{ji}} \leq 1\ \forall i, and\ u_k v_j\ \geq 0\ \forall k, j \tag{5.2}$$

Where: equals the amount of output *k* (cargo handled, ship call, and container throughput) produced by DMUi (SACU Ports); equals the amount of input *j* (quay cranes, number of tug boats, quay length, draft, and number of quays) utilised by DMUi; equals the weight given to output *k* and equals the weight given to input *j*.

The above computations can be converted to linear programming form:

$$max\ \sum\nolimits_{k=1}^{s} u_k y_{kp} = \theta_p \tag{5.3}$$

$$Subject\ to\ \sum\nolimits_{j=1}^{m} v_j y_{jp} = 1 \tag{5.4}$$

$$\sum\nolimits_{k=1}^{s} u_k y_{ki} - \sum\nolimits_{j=1}^{m} v_j x_{ji} \leq 0\ \ \forall i, u_k v_j \geq 0\ \forall k, j. \tag{5.5}$$

The above models can be combined to form DEA-CCR and DEA-BCC models as shown below:

CCR Model Max $\emptyset_k$

$$S.t \sum_{j=1}^{n} \lambda_j x_{ij} \leq \emptyset_r x_{ir} \;\; i = 1,2 \ldots, \; m; \tag{5.6}$$

$$\sum_{j=1}^{n} \lambda_j y_{rk} \quad r = 1,2, \ldots,_{s;} \tag{5.7}$$

$$\lambda_j \geq 0 \;\; \forall j \tag{5.8}$$

BCC Model

$$\sum_{j=1}^{n} \lambda_j = 1 \tag{5.9}$$

Where $\emptyset_k$ represents the efficiency of an output for DMU.

DEA allows for the determination of efficient input and output targets for the inefficient DMUs and a reference set (or peer group) of efficient DMUs (Camanho and Dyson, 1999).

Furthermore, under the assumption of variable returns to scale (VRS) or constant returns to scale (CRS), efficiency can be calculated. The preference between CRS and VRS influences the shape of the surface of the envelope and, therefore, the number of successful DMUs. If all inputs contribute to a proportional increase in output, CRS achieves proportional growth. DEA models using the CRS are known as models of CCR (Charnes, Cooper, and Rhodes). From many inputs and one output to several inputs and many outputs, the CCR model introduces the efficiency estimation principle of the Farrells. The performance limit calculations for the calculation of relative efficiency would be the ratio of these simulated outputs to input combinations, provided that the yield is constant (Karimzadeh 2012).

The CRS model is more traditional relative to the alternative VRS and provides fewer efficient units and lower efficient scores (Karimzadeh 2012). VRS can decrease or increase. Increasing scale returns require a proportional increase in all inputs of the production factor, leading to a more proportional increase in output, while the reverse is true for decreasing scale returns where a proportional decrease in inputs of the factor corresponds to a decrease in output less than proportional (Titko 2014).

Models applying the VRS are called the BCC's (Banker, Charnes and Coopers 1984) model. In comparison to the set yield in the CRR model, the BCCs model assumes a variable output for the scale. Tahir, Bakar and Haron (2009) say that a VRS-efficient firm is considered to be technically efficient; pure technical efficiency (PT) is expressed in the VRS ratings, whereas a CRS-efficient firm is technical efficient and therefore uses the most efficient scale of operation. Scale-efficiency (S) is derived from the calculations of technical efficiency (T) and pure technical efficiency (PT).

$$S = \frac{PT}{T} \tag{5.10}$$

Or

$$S = \frac{CRS}{VRS} \tag{5.11}$$

Where If the value of S equals 1, the firm is scale efficient and all values less than 1 reflect scale inefficiency. A calculation of technical efficiency is defined as a measure of overall technical efficiency (OTE) under the assumption of constant returns-to-scale (CRS). Because of the input/output configuration as well as the scale of operations, the OTE test helps to assess inefficiency. The OTE measure in DEA has been broken down into two components that are mutually exclusive and non-additive: pure technical efficiency (PTE) and scale efficiency (SE) (Tahir., 2009). This breakdown provides an insight into the origins of inefficiencies. By calculating the efficient frontier under the assumption of variable returns-to-scale, the PTE calculation is obtained. It is a measure of technical efficiency without scale efficiency and represents purely the managerial success of arranging the inputs in the production process (Tahir., 2009). Therefore, to collect management efficiency, the PTE measure is used as an index. The OTE to PTE ratio offers a SE scale.

The SE measure provides management with the option to select the optimal resource size, for example, to decide on the size of the port or, in other words, to choose the production rate that will reach the expected amount of production (Tahir., 2009). Often an insufficient port size (too big or too small) may be a source of technical inefficiency. This is called scale inefficiency which takes two forms: decreasing returns-to-scale (DRS) and increasing returns-to-scale (IRS). Decreasing returns-to-scale (also referred to as scale diseconomies) means that a port is too big to take maximum advantage of the scale and has a super-optimum scale size (Tahir., 2009). A port with increasing returns-to-scale (also known as economies of scale) is, on the other hand, too small for its scale of operations and, thus, runs at a sub-optimum scale. A port is efficient in scale if it runs at constant returns-to-scale (CRS).

5.5 First stage analysis-data envelopment analysis (DEA)

To measure the efficiency scores for each of the sample ports, the author used DEA. The author ran an output-oriented model with variable returns to scale using Rstudio to approximate the individual port efficiency ratings (VRS). The VRS model computed the pure technical efficiency and scale efficiency for each of the sample ports. From the VRS model, the author evaluated whether the output of ports implied a rising return to scale, a constant return to scale, or a declining return to scale. On the premise that there are variable scale returns and not all ports function optimally, the VRS paradigm was implemented.

5.6 Data Analysis for Port Technical Efficiency

Using secondary data relating to variables that have been defined as influencing port output, quantitative mathematical research was performed to determine and evaluate the technical efficiency of 10 SACU ports against each other. DEA has been used for this purpose. The DEA was selected as an important non-parametric instrument to measure the utility of a DMUU (Cullinane et al., 2005, Cullinane Wang, Song and Ji, 2006). In several industries, including the wider transport industry, DEA is commonly used (Cullinane et al., 2006). It is also a technique that places minimum input and output weights constraints (Doyle and Green, 1994).

5.7 Model Specification

In this analysis, an output-oriented model is used based on the suggestion of Wu and Goh (2010). This orientation allows for an efficient evaluation of the output potential of a port and is simple to interpret based on the multiple output variables.

$$In\ (Q_{it}) + (R_{it}) + (S_{it}) = \alpha + \beta_1\ In(A_{it}) + \beta_2\ In\ (B_{it}) + \beta_3\ In(C_{it}) + \beta_4\ In(D_{it}) + \beta_5\ In(E_{it}) \quad (5.12$$

$$\forall\ i = 1, \dots, N\ \ and\ t = 1, \dots, T \quad (5.13)$$

Q_{it} is the cargo handled (in metric tonnes) by port i in a period t; R_{it} is the container throughput (in twenty-equivalent foot unit (TEU)) by port i in a period t; S_{it} is the number of ship calls by port i in a period t; A_{it} is the number of quay cranes owned by port i in a period t; $B_{it}$is the number of tugboats of port i in a period t; $C_{it}$is the draft (water depth inside a port measured in meters) of a port i in a period t; $D_{it}$is the total length (in meters) of quays of a port i in a period t; $E_{it}$is the number of quays owned by port i in period t; and $T_t$is a time pattern reflecting aggregate improvements in overtime efficiency. Within the model, v_{it} is a random error term supposed to be independent of u_{it}, which is supposed to be a truncated standard random variable linked to technical inefficiency. Rstudio was used to analyse technical efficiency.

5.8 Second Stage- Econometric Analysis (Tobit Regression)

Furthermore, if efficiently operating ports have some common features, this allows the identification of possible causes of inefficiency. Thus, after calculating the efficiency score in the second stage of the research, the study regressed inputs as an explanatory variable on the efficiency score to determine its effect on the technical efficiency of the ports.

Using the VRS (variable return to scale) efficiency score (BCC ratings) as a dependent variable, and given that the scores are right-censored, a Tobit regression model would be used to approximate the adjusted efficiency scores for each port (i.e. upper limit of 100 percent). Because, by definition, the DEA scores take on values between 0 and 1, and since some of the results appear to be clustered (i.e. censored at 1) on these boundary values, a regression cannot be calculated at least by ordinary squares (Elfeijani, 2015). So some empirical studies are using the Tobit model. The study uses a univariate regression in which the efficiency score of the VRS was regressed on the explanatory variable.

The Tobit receives predictions for the linear Tobit model, where the dependent variable is either zero or one (Elfeijani, 2015). The method used is maximum likelihood under the assumption of natural homoscedastic disturbances. The basic Tobit model includes truncation of the dependent variable below zero (Elfeijani, 2015). The efficiency score was censored to 100 percent (upper limit) for this analysis, and so the model defined a 100 percent upper limit. The Tobit regression model used below is:

$$\text{Tobit }(yj) = a0 + a1xj1 + a2xj2 + a3xj3 + \ldots + \varepsilon j \qquad (5.14)$$

The yj is the constant return to scale efficiency score for the jth SACU ports, the xj is the explanatory variable, an is the coefficient whose values cannot be interpreted but whose signs are useful for this study, and the πj is the disturbance term assumed to be normally distributed with mean μ and standard deviation γ. The Tobit regression is estimated using Rstudio.

5.9 Evaluating the Efficiency of SACU Ports

To evaluate technical efficiency and to equate each SACU port with ten (10) SACU ports (Cape Town, Durban, East London, Luderitz, Mossel Bay, Ngqura, Port Elizabeth, Richard's Bay, Saldanha Bay, and Walvis Bay), a quantitative analysis using DEA analysis was conducted. This contrast was aimed at establishing rating relationships and verifying the results of the descriptive study. The DEA literature on the maritime industry has been analysed in chapter four to help understand how the DEA has been applied in many studies to measure port performance and to consider the various variables impacting port technical efficiency.

First, efficiency refers to any organization's efficiency according to the benchmark (Liu, 2010). Technical efficiency is known as the ability of such inputs to get the highest output, referred to as 'output orientation.' The ability of decision-making units (DMUs) to reduce the information needed to obtain the output levels is referred to as 'input orientation (Reilly, 2007). In this study, the DMUs are the ports.

The reasons attributed to port competitiveness can be better known (Yuen, Zhang & Cheung 2012). These factors can be used to calculate the efficiency of the port and to find flaws that prevent an inefficient port and help create business plans that contribute to business outcomes (Gonzalez and Trujillo, 2009).

5.10 Identifying the Variables

The output and input variables used for a port efficiency assessment should reflect as accurately as possible the port production process and the actual targets (Lin and Tseng, 2007). This section, therefore, identifies the output variables used for measuring technical efficiency. It also identifies the input and output variables that are based on the literature that influences the technical efficiency of ports. From the port efficiency literature, it can be seen that all port resources contribute to efficiency. Improved efficiency means improved port throughput from using existing port resources as inputs to achieve that throughput.

Several factors influence the port's technical efficiency. These factors concern the port infrastructure, superstructure, and human resources. As input variables in the DEA analysis, some influential factors are included. Also, the output variables convey efficiency parameters such as cargo throughput, number of ship calls, ship transit time, and other factors relevant to service quality and customer satisfaction (Elfeijani, 2015). However, cargo handling, as it is closely related to cargo handling facilities and infrastructure, is the most common criterion for calculating port technical efficiency and the most crucial indicator of port output (Elfeijani, 2015).

Literature studies also found that some arrays of inputs and outputs have been used to measure the technical efficiency of ports and terminals. Nevertheless, any analysis testing any of the SACU ports using the DEA model is not published in the literature. Hence, in this study, a variety of input variables are used to assess the technical efficiency of SACU ports. This includes infrastructure variables such as the depth of water (draft) to ensure the safe passage of cargo ships, the length of the quay for safe docking, the number of quays to ensure that different vessels will use different quays for different reasons (the quay built for container ships cannot be used by a bulk carrier ship) and the number of tugboats to push ships inside the port area. The superstructure factors include those related to the amount of equipment carrying containers bulk cargo such as quay cranes (QCs), conveyancer belts, skips, and reach-stackers.

5.10.1 Output Variables

The efficiency of the container port will be measured by various metrics, such as income, throughput per unit time, QC throughput, yard throughput, human resources outcomes, dwelling time, idle machinery duration, number of ship calls, and use of quays (Ghashat, Cullinane and Wilmsmeier, 2011). The key benchmark metrics for assessing the consistency of container port efficiency are cargo handled, container throughput, ship calls, and ship turnaround times (Yuen et al., 2012, Zegordi and Nahavandi, 2002). For this study cargo handled, container throughput and ship calls variables are considered as output variables to measure the technical efficiency of SACU ports.

5.10.2 Input Variables

Port facilities include some specific functions which are historically considered in two different categories: port infrastructure and port superstructure (Liu, 2010). These facilities are considered input variables for the DEA analysis in this study.

To maximize the number of containers shipped, the historical evolution of container shipping indicates a dramatic increase in the dimensions of container ships (Liu, 2010). The total ship length, width, freeboard, and draft are protected by this rise. Many container ports, though, like SACU ports, were built decades earlier to handle the smaller-sized container ships of the previous century. The evidence for this is that only a couple of ports worldwide will dock the latest crop of ultra-large container vessels (Kremer, 2013).

Despite these increases, if a strategic edge is to be manufactured or retained, container ports must handle ultra-large container vessels and improve performance (Kremer, 2013). This may be achieved by providing a specific port system appropriate for container vessels of the current century. The focus should not be solely on the container vessels but also on very large bulk carriers (VLCCs). To ensure navigational protection and allow those ships to reach the port and moor, the necessary port infrastructure requires water depths greater than the drafts of such ships (Kremer, 2013). It also provides long quays to ensure safe loading, adjusted to the overall duration of the inbound cargo vessels. An optimal storage yard area that can absorb the amount of off-loaded containers from such ships must also be included.

The carriers say to the ports: "If you don't expand, if you don't build new quays and deepen the ports and have high-speed cranes, we're going to take our company elsewhere" (Kremer 2013). In addition, a port has terminals, terminals refer to a part of a port devoted to a specific type of service, such as containers, bulk, or cars, and certain terminals have certain docks. The port infrastructure, as represented by water depth, quay length, the number of quays, and the number of tugboats, are therefore considered as the most important input variables in this study.

Similarly, the promotion of this new generation of ships involves necessary and efficient port superstructure. The port superstructure comprises all the container shipping and transport facilities used within the port. That includes quay cranes, trucks, trailers, entrance stackers, forklifts, and yard cranes (Elfeijani, 2015). Depending on various variables, such as container movement, storage yard dimensions, and construction costs, each container terminal uses different types in these categories of facilities. For example, during seaside operations and the 1960s, container vessels were loaded and discharged using normal shore cranes and wire slings.

Container ports have been modified, though, to deploy more modern and specialized handling devices, at the same time as container ship modifications (Elfeijani, 2015). Container ports deployed Panamax QCs on the seaside as the container ships entered service. At the time, this type of crane was adequate to deal with Panamax container vessels. The QCs were updated again from Panamax QC to post-Panamax. Likewise, after the super post-Panamax container ships entered operation with greater dimensions, super post-Panamax cranes were deployed to accommodate this growth in the scale and capability of container ships (Elfeijani, 2015). Furthermore, to handle the increased amount of containers borne cargo by the new wave of container vessels, these types of cranes have higher rates of rotation Higher container volumes and higher container ship sizes demanded the evolution of cranes (Elfeijani, 2015).

Both of these developments dictated how comparative benefits were extracted from ports and terminals and held pace with changes in container shipping and cargo ships (Elfeijani, 2015). Container ports, though, do not use the same specialized QCs. With varying rates of movement, height, and outreach, each container port uses different QCs. The performance of these ports, and hence their performance, is different due to these variations in requirements.

Containers are transported by horizontal transport vehicles such as trucks, reach stackers, trailers, and tractors to storage yards and vice versa from the seaside and the landside. Every container port uses different transport facilities, dictated by factors such as the area of the port or terminal, the number of containers being handled, and the number of resources available (Lau and Zhao, 2008, Ioannou et al., 2000).

It has to be stacked before a container is shipped to the storage yard at a certain location. That will be achieved by forklift or reach-stacker. The choice of equipment depends on the stacking mode, the area of the storage yard and the number of containers at the port, and the investment area (Lau and Zhao, 2008). The adoption of a particular container port superstructure results in a performance distinction between container ports. The number of equipment carrying containers is then known as a variable for the inputs.

5.11 Data Sources for Measuring Port Technical Efficiency

To determine the technical efficiency of the SACU ports, secondary data is used. Other researchers obtained and compiled the secondary data for another purpose (Mienie, Sharp, & Bretteny, 2017). Secondary data is chosen because it is especially cost-effective and time-saving, covering a larger geographical area and a longer span of comparison at no cost (Appannaiah, Reddy and Ramanath, 2010). Yin (1994) suggested that the use of multiple sources of data (triangulation) and the creation of a chain of evidence could improve the construct's validity. Therefore, to improve authenticity, the study used secondary data analysis to assess the influence of such influential variables on the technical efficiency of SACU ports. In the primary study, the information was linked to a variety of most relevant variables. The secondary statistical data included data concerning 10 ports of the SACU. The primary analysis of this study is to broadly analyse the SACU ports' technical efficiency.

Secondary data from reports and statistics provided by approved organizations such as Transnet Port Terminals, Namports, UNCTAD, and the websites and annual reports of the sample ports have been compiled. Port water draft, quantity and length of quay and length, tugboats, and the number of quay cranes consisted of these data; these were used as input variables. Cargo treated, estimated in metric tons, TEUs, and ship calls were also obtained and used as an output variable in this study.

Cape Town, Durban, East London, Lüderitz, Mossel Bay, Ngqura, Port Elizabeth, Richards Bay, Saldanha Bay, and Walvis Bay were the ten (10) ports included in that survey. These ports have been picked because they belong to countries that have separate port authorities. Therefore, they all use diverse facilities for cargo handling and have distinct infrastructure features. Also, separate governing mechanisms control and operate them. South African ports, for example, are controlled by TNPA, while Namibian ports are operated by Namport. All of these variations include a detailed measuring environment to determine variables that make a certain port more physically effective and can be used to identify the technical inefficiencies or deficiencies of other SACU ports.

5.12 Summary

The port's technical efficiency is evaluated by testing whether the actual output reaches its optimum output. Due to inadequate facilities, the port's poor performance depends on the time spent staying, delaying surcharge, and ignorance from larger ships. Container terminals are the main factors in the operational technical efficiency of a port by-ship transit times and thus maximizing terminal performance. Commonly used methods for the measurement of technical efficiency include SFA, DEA, VEM, COLS, and OLS. The study uses DEA to evaluate the technical efficiency of SACU Ports and then it uses the Tobit model to determine which variables led to inefficiency among the ports.

CHAPTER SIX

PRESENTATION THE OF EMPIRICAL RESULTS

6.1 Introduction

This chapter presents the main findings of the study. The main objective of this dissertation was to evaluate the technical efficiency of SACU ports. The technical efficiency in the context of this dissertation was defined in Chapter 4 as a principal element in economic profitability as it measures the ability of the firm to produce maximum output from a given set of inputs. The chapter begins by presenting descriptive statistics. Secondly, DEA results are presented and interpreted. In this context, ports that have less than 1 are regarded as being inefficient and those that have a scale efficiency of 1 or more are regarded as being efficient. The last section of the chapter presents the results of the Tobit model.

6.2 Descriptive Statistics

Table 6.1 tabulates the descriptive statistics. The table illustrates raw data for descriptive statistics. For each variable, the following was derived; mean, minimum, maximum, median, standard deviation, skewness, kurtosis, jarque-bera test, and the probability values.

Table 6.1 Descriptive Statistics

	Inputs					**Outputs**		
	Quay Cranes	**Number of Tugboats**	**Quay Length (m)**	**Draft (m)**	**Number of Quays**	**Cargo handled (metric tons)**	**Container Throughput (TEUs)**	**Ship Calls**
Mean	4.800000	4.100000	2209.400	14.53500	16.70000	25733582	463006.5	1095.750
Median	2.000000	3.000000	2300.000	15.20000	9.500000	5373675	69097.00	721.0000
Max.	20.00000	8.000000	5248.000	21.50000	59.00000	10.04+08	2956670	3963.000
Min.	0.000000	1.000000	686.0000	7.000000	3.000000	91939.00	0.000000	291.0000
Std. Dev	6.454009	2.136844	1276.118	4.389436	17.23841	34249753	812550.2	938.8599
Skewness	1.283203	0.373339	1.014299	-0.302387	1.500739	1.128676	2.104582	1.672723
Kurtosis	3.506348	1.925075	3.755475	2.041456	4.027041	2.645515	6.212447	4.851113
Jarque-Bera	17.10707	4.282481	11.71488	3.211397	25.15922	13.05324	70.09221	36.54659
Probability	0.000193	0.007509	0.002859	0.200749	0.000003	0.001464	0.001464	0.000000
Observation	60	60	60	60	60	60	60	60

From the table, it can be noted that the maximum values for the following variables: quay cranes, quay length, number of quays, cargo handled, container throughput, and ship calls are roughly away from the mean, thus exhibiting large spread or variation. This fact can be seen from the relatively high standard deviation from each variable. From these results, it can be concluded that high magnitude variation in the data exists except for the Draft which consists of a maximum value roughly close to the mean and a relatively small standad deviation.

6.3 Data Envelopment Analysis Results

This section presents the results of the technical efficiency of 10 ports in the SADC region. Panel data covering the period between 2014 to 2019 was estimated by applying DEA-BCC and CCR model output-orientation.

Their versions are the predictions of production possibilities sets. " is assumed by the CCR, i.e. the increase in investment by one unit generating output by one unit." On the other hand, the BCC assumes that "variable returns to scale" i.e. the scale of production varies. "Overall technical efficiency" is the efficiency value evaluated in the CCR, while "pure technical efficiency" is the efficiency value determined in the BCC.". Size performance" is the former divided by the latter. Scale efficiency is the former divided by the latter. The contrast of the importance of scale efficiency and pure technical efficiency value sheds light on the key cause of DMU inefficiency, whether it is the technical issues involved with the sum and mix of input and output variables or the whole operating scale. The study of scale return will identify whether it is in the stage of increase or decrease.

Efficiency scores according to the specifications suggested by the Banker, Charnes, and Cooper (BCC) model are shown in Table 6.2. If the scale efficiency is equal to 1, then the law of constant returns to scale (CRS) dominates, but, if the sum is greater than or less than 1, then DRS and IRS respectively dominate, within an output-oriented model (Wanke, 2013).

Table 6.2 DEA Results

Country	Ports/DMU	Year	CCR*	BCC *	Scale Efficiency*	Returns to Scale
South Africa	**Richards Bay**	2014	0,9799	1	0,9799	Decreasing
		2015	1	1	1	Constant
		2016	0,71259	0,71259	1	Constant
		2017	0,97055	0,97055	1	Constant
		2018	1	1	1	Constant
		2019	1	1	1	Constant
South Africa	**Durban**	2014	1	1	1	Constant
		2015	0,94016	0,940156	1	Constant
		2016	1	1	1	Constant
		2017	1	1	1	Constant
		2018	1	1	1	Constant
		2019	1	1	1	Constant
South Africa	**East London**	2014	0,62692	0,63607	0,985614791	Decreasing
		2015	0,93131	0,93337	0,997792944	Decreasing
		2016	1	1	1	Constant
		2017	0,09199	0,91575	0,10045318	Decreasing
		2018	0,83151	0,83151	1	Constant
		2019	0,6644	0,67564	0,983363922	Decreasing
South Africa	**Ngqura**	2014	0,93172	0,93172	1	Constant
		2015	0,86231	0,86231	1	Constant
		2016	1	1	1	Constant
		2017	0,52486	0,38536	1,36199917	Increasing
		2018	1	1	1	Constant
		2019	1	1	1	Constant

South Africa	**Port Elizabeth**	2014	0,6572	0,71871	0,914416107	Decreasing
		2015	0,59081	0,6501	0,908798646	Decreasing
		2016	0,601191	0,70945	0,847404327	Decreasing
		2017	0,57784	0,66528	0,868566619	Decreasing
		2018	0,57388	0,64012	0,896519403	Decreasing
		2019	0,7845	0,52897	1,483070874	Increasing
South Africa	**Mossel Bay**	2014	1	1	1	Constant
		2015	0,91076	1	0,91076	Decreasing
		2016	0,55697	0,72733	0,765773445	Decreasing
		2017	0,45576	0,69269	0,657956662	Decreasing
		2018	0,36437	0,73861	0,493318531	Decreasing
		2019	0,33277	0,60643	0,548736045	Decreasing
South Africa	**Cape Town**	2014	1	1	1	Constant
		2015	0,97977	0,99951	0,980250323	Decreasing
		2016	1	1	1	Constant
		2017	0,896432	0,98464	0,91041599	Decreasing
		2018	0,8321	0,96928	0,858472268	Decreasing
		2019	0,88648	0,95627	0,92701852	Decreasing
South Africa	**Saldanha Bay**	2014	0,90379	0,90379	1	Constant
		2015	1	1	1	Constant
		2016	0,92634	0,92634	1	Constant
		2017	0,9739	0,9739	1	Constant
		2018	0,88309	0,88309	1	Constant
		2019	1	1	1	Constant
Namibia	**Walvis Bay**	2014	0,99909	1	0,99909	Decreasing
		2015	0,92876	0,92956	0,999139378	Decreasing
		2016	0,5507	0,58355	0,943706623	Decreasing
		2017	0,86696	0,88744	0,976922383	Decreasing

		2018	0,70996	0,7114	0,997975822	Decreasing
		2019	0,65112	0,67061	0,970936908	Decreasing
Namibia	**Lüderitz**	2014	0,93602	0,93602	1	Constant
		2015	1	1	1	Constant
		2016	0,4814	0,51898	0,927588732	Decreasing
		2017	0,94832	0,94832	1	Constant
		2018	0,9509	0,9509	1	Constant
		2019	1	1	1	Constant

***CCR – Constant Returns to Scale. It is named after its founders Charnes, Cooper and Rhodes**

***BCC – Variable Returns to Scale. It is named after Banker, Cooper and Charnes**

***Scale-efficiency = CCR/BCC**

The above results are explained in the following sub-sections.

6.3.1 Port of Richards Bay

The results in table 5.2 above show that Port of Richards Bay had full pure technical efficiency of 1.00 in 2014, 2015, 2018, and 2019. In 2016 and 2017, the port underperformed in terms pure technical efficiency (BCC score = 0,71259 and 0,97055 respectively). To reach a score of 1, Port of Richards Bay needed to improve efficiency by 28.8 percent and 5.99 percent in 2016 and 2017 respectively. The scale efficiency of Richards Bay was 0.9799 in 2014; meaning that the port experienced decreasing returns to scale. Nonetheless, the Port of Richards Bay in 2015, 2016, 2017, 2018 and 2019 had a scale efficiency of 1.000; meaning that the port experienced constant returns to scale.

6.3.2 Port of Durban

The port of Durban almost had full pure technical efficiency of 1.000 during the period under review, except for 2015 where it had pure technical inefficiency of 0.9401 to reach a score of 1, the port needed to improve efficiency by 5.99 percent in 2015. However, in terms of scale efficiency, the port scored 1.000 throughout the period under review; meaning that the port was technical efficient because it was operating at its optimal size as shown by the results of scale efficiency.

6.3.3 Port of East London

The port of East London had full pure technical efficiency of 1.000 in 2016 and 2018. For all the other years during the period under review, the port was inefficient. In 2014, the port had pure technical efficiency of 0.9856, meaning that the port fell short by 1.4 percent to reach the efficiency level. In 2015, the port had pure technical efficiency of 0.9977, whilst in 2017 and 2019 it had pure technical efficiency of 0.1004 and 0.9833 respectively; implying that the port needed 0.23 percent, 89.96 percent, and 1.67 percent for the years 2015, 2017 and 2018 respectively to reach the efficiency level.

East London was fully scale-scale efficient and experienced constant returns to scale in 2016 and 2018, this means that the input and output variables change by the same amount. In 2014, 2015, 2017 and 2019, East London experienced scale-inefficiencies of 0.9956 for 2014 and in 2015 the scale-efficiency score was 0.9977. In 2017, the port had a scale-efficiency of 0.1004, and the year 2019, the port scale-efficiency of 0.9833. During these years, the port experienced decreasing returns to scale, this means that the port was technically inefficient because, the scale-efficient results for 2014, 2015, 2017 and 2019 implies that the port was too large or was unable to utilise resources to take full advantage of scale and has supra-optimum scale size.

6.3.4 Port of Ngqura

Ngqura had full pure technical efficiency of 1.000 in 2016, 2018 and 2019. It had technical inefficiency with a score of 0.38536 in 2017 meaning that the port fell short of 61.47 percent to reach an efficiency score of 1. Both in 2014 and 2015, the port had pure technical inefficiency of 0.9317 and 0.8623 respectively. The port fell short of 6.83 and 13.77 percent in 2014 and 2015 respectively. Ngqura experienced constant returns to scale throughout the period under review except for 2017 where it experienced increasing returns meaning that the input and output variables changed by the same amount during these years. However, in 2017 the port had increasing returns to scale. The scale efficiency results show that the port was scale efficient and experiencing constant returns throughout the period under review except for 2017, these results mean that the port was operating at its optimal size. However, in 2017, the port experienced increasing returns to scale, this meant that the port was too small for its scale of operations and, thus, operates at sub-optimum scale size, this is because it experienced increasing returns.

6.3.5 Port of Port Elizabeth

Port of Port Elizabeth port did not have full pure technical efficiency during the period under review. In 2014, the port had a score of 0.7187 of pure technical efficiency. In 2015, the port had pure technical efficiency of 0.6501. In 2016, the port continued to be inefficient with a score of 0.7094. This inefficiency continued into 2017 and 2018 with a pure technical efficiency of 0.66528 0.64012 respectively. In 2019, the port had pure technical efficiency of 0.52897 which meant the port needed 47.1 percent. Port Elizabeth port was scale-inefficient from 2014 to 2018. The port experienced decreasing returns to scale throughout the period under review except for 2019 when the port experienced increasing returns to scale. The scale-efficiency results from 2014 to 2018 shows that the port was not operating at its optimal size, the port was too large to take full advantage of scale and has supra-optimum scale size. In 2019 the port experienced increasing returns to scale, this meant that whatever change took place in the outputs, was greater than the change in inputs. Also, it meant that was too small for its scale of operations and, thus, operates at sub-optimum scale size.

6.3.6 Port of Mossel Bay

The port of Mossel Bay had full pure technical efficiency of 1.000 in both 2014 and 2015. In 2016, the port had pure technical efficiency of 0.7273 and 0.6926 in 2017, this meant that the port in 2016 needed to improve efficiency by 27.2 percent and in 2017 by 30.7 percent. In 2018, the port scored 0.7386, whilst in 2019, it scored 0.6064. In 2018, the port needed to improve efficiency by 26.1 percent whilst in 2019, the port needed to improve efficiency by 39.3 percent. Mossel Bay was scale-efficient and experienced constant returns to scale only in 2014. This implies that in 2014 the input and output variables changed by the same amount and also the port was operating at its optimal size. From 2015 to 2019, the port experienced decreasing returns to scale meaning that the port was experiencing some inefficiencies. From 2015 to 2019, the port was scale-inefficient and experienced decreasing returns to scale this means that whatever change in inputs, there will be less change in outputs and it was scale-inefficient. Further, the scale-efficient results imply that a port is too large to take full advantage of scale and has supra-optimum scale size.

6.3.7 Port of Cape Town

Both in 2014 and 2016, Cape Town port had full pure technical efficiency of 1.000 respectively. However, during the other years in this period, the port did not have full pure technical efficiency. In 2015, the port had pure technical efficiency of 0.9995. In 2017, the port had pure technical efficiency of 0.9846, whilst in 2018, pure technical efficiency was 0.9692. In 2017, the port needed to improve by 1.5 percent whilst in 2018, the port needed to improve by 3 percent to be efficient. In 2019, the port had pure technical efficiency of 0.9502. Cape Town was fully scale-efficient in 2014 and 2016, as indicated by the constant returns to scale, this meant that the input and output variables changed by the same amount, these results also show that the port was operating at its optimal size. However, in 2015, 2017, 2018, and 2019 the port was scale-inefficient as it also experienced decreasing returns to scale this meant that whatever change took place in the outputs, was greater than the change in inputs, further, implies that a port was too large to take full advantage of scale and has supra-optimum scale size.

6.3.8 Port of Saldanha Bay

In 2015 and 2019 Port of Saldanha had full pure technical efficiency of 1.000. In 2014, the port had pure technical efficiency of 0.9037 and therefore needed 9.6 percent to improve efficiency. In 2016, the port under-performed again with a pure technical efficiency of 0.9734 which meant that the port needed to improve efficiency by 2.6 percent. In 2017, the port had low pure technical efficiency of 0.9739, meaning that the port needed to improve efficiency by 2.6 percent. In 2018, the port had a pure technical efficiency of 0.8830 meaning that it needed to improve efficiency by 11.7 percent. The port of Saldanha Bay was scale-efficient and experienced constant returns throughout the period under review. The port of Saldanha Bay was scale-efficient and experienced constant returns throughout the study period, these results show that the port was operating at the optimal size.

6.3.9 Port of Walvis Bay

The port of Walvis Bay had a pure technical efficiency of 1.000 only in 2014. From 2015 to 2019 the port was under-performing. The port under-performed in 2015 by 0.9295 of pure technical efficiency and thus needed to improve efficiency by 7.05 percent. It further, under-performed in

2016, 2017, 2018 and 2019 with pure technical efficiency of 0.5835, 0.8874, 0.7114 and 0.6706 respectively and as such needed to improve efficiency by 41.6 percent, 11.2 percent, 28.8 percent and 32.9 percent for the years 2016, 2017, 2018 and 2019 respectively. The port was scale-inefficient throughout the period under review. The port also experienced decreasing returns to scale which confirms the inefficiency in this port. The scale-efficiency results implied that a port is too large to take full advantage of scale and has supra-optimum scale size.

5.3.10 Port of Lüderitz

Port of Lüderitz had a full pure technical efficiency of 1.000 both in 2015 and 2019. However, the port did not achieve full pure technical efficiency in 2014 as it had a score of 0.9360. The port needed to improve efficiency by 6.4 percent. In 2016, the port scored 0.5189 for pure technical efficiency which meant that the port needed to improve efficiency by 48.1 percent. In 2017, Port of Lüderitz had low pure technical efficiency of 0.9483 meaning that the port needed to improve efficiency by 5.1 percent. Further, the port had pure technical efficiency of 0.9509 in 2018. This score means that the port needed to improve efficiency by 4.9 percent. The port was scale-efficient and experienced constant-returns to scale throughout the period under review except for 2016 where it scored 0.9275 with decreasing returns to scale. Therefore, the port was operating at its optimal size except for 2016 where it was not operating at its optimal size. The decreasing returns to scales in 2016 meant that whatever change took place in the outputs, was greater than the change in inputs.

6.4 Tobit Model

Using time-series context, the analysis went further to include the Tobit model covering the period from 2014 to 201 using 60 observations. The specialisation of bootstrapped Tobit regression in the subject's data is attempted so that the differentiation in efficiency scores of ports could be further explained.

The table below shows the results of the Tobit model.

Table 6.3 Tobit Model Results

Dependent variable: Technical Efficiency (BCC); no of obs. = 60				
	Coefficient	Std. Error	z value	Pr (>|z|
(Intercept)	7.099e-01	6.764e-02	10.496	2e-16 ***
Quay Cranes	-1.601e-02	7.395e-03	-2.165	0.03040 **
Number of Tugboats	1.521e-03	1.448e-02	0.105	0.91636
Quay Length	-4.484e-05	2.422e-05	-1.851	0.06411 *
Draft	1.362e-02	2.422e-05	-1.851	0.06411*
Number of Quays	7.949e-03	2.853e-03	2.786	0.00533 ***
Level of significance: * = 10%, ** = 5%, *** = 1%				

The variable quay cranes is statistically significant (P > |z| = -1.601e) and negatively related to the efficiency of the ports. The results mean that more quay cranes cause inefficiency. This is because of yard operations problems. These results confirm the statement that was said during an interview conducted by Carte Blanche on South African ports in 2019, showed that yard operations problems are affecting the port's efficiency (Carte Blanche, 2020). In the interview, it was said that trucks that came to fetch containers are delayed at the entrance of the South African Ports. These delays lead to quay cranes being inefficient because they remain idle, not being utilised. Thus, more cranes lead to inefficiency. Yard problems affect quay cranes' performance since they work hand to hand. Quay offload a container from a vessel then load to yard cranes (YCs) or reach-stackers. YCs and reach-stackers then proceed to move the containers inside the yard.

According to Kizilay and Eliiyi (2020), the yard-side problems in container terminals include the scheduling of containers on yard cranes and yard trucks (YTs), the routing of vehicles inside the terminal, and the distribution of container storage positions, and the stacking of storage block operations (Kizilay and Eliiyi 2020). For a certain amount of time, all inbound and outbound containers are placed at the container ports to wait for the ships to be delivered, or consumer trucks carry them to end-users. The YCs manage container replacements for the storage blocks or YTs (Kizilay and Eliiyi 2020).

The YCs also perform housekeeping activities, such as pre-marshalling and relocation of containers. YC scheduling and dispatching operations thus play a vital role in the terminals' overall efficiency (Kizilay and Eliiyi 2020). Besides the YC processes, the YTs transport the inbound and outbound containers inside the terminal. The dispatch and scheduling of these transport vehicles, as well as their routing, therefore affect the congestion of traffic inside the terminal and on the performance of the operations (Kizilay and Eliiyi, 2020).

Further, these results correspond with Amakali (2017) and Ocean Shipping Consultants studies. These studies have argued that there is a proliferation of ports in Sub-Saharan Africa, few of which are wide by world standards. Generally, they are poorly equipped and work at low productivity levels. Few can handle the largest ships of the modern century and are normally unprepared for the dramatic shifts in trade and shipping trends that are now taking place. In essence, the SACU port equipment is not maintained regularly, for example, Herald Live (2018) reported that the Port of Port Elizabeth quay crane by wind and has not been fixed till now 2021.

(2020) claimed that the ports of Namibia are having a problem with broken equipment in their ports. Moreover, the quay cranes could be inefficient because the people operating them are not skilled enough.

The number of tugboats is statistically insignificant (P > |z| = 0.9163) and positively related to the efficiency of the port. The results mean that the ports have sufficient tugboats to handle ships that use that particular port. The number of tugboats a port possesses are well equipped to large vessels and smalls. They meet the requirements that are needed to service that particular port.

Quay length is statistically significant (P > |z| = 0.06411) and negatively related with the efficiency of the ports. The results show that the longer quays have resulted in some ports being inefficient. Longer quays have different drafts. A quay length could be 40 meters long but only 50 percent of the quay can be utilized because of the draft surrounding that quay and also because of the available equipment on the quay. Longer quays can confuse port operators. For example, a port operator would allocate a vessel in the wrong position along the length of the quay which would disrupt quayside operations. This would result in a problem called Berth Allocation Problem.

To maximize certain efficiency metrics, the berth allocation problem (BAP) is the problem of assigning incoming vessels to berthing positions within a terminal. Controlling berth allocation for incoming vessels is particularly critical in multi-user ports, as poor choices can cause unnecessary delays in ship boarding and consequent annoyance with the carrier. Furthermore, it should be remembered that ship berthing enables the function of other port assets, such as the huge, expensive quay cranes used for unloading and loading containers from and onto ships, as well as yard cranes and jockey trucks crews. Poor use of quays may also contribute to the under-use of these facilities and an overall decline in port efficiency.

The draft is found to be statistically significant ($P > |z| = 0.07110$) and positively related to the efficiency of ports. The results show that the SACU ports have the required draft to accommodate ships that use those particular ports. Most SACU ports are classified as "Deepwater ports". Deepwater ports are considered deep-water ports, are the ones whose draft (draft mean by the vertical distance from the water surface to the seafloor) in both the entrance channel and in the terminal area, exceeds 13.72 m.

The number of quays is statistically significant ($P > |z| = 0.00533$) and positively related to port efficiency. The results show that the ports have different quays that allow different types of vessels to use a port.

6.5 Summary

The chapter aimed to ascertain technical efficiency in SACU ports between 2014 and 2019. The study identified, developed, and estimated a model for the relationships based on the DEA-BCC model. The results of the DEA model were further analysed by the Tobit model to identify the variables that have led to technical inefficiencies in SACU ports. The descriptive statistics showed that the variables were exhibiting a large spread. This was confirmed by the high standard deviation of the variables.

From the results of DEA, the port of Richards Bay and Durban were the ports that performed or rather were efficient throughout the study period. The Port of Ngqura technical efficiency scores show that the port was technical in most years, however, scale efficiencies showed that the port was operating at an optimal level, except for one year where it experienced increasing returns to scale. The results of the Tobit model showed that quay cranes, quay length, draft, and a number of quays were statistically significant while quay cranes and quay length have a negative relationship meaning that they contribute to inefficiency. Quay cranes were inefficient because of yard problems and poorly maintained cranes.

CHAPTER SEVEN

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

7.1 Introduction

This chapter includes the results of the research and the study's policy recommendations. The chapter includes a concise overview of all the chapters used in the analysis. The second section would examine the policy implications and recommendations of the outcomes achieved in the study. Areas for further study will be proposed in the final section.

7.2 Summary

Ports are the backbone of foreign commerce; more than 90% of global trade is carried by marine transport. The globalization of the world economy drives this. The current outlook and growing globalization of economies call for greater productivity on the part of all players in the transport sector, in particular the ports, where significant public contributions are made to their development processes. Seaport authorities have been constantly under pressure to boost performance by ensuring that services are offered on a competitive international basis. Therefore, changes in the performance of container ports are expected. A powerful operating system can greatly help to enable the best use of the services and facilities of ports. Chapter 1 addressed the aims of the project from this point of view and research questions were formulated to be explored in this study.

This analysis offered a basis for assessing the technical efficiency of SACU ports over six years (2014-2019). This was looked at from the viewpoint of how quality and competitiveness were influenced over time by port operations. By providing a historical and maritime overview of the ports, the thesis aimed to present insight into SACU ports. This research was also intended to generate policy recommendations that could be introduced in other port types and regions of the world, particularly for Southern African ports.

Chapter 2 presented a historical overview of Namibian and South African ports and also gave an overview of the maritime industry. From the historical overview of the ports, all of the ports in the study dates back to colonial times except for the Port of Ngqura which was started operating in 2009. Ngqura remains the only port that is not being named after the city or town that is built-in.

It can be said that the ports Richards Bay, Durban, East London, Port Elizabeth, and Saldanha Bay have strong links with discovery mineral resources in South Africa. The ports are operated by state-owned companies Namibian Port Authority (Namport) and Transnet National Port Authority (TNPA). Namibia has 2 ports Walvis Bay and Lüderitz. South Africa has 8 ports, namely, Port of Richards Bay, Durban, East London, Ngqura, Port Elizabeth, Mossel Bay, Cape Town, and Saldanha Bay. The ports handle 90 percent of the trade of their respective countries. However, these ports also handle the trade of the SADC region landlocked countries. The location of the SACU ports is on the international trade routes which allow some ports to be transhipment hubs.

The ports have different types of terminals. Ports that handle containers are the ports of Durban, Ngqura, Port Elizabeth, Cape Town, and Walvis Bay. However, all other ports do handle few containers except for Mossel Bay which does not handle any containers because of its drafts and it specializes in fisheries. Bulk terminals can be found in all of the ports except for Mossel Bay. The Port of Mossel does not cater to large vessels. The only large vessels that use the ports are tankers that use the single point mooring that is on the ports limit. The port of Richards Bay handles most of the bulk cargo followed by the port of Saldanha Bay. Port of Richards Bay is known for coal exports while the port of Saldanha Bay is known for exporting iron ore and also the port is the deepest in South Africa with a draft of 23 meters.

Ports with automotive terminals are the ports of Durban, Port Elizabeth, and East London. The automotive terminals serve different automobile companies that have plants in South Africa. The Port of Durban serves BMW, Ford and Toyota, meanwhile, the Port of East London serves Daimler (Mercedes Benz). The Port Elizabeth terminal serves Volkswagen and Isuzu. The SACU ports also have passengers' terminals where people can embark and disembark passenger's vessels. These terminals are in Durban, Cape Town, and Walvis Bay. Having been a busy port in Southern Africa, the Port of Durban has more quay cranes compared to other ports in the study while the Port of Cape Town has the most tugboats.

Chapter 3 focused on the port operations. The chapter started by differentiating between port performance, productivity, and quality. It went on to look in-depth at the three main operational phases of a port or a terminal work. The operational phases are seaside, landside, and terminal operations. These three independent, yet interconnected and organised operations make up the entirety of port efficiency. The study focused on the seaside and terminal operations. Before, it explained seaside operations and terminal operations, it explained the layout of the container terminal and dry bulk terminal. It went on to discuss the seaside problems such Berth Allocation Problem (BAP), Quay Crane Allocation Problem (QCAP), Quay Crane Scheduling Problem (QCSP) and Yard Scheduling Problem (YSCP) Seaside operations include berthing, docking, dredging, ships arrival, and port entrance. Terminal operations include all cargo handling operations starting with loading/offloading cargo on vessel and loading on yard truck or yard cranes.

Chapter 4 concentrated on the theoretical literature and literature review. The literature review looked at theories that connected production factors to performance, the theory of production, and the theory of the business. These theories played a crucial role in evaluating each port's success and development, by analysing the inputs, and how they contribute to cargo treated production and container throughput. The theoretical approach has its merits and in microeconomics, it was valid throughout the past decades. However, the uniqueness of the port industry, considering its dynamic existence and the interrelationship between key players, the various stages of activity, and the goals of the port itself, has demonstrated that the current production theory and the strategy of the business could not have sufficiently produced conclusive insights specifically relevant to the port industry. However, the output principle has been the most commonly used in the port industry's calculation of efficiency/productivity, which has been proved useful in previous research and definitely for this research. The theory of X-efficiency applies to technical efficiency and has given an interpretation of the actions of the port authorities of the SACU.

The empirical literature review focused on literature from global countries and SACU countries. Studies used DEA and SFA models to measure efficiency, some studies combined the models then compare efficiency scores. Other studies combine DEA or SFA with the Malmquist Productivity Index (MPI) model or Tobit model. Having recognized these methods, the methodological studies related to port technical efficiency and productivity research were then studied. This captured the study of cross-sectional as well as panel results. Finally, a judgment on the use and rationale for the use of the non-parametric test based on the DEA was used. A performance assessment framework that specifies the necessary steps for carrying out the next study steps was used to explain the output principle and its importance for calculating efficiency/productivity analysis.

In line with the literature review, Chapter 5 reveals justifications for the study and what the author wished to achieve, selecting the right inputs and output for analysis, gathering data, going about the iterative processes by which the final sample and size are calculated as the way forward. The DEA-based model was then defined according to Rstudio, the mathematical programming software that was used. Tobit model was then applied to pinpoint the variables that have led to inefficiency in the ports.

Chapter 6 presents the results of applying the DEA model to the sample data. Thereafter, results of the DEA tests were further analysed by the Tobit model where it identified quay cranes and quay length as the cause of inefficiency. Applying CCR and BCC methods, technical efficiency for the sample was checked. For the sample duration chosen, each approach provided comparable and persuasive efficiency ratings. In addition, the Tobit model analysis was found on series results, and over time its multiple decompositions were analysed. Also, these observations helped analyse and answer all the study questions.

7.3 Conclusion

The purpose of the study was to evaluate the technical efficiency of SACU ports using DEA. Also, one of its objectives was to determine the returns to scale of the ports. The DEA results included returns to scale for further analysis of the results. The results showed that the majority of the ports were technical inefficient in most of the selected years. The Port of Durban was the only port to be technical efficient throughout the study period. The Port of Richards Bay was almost technical efficient throughout the study period, however, in 2014 the port was technical inefficient. The Port of Saldanha Bay was only technical inefficient twice (in 2015 and 2019) throughout the study period, but the scale efficiency of the port showed a different pattern. The port was experiencing constant returns to scale which indicated that the port was operating at an optimal level. The study found that the Port of Ngqura had some years of technical efficiencies and years of technical inefficiencies. The scale efficiency of the port showed that the port was operating at an optimal level, only in 2017 where it had experienced increasing returns which meant that the port was operating sub-optimum scale size.

Tobit model having shown that quay cranes and quay length are the results of technical inefficiency in most SACU Ports. Ports that have quay cranes are ports with container terminals such as the ports of Durban, Ngqura, Port Elizabeth, Cape Town, and Walvis Bay. These ports were technical inefficient and scale inefficient in some years during the study period except for Durban. Quay cranes work with yard operations, whatever happens in the yards is going to affect the performance of the quay cranes. The case of this study is the reason why quay cranes are inefficient. Quay length could also be inefficient because of quay cranes since quay cranes are installed in quays. However, ports without quay cranes cannot place the responsibility of inefficiency on the ports on quay cranes. The cause of inefficiency in ports without quay cranes but have longer quays, the inefficiency comes from the quay length not being utilized properly because of available resources along the quay and also have uneven draft along the length of the quay whereby the depth of the draft is not equal along the quay, so the part of the quay that has a shallow draft cannot be used.

7.3 Recommendations and Future Research

For the port terminals, the equipment needs to be physically and functionally sound and completely used to achieve the desired technical efficiency. Equipment downtime is a major technical efficiency problem, so continuous servicing is expected at a short-term level with an intelligent crane management system. It serves as a diagnostic tool that facilitates feedback status in real-time and detects early warning of loss of equipment. Crane operators or any personnel is involved in any machinery operation must qualify and be informed of the requirements of the equipment/machinery. Different forms of maintenance exist: scheduled or reactive maintenance where machinery is inspected to prevent disruption and corrective maintenance is carried out after the failure of the equipment. The use of a smart crane management system facilitates predictive maintenance where information is gathered by the sensors and forecasts potential maintenance based on historical evidence.

The long-term solution is to buy new or upgrade new machinery which requires a lot funding or investment. Proper equipment servicing ensures continuous cargo activities, thereby increasing efficiency and the lifetime of the equipment. Another alternative is to adopt a principle that has been tried and tested in the port of Singapore to simultaneously operate cranes for loading and discharging operations. Yard cranes often work at the same time with RTG sizes in the yard that allows movement over another to improve the speed of operations. This would increase the performance of yard operations and, as a result, improve the performance of quay cranes, which would improve the overall port productivity. In ensuring that all operators have the desired expertise to fulfil their assigned duties, preparation and instruction are important for an organization, so a company can have training policies in place. Training not only increases productivity but encourages the growth of human capital. If the staff is well trained, they can run the machines more effectively and increase efficiency.

In addition, it helps workers to act confidently as they obtain a sense of job stability and safety. As expected by the organization, all operators must be constantly motivated to attend training; In addition, it helps workers to act confidently as they obtain a sense of job stability and safety. As expected by the organization, all operators must be constantly motivated to attend training; administrators must ensure fairness in the rotation of staff when it comes to training. To deal with increases in the size of vessels, the port authorities should propose deepening the port draft for Port Elizabeth, East London, Walvis Bay, and Luderitz to fit, expand port capability and enhance port access by dredging. There is no need to dredge the Port of Mossel Bay as it does not handle big vessels. Further, basic requirements for a port to be a transhipment is to be deep-water port, be located outside CBD and have a lot of land for storage of containers and technical efficient. The Port of Ngqura meets the requirements of being a transhipment hub. It only lacks technical efficiency. Transnet Port Terminals (TPT) can expand the size of the yard for Ngqura in order for the port to be efficient.

As the contents of this research emphasize specifically the issue of technical efficiency, it has ignored the financial performance of the sample container ports. Another important aspect of overall economic efficiency that the research has deliberately not addressed, however, is the influence of factor prices. Accounting for this is achieved by examining the allocative efficiency of the sample under study. An interesting extension to the study contained within this research, therefore, could be to examine the relationship between technical and allocative efficiency for the port industry. This is especially significant in that optimum technical efficiency in the processing of inputs into outputs does not necessarily guarantee the financial success or survival of a port.

Other areas for future research lie with forming suitable clusters of ports in the sample that can be benchmarked against one another to determine causes of inefficiency and measures for its improvement; extending the set of input variables to consider environmental or instrumental variables, such as geographical proximity to main trade routes, accessibility to other ports via the liner shipping network (Wang & Cullinane, 2006a) and hinterland locations via the general transport network serving the port; determining the causal elements that affect port efficiency (Cullinane & Song, 2006).

7.4 Limitations and Criticism of the study

The study results are based on data collected from the website of the port authorities. The data collected is averaged and thus restricts the author's ability to use other methods to draw a valid research inference. In the SACU area, the DEA findings are focused on fewer selected DMUs and caution should be taken when interpreting the results. It should be remembered that the information is collected from the websites and other reputable sources of the port authority; however, it does not necessarily ensure that the data is up-to-date. Due to difficulties in obtaining details, many ports, such as ports from Mozambique and other factors such as labour, transportation, reach stackers, yard cranes, financial indicators, and running time, could not be included in the study. In the future, existing research can be expanded by collecting primary KPI data including labour, running time, and financial measures. More African ports and details regarding port connections should be included.

Reference List

Abdullah, J., Ahmad, Z., Shah, R.N.H.R.A. and Anor, N., 2012. Port city development and quality of life in Pasir Gudang Port, Johor, Malaysia. Procedia-Social and Behavioral Sciences, 35, pp.556-563.

Acosta, M., Coronado, D. and Mar Cerban, M., 2007. Port competitiveness in container traffic from an internal point of view: the experience of the Port of Algeciras Bay. maritime Policy & management, 34(5), pp.501-520.

Africa Ports. 2020. Port of Cape Town, South Africa. [online] Available at: https://africaports.co.za/cape-town/> [Accessed 24 April 2020].

Africa Ports. 2020. Durban - Africa Ports. [online] Available at: <https://africaports.co.za/durban/> [Accessed 24 April 2020].

Africa Ports. 2020. East London - Africa Ports. [online] Available at: <https://africaports.co.za/east-london/> [Accessed 24 April 2020].

Africa Ports. 2020. Luderitz - Africa Ports. [online] Available at: <https://africaports.co.za/luderitz/> [Accessed 24 April 2020].

Africa Ports. 2021. Mossel Bay - Africa Ports. [online] Available at: <https://africaports.co.za/mossel-bay/> [Accessed 24 April 2020].

Africa Ports. 2020. The Port of Ngqura - Africa Ports. [online] Available at: <https://africaports.co.za/coega/> [Accessed 24 April 2020].

Africa Ports. 2020. Port Elizabeth - Africa Ports. [online] Available at: <https://africaports.co.za/port-elizabeth/> [Accessed 24 April 2020].

Africa Ports. 2020. Richards Bay - Africa Ports. [online] Available at: <https://africaports.co.za/richards-bay/> [Accessed 24 April 2020].

Africa Ports. 2020. Saldanha Bay. [online] Available at: <https://africaports.co.za/saldanha-bay/> [Accessed 24 April 2020].

Africa Ports. 2020. Walvis Bay. [online] Available at: <https://africaports.co.za/walvis-bay/> [Accessed 24 April 2020].

Alessandri, A., Sacone, S. and Siri, S., 2007. Modelling and optimal receding-horizon control of maritime container terminals. Journal of Mathematical Modelling and Algorithms, 6(1), pp.109-133.

Al-Rashidi, A., 2016. Data envelopment analysis for measuring the efficiency of head trauma care in England and Wales (Doctoral dissertation, Salford University).

Amakali, H.M., 2017. The history of port governance and performance in Namibia: a case of Port of Walvis Bay.

Appannaiah, H.R., Reddy, P.N. and Ramanath, H.R., 2010. Business Research Methods:(including Skill Development). Himalaya Publishing House.

Babounia, A. and El Imrani, O., 2016. The logistics of port container terminals: What prospects for fostering the role of Tangier Med port in the global maritime logistics? Revue de Gestion et d'Économie, 4(1), pp.30-49.

Bates, D., Sarkar, D., Bates, M.D. and Matrix, L., 2007. The lme4 package. R package version, 2(1), p.74.

Baumol, W.J., 1959. Business behavior, value and growth.

Banker, R.D., 1984. Estimating most productive scale size using data envelopment analysis. European journal of operational research, 17(1), pp.35-44.

Beaudreau, B.C., 2016. Competitive and comparative advantage: Towards a unified theory of international trade. International Economic Journal, 30(1), pp.1-18.

Begum, H., 2003. Impact of port efficiency and productivity on the economy of Bangladesh: a case study of Chittagong port.

Bergantino, A.S., Musso, E. and Porcelli, F., 2013. Port management performance and contextual variables: Which relationship? Methodological and empirical issues. Research in Transportation Business & Management, 8, pp.39-49.

Bergström, L., 2008. Learning from Experience. Namibia–Sweden Development Cooperation in the Area of Public Administration 1990–2006.

Beškovnik, B., 2008. Measuring and increasing the productivity model on maritime container terminals. Pomorstvo, 22(2), pp.171-183.

Blonigen, B.A. and Wilson, W., 2006. New measures of port efficiency using international trade data (No. w12052). National Bureau of Economic Research.

Botha, C.G., 1926. Place names in the Cape Province. Juta and Company Ltd, Cape Town.

Bonney, J. 2014. Back to basic. Journal of Commerce (15307557), 15, 72-74.

Brand, A. 2014. History: The forgotten people. [Online] available at http://www.sawest coast.com/history.html. Accessed 1 April 2014.

Brooks, M.R. and Schellinck, T., 2013. Measuring port effectiveness in user service delivery: What really determines users' evaluations of port service delivery? Research in Transportation Business & Management, 8, pp.87-96.

Brettenny, W. and Sharp, G., 2018. Evaluation of the effectiveness of the National Benchmarking Initiative (NBI) in improving the productivity of water services authorities in South Africa. Water SA, 44(1), pp.37-44

Camanho, A.S. and Dyson, R.G., 1999. Efficiency, size, benchmarks and targets for bank branches: an application of data envelopment analysis. Journal of the Operational Research Society, 50(9), pp.903-915.

Cape Town History. 2020. Welcome to our History Tour. [online] Available at: <http://capetownhistory.com/> [Accessed 28 December 2020].

Carte Blanche. 2019. Ports in Peril. [online] Available at: <https://m-net.dstv.com/show/carte-blanche/videos/ports-in-peril/video> [Accessed 6 September 2020].

Chang, Y.T., Lee, S.Y. and Tongzon, J.L., 2008. Port selection factors by shipping lines: Different perspectives between trunk liners and feeder service providers. Marine Policy, 32(6), pp.877-885.

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

Chen, T., 1999. Yard operations in the container terminal-a study in the ‘unproductive moves’. Maritime Policy & Management, 26(1), pp.27-38.

Chen, J. H., Lee, D.-H. & Cao, J. X. 2011. Heuristics for quay crane scheduling at indented berth. Transportation Research Part E: Logistics and Transportation Review, 47, 1005-1020

Cheung, R.K., Li, C.L. and Lin, W., 2002. Interblock crane deployment in container terminals. Transportation Science, 36(1), pp.79-93.

Chinda, T., 2010. Structural Equation Modelling of Productivity Enhancement. Suranaree Journal of Science & Technology, 17(3).

Chu, C.Y. and Huang, W.C., 2002. Aggregates cranes handling capacity of container terminals: the port of Kaohsiung. Maritime Policy & Management, 29(4), pp.341-350.

Chun, H. and Keleş, S., 2010. Sparse partial least squares regression for simultaneous dimension reduction and variable selection. Journal of the Royal Statistical Society: Series B (Statistical Methodology), 72(1), pp.3-25.

Clark, X., Dollar, D. and Micco, A., 2004. Port efficiency, maritime transport costs, and bilateral trade. Journal of development economics, 75(2), pp.417-450.

Cooper, W.W., Seiford, L.M. and Zhu, J., 2011. Data envelopment analysis: History, models, and interpretations. In Handbook on data envelopment analysis (pp. 1-39). Springer, Boston, MA.

Coto-Millan, P., Banos-Pino, J. and Rodriguez-Alvarez, A., 2000. Economic efficiency in Spanish ports: some empirical evidence. Maritime Policy & Management, 27(2), pp.169-174.

Cohen, K.J. and Cyert, R.M., 1975. Resource allocation in a market economy. Theory of the Firm. Prentice-Hall, Inc., Englewood Cliffs, NJ, pp.17-28.

Cooper, W.W., Huang, Z., Li, S., 1996. Satisficing DEA models under chance constraints. Annals of Operations Research 66, 279–295.

Cooper, W.W., Park, K., Pastor, J.T., 1999a. RAM: Range adjusted measure of inefficiency for use with additive models and relations to other models and measures in DEA. Journal of Productivity Analysis 11 (1), 5–42.

Cooper, W.W., Park, K.S., Yu, G., 1999b. IDEA and AR-IDEA: Models for dealing with imprecise data in DEA. Management Science 45, 597– 607.

Cooper, W.W., Li, S., Seiford, L.M., Tone, K., Thrall, R.M., Zhu, J., 2001. Sensitivity and stability analysis in DEA: Some recent developments. Journal of Productivity Analysis 15, 217–246.

Cooper, W.W., Huang, Z., Li, S., 2004. Chance constraint DEA. In: Cooper, W.W., Seiford, L.M., Zhu, J. (Eds.), Handbook on Data Envelopment Analysis. Kluwer Academic Publishers, Norwell, MA.

Cooper, W.W., Seiford, L.M., Tone, K., 2006. Introduction to Data Envelopment Analysis and its Uses. Springer Science, p. 351.

Cooper, W.W., Seiford, L.M. and Zhu, J., 2011. Data envelopment analysis: History, models, and interpretations. In Handbook on data envelopment analysis (pp. 1-39). Springer, Boston, MA.

Cullinane, K., Ji, P. and Wang, T.F., 2005. The relationship between privatization and DEA estimates of efficiency in the container port industry. Journal of economics and business, 57(5), pp.433-462.

Cullinane, K., Wang, T.F., Song, D.W. and Ji, P., 2006. The technical efficiency of container ports: Comparing data envelopment analysis and stochastic frontier analysis. Transportation Research Part A: Policy and Practice, 40(4), pp.354-374.

Cyert, R.M. and March, J.G., 1963. A behavioral theory of the firm (Vol. 2, No. 4, pp. 169-187).

Dai, J., Lin, W., Moorthy, R. and Teo, C.P., 2008. Berth allocation planning optimization in container terminals. In Supply chain analysis (pp. 69-104). Springer, Boston, MA.

Dappe, M.H., Jooste, C. and Suárez-Alemán, A., 2017. How does port efficiency affect maritime transport costs and trade? evidence from Indian and western Pacific Ocean countries. The World Bank.

De Koster, M.B.M., Balk, B.M. and Van Nus, W.T.I., 2009. On using DEA for benchmarking container terminals. International Journal of Operations & Production Management, 29(11), pp.1140-1155.

de Langen, P., Nidjam, M. and van der Horst, M., 2007. New indicators to measure port performance. Journal of Maritime Research, 4(1), pp.23-36.

Demsetz, H., 1997. The firm in economic theory: A quiet revolution. The American economic review, 87(2), pp.426-429.

Domínguez-Torres, C. and Briceño-Garmendia, C., 2011. Mozambique's Infrastructue: A Continental Perspective. World Bank.

Doyle, J. and Green, R., 1994. Efficiency and cross-efficiency in DEA: Derivations, meanings and uses. Journal of the operational research society, 45(5), pp.567-578.

Ducruet, C., Itoh, H. and Merk, O., 2014. Time efficiency at world container ports.

Dunford, M. and Yeung, G., 2009. Regional development: Port-industrial complexes. In: Kitchin R and Thrift N (eds) International Encyclopaedia of Human Geography. Amsterdam: Elsevier, Vol. 8,pp. 285–294.

Dunford M and Yeung G (2009) Regional development: Port-industrial complexes. In: Kitchin R and Thrift N (eds) International Encyclopaedia of Human Geography. Amsterdam: Elsevier, Vol. 8,pp. 285–294.

Dwarakish, G.S. and Salim, A.M., 2015. Review on the Role of Ports in the Development of a Nation. Aquatic Procedia, 4, pp.295-301.

Elferjani, I., 2015. Examination of port performance in a developing economy: A case study of Libyan ports. Doctorial Thesis, RMIT University, Melbourne, Australia.

Elsayed, A. and Khalil, N.S., 2017, October. Evaluate and Analysis Efficiency of Safaga Port Using DEA-CCR, BCC and SBM Models–Comparison with DP World Sokhna. In IOP Conference Series: Materials Science and Engineering (Vol. 245, No. 4, p. 042033). IOP Publishing.

Engle, R.F. and Granger, C.W., 1987. Co-integration and error correction: representation, estimation, and testing. Econometrica: journal of the Econometric Society, pp.251-276

Estache, A., González, M. and Trujillo, L., 2002. Efficiency gains from port reform and the potential for yardstick competition: lessons from Mexico. World development, 30(4), pp.545-560

Ernst, A.T., Oğuz, C., Singh, G. and Taherkhani, G., 2017. Mathematical models for the berth allocation problem in dry bulk terminals. Journal of Scheduling, 20(5), pp.459-473.

Faber, M., Proops, J.L. and Baumgärtner, S., 1996. Every production is joint production: a thermodynamic analysis. Wirtschaftswissenschaftliche Fakultät, Universität Heidelberg.

Fair, D. and Jones, T., 1991. The ports of Sub-Saharan Africa and their hinterlands: an overview.

Färe, R., Grosskopf, S. and Lovell, C.K., 2013. The measurement of efficiency of production (Vol. 6). Springer Science & Business Media.

Farrell, M.J., 1957. The measurement of productive efficiency. Journal of the Royal Statistical Society: Series A (General), 120(3), pp.253-281.

Feng, M., Mangan, J. and Lalwani, C., 2012. Comparing port performance: Western European versus eastern Asian ports. International Journal of Physical Distribution & Logistics Management.

Ferguson, R., 2008. Word of mouth and viral marketing: taking the temperature of the hottest trends in marketing. Journal of consumer marketing.

Foster, V. and Pushak, N., 2011. Nigeria's infrastructure: a continental perspective. The World Bank.

Fransman, L., Jenkins, A.K. and Savage, C.J., 2013. Logistics in Namibia: Issues and challenges. Journal of Transport and Supply Chain Management, 7(1), pp.1-8.

Fried, H.O., Schmidt, S.S. and Lovell, C.K. eds., 1993. The measurement of productive efficiency: techniques and applications. Oxford university press.

Fujita, M. and Mori, T., 1996. The role of ports in the making of major cities: self-agglomeration and hub-effect. Journal of development Economics, 49(1), pp.93-120.

Fuss, M. and McFadden, D. eds., 2014. Production economics: A dual approach to theory and applications: Applications of the theory of production. Elsevier.

Gallegos, C.M., 2009. Trends in maritime transport and port development in the context of world trade.

Gekara, V.O. and Chhetri, P., 2013. Upstream transport corridor inefficiencies and the implications for port performance: a case analysis of Mombasa Port and the Northern Corridor. Maritime Policy & Management, 40(6), pp.559-573.

Ghashat, H., Cullinane, K.P.B. and Wilmsmeier, G., 2011. Identifying the right “fit”: What can Libya learn from port devolution in Malaysia. International Journal of Euro-Mediterranean Studies, 4,(1), 83, 117.

Giallombardo, G., Moccia, L., Salani, M. and Vacca, I., 2010. Modeling and solving the tactical berth allocation problem. Transportation Research Part B: Methodological, 44(2), pp.232-245.

Goedhart, G.J., 2002. Criteria for (un)-loading Container ships.

González-Páramo, JM, 1995. Privatization and efficiency: is ownership irrelevant? Economists, 13 (63), pp.32-43.

Gonzalez, M.M. and Trujillo, L., 2009. Efficiency measurement in the port industry: a survey of the empirical evidence. Journal of Transport Economics and Policy (JTEP), 43(2), pp.157-192.tre

Grote, M., Mazurek, N., Gräbsch, C., Zeilinger, J., Le Floch, S., Wahrendorf, D.S. and Höfer, T., 2016. Dry bulk cargo shipping—An overlooked threat to the marine environment? Marine pollution bulletin, 110(1), pp.511-519.

Gumede, S. and Chasomeris, M., 2015. Maritime port pricing and governance in South Africa: trends and stakeholder comments. Journal of Economic and Financial Sciences, 8(1), pp.47-62.

Haezendonck, E., van den Broeck, J. and Jans, T., 2011. Analysing the lobby-effect of port competitiveness’ determinants: a stochastic frontier approach. Journal of Productivity Analysis, 36(2), pp.113-123.

Hall, P., 2000. Regional development and institutional lock-in: a case study of Richards Bay. Critical Planning, pp.87-102.

Han, X., Gong, X. and Jo, J., 2015. A new continuous berth allocation and quay crane assignment model in container terminal. Computers & Industrial Engineering, 89, pp.15-22.

Hendriks, M.P.M., Lefeber, E. and Udding, J.T., 2013. Simultaneous berth allocation and yard planning at tactical level. OR spectrum, 35(2), pp.441-456.

Herald Live. 2018. Shipping movement suspended following harbour crane collapse. [online] Available at: <https://www.heraldlive.co.za/news/2018-11-01-shipping-movement-suspended-following-harbour-crane-collapse/> [Accessed 27 December 2020].

Hlali, A., 2018. Efficiency Analysis with Different Models: The Case of Container Ports. Journal of Marine Science: Research & Development, 8(2), pp.6-10.

Hockly, H.E., 1948. The Story of the British Settlers of 1820. Juta.

Holmstrom, B.R. and Tirole, J., 1989. The theory of the firm. Handbook of industrial organization, 1, pp.61-133.

Hönke, J. and Cuesta-Fernandez, I., 2017. A topographical approach to infrastructure: Political topography, topology and the port of Dar es Salaam. Environment and Planning D: Society and Space, 35(6), pp.1076-1095.

Horwood, O.P.F., 1969. The Port of Durban (Vol. 15). Department of Economics, University of Natal.

Huisman, H.L., 1971. Structures. of historic interest (1): how Port Elizabeth got its first jetty. Civil Engineering= Siviele Ingenieurswese, 1971(v13i7), p.255.

Huang, W.C. and Chu, C.Y., 2004. A selection model for in-terminal container handling systems. Journal of Marine Science and Technology, 12(3), pp.159-170.

Huil, M., 2014. Critical view on Leibenstein's X-Efficiency Theory (Bachelor's thesis, University of Twente).

Ilmer, M., 2006. Beating congestion by building capacity: An overview of new container terminal developments in Northern Europe. Port Technology International, 2, p.2006.

Imai, A., Nishimura, E. and Papadimitriou, S., 2008. Berthing ships at a multi-user container terminal with a limited quay capacity. Transportation Research Part E: Logistics and Transportation Review, 44(1), pp.136-151.

Inggs, E.J., 1986. Liverpool of the Cape: Port Elizabeth Harbour Development, 1820-70. Department of Economics and Economic History, Rhodes University.

Infante Jiménez Z., Gutierrez A., Ortiz-Paniagua C.-F. (2013), Port efficiency in APEC, in: Proceedings of APEC Study Centre Consortium Conference 2013, https://www.researchgate.net/publication/262637197_Port_Efficiency_in_APEC [08.09.2018].

Ioannou, P.A., Jula, H., Liu, C.I., Vukadinovic, K., Pourmohammadi, H. and Dougherty, E., 2000. Advanced material handling: Automated guided vehicles in agile ports. Center for Advanced Transportation Technologies, Univ. Southern California, Los Angeles.

Jehle, G.A., 2002. On the geometry of constant returns. The Journal of Economic Education, 33(1), pp.53-68.

Kao, C., 2017. Network data envelopment analysis. Springer, 10, pp.26-33.

Kao, C., Chen, L.H., Wang, T.Y., Kuo, S. and Horng, S.D., 1995. Productivity improvement: efficiency approach vs effectiveness approach. Omega, 23(2), pp.197-204.

Kahyarara, G. and Simon, J., 2018. Maritime Transport In Africa: Challenges, Opportunities, and an Agenda for Future Research.

Karimzadeh, M., 2012. Efficiency analysis by using Data Envelop Analysis model: evidence from Indian banks. International Journal of Latest Trends in Finance & Economic Sciences, II (3).

Kim, K.H. and Park, Y.M., 2004. A crane scheduling method for port container terminals. European Journal of operational research, 156(3), pp.752-768.

Kizilay, D. and Eliiyi, D.T., 2020. A comprehensive review of quay crane scheduling, yard operations and integrations thereof in container terminals. Flexible Services and Manufacturing Journal, pp.1-42.

Kraaijenbrink, J. and Spender, J.C., 2011, November. Theories of the firm and their value creation assumptions. In Annual International Conference of the Strategic Management Society (pp. 6-9).

Kremer, W., 2013. How Much Bigger Can Container Ships Get?. BBC World Service, 19.

Kurz, H.D. and Salvadori, N., 1997. Exhaustible resources in a dynamic input–output model with ‘classical’features. Economic Systems Research, 9(3), pp.235-252.

Kutin, N., Nguyen, T.T. and Vallée, T., 2017. Relative efficiencies of ASEAN container ports based on data envelopment analysis. The Asian Journal of Shipping and Logistics, 33(2), pp.67-77.

Lau, H.Y. and Zhao, Y., 2008. Integrated scheduling of handling equipment at automated container terminals. International journal of production economics, 112(2), pp.665-682.

Le-Griffin, H.D. and Murphy, M., 2006, February. Container terminal productivity: experiences at the ports of Los Angeles and Long Beach. In NUF Conference (pp. 1-21).

Lee, Y. and Chao, S.L., 2009. A neighborhood search heuristic for pre-marshalling export containers. European Journal of Operational Research, 196(2), pp.468-475.

Lee, D.H. and Jin, J.G., 2013. Feeder vessel management at container transshipment terminals. Transportation Research Part E: Logistics and Transportation Review, 49(1), pp.201-216.

Lee, S.W., Song, D.W. and Ducruet, C., 2008. A tale of Asia’s world ports: the spatial evolution in global hub port cities. Geoforum, 39(1), pp.372-385.

Leibenstein, H., 1966. Allocative efficiency vs." X-efficiency". The American Economic Review, 56(3), pp.392-415.

Leibenstein, H., 1978. General X-efficiency theory and economic development. Oxford University Press.

Li, W., Wu, Y., Petering, M.E., Goh, M. and de Souza, R., 2009. Discrete time model and algorithms for container yard crane scheduling. European Journal of Operational Research, 198(1), pp.165-172.

Liang, C., Huang, Y. and Yang, Y., 2009. A quay crane dynamic scheduling problem by hybrid evolutionary algorithm for berth allocation planning. Computers & Industrial Engineering, 56(3), pp.1021-1028.

Ligteringen, H., 1999. Ports and Terminals. Lecture note CTwa4330.

Lin, L.C. and Tseng, C.C., 2007. Operational performance evaluation of major container ports in the Asia-Pacific region. Maritime Policy & Management, 34(6), pp.535-551.

Linn, R.J. and Zhang, C.Q., 2003. A heuristic for dynamic yard crane deployment in a container terminal. IIE transactions, 35(2), pp.161-174.

Liu, Q., 2010. Efficiency analysis of container ports and terminals (Doctoral dissertation, UCL (University College London)).

Liu, C.C., 2008. Evaluating the operational efficiency of major ports in the Asia-Pacific region using data envelopment analysis. Applied economics, 40(13), pp.1737-1743.

Lodewijks, G., Schott, D.L. and Ottjes, J.A., 2007. Modern dry bulk terminal design. Bulk Solids Handling, 27(6), p.364.

Lovell, C.K. and Schmidt, P., 1988. A comparison of alternative approaches to the measurement of productive efficiency. In Applications of modern production theory: Efficiency and productivity (pp. 3-32). Springer, Dordrecht.

Lu, Z., Han, X., Xi, L. and Erera, A.L., 2012. A heuristic for the quay crane scheduling problem based on contiguous bay crane operations. Computers & Operations Research, 39(12), pp.2915-2928.

Maharaj, A. and Mather, A.A., Durban and its Port: An Investigation into the relationship between the City and port of Durban’. Capsule Professionelle, 2, pp.127-141.

Mangat, M., 2006. Productivity concepts and definitions. Lahore: University of Management and Technology, Lahore.

Maritimesa. 2016. Test Yourself: Southern African Ports | Maritime Economics SA Grade 11. [online] Maritimesa.org. Available at: <https://maritimesa.org/grade-11/2016/08/22/test-yourself-southern-african-ports/> [Accessed 13 May 2019].

Marris, R., Maclean, I. and Bernau, S., 1964. The economics of capital utilisation (No. 10). CUP Archive.

Marshall, M., 1940. The Growth andDevelopment of Cape Town. Master's thesis, Cape Town, Environmental and Geographical Department, University of Cape Town.

Meisel, F., 2009. Seaside operations planning in container terminals. Berlin: Physica-Verlag.

Meyiwa, A. and Chasomeris, M., 2016. Restructuring port governance in South Africa. Journal of Economic and Financial Sciences, 9(3), pp.854-873.

Mienie, B., Sharp, G. and Brettenny, W., 2017. Ranking selected container terminals in Africa using data envelopment analysis. Management Dynamics: Journal of the Southern African Institute for Management Scientists, 26(1), pp.16-29.

Mossel Bay Municipality. 2014. History. [Online] available at http://www.mosselbay.gov.za/about_us/history. Accessed 10 January 2021.

Muller, C.F.J. ed., 1969. Five hundred years: a history of South Africa. Pretoria: Academica.

Munim, Z.H. and Schramm, H.J., 2018. The impacts of port infrastructure and logistics performance on economic growth: the mediating role of seaborne trade. Journal of Shipping and Trade, 3(1), pp.1-19.

Mwendapole, M.J., 2015. Analysis on the Factors Contributing to Poor Seaport Performance in Tanzania.“Case Study of Dar es Salaam Port (Doctoral dissertation, The Open University Of Tanzania).

Mwenyo, E 2020. [online] Available at: <https://www.youtube.com/watch?v=CyfhCd0s7ng&ab_channel=TransportEventsLimited> [Accessed 6 January 2021].

Nabee, S.G. and Walters, J., 2018. Liner shipping cascading effect on Southern African Development Community port strategies. Journal of Transport and Supply Chain Management, 12(1), pp.1-12.

Nam, K.C., Kwak, K.S. and Yu, M.S., 2002. Simulation study of container terminal performance. Journal of Waterway, Port, Coastal, and Ocean Engineering, 128(3), pp.126-132.

Namport. 2019. [online] Available at: <https://www.namport.com.na/files/documents/e28_Annual%20Report%2012%20months%20ended%2031%20March%202019.pdf> [Accessed 17 June 2019].

Namport. 2018. [online] Available at: <https://www.namport.com.na/files/documents/dee_Annual%20Report%2012%20months%20ended%2031%20March%202018.pdf> [Accessed 24 April 2020].

Namport. 2017. [online] Available at: <https://www.namport.com.na/files/documents/6a0_Annual%20Report%2012%20months%20ended%2031%20March%202017.pdf> [Accessed 24 April 2020].

National Port Plan, 2017. [online] Available at: https://www.transnetnationalportsauthority.net/Infrastructure%20and%20Port%20Planning/Documents/National%20Ports%20Plan%202017%20update.pdf [Accessed 23 November 2019]

Neysi, A., Jafari, H. and Zangoui, A., 2013. Empirical Analysis of the Containers Dwell Time in Container Ports Using Multiple-Criteria Decision-Making Methods. Applied mathematics in Engineering, Management and Technology, 2(1), p.2013.

Nidec-netherlands. 2021. [online] Available at: <https://www.nidec-netherlands.nl/media/2928-an-introductory-guide-to-port-cranes-and-the-application-of-variable-speed-drives-iss1x-0704-0005-01x.pdf> [Accessed 23 January 2021].

Notteboom, T., Coeck, C. and Van Den Broeck, J. (2000) ‘Measuring and explaining the relative efficiency of container terminals by means of Bayesian stochastic frontier models’, International Journal of Maritime Economics, Vol. 2, pp.83–106.

Oghojafor, B.E.A., Kuye, O.L. and Alaneme, G.C., 2012. Concession as a Strategic Tool for Ports Efficiency: An Assessment of the Nigerian Ports.

Orinda, E.O. and Malunde, J.M., Cargo System Utilisation and Service Delivery in Dar Es Salaam Port, Tanzania.

Olivier, D. and Slack, B., 2006. Rethinking the port. *Environment and Planning A*, *38*(8), pp.1409-1427.

Osterwald-Lenum, M., 1992. A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics 1. Oxford Bulletin of Economics and statistics, 54(3), pp.461-472.

Pallis, A.A. and Syriopoulos, T., 2007. Port governance models: financial evaluation of Greek port restructuring. Transport Policy, 14(3), pp.232-246.

Palmer, S. and Torgerson, D.J., 1999. Definitions of efficiency. Bmj, 318(7191), p.1136.

Porcelli, F., 2009. Measurement of Technical Efficiency. A brief survey on parametric and non-parametric techniques. University of Warwick, 11, pp.1-27.

Ports Regulator, 2015. [online] Available at: <https://www.portsregulator.org/images/documents/SA-port-benchmarking-report-2015-16.pdf> [Accessed 23 January 2021].

Peterkofsky, R.I. and Daganzo, C.F., 1990. A branch and bound solution method for the crane scheduling problem. Transportation Research Part B: Methodological, 24(3), pp.159-172.

Raballand, G., Refas, S., Beuran, M. and Isik, G., 2012. Why does cargo spend weeks in sub-Saharan African ports? Lessons from six countries. The World Bank.

Reilly, A., 2007. Using data envelopment analysis to evaluate the performance of post-hurricane electric power restoration activities.

Robenek, T., Umang, N. and Bierlaire, M., 2012. Integrated berth allocation and yard assignment in bulk ports using column generation. In 12th Swiss Transport Research Conference.

Robinson, R., 2002. Ports as elements in value-driven chain systems: the new paradigm. *Maritime Policy & Management*, *29*(3), pp.241-255.

Rothbard, M.N., 1995. An Austrian Perspective on the History of Economic Thought: Classical Economics (Vol. 2). Ludwig von Mises Institute

Ruto, W.K. and Datche, E., 2015. Logistical factors influencing port performance a case of kenya ports authority (KPA). International Journal of Current Research and Review, 7(12), p.52.

Saslavsky, D. and Shepherd, B., 2012. Facilitating international production networks: The role of trade logistics. The World Bank.

Scholvin, S. and Plagemann, J., 2014. Transport Infrastructure in Central and Northern Mozambique: The Impact of Foreign Investment on National Development and Regional Integration.

Schott, D.L. and van den Hoed, M., 2017. Break Bulk and Bulk Terminals. Encyclopedia of Maritime and Offshore Engineering, pp.1-10.

Shepherd, D., 2015. Party On! A call for entrepreneurship research that is more interactive, activity based, cognitively hot, compassionate, and prosocial. Journal of Business Venturing, 30(4), pp.489-507.

Simon, H.A., 1959. Theories of decision-making in economics and behavioral science. The American economic review, 49(3), pp.253-283.

Slack, B., Comtois, C., Wiegmans, B. and Witte, P., 2018. Ships time in port. International Journal of Shipping and Transport Logistics, 10(1), pp.45-62.

Spiegel, J.R., Mckenna, M.T., Lakshman, G.S. and Nordstrom, P.G., Amazon Technologies Inc, 2011. Method and system for anticipatory package shipping. U.S. Patent 8,086,546.

Stahlbock, R. and Voß, S., 2008. Operations research at container terminals: a literature update. OR spectrum, 30(1), pp.1-52.

Steenkamp, J.M., 2015. A toponymical study of place name heritage in Mossel Bay (Western Cape) (Doctoral dissertation, University of the Free State).

Steenken, D., Voß, S. and Stahlbock, R., 2004. Container terminal operation and operations research-a classification and literature review. OR spectrum, 26(1), pp.3-49.

Stigler, G.J., 1976. The Xistence of X-efficiency. The American Economic Review, 66(1), pp.213-216.

Stuebs, M. and Sun, L., 2010. Business reputation and labor efficiency, productivity, and cost. Journal of Business Ethics, 96(2), pp.265-283.

Tahir, I.M., Bakar, N.A. and Haron, S., 2009. Evaluating efficiency of Malaysian banks using data envelopment analysis. International Journal of Business and Management, 4(8), pp.96-106.

Tavakkoli-Moghaddam, R., Makui, A., Salahi, S., Bazzazi, M. and Taheri, F., 2009. An efficient algorithm for solving a new mathematical model for a quay crane scheduling problem in container ports. Computers & Industrial Engineering, 56(1), pp.241-248.

Tiesnese, L., 2012. Local effects of small port expansion and consequent changes in port-town relationship: the case of Salacgriva, Latvia (Doctoral dissertation).

Titko, J. and Jureviciene, D., 2014. DEA application at cross-country benchmarking: Latvian vs Lithuanian banking sector. Procedia-Social and Behavioral Sciences, 110, pp.1124-1135.

Tello-Trillo, C., 2013. THE IMPACT OF TRADE COMPETITION ON MANAGERIAL INCENTIVES AND PRODUCTIVITY. Economic and Social Development: Book of Proceedings, p.1346.

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

TomekoviĆ, T., 1962. Level of knowledge of requirements as a motivational factor in the work situation. Human Relations, 15(3), pp.197-216.

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

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

Tozer, D. and Penfold, A., 2001. Ultra-Large Container Ships (ULCS): designing to the limit of current and projected terminal infrastructure capabilities. Lloyd's Register of Shipping.

Transnet National Port Authority (TNPA). 2020. Port Statistics. [online] Available at: <https://www.transnetnationalportsauthority.net/Commercial%20and%20Marketing/Pages/Port-Statistics.aspx> [Accessed 16 September 2020].

Transnet National Port Authority (TNPA). 2019. [online] Available at: <https://www.transnet.net/InvestorRelations/AR2019/Transnet%20National%20Ports%20Authority.pdf> [Accessed 24 July 2020].

Transnet Port Terminals (TPT), 2017. [online] Available at: <https://www.transnet.net/InvestorRelations/AR2017/OD%20Reports/8335_Transnet%202017_Port%20terminals%20HR.pdf> [Accessed 12 December 2019].

Transnet National Ports Authority, (2013), Improving Operational Efficiency in the Port System: Customer Conference Paper, pp. 1-26.

Transnet National Ports Authority (TNPA), (2013), Port Development Plan, www.transnet.net (Accessed: 31 March 2019)

Transnet: Integrated Report. 2014. [online] Available at: <https://www.transnet.net/InvestorRelations/AR/2014/Integrated%20Report.pdf> [Accessed 16 March 2020].

Transnet Port Terminals., 2020. EASTERN CAPE HERITAGE mirrored in its port terminals. [online]. Availableat:https://www.transnetportterminals.net/Media/Publications%20Paper%20and%20Presentation/Transnet%20Port%20Heritage%20Eastern%20Cape%20Terminals.pdf> [Accessed 27 December 2020].

Umang, N., Bierlaire, M. and Vacca, I., 2013. Exact and heuristic methods to solve the berth allocation problem in bulk ports. Transportation Research Part E: Logistics and Transportation Review, 54, pp.14-31.

UNCTAD, G., 1975. International Subcontracting Arrangements in Electronics Between Developed Market-Economy Countries and Developing Coun tries. *UNCTAD*.

Valentine, V.F. and Gray, R., 2001, July. The measurement of port efficiency using data envelopment analysis. In Proceedings of the 9th world conference on transport research (Vol. 22, p. 27). South Korea: Seoul.

Van der Molen, W. and Moes, H., 2009, July. General characteristics of South African ports and the safe mooring of ships. In Proceedings of the 28th Southern African Transport Conference (SATC 2009) (Vol. 6, p. 9).

van Dyck, G.K., 2015. Assessment of port efficiency in West Africa using data envelopment analysis. American Journal of Industrial and Business Management, 5(04), p.208.

Vitsounis, T.K. and Pallis, A.A., 2012. Port value chains and the role of interdependencies. In Maritime Logistics. Emerald Group Publishing Limited.

Verhoeven, P., 2010. European port governance. *European Sea Ports Organization (ESPO)*.

Wang, W., Zheng, T. and Peng, Y., 2018, March. The Study of the Influence of Port Scale on Tugboat Configuration Based on System Simulation. In 2018 International Conference on Mathematics, Modelling, Simulation and Algorithms (MMSA 2018) (pp. 4-7). Atlantis Press.

Wanke, P.F., 2013. Physical infrastructure and shipment consolidation efficiency drivers in Brazilian ports: A two-stage network-DEA approach. Transport Policy, 29, pp.145-153.

Welman, L. and Ferreira, S.L., 2016. The co-evolution of Saldanha Bay (town and hinterland) and its Port. Local Economy, 31(1-2), pp.219-233.

Worden, N., 1994. Unwrapping history at the Cape Town waterfront. The Public Historian, 16(2), pp.33-50.

World Port Source. 2020. Port of Cape Town. [online] Available at: <http://www.worldportsource.com/ports/review/ZAF_Port_of_Cape_Town_42.php> [Accessed 28 December 2020].

Wu, G., 2009. The Impact of Inter-Company Network Technology on correlations between Supply Chain Drivers and performance Measures.

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

Wu, Y.C.J., Yuan, C.H., Goh, M. and Lu, Y.H., 2016. Regional port productivity in APEC. Sustainability, 8(7), p.689.

Xiao, L. and Hu, Z.H., 2014. Berth allocation problem with quay crane assignment for container terminals based on rolling-horizon strategy. Mathematical Problems in Engineering, 2014.

Xin, J., Negenborn, R.R. and Van Vianen, T., 2018. A hybrid dynamical approach for allocating materials in a dry bulk terminal. IEEE Transactions on Automation Science and Engineering, 15(3), pp.1326-1336.

Xu, D., Li, C.L. and Leung, J.Y.T., 2012. Berth allocation with time-dependent physical limitations on vessels. European Journal of Operational Research, 216(1), pp.47-56.

Yang, C., Wang, X. and Li, Z., 2012. An optimization approach for coupling problem of berth allocation and quay crane assignment in container terminal. Computers & Industrial Engineering, 63(1), pp.243-253.

Yin, R.K., 1994. Discovering the future of the case study. Method in evaluation research. Evaluation practice, 15(3), pp.283-290.

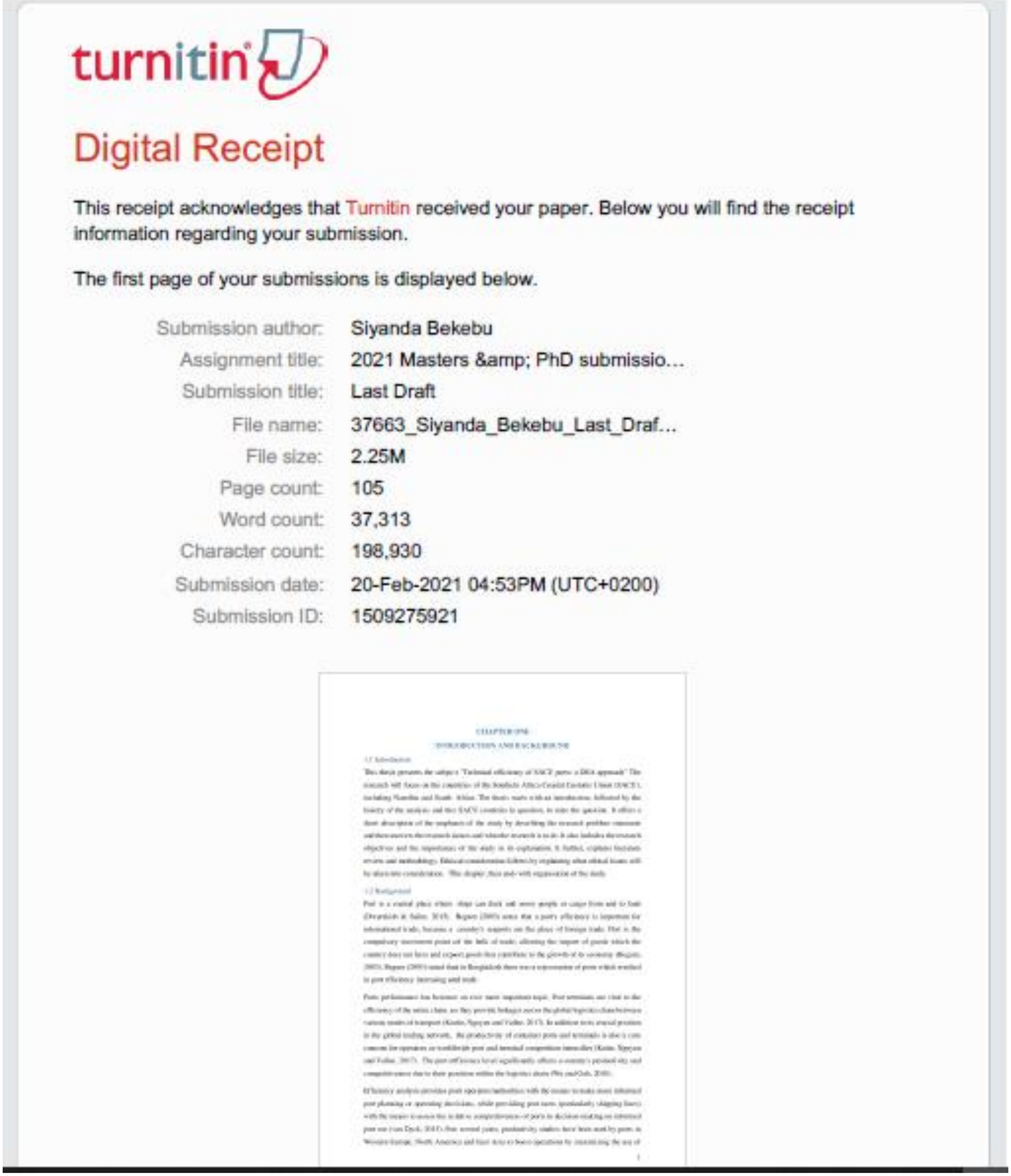
Yuen, C.L.A., Zhang, A. and Cheung, W., 2012. Port competitiveness from the users' perspective: An analysis of major container ports in China and its neighboring countries. Research in Transportation Economics, 35(1), pp.34-40.

Zegordi, S. and Nahavandi, N., 2002. Measuring productivity indexes and efficiency in the container terminal at port Rajaei.

Zhang, Z., Liu, M., Lee, C.Y. and Wang, J., 2018. The quay crane scheduling problem with stability constraints. IEEE Transactions on Automation Science and Engineering, 15(3), pp.1399-1412.

Zhou, P.F. and Kang, H.G., 2008. Study on berth and quay-crane allocation under stochastic environments in container terminal. Systems Engineering-Theory & Practice, 28(1), pp.161-169.

Appendix A



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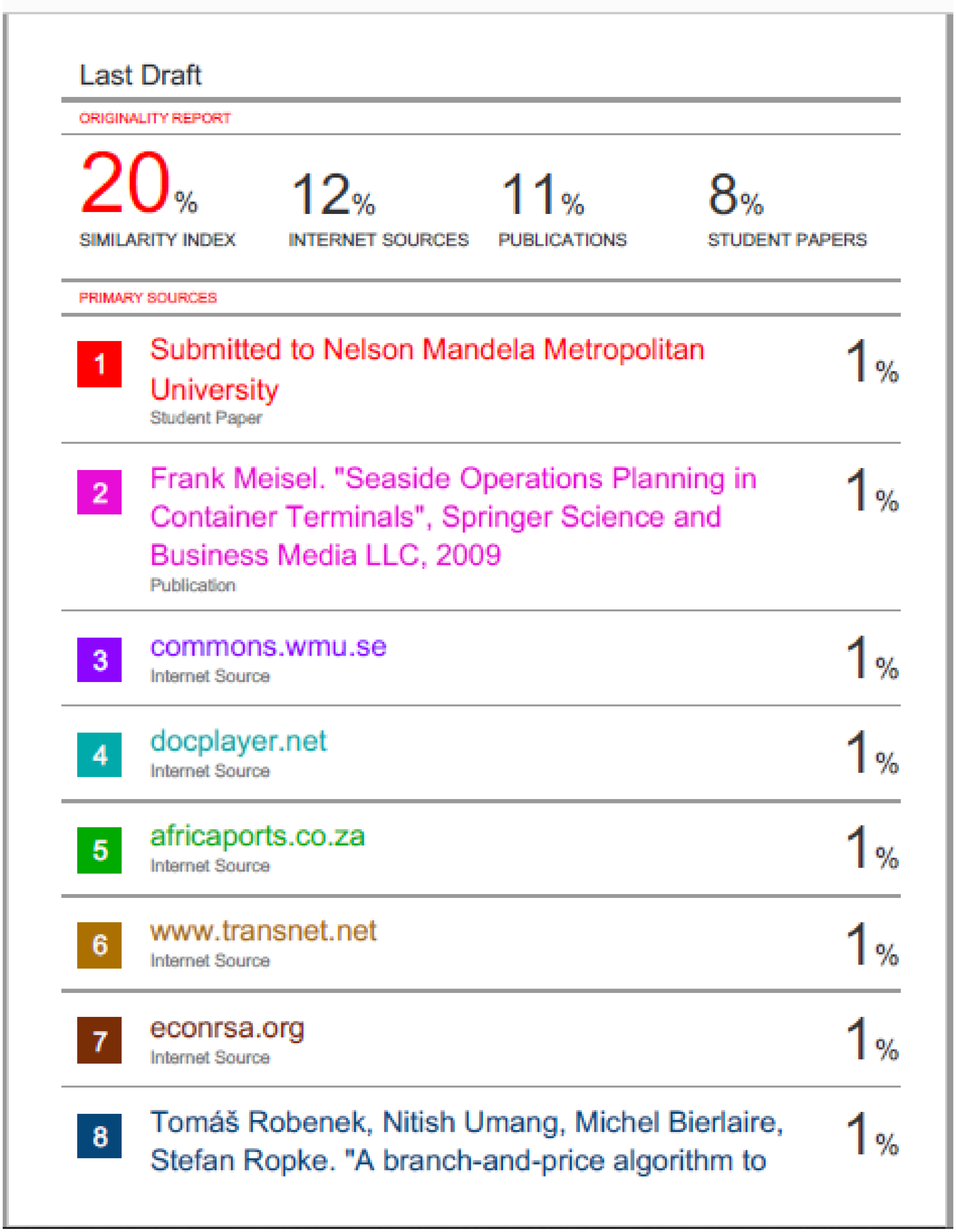

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