UNIVERSITY OF KWAZULU-NATAL

Examining container handling equipment to reduce port congestion at Durban Container Terminal

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DECLARATION

I Rowen Naicker declare that

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LIST OF ABBREVIATIONS

DCT	Durban Container Terminal
GCH	Gross crane hour
KPI	Key performance indicators
RMG	Rail Mounted Gantry
RTG	Rubber tyred gantries
SA	South Africa
STS	Ship to-shore
SWH	Ship working hour
TAS	Truck Appointment System
TEU	Twenty-foot equivalent unit
TNPA	Transnet National Ports Authority
TTU	Tractor Trailor Unit
TPT	Transnet Port Terminals
PRSA	Ports Regulator of South Africa

ABSTRACT

Port congestion has become a major problem around the Durban Container Terminal (DCT) precinct and investors and key stakeholders have raised concerns and expressed their frustration over the poor productivity and capacity limitations. The aim of this study was to examine container handling equipment that should reduce port congestion at the DCT. The objectives are: 1) to examine the productivity of the DCT in comparison to other ports nationally and internationally; 2) to examine the performance of current container handling equipment used at the DCT and 3) to examine and compare the costs and productivity of using a Rubber Tyre Gantry (RTG) system versus Straddle Carrier (SC) system at the DCT. This desktop study collected and analysed secondary data on container handling productivity and costs of the container handling equipment used at the DCT. Cost effective analysis was applied to the available equipment data and associated costs were retrieved and studied. A compound interest formulae and inflation calculator were used to convert all costs to their 2021 approximate values. The performance results between 2015 to 2020 showed that the DCT was performing poorly. The DCT, Pier 1 and Pier 2 use RTG and SC respectively. RTGs performed exceptionally well compared to SCs. Examining the advantages and disadvantages of the RTG and SC showed that the RTG was the preferred option. Although RTGs were more expensive to purchase and operate, the SCs were costlier to maintain. Analysis of the equipment used by leading container ports shows that top ports have adopted the RTG system and that 2018 and 2019, more RTGs were purchased than Rail Mounted Gantrys (RMGs) and SCs combined by major ports globally. The results indicate the most viable option would be for the DCT to adopt a RTG system of operation due to its high efficiency levels and cost effectiveness.

KEYWORDS

Container handling equipment, port congestion, port productivity

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Transporting cargo by sea is the most common method of trading globally today. When various ports across six nations were examined and it was concluded that the typical goods waiting time is approximately 20 days (Gidado, 2015). Most of the dwell time of goods are spent in ports prior to being delivered to customers. Cargo dwell time means the timeframe between storage yard and export or import (African Development Bank, 2014). One way of measuring port productivity is to determine the dwell time. Approximately 90 per cent of imports and exports are routed through ports (Ports Regulator of South Africa, 2016). Ports in South Africa (SA) play a crucial role in the achievement of the country's social and economic growth intentions. A frequent topic discussed in the Ports Regulator's stakeholder meetings is port congestion due to the inefficient operations at SA ports that is resulting in the lack of competitiveness. There are serious concerns about poor outputs with Gross Crane Moves per hour and the fact that vessels berth and anchorage time is too long which lead to port congestion (Ports Regulator of South Africa, 2016). This study focuses on the port equipment used between the quay and yard vicinity at the DCT, Pier 1 and Pier 2 and which of these equipment is the most efficient to reduce port congestion. Figure 1.1, obtained from google earth, indicates the location and layout of the area that will be investigated.

Figure 1.1: Layout Map for the DCT

Source: (Google Maps, 2021)

Pier 2 is separated into North, East and South Quays. This terminal was developed in the 1970's. The pavement was initially designed to withstand one over two SCs and stacking containers two high (Transnet Port Terminals, 2021). Currently at the DCT Pier 2, when the new ship-to-shore cranes offload ships, the single-lift straddles transport these containers to the storage yard. These straddles can only stack up to a maximum of 3 high (1 over 2) (Transnet Port Terminals, 2021).

The world is turning towards shipping as the most economical option to move goods, thus creating a demand for the use of efficient container handling infrastructure. The DCT plays a major role in turning the economy in either a positive or negative direction thus the selection of appropriate container handling equipment to reduce port congestion needs careful evaluation. The number of containers that the DCT handles increased from 2.7 million twenty foot-equivalent units (TEUs) to 4.6 million TEUs between 2012 and 2019 and is expected to increase further in the next decade. This will place extreme pressure on the existing system at the port and the type of port equipment will need to be upgraded to manage the increase and reduce port congestion (Transnet Port Terminals, 2021).

When the size of vessels increase, ports will need to ensure they have the infrastructure to offload and load ships and to empty the yard faster. If the operations are slow, containers will need to be reshuffled when trucks arrive at the port to load or offload goods which results in port congestion. The impact is that vessel dwell times are longer and ships are left with no choice but to look for alternative ports to conduct business with (Poineer Freight, 2020).

Transnet plans to create berths that are deeper at the DCT Pier 2's North Quay to enable the Port of Durban to receive modern container vessels. Currently, bigger vessels are towed in by tug boats at high tide and occupy two berths (Barradas, 2018). Recently the Public Enterprise minister, Pravin Gordon, has announced there is a master plan that has been developed to upgrade the current infrastructure at the ports to redcue port congestion and is seeking private investment worth 100 billion rand despite the recent state capture debacle that has impacted negatively on foreign investment potential (Khumalo, 2021).

Ultimately, port congestion will affect all industries, and this will have major consequences on business such as slowing down of operations, shortages of critical supplies especially essential goods. Goods that are seasonal may be impacted and not arrive as scheduled. The consumers as well as the economy will also suffer major losses (Poineer Freight, 2020).

The DCT, Pier 2 currently operates with the pure straddle carrier system. The SC is a very popular type of port equipment due to its space efficiency and flexibility, however, certain disadvantages such as accidents, lower stacking ability and breakdowns makes it unfavourable (Mohseni, 2011). The RTG stacks higher, encounters fewer breakdowns, and produces greater efficiencies making it an ideal choice to improve productivity, which ultimately reduces port congestion (Brinkmann, 2011). Although the RMG has similar advantages to the RTGs, the costs to implement and maintain are exorbitant. It is also not as flexible as the SC and RTGs (Urban-Econ (PTY) Ltd, 2012).

1.2. Problem statement

There are two container Piers within the DCT, namely Pier 1 and Pier 2. Pier 1 includes berths 101-107 and berths 108-205 form part of Pier 2. Pier 1 has installed a Tractor Trailor Unit (TTU) and RTG operational system, while SCs have become the method of container movement at Pier 2. The seven ZPMC STS cranes used in Pier 2, can move two 40-foot containers or four 20-foot containers simultaneously. The STS cranes need to work seamlessly with the SC operations in Pier 2 and if not, then an appropriate system needs to be determined.

DCT spends a longer time per container moving across the various vessel call size groups when compared to other SA ports (Coetsee 2021:42). Vessels calling at DCT spend the most time at the arrival and cargo operations processes as compared to other SA ports, which will result in port congestion due to the time wastage (Business Insider SA, 2021). This suggests the type of container handling equipment used on the landside and quayside seaside of DCT needs to be re-evaluated so the appropriate type of equipment is utilized. It is for this reason that this study was undertaken.

Port congestion has serious impacts on container movement globally (Nze, 2018). Port inefficiency has detrimental effects on the organisation and on the economy. (Munim & Schramm, 2018). There are several factors that contribute toward congestion, however at the DCT it has been identified in this study that the port equipment will need to be upgraded to improve the efficiency at the port and to reduce port congestion.

Some of the issues that could be experienced due to poor container handling equipment are (Shan, 2015):

- Traffic congestion both on the road and sea, resulting in delays;
- Long turnaround times of both loading and offloading, resulting in customers turning to other countries to trade rather than SA; and
- Frustration of employees and customers as targets need to be met which could lead to accidents on the roads and in the port.

Berth's productivity performance has worsened even though the targets are mostly set below the installed norm. Interventions are required as terminals are struggling to achieve low targets. According to the World Bank Report, the Port of Durban has been ranked amongst the worst performers landing in the bottom three when compared to the 351 competent container terminals around the world. Amongst the worst performers are the Port of Ngqura, Port Elizabeth and Cape Town (Mchunu, 2021). The ranking is a cause for concern as investors would be reluctant to invest in the Port of Durban. If the Port of Durban cannot perform at optimum level it would not remain competitive and would be unable to meet current and future demands as it is a strategically placed gateway to the economy. The World Bank Report 2020 results substantiated the need for this study.

The investors and key stakeholders are aware of the constraints at the DCT and have raised concerns and expressed their frustration over the poor efficiency and capacity limitations (Ports Regulator of South Africa, 2016).

Equipment breakdowns, the costs to maintain equipment and the turnaround time for delivery of parts is another major challenge experienced at the port which results in port congestion on both land and sea.

1.3. The research aim

The aim of this research is to determine the most suitable container handling equipment that should be installed at the DCT to reduce port congestion.

1.4. Research Questions

- How is the Durban Container Terminal performing compared to other ports nationally and internationally?
- How is the current container handling equipment performing at the Durban Container Terminal?
- What are the costs of using a Rubber Tyre Gantry system versus Straddle Carrier system at the Durban Container Terminal?

1.5. Objectives of the research

This research investigates the reasons for the port congestion by examining the productivity of the DCT in comparison to other ports. The DCT will be compared to ports locally and internationally to determine the state of efficiency of the DCT when compared to other ports. Once the current state has been established, the study will then examine the RTG and SC container movements between the quay and stack in Pier 1 and Pier 2 respectively to understand which of the two are the better performers. The container handling equipment used by leading ports, according to the World Bank Report, will be studied to further substantiate the recommendation. Furthermore, a cost comparison, using the compound interest formulae and inflation calculator, will be conducted to identify the cost to purchase, operate and maintain RTGs and SCs.

Research Objectives:

- To examine the productivity of the Durban Container Terminal in comparison to other ports nationally and internationally.
- To examine the performance of current container handling equipment used at the Durban Container Terminal.
- To examine and compare the costs of using a Rubber Tyre Gantry system versus Straddle Carrier system at the Durban Container Terminal.

1.6. Research methodology

This is a desktop study analysing secondary data from available online databases and to compare trends in Port Container Terminal productivity from 2019 to 2020 and (in some cases where data are available), to examine the data to the present. The secondary container terminal trade data are made available from public databases and other organisations that provide data online.

A literature review was conducted to explore various container terminal port items of equipment and opportunities to adopt new technology to reduce container terminal port congestion. The literature review included secondary data acquired from academic journals, books, and electronic sources. The review assisted in providing an understanding of the issues identified and measures taken to address them globally. This dissertation will provide a thorough understanding of what container terminal port equipment is, the existing issues related to port equipment and opportunities to upgrade container handling equipment. The impact on the supply chain is discussed together with proposals that port authorities have introduced as measures to improve the challenges faced relating to port congestion.

This study used a quantitative methodology as the most current available statistics such as Berth Productivity (total volumes handled during total time of ship alongside), Cargo Dwell Time (average time spent by cargo at the terminal), Ship Working Hours (total volumes handled during total ship productive hours) and Terminal Throughput (total volumes handled) are expressed numerically and were sourced and compared to international benchmarks to determine the most suitable container handling equipment for the DCT. Equipment productivity between Pier 1 and 2 were compared in the dissertation as part of the supporting data for the selection of the most suitable port equipment. The type and operation costs of equipment were considered as part of the analysis. Cost effective analysis was applied and the available equipment data and associated costs were retrieved and studied. A compound interest formulae and inflation calculator were used to convert all costs to their 2021 approximate values. Ultimately the result should present the most efficient equipment that is cost effective.

1.7. Limitations and Delimitations of study

This study will concentrate on the assessment and proposal of the most suitable container handling equipment for the DCT between the quay and stack area only. This will be properly addressed by collecting as much data as possible to gain a deep understanding of it from across the world and by critically reviewing the operating container handling systems in SA.

The research will exclude studies on road traffic congestion on major arterial roads leading to the port as well as sea traffic.

1.8. Overview of chapters

This dissertation comprises of five chapters. Chapter one will present the title of the research, gives the background knowledge of the investigation, and underlines the problem, aims and the extent of the study. Chapter two reviews the literature on the causes of port congestion, the container handling equipment used at the DCT, and performance of the Port of Durban. Chapter three talks about the research approach used in the analysis and describes the reasoning behind the chosen methodology. Chapter four is the presentation of the data received from the research conducted. Chapter five presents the findings of the primary investigation combined with the data attained from the literature review and provided proposals based on the outcomes drawn from the research.

1.9. Chapter summary

In our current environment, where there is a rapid increase in global trade, ports play a pivotal role in the flow of goods. It is therefore imperative to select the most efficient port equipment to produce the most efficient outputs to remain competitive. The increase in the size of vessels has an influence on the port operations and the type of equipment being used, ultimately defining the level of efficiency (Ports Regulator of South Africa, 2016). Ships sizes can range between 9000-24000 TEUs and these continue to grow. To meet the supply and demand ports will need to ensure that they have enough skilled labour and the right equipment to offload ships efficiently to reduce congestion (Manaadiar, 2020).
The World Bank concluded that the DCT has one of the worst performing ports in the world, rating it three out of the world's 351 competent container handling facilities. The study analysed publicly available data in relation to the DCT to understand the possible causes for the poor rating by the World Bank. A comparison between the equipment used in Pier 1 and Pier 2 was carried out and thereafter a purchase and operating cost analysis was presented to support the outcome of the study.

A literature review was conducted to understand what port equipment is and to explore opportunities to implement current technology. The impact on the supply chain due to port congestion was briefly discussed. This chapter sought to present a summary of the research performed, specifying the necessity for the study, the objectives of the research, how it was performed and the constraints of the study. The dissertation will therefore proceed to the literature review on this basis, in which the main theories that relate to the study are investigated.

LITERATURE REVIEW
CHAPTER 2

2.1. Introduction

The purpose of this chapter is to conduct a literature review of available information relating to port container handling equipment and opportunities to adopt new technology to reduce container terminal congestion. It will present information of what port equipment is, the existing issues related to port equipment and opportunities to upgrade container handling equipment. The impact on the supply chain is discussed together with proposals that port authorities have introduced as measures to improve the current challenges faced relating to port congestion.

Maritime transportation is the pillar of world export and imports trade. More than four fifths of the world's trading cargo are transported by sea. One of the main reasons is because this is the most reliable and efficient transportation means, with cargo volumes increasing annually by almost 4 per cent (UNCTAD, 2018).

The size of container ships has increased by over 1400 per cent in the last 50 years and this is one of the reasons port congestion is increasing (see figure 2.1). To reduce the anchorage time of these Ultra Large Container Ship, ports terminals are required to expand their fleet of gantry cranes, equipment, and labour. The increase in offloading will also require the container yard to be cleared simultaneously or it will reach its full capacity. This will result in shuffling of containers when trucks arrive (Poineer Freight, 2020).

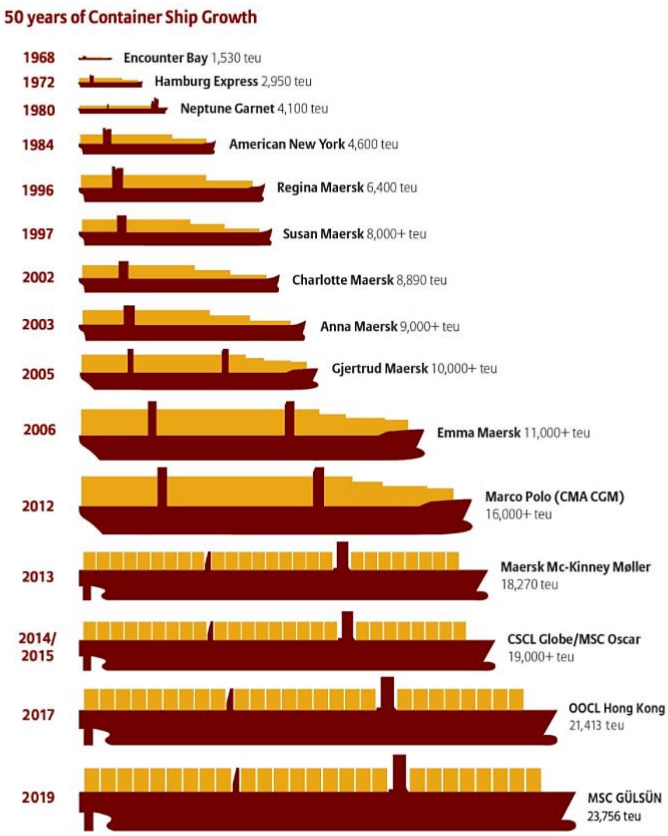


Figure 2.1: 50 years of container ship growth

Source: (Poineer Freight, 2020:18)

Ever since the inception of world trading, ports have played a fundamental role in the social and economic growth of cities and regions. Containerisation expansion has resulted in an evolution in the location and the type of goods produced (Hlali, 2018). Economies have strengthened around the globe due to trading through container terminals. In most instances, successful port operations are a result of constant improvements and maintenance of port infrastructure. Ports can only perform at optimum level if the infrastructure is efficient as this is a crucial element of the terminal that would ensure ports remain competitive and have the ability to meet the current and future demands (Munim & Schramm, 2018).

Sanchez et al., (2003) recognised a relationship between terminal productivity and the rate of global trade using principal component analysis. They concluded that a pertinent element determining a countries' competitiveness hinges on port efficiency. The efficiency of ports can easily be influenced by public policies. Clark et al., (2004) established that a decrease in ports trade inadequacies regarding transportation expenses, between the 25th to 75th percentiles resulted in a 25 per cent increase in consensual trade. Further, the outcome suggested that port regulation surges efficiency in ports, however extreme regulation can be harmful (Clark, et al., 2004).

Gumede and Chasomeris (2013) reviewed comments from various stakeholders regarding port pricing and governance and stated that port terminals in SA are faced with issues such as the nonexistence of principles that are based on cost; pricing methods that are not reasonable, low production levels and poor efficiencies, port congestion, unacceptable prices on products and inadequate service delivery.

The performance of ports is a key factor for successful maritime integration. The infrastructure in ports can be aligned to variables such as cranes, draught and yard storage. Some of the factors that influence port planning are the location, terminal layout, equipment available and the types of vessels that arrive at the port. Insufficient cranes, land, odd-shaped yards and inadequate berths, gate facilities and access are limiting factors in port planning (UNCTAD, 2018).

Meyiwa and Chasomeris (2016) indicated that SA port terminals production outputs are amongst the most inefficient when compared to the rest of the world. Although port pricing in SA is exorbitant, they remain amongst the most unproductive.

2.2. Port of Durban-DCT

The Port of Durban consists of 58 berths and 300km of rail track. There are five main terminals namely, the bread bulk terminal, roll-on roll-off terminal, the cruise terminal, Maydon Wharf and the DCT (see figure 2.2) (Rodrigue, et al., 2014). The Port of Durban handled 81.2 million tonnes, 30 million tonnes of which was handled by the DCT in 2019 accounting for 60 per cent of the total traffic through SA's ports (Africa's Ports and Ships, 2021). The DCT is divided into Pier 1 and Pier 2 and has the capacity to accommodate approx. 3.6 million TEUs (Ports Regulator of South Africa, 2020). Most containers are moved on road between Durban and Johannesburg through arterial roads. Cargo dwell time in Durban is usually between 3-4 days, however in certain cases, such as when there is industrial action, it could be prolonged to more than 5 days (Africa's Ports and Ships, 2021).

Meyiwa and Chasomeris (2016) pointed out the when a study was conducted by the Organization for Economic Cooperation and Development in 2014 on port competitiveness, it was established that ship dwelling time at the Port of Durban increased from 26.14 to 55.14 between 2001 to 2007. It was further stated that factors that contributed toward the increased in dwell time was lack of port infrastructure investment and port congestion. In 2012 to 2013 many ships experienced a turnaround time of 70 hours. The average standing time of container flow is regarded as amongst the worst in Sub-Saharan terminals.

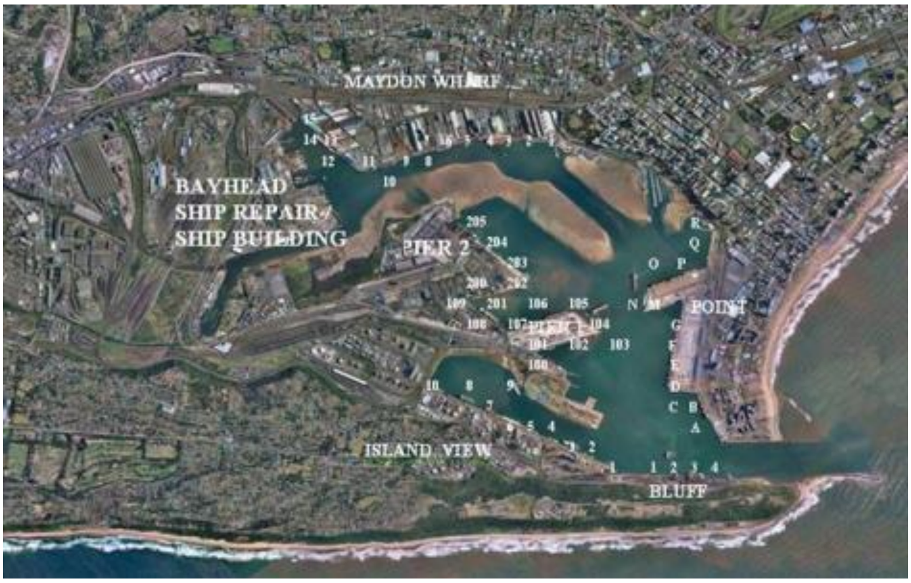


Figure 2.2: Port of Durban

Source: (Rodrigue, et al., 2014:35)

The Durban port is the gateway between major trade routes in Africa. Approximately 60 per cent of Southern African trade involves imports and exports passing through the Port of Durban (Humphreys, et al., 2019). It is therefore crucial for the Port of Durban to ensure they remain competitive in the global market by ensuring they are operating efficiently with minimum downtime. According to the Port Management Association of Eastern & Southern Africa, SA ports are space constrained and the dwelling time is far too long (Humphreys, et al., 2019).

There are plans to utilise the railway mode of transporting goods to reduce the truck congestion (Transnet, 2020). Port authorities have also approach private landowners to discuss opportunities to create back of port hubs to ease port congestion (Transnet, 2020). The DCT currently has a fleet of 73 straddle carriers and training programmes have been deployed to ensure that the employees are competent to operate the carriers efficiently (Transnet, 2020).

2.3. Challenges faced by the Durban port and its customers

The world is turning towards shipping as the most economical option to move goods, thus creating a demand for the use of efficient container handling infrastructure. The DCT plays a major part in turning the economy in either a positive or negative direction thus the selection of appropriate container handling equipment for this port needs careful evaluation.

To meet the demand within the maritime sector, the location of ports needs careful thought as it would need to provide easy access to land and water. Larger ships can be accommodated by ports with deeper waters, however smaller ports need to wait for high tide to haul ships in using tugboats in conjunction with helicopters (Dasgupta, 2021). Although the DCT’s entrance channel has been deepened, the quayside has not been deepened and therefore larger ships require the assistance of tugboats to eliminate the risk of them running aground. This process alone is time-consuming (Creamer, 2010).

The biggest threat faced by the maritime industry is port congestion (Manaadiar, 2020). It is challenging to schedule deliveries if there are interruptions to plans. Businesses operational costs increase because of unexpected congestion. Upgrading of port equipment plays a pivotal role when trying to mitigate port congestion (Manaadiar, 2020).

The DCT congestion is causing frustration among the key stakeholders due to the impact on the supply chain. Customers are dependent on the port as volume transported through the DCT has increased by more than 4,6 million TEUs (Transnet Port Terminals, 2019). Recent studies have indicated that port congestion has become a major problem around the Durban precinct (Brook, 2011).

The fast-growing sizes of ships in the world has led to the purchase and installation of seven tandem lift ZPMC ship-to-shore cranes at the DCT. These cranes cater for movements of either four 20-foot containers or two 40-foot containers loading or offloading. This idea was brilliant on the seaside, but it is pertinent that landside operations accommodate the increase in volumes (Bigala, 2012).

Limited straddle carriers due to breakdowns and lengthy procurement processes have caused major backlogs on roads and sea. In 2017 the DCT had a total of 120 straddle carriers, however currently there are only 73 in operation. Lack of maintenance could be one of the root causes of breakdowns and redundant straddles (South African Association of Ship Operators and Agents, 2020).

It is for this reason that opportunities to improve operations by exploring other methods and equipment used in leading ports will be investigated.

2.4. Factors Contributing to Congestion and Delays

Congestion and delays are common at container ports globally. SA is facing a similar challenge, which is negatively impacting businesses and the economy. Congestion can be a consequence of either internal or external issues:

- Internal Factors: may refer to factors such as inefficient container handling equipment that results in poor throughput that is below the international norm. Other factors could be because of human errors, internal striking or breakdown of equipment (Brook, 2011).
- External factors: may refer to matters affecting prompt collection or delivery of cargo such as accidents or breakdowns on the port route that cause delays or adverse weather conditions both on land and sea (Brook, 2011).

Common causes for port congestion:

- Lack of port handling equipment such as SC and RTG will result in longer waiting time for trucks and ships. Efficiencies when handling containers have become important as international trade has increased dramatically. Insufficient port handling equipment is a major factor (Pilsch, 2017).
- When there are limited berths available vessels wait longer for ports to load or offload containers which leads to congested sea traffic. These vessels also fall behind schedule which then disrupts the entire supply chain (Pilsch, 2017).
- Outdated and unreliable port equipment and infrastructure causes major delays and ports are now dependent on current technology rather than on labour-intensive equipment to remain competitive (Pilsch, 2017).
- Many ports globally affected by pandemics such as Covid-19 will be forced to decrease their staff complement to reduce the risk of spreading the virus. This will result in a shortage of employees attending to ships and containers which will cause lower productivity outputs (Poineer Freight, 2020).
- Once a ship arrives at the port adverse weather conditions can affect its ability to manoeuvre which can be detrimental to efficiency. Ports generally shut down operations especially when it is extremely windy (Moura, et al., 2020).
- (Rodrigue & Notteboom, 2020), states that limited space available at ports and outdated equipment becomes a hinderance to volume growth and competitiveness.

The DCT internal delay:

Misra (2021), stated that one of the contributing factors that causes port congestion at the DCT is the frequent breakdowns that occur due to lack of maintenance and inefficient port equipment. The procurement process within Transnet is lengthy and is governed by budgetary constraints. This then results in equipment not being maintained or purchased timeously leading to inefficient operations (Misra, 2021).

The DCT external delay:

The Port of Durban experienced major disruption to their operations in July 2021 caused by violence leading to looting and destruction. The supply chain came to a halt as all leading roads to the port experienced congestion. All delivery schedules were delayed, and most goods had to be diverted. Transnet had no choice, but to declare a force majeure (Charles, 2021).

2.5. Types of container handling infrastructure

Straddle carriers

As shown in figure 2.3, a SC stacks container in rows with lane widths between rows for the wheels of the SC (Konecranes, 2021). This piece of equipment is quite efficient and flexible and can carry out various kinds of both horizontal and vertical placements. SCs can either lift either 1 over 2 or 1 over 3 (Mohseni, 2011).

Figure 2.3: Straddle carrier stacking containers

Source: (Konecranes, 2021)

The SC is commonly used around the world and is commonly used at ports that are restricted with space (Mohseni, 2011). These carriers can carry out various functions such as loading, offloading, stacking, and hauling containers from the quay to stack. Figure 2.4 shows a typical block stacking configuration. SCs are commonly used for terminals that are classified as either medium or large (Mohseni, 2011).

Figure 2.4: Block Stacking

Source: (Mohseni, 2011)

When adopting a straddle carrier system, it is much simpler to alter the container yard stack configuration according to operational requirements. The average number of straddles an STS crane requires is between 4 to 5 straddles (Mohseni, 2011).

Rubber tyred gantries with tractor trailer units

A RTG is used as part of operational requirements to either ground or stack containers. When vessels berth, the STS crane will offload and place the container on a TTU which will then handover the container to an specified storage area where the RTG then places containers in stacks of up to 7 high and 5-8 rows inclusive of the truck handover lane (see figure 2.5) (Brinkmann, 2011).

Figure 2.5: Rubber Tyred Gantry Crane with Tractor Trailer Units

Source: (Konecranes, 2021)

The stacking density is relatively high with RTGs because of the capability of stacking high over multiple rows that are stacked against each other (Brinkmann, 2011). It does not require spaces for wheel movement in between containers like SCs and therefore utilises the stack area effectively (Brinkmann, 2011). Long distances will not be a challenge as the TTU is flexible and it is generally quicker than SCs. RTGs can be used efficiently for handling loading and offloading on trucks and rail cars (Brinkmann, 2011).

Ship-to-shore cranes

The STS crane is a large quay-side crane used by container terminals for offloading and loading vessels. These cranes have a framework that runs on rails and can travel the length of the quay. It has a spreader rather than a hook. The spreader locks onto the container through a twist lock mechanism (Brinkmann, 2011). Seven tandem lift STS cranes were delivered to the DCT in 2012 (see figure 2.6). These cranes can load and unload four twenty foot or two forty-foot containers (Anthony, 2013).

Figure 2.6: ZPMC Ship to Shore Cranes

Source: (Anthony, 2013)

Rail mounted gantries

RMG cranes can stack wider and quicker and are ideal for very large terminals. Generally, they have the capability to stack twelve containers wide and up to 5 boxes high (see figure 2.7). They can maximise storage space, however, are only used in terminals with good soil conditions. it is not recommended that terminals built on reclaimed land adopt full RMG system as loads are distributed evenly downward as compared to SCs and RTGs (Mohseni, 2011).

Figure 2.7: Rail Mounted Gantry Cranes

Source: (Liebherr, 2021)

Unfortunately, the cost to install and maintain RMG cranes is exorbitant and they are not as flexible as the SCs and RTGs. This then makes it difficulty when the terminal wants to reconfigure stacks or to change operation strategies as the RTGs are fixed on rails that are built on beams. This is more of a permanent solution. Another reason this may not be suitable is that the DCT is a medium-large terminal and RMGs are used in very large terminals due to the constraints around the use of this type of equipment. As discussed previously, this study examines only the SC and RTG for the above reasons.

2.6. Impact of inefficient port equipment on the supply chain

The most used definition for supply chain interruption was by Craighead et al., (2007: 13) who observed that:

> "A supply chain disruption is an unplanned for and unanticipated event that ends up disrupting the normal flow of goods and materials within the supply chain network".

There are more than 90% of goods that are traded through ports and therefore SA plays a critical role in achieving the country's social and economic objectives (Chasomeris, 2006).

One of the pressing matters that is affecting SA's trade and competitiveness with its counterparts is the inefficient port operations (Ports Regulator of South Africa, 2016).

Maritime trade partners are constantly pursuing lower trading costs in containerisation, vessels development and agreements to be competitive in the supply chain globally. Terminals need therefore to look for innovative ways to reduce turnaround times as poor efficiencies can discourage key partnerships and support within the supply chain globally (Ports Regulator of South Africa, 2016).

Prolonged dwelling time of cargo and vessels at ports, longer ship turnaround times, crane movements and loading and offloading speeds are important gauges when measuring efficiencies at ports. When addressing performance at ports these gauges will need to be considered as they affect the cost at port and the capacity requirements (Ports Regulator of South Africa, 2016).

Seaports play a critical role in ensuring there is continuity in the supply chain. Seaports are no longer just gateways but are adding value to the supply chain through the implementation of more complex activities that are logistics related (UNCTAD, 2018). This has allowed for integration between ports and the supply chain and therefore the occurrence of disruption in the supply chain has intensified. The desire for a seamless flow of operations in ports and continuity of upstream and downstream supply chains is sought after through the implementation of the most suitable port management measures (UNCTAD, 2018).

Ports are the main connection in the supply chain structure that captures value and strategically positions it in the industry. This is because ports can connect logistics through the supply chain and affect the flow of goods (UNCTAD, 2018).

There is a close association of operations at the terminals, handling of goods and the supply chain processes. The appropriate model of port operations in supply systems is mentioned in figure 2.8 below (Seethamsetty & Ogoti, 2020).

The process that will support the handling of goods and is associated with the transportation system is shown above (see figure 2.8). Logistics logistic systems are represented, and it is in this area where value services play a significant role in the process (Seethamsetty & Ogoti, 2020).

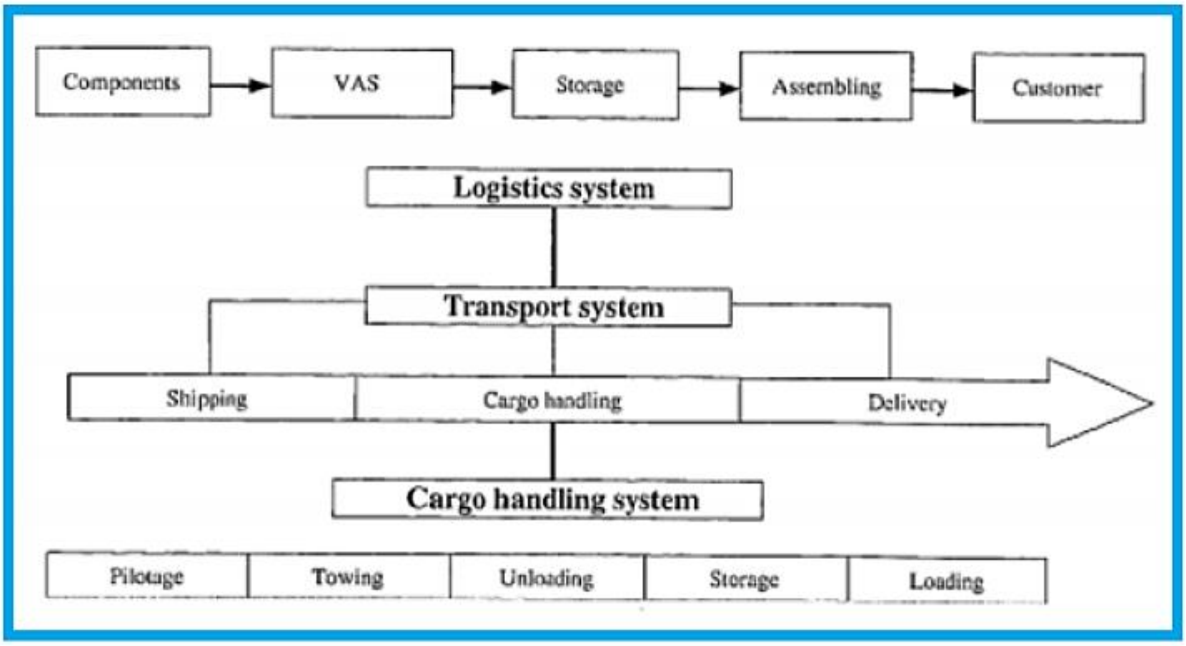


Figure 2.8: Model of port operations in supply chain management

Source: (Seethamsetty & Ogoti, 2020:3705)

Current businesses are creating opportunities for other enterprises to develop their organisations in the global market such as imports and exports. Ports play a key role in the logistics sector and port authorities need to take an active role in planning for innovation to make international trade effortless (Seethamsetty & Ogoti, 2020).

2.7. Infrastructure development

The DCT Berth Deepening Project is a Priority 1 Shareholder Compact project, with key agreed upon milestones that need to be achieved in line with the agreement with the Department of Public Enterprises (Transnet, 2019).

The larger Post Panamax container vessels currently calling at the Port of Durban have increased in length and draft, resulting in the Durban Container Terminal (DCT) North Quay operating beyond its original design of water depth specification (under keel clearance). The depth and length insufficiencies have resulted in the design capacity of the DCT Pier 2 reducing from 2.9 million TEUs to 2.4 million TEUs (Transnet, 2019).

Currently the DCT berths can safely accommodate Post Panamax vessels with drafts less than -12.2m but cannot accommodate fully laden larger Post Panamax vessels with drafts of -14.5m operating on the east-west trade route. These vessels have deeper drafts thus must enter the port partially laden and must make use of the tidal window when entering and departing the port on a rising tide. These restrictions have resulted in the DCT berths operating less efficiently and less safely. It is for this reason that the Berth Deepening project is underway. The project will entail expanding the berth length, piling, constructing a quay wall and dredging to accommodate larger vessels and reducing the risk of them running aground (Transnet, 2019).

Dyer (2014) pointed out that past research regarding congestion has emphasised the benefits of expanding the port. He further indicated that an alternative to port expansion is to identify opportunities to improve port efficiencies with the existing infrastructure.

The SA government is working in collaboration with private companies to invest approximately 100 billion Rands in infrastructure development at the Port of Durban. There is an expectancy that in 10 years, the Port of Durban will manage 60 per cent of the container imports and exports after the upgrade. The President of SA, is eager to propel the Port of Durban back to a competitive state especially after the impacts suffered by Covid-19 (Magubane, 2021).

This study will address the issue of selecting appropriate container handling equipment at the DCT as accommodating these larger vessels will add further pressure to current operations and if not dealt with it will result in port congestion.

2.8. Equipment at the DCT

Rosario (2020) indicates that when using an illustration on the quay side to demonstrate the requirements to move 1.3 million containers in the 300 days of operations per annum the result would be an average of 4300 containers each day. Of the 12 gantries assigned, each gantry would be required to achieve 360 moves in 24 hours at a frequency of 15 moves per hour. It is clear from his evaluation there is a spare capacity of 25 per cent (Rosario, 2020).

On the land side the DCT is equipped with a total of three towers serving the North, East and South Quays and providing roughly 25 bays. If possible, nine straddle carriers are required to achieve 9 moves each hour indicating 5800 containers can be moved each day under reasonable conditions (Rosario, 2020).

As indicated by Rosario (2020), there are 1.3 million container moves over a 360-day working period which reduces a requirement for 3600 containers needed to be moved each day. When the capacity is equated with demand, there is an unused capacity of 38 per cent. It can be interpreted that when 9 straddles are assigned to 27 towers, there should be minimum congestion on the road, provided the equipment is properly maintained (Rosario, 2020).

Rosario (2020) has then recommended procurement plans to be in place for the DCT, including proper maintenance manuals to be developed and incentive schemes to be offered to operators for performance. However, Rosario (2020) has unfortunately not considered the pros and cons of using such equipment and opportunities to restructure port operations and relook at other types of equipment that could prove more valuable. This study will attempt to do so.

2.9. Financial impact on the supply chain due to port congestion

Raballand, Refas, Beuran, & Isik (2013), state that an efficient and well-structured transport system will ensure African countries are competative. Hummels & Schaur (2013), indicated that prolonged and unecessary delays can minimise trade and increase costs. Slow export and import processes will increase inventories and costs. Lewis, Erera & White (2006), points out that shut downs at ports and disruptions are some of the factors that increase costs and delays in the supply chain (Lewis, et al., 2006). A quantative study found that impermanent port closures result in more than 136 per cent in inventory and penalty costs. Therefore, the author emphasies the importance of investing in efficient port equipment and timeous maintaince (Lewis, et al., 2006). Torey (2017), through the use of statistical models, established truck delays due to congestion resulted in an estimated loss of US $ 49.6 billion. Such research can prove useful when considering the impact congestion has on other ports. Wiegmans & Konings (2015), stated that when referring to standing time at ports, the cost associated are for fuel, labour and capital. The Port of Durban imposes an penalty fee of $ 500 per day when containers are not cleared by shipping operators (Hutson, 2019).

2.10. Truck Appointment Process

Truck drivers experience various challenges when driving on roads leading to ports apart from congestion. Some of the roads leading to terminals have deteriorated and have become a safety hazard (Goddard, 2021).

A typical occurrence on Bayhead Road is shown below (see figure 2.9), which is the main arterial road leading to the DCT. Truck queues are almost a kilometer long into the terminal and have now become the norm for nearby citizens who have become frustrated with this situation (Goddard, 2021).

Figure 2.9: Congestion on Bayhead Road-DCT

Source: (Goddard, 2021)

Innovation with the use of existing port infrastructure has become the pressing issue especially since land around the port is limited (Goddard, 2021).

In May 2020, the DCT together with key stakeholders implemented the Truck Appointment System (TOS) to ease congestion and to ensure optimal utilisation of resources. Trucks will need to notify the terminal when they expect to arrive, however, the benefit of adopting the TOS is still being evaluated (Daly, 2020).

The TOS had been introduced to ease congestion caused by the global Covid-19 pandemic. There are 30 slots allocated every 24 hours with a 15-minute waiting period before and after that being allocated. Unfortunately, trucks will not be allowed to enter the port without an appointment (Dass, 2020).

The appointment requirement has now created another issue, where truck drivers are arriving at the port without an appointment and causing even more congestion (Comins, 2020). Despite the challenges faced, the Port of Durban General Manager has advised that he is satisfied with the turnaround times in and out of the port (Comins, 2020). It is also imperative that the yard side operations are efficient as the TAS will need to work collaboratively with this system to reduce port congestion.

2.11. Importance of innovation

Merriam-Webster, (2021) describes innovation as:

"an introduction of something new, such as a new idea, method or device".

Innovation can be either major or minor. For instance, minor innovation can involve changes made to operations or procedures at the port. Major innovations refer to implementing new technology or procedures (McDermott & O'Connor, 2003). Transnet has taken an initiative towards innovation by implementing the TAS at the Port of Durban. However, significant changes between the quay and yard areas will be required to collaborate with the TAS (Comins, 2020).

Adopting programmes to change the attitude of the workforce is shown below (see table 2.1 and figure 2.10). This could prove to be beneficial before allocating huge capital to adopt the current technology. It is critical for organisations to change the mindsets before adopting new technology as failure to do so might result in duplication of work. Organisations might end up with the efficient technology, however the outputs might remain the same or worsen as the workforce behaviour and attitudes might not change (Kahn & Kenneth, 2002). It is therefore critical to strike a balance between the mindset and processes.

Table 2.1: Innovation explained

Element	Strategic focus	Strategic question	Consideration
Innovation is an outcome	Ends	What do you want to happen?	– Product innovation – Process innovation – Marketing innovation – Business model innovation – Supply chain innovation – Organizational innovation
Innovation is a process	Ways and Means	How will you make it happen?	– Innovation process – Product development process
Innovation is a mindset	State	What should be instilled and ingrained to prepare for the what and the how?	– Individual mindset – Organization culture

Source: (Kahn & Kenneth, 2002:133)

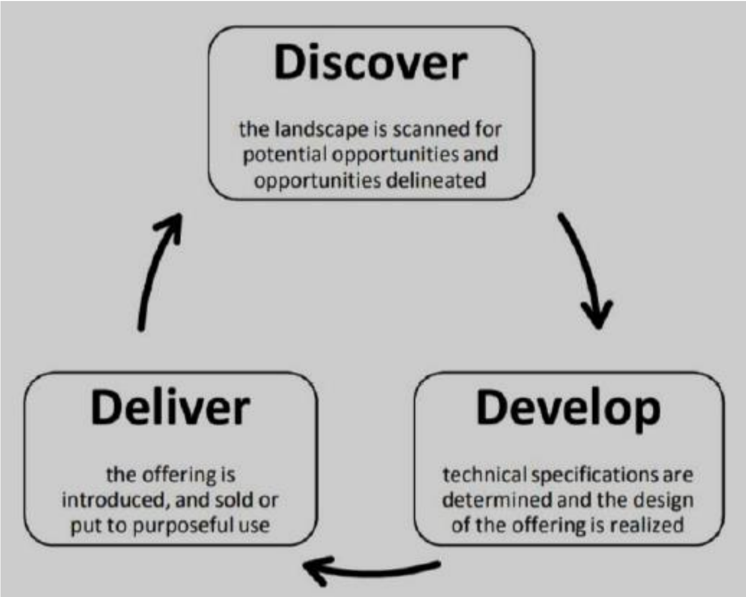


Figure 2.10: The cycle showing the innovation process

Source: (Kahn & Kenneth, 2002:134]

Important developments are associated with enhancing the transport technology to improve the intermodal transportation within the port. Poor port efficiencies emerged as the main reason for delays within the transit corridor and the detangling of port congestion issues will prove to be extremely beneficial in SA (African Development Bank, 2014).

2.12. Current ranking of SA ports as compared to other ports

SA ports generally receive vessels that carry 5100 TEUs and a lot of time is spent in port calls on arrival (Traffic, 2021). Breakdowns are very common and major review of processes, procedures and equipment is required. The waiting time between arrival and departure in the anchorage zone needs to be revisited (Misra, 2021). Since SA ports are way ports and not destination ports, handling costs are more expensive as compared to other ports (Misra, 2021).

As shown in figure 2.11, SA has produced a steady throughput of 4 million TEUs from 2010 to 2019 as compared to Djibouti and Kenya during the same time, producing an average of 1 274 350 and 1 000 000 TEUs per annum respectively. Most of the time is taken when ports formally clear ships to offload or load so technological improvements is one of the key upgrades that is required.

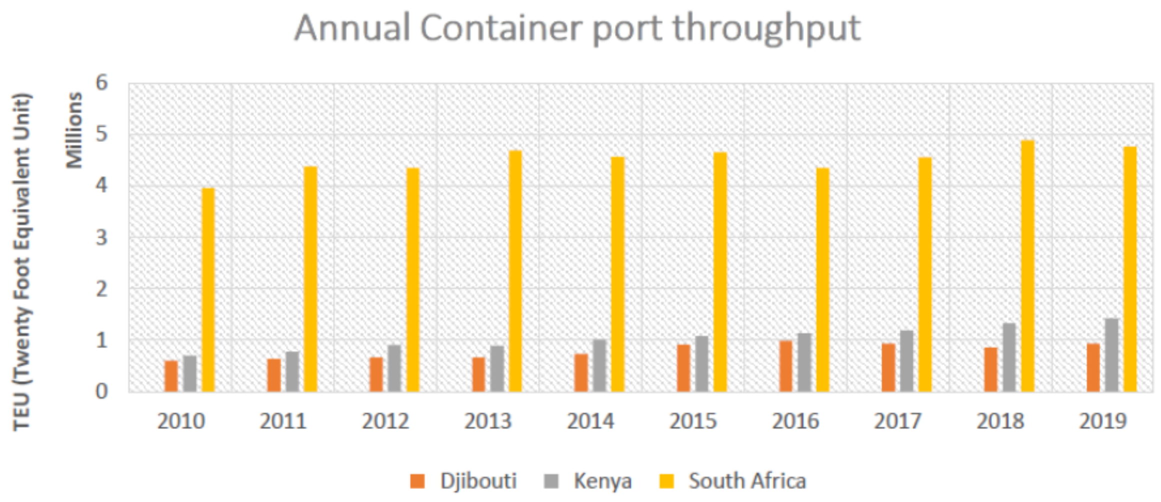


Figure 2.11: Throughputs of SA, Djibouti and Kenya

Source: (CEIC 2021: 26)

Ports being able to accommodate post-panamax ships is also a critical matter as global shipping operators are using 18000 TEU ships and greater. Durban key berths have drafts of just over 12 meters, which makes it difficult to accommodate larger vessels (Offshore Energy, 2018). The DCT can accommodate 2.8 million TEUs and will soon reach its full capacity due to volumes reaching a total of 2.8 million TEUs in 2019/2020. The DCT records a throughput of 1274 TEUs per meter for each berth (Ports Regulator of South Africa, 2020).

The Port of Durban was one of the worst achieving container terminals in the world in 2020 according to a report by the World Bank. There was a total of 351 terminals rated on the statistical chart and Durban was rated in the bottom 3 terminals (Magubane, 2021).

2.13.Chapter summary

This chapter has presented a topical view of the literature on port congestion, on the causes and on previous studies that suggested possible opportunities to improve the current operations at the Port of Durban to relieve the congestion on both the land and sea.

Of the many critical insights that have emerged from the literature review consider the following three main areas of findings: It is critical for port authorities to invest in modern technology and employ competent staff to better prepare the port to manage modern container vessels. Although the TAS was implemented at the DCT congestion still seems to be a major problem at the port. The bottleneck seems to be between the quay and the stack area. The current port equipment would need to be re-evaluated as it may not be suitable to handle larger vessels. Although many studies have suggesting port expansion could be the possible solution to congestion, there has been neglect in the sense that opportunities to improve the type of port equipment rather than expansion was seldom explored. The current Berth Deepening expansion might not be the ultimate resolution to port congestion.

Secondly, it is important for cargo traders to plan their capacity requirements adequately and adhere to these plans to ease pressure faced at ports. The stakeholders that are impacted by the port delays should engage regularly to identify issues before they become uncontrollable.

Thirdly, the opportunity to place emphasis on the extended gate concept is an ideal opportunity to ease congestion at the Port of Durban. If this is implemented correctly, there are numerous benefits such as improved supply chain and port performance. It will result in a fundamental change in the role that seaports play globally.

These focus areas would ensure ports are managed effectively and congestion is eased. The proceeding chapters should inform these recommendations as detailed research and analysis of various alternatives are explored.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Introduction

The purpose of this chapter is to provide understanding into the research method used in this investigation and the way in which information was gathered. In chapter two, the literature review discussed the importance of adopting the most efficient container handling equipment and highlighted this as one of the critical factors that congests ports. Other factors that cause port congestion were discussed very briefly. It also discussed port equipment used in leading international ports and the opportunities to upgrade the DCT. There was adequate information available in the public domain to address these concerns.

The port productivity in SA ports has been poor over the last 5 years despite efforts to improve the situation such as the Truck Appointment System (TAS) that was implemented (Goddard, 2021). The poor performance has contributed immensely to port congestion (Transnet Port Terminals, 2021). This research intends to test a hypothesis that, the current available container handling equipment is inefficient and a re-evaluation of the type of equipment used at the DCT, Pier 2 is required urgently.

3.2. Aims and Objectives

The methodology seeks to test some of the outcomes stated in the literature review. This chapter has four aims: (1) to describe the study method, (2) to explain the thinking behind the choice of the information and benchmarks used, (3) to define the mechanisms used to collect the data, and (4) to expound on the evaluation design of the data that has been gathered.

The following are the objectives of this study:

- To examine the productivity of the Durban Container Terminal in comparison with other ports nationally and internationally.
- To examine the performance of current container handling equipment used at the Durban Container Terminal; and
- To examine and compare the costs of using a Rubber Tyred Gantry system versus Straddle Carrier system at the Durban Container Terminal.

3.3. Research methods

Research is defined by Sekaran & Bougie (2009, p.3) as:

> "…an organised, systematic, data based, critical, objective, scientific enquiry or investigation into a specific problem".

This study should allow researchers to present information from their perspectives that is not influenced by personal opinions or beliefs (Denscombe, 2010). Researchers need to implement objective methods to collect data and to analyse the data in order to carry out the research as accurately as possible. This approach increases the chances of retrieving accurate data (Goundar, 2012).

There are three different methods which one can utilise for research, namely qualitative, quantitative or a mixed methods approach.

This research methodology adopted a quantitative approach to capture relevant and adequate data to aid in the trend analysis. The quantitative analysis will be centred on the capacity data of the container handling equipment at the terminal, in line with the key performance indicators (KPI) published by TPT in the 2019/2020 financial year. This will include the turnaround time at ports, berth occupation, container movements per ship working hour (SWH), container movements per gross crane working hour (GCH), dwelling time and the turnaround time of trucks.

3.4. Analysis of Secondary Data

In order to evaluate of landside operations (RTG, TTU, SC) performance, the SWH and GSH will be used. This will involve collecting and examining efficiency data and comparing the information with other international ports. The disparities will be discussed and a benchmarking analysis on similar ports outside SA will be undertaken. The information pertaining to the benchmarking study will be extracted from the public domain. Most information relating to port statistics are available on the organisations website. The annual reports contain relevant information that should make a meaningful contribution to the study.

This study will review the throughputs achieved by the DCT in the last 5 years. A study of the performance of the RTG and SC used in Pier 1 and Pier 2 respectively will be examined and conclusions drawn. Data from the public domain such as Transnet and Government official websites were collected and analysed to study container throughput between the quay and stack area in the DCT Pier 1 and Pier 2. The results were analysed for a single shift to determine which of the two Piers was performing most efficiently. The SC raw data was retrieved and was plotted onto a graph to indicate performance outputs more clearly. The results are presented in chapter 4.

This study adopts a descriptive research design as the data collected will be analysed and presented in the most understandable way. Cost effective analysis was applied to the available equipment and to associated costs that could be retrieved. The compound interest formulae and inflation calculator was used to convert all costs to their current approximate values since the only available costs in the public domain that could be used to support this presentation dated back to 2012. The latest costs of such equipment could have been sourced from suppliers but these costs would exclude Transnet's overhead costs. The latest Transnet overhead costs were not made available to the public as this is company-sensitive information therefore the data from 2012 was converted into today's currency.
This data provides labour costs for two operators per item of equipment, purchase costs for SCs and RTGs, maintenance costs to properly run the equipment and a comparison of all these costs with the international norm.

The number of RTGs purchased globally was compared to the purchase of SC and RMGs to identify which piece of equipment was most popular. It will also discuss the main advantages and disadvantages of the current and recommended port equipment.

Further, the number of RTGs purchased in 2019 internationally was examined and compared to RMGs and SCs purchases, and the results were used to substantiate the recommendations regarding the type of port equipment the DCT should adopt.

Other international ports' equipment and operations were analysed to identify gaps in the DCT. Graphs were developed with the quantitative data collected to present a visual understanding of the outcomes.

This study (protocol number: HSSREC/00003510/2021) was granted full approval by the Humanities and Social Science Research and Ethics Committee (Appendix 4).

3.5. Research Limitations

The following limitations must be acknowledged.

The research is based on the DCT Pier 1 and Pier 2 and was not expanded to include other parts of the Port of Durban such as the RORO terminal. The reason being that the nature of the study would then be too broad due to separate challenges and varying operational requirements as well as there being time and data constraints. Most data have been retrieved from the public domain and journals related to the topic being discussed. Transnet reserves the right to withhold certain sensitive information from the public, however, a lot of effort has been made to identify the most recent and correct data made available publicly. The data is based on normal operating conditions and may have changed due to the Covid-19 pandemic and the impacts thereof. Most of the data used in this study was available data prior to the DCT experiencing the full impact of Covid-19 pandemic.

Transnet is undergoing major organisational structure changes since Covid-19 began and it has shed over 3000 employees through Voluntary Severance Packages (Ginindza, 2021). Of the 3000 employees that have taken the package, 42 per cent were senior managers with over 27 years of experience. Their experience would have been valuable to this research. The Covid-19 pandemic also brought about other challenges as most employees now work from home and many have no access to computers or to the internet (Transnet, 2020). Another issue being faced at Transnet was the recent cyber-attack which forced Transnet to declare force majeure at the main SA terminals including the DCT. Transnet operations shut down for almost two weeks and are still feeling the impact today. (Smith, 2021). Therefore, due to the current circumstances at Transnet it was difficult to circulate questionnaires and surveys and a full desktop study was conducted. The desktop study received full approval from the Humanities and Social Science Research and Ethics Committee (Appendix 4).

Furthermore, it was challenging to obtain approval to approach individuals involved in operations management for information due to a conflict of interest and therefore the study was limited to a desktop study. However, in saying this, there was sufficient information already available in the Transnet and Government official websites to conduct this study and an effort was made to retrieve the most recent available information. The data obtained from official websites are reliable and accurate and previous researchers have been using these sites as a source for gathering statistics. The inflation calculator was used as a conversion tool in this study and is an accurate method to represent data for the pricing of goods and services that change over a period of time.

3.6. Chapter summary

The purpose of this third chapter was to explain the research approach used for this study. The aims and objectives were described, and the data compilation methods discussed. The data were sourced from the Transnet and Government official websites as well and journals related to the topic. Port performance KPIs were retrieved and analysed. Benchmarking techniques were adopted by comparing other port performances and rankings to those in SA. A descriptive analysis was conducted of the relevant data that were collected, examined, and presented in the most logical way as substantial evidence for the recommendations. A cost effectiveness analysis was carried out to describe the purchasing cost of equipment and labour in today's currency. Port productivity stats for the SC and RTGs were retrieved and discussed in detail. Comparisons between the SCs and RTGs were carried out by discussing the advantages and disadvantages of the two. The preferences of ports regarding this equipment were discussed by researching how many SCs and RTGs were purchased in 2019 globally. The data collected will be examined and displayed in the form of graphs and tables, and then discussed substantially in Chapter 4. The research approach will cover the necessary information that ought to be adequate to deal with the research questions and to bring in a significant conclusion on efficiency capabilities in the SA container segment.

CHAPTER 4

ANALYSIS AND DISCUSSION

4.1. Introduction

The purpose of this chapter is to demonstrate the efficiency gaps at the DCT and to provide recommendations for the acquisition of the most appropriate container handling equipment to reduce port congestion. Selecting the most appropriate container handling equipment is imperative to improve performance at the DCT and to prevent unnecessary backlogs. The preceding sections attempted to provide reasons for the need to upgrade the port container handling equipment at DCT. The main outcomes are presented together with an analysis and discussion.

This chapter is structured as follows. Section 4.1 states the purpose of the chapter and provides an overview of the contents of each subsection. Section 4.2 highlights the importance of selecting the correct container handling equipment. The use of sea-to-trade has increased and therefore the operation from ship-to- shore need to function efficiently. Section 4.3 analyses TPTs latest KPIs to determine the current situation. Operational performance and productivity were the focus of this discussion and set the tone for the rest of the chapter. While examining the latest KPIs it was evident that the operational performance and productivity was impeded by the type of port equipment in use and the related breakdowns. Section 4.4 examines the infrastructure used at the Port of Durban in 2019 as well as, container volumes handled, vessel calls, capex allocation and maintenance budget. This analysis was used to prove that although Durban was handling the bulk of containers in SA, there was a decrease in capex expenditure and increase in maintenance costs. The causes are discussed further in this subsection. In section 4.5, SA ports are examined from a global perspective and specific reference is made to the recent World Bank Report (World Bank Group, 2020). This report ranked SA ports in the bottom five out of 351 container handling ports worldwide, with the Port of Durban being the last when ranked from an administrative perspective and third from the bottom when a statistical approach was applied (World Bank Group, 2020). Section 4.6 analyses how SA ports are performing when compared to neighbouring countries to SA such as the Port of Mombasa in Kenya. Furthermore, it looked at the response from Transnet and the SA president regarding the ranking and mitigations they are putting in place to avoid a similar ranking in the future. Section 4.7 and 4.8 assesses the container handling infrastructure currently used at the Port of Durban between the quay and stack area in Pier 1 and Pier 2. Pier 1 and Pier 2 operate with different port equipment and it is for this reason both Piers were compared. The results were analysed, conclusions were drawn, and recommendations were made. The advantages and disadvantages for SCs and RTGs were investigated to assist in determining the most appropriate container handling infrastructure for the DCT, Pier 2. The production outputs for SCs and RTGs were analysed and results were plotted onto a graph to have a much clearer view of production rates and time wastage. Cost effectiveness analysis was applied in section 4.9 and the available equipment and associated costs were retrieved and studied. The compound interest formula and online inflation calculators had to be used to bring the data up to the most current approximation costs since the only readily available costs that could be used to support this presentation dated back to 2012. In section 4.10 the total number of most popular container handling equipment items purchased between 2018 and 2019 were discussed. The number of RTGs purchased in 2019 internationally was examined and compared to RMGs and SCs purchases, and the results were used to substantiate the recommendation regarding the type of port equipment the DCT should adopt. Section 4.11 examines Port of Yokohama- Japan and King Abdullah Port, the leading ports ranked first and second place according to the World Bank Report (World Bank Group, 2020). In this section the ports container handling equipment, throughputs and current technology adopted were discussed to justify the port's equipment recommendations made for the DCT. Lastly section 4.12 concludes the analysis, highlighting the main outcomes and recommendations. The shortcomings are also discussed as future research opportunities exist in particular areas.

4.2. The importance of Container Terminal Handling Equipment

It is imperative that terminals acquire the most efficient container handling equipment for operations (Huang, 2004). The global increase in the use of sea as a means of trade places pressure on ports to ensure that the entire process from ship-to-shore is timeous, and downtime is reduced. One of the critical items of equipment is the quay crane, and the performance will set the benchmark for the rest of the port (Jonker, et al., 2021). The purchase of seven tandem lift ship-to-shore quay cranes seems like a good start at the DCT Pier 2, however much exploration is required to look at other areas of improvement in the port handling equipment selection as the congestion has not been reduced (Bigala, 2012).

Another factor that plays an important role is the supporting structure for operations once the containers have been offloaded. If the operations do not flow, then this will result in backlogs that will have a ripple effect across the port and eventually the end consumer. The roads leading to DCT such as Bayhead Road have a history of traffic congestion and the major contributor is delays with equipment breakdown and selection of unsuitable or inefficient port equipment (Misra, 2021). Shipping lines prefer using ports with quicker turnaround times. If ports can reduce the dwell times, port calls will increase and more income will be generated (UNCTAD, 2019).

4.3. Overview of KPIs at the Port of Durban for the 2017-2020 financial year

The KPIs for the 2019/2020 financial year at Transnet Port Terminals (TPT) were sourced and analysed (see table 4.1). The prime berths for 2018/19 are berths 108, 203 and 204 (Transnet Port Terminals, 2019). The operation performance volumes for containerised cargo fell 2 per cent below the target for 2019 and when compared to the previous year data shows a 2.8 per cent decrease.

Table 4.1: Overview of KPIs at Transnet Port Terminals, 2017 to 2020

Overview of key performance indicators

Key performance area and indicator	Unit of measure	2017 Actual	2018 Actual	2019 Target	2019 Actual	2020 Target
Operational performance						
Volume growth						
Containers	'000 TEUs	4 396	4 664	4 625	**4 534**	4 863
Break-bulk	mt	10,0	11,2	19,5	**19,8**	21,7
Bulk	mt	88,1	91,0	86,5	**82,4**	85,6
Vehicles	units	679 792	704 052	725 401	**743 350**	724 141
Operational efficiency and productivity						
Container dwell time						
Durban Container Terminal (DCT) – Pier 1						
Imports	days	2,7	3,1	≤ 3	**2,9**	≤ 3
Exports	days	4,7	5,3	≤ 5	**5,0**	≤ 5
Transshipment	days	5,4	6,6	≤ 10	**5,6**	≤ 10
DCT – Pier 2						
Imports	days	2,2	2,5	≤ 3	**2,3**	≤ 3
Exports	days	5,5	6,1	≤ 5	**5,9**	≤ 5
Transshipment	days	5,9	7,8	≤ 10	**6,7**	≤ 10
Moves per gross crane hour						
DCT – Pier 1	moves per hour	26	25	26	**24**	26
DCT – Pier 2 (prime berths[2])	moves per hour	24	23	32	**21**	28
CTCT	moves per hour	32	30	33	**22**	28
Port Elizabeth	moves per hour	25	23	25	**21**	25
Ngqura Container Terminal (NCT)	moves per hour	31	25	32	**21**	28
Truck turnaround time						
DCT – Pier 1	minutes	37	35	35	**41**	35
DCT – Pier 2[5]	minutes	79	72	35	**69**	65
CTCT	minutes	21	36	35	**35**	35
NCT	minutes	32	36	35	**36**	35
Richards Bay Multi-Purpose Terminal (MPT)	minutes	25	22	35	**31**	35

Source: (Transnet Port Terminals, 2019)

Containers that were exported were 2.7 per cent above the target whereas imports and transhipments fell by 1.5 per cent and 11 per cent lower than the target respectively (Transnet Port Terminals, 2019). TPT had reported that the poor outcomes were as a result of adverse weather conditions for most part of the year. According to TPT, the impact of the unforeseen weather patterns caused stoppages, prolonged cargo dwelling time and forced cancellations by shipping lines. Further to this, it was reported by the state-owned enterprise that the adverse weather coupled with port equipment and staff challenges impacted negatively on its performance to achieve results within the budgets. TPT reported container moves per ship working hour (SWH) improved despite not meeting the targets for 2019 (Transnet Port Terminals, 2019).

According to table 4.1, the DCT Pier 1 has increased SWH results from 46 to 48 moves in 2019 while Pier 2 has just surpassed its target from 53 to 54 SWH. Although the target was met TPT advised they expected better performance, however the adverse weather conditions, yard congestion and unreliable equipment were the main causes of the staggered performance (Transnet Port Terminals, 2019).

According to table 4.1, the gross crane moves suffered a sharp decline from 25 moves in 2018 to 22 moves in 2019. Truck turnaround time was better performing than the other indicators achieving 42 minutes turn-around time, which is above the 35-minute target. TPT have committed to providing 10 empty container handlers for the DCT Pier 2, and 18 haulers for DCT Pier 1 to improve operation outputs. A target of 53 moves for 2020 was set once the equipment is delivered. Improvement of gangs and support equipment will be the focus when improving crane deployment to ships (Transnet Port Terminals, 2019).

Wind mitigation seemed to be the most common theme that was highlighted when it came to poor results and TPT have committed to investigate the use of anti-sway and far-reaching technology for larger vessels. An important mitigation measure that was highlighted by the state-owned enterprise was the commitment to work closely with shipping lines to seek opportunities to improve production. TPT are investigating the opportunities that may still lie in back of port container warehousing and value-added services (Transnet Port Terminals, 2019).

4.4. Port of Durban infrastructure

Table 4.2 below shows the number of berths the berth lengths and berth drafts. According to table 4.2, there are a total of 50 berths that exist in the Port of Durban, however, they exist in various precincts. The DCT has 9 berths with a total berth length of 2108m and maximum draft of 12.3m. The 9 berths can accommodate 4500 DWT TEU vessels (Ports Regulator of South Africa, 2020).

Table 4.2: Port of Durban Capacity

Cargo Type	No. of Berths	Total Berth Length	Berth Draft
Containers	9	2 108m	8,2m - 12,3m
Dry Bulk	9	1 610m	8,6m - 10,8m
Break Bulk	18	3 248m	5,1m - 13,7m
Liquid Bulk	9	1 965m	8,7m - 12,5m
Ro-Ro	5	1 381m	10,1m - 10,6m

Source: (Ports Regulator of South Africa 2020:28)

Approximately 4.6 million containers are managed by SA ports per annum and 2.8 million are transported through the Port of Durban. The maximum capacity of the DCT is 2.9 million TEUs and container volumes will soon exceed the container terminals capacity. The terminal reached 2.8 million TEUs in 2019. There was an increase of 3 per cent between 2015/16-2019/20 across all SA terminals. The DCT handles 61 per cent of all containers handled in the country and documented an increase of 4 per cent between 2015/16-2019/20, while the Port of Ngqura verified an increase of 18 per cent over the same period (see figure 4.1) (Ports Regulator of South Africa, 2020).

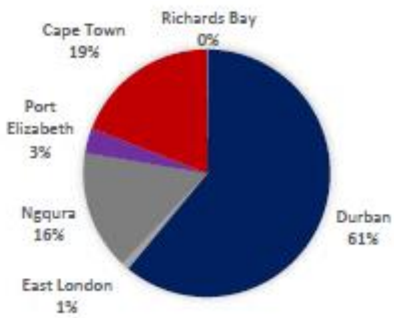


Figure 4.1: Container Volumes for 2018/2019

Source: (Ports Regulator of South Africa 2020:57)

The Port of Durban has 3515 vessel calls on average per annum and 37 per cent of container calls are within the DCT in SA (see figure 4.2 and 4.3) as compared to the second highest, The Port of Cape Town receives which receives 26 per cent of vessel calls. The number of vessels calling over the 5-year period has decreased by 29 per cent in the Port of Durban (Ports Regulator of South Africa, 2020). The vessels have been bypassing the port due to adverse weather conditions and port congestion. Shipping lines have also been concerned about the lack of plans to deal with congestion issues and port upgrade delays. Vessels have been bypassing the Port of Durban and moving towards Maputo as this port is seen to be more cost effective and efficient (Morris, 2019).

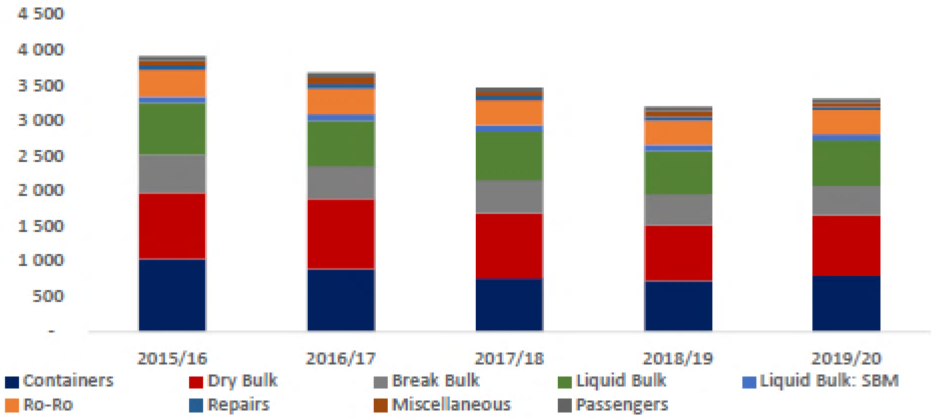


Figure 4.2: Vessel calls at the Port of Durban

Source: (Ports Regulator of South Africa 2020:30)

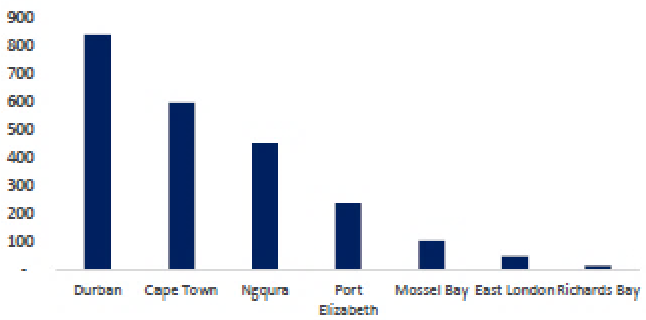


Figure 4.3: Average vessel calls in SA ports between 2015 to 2020

Source: (Ports Regulator of South Africa 2020:57)

The Port of Durban has been allocated 32 per cent of the CAPEX spend over a five-year period with an average expenditure amounting to ZAR476 million per annum. Unfortunately, the lack of execution of critical projects has caused a decline in the CAPEX by 146 per cent over a 5-year period (Ports Regulator of South Africa, 2020). Some of the planned projects that have a huge impact on expenditure are the reconstruction of Maydon Wharf berths, widening of the channel, berth deepening at Pier 2, Island View reconstruction and the new tug jetty. On average, during the 5-year period, ZAR86 million was spent on port asset maintenance. A steep increase since 2015 was shown, indicating port equipment costs are rising possibly due to outdated equipment and frequent breakdowns (see figure 4.4) (Ports Regulator of South Africa, 2020).

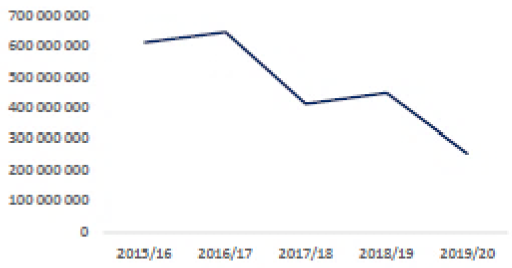


Figure 4.4: Capex allocation for the Port of Durban

Source: (Ports Regulator of South Africa 2020:30)

An area of concern is the increase in maintenance costs over the last 5 years (see figure 4.5) (Transnet Port Terminals, 2019). Outdated equipment leads to unnecessary breakdowns (Transnet Port Terminals, 2019). Opportunities to adopt the correct port equipment can be identified through this analysis.

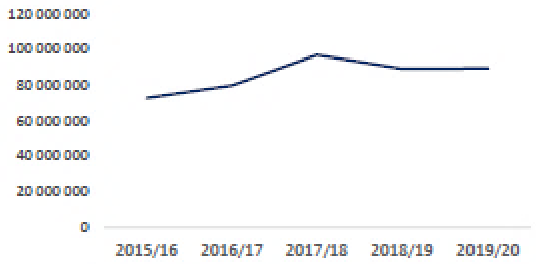


Figure 4.5: Maintenance spend for the Port of Durban

Source: (Ports Regulator of South Africa 2020:30)

The information above indicates that the DCT is performing poorly overall. One of the concerns is that vessel calls have decreased by 27 per cent in the last 5 years. The possible reasons could be shipping lines may be considering other terminals and bypassing the DCT and using ports in neighboring countries like Maputo (Business Insider SA, 2021). Transnet have indicated adverse weather conditions were the primary reason for performing poorly (Transnet Port Terminals, 2019), however other areas require investigation to establish opportunities to improve efficiency as well as to reduce port congestion. It is also evident that container volumes have reached their capacity at the port and yard congestion could become a major issue. Opportunities to explore back of port warehousing to ease congestion should be considered as a mitigation. The following analysis will discuss equipment efficiencies at Pier 1 and Pier 2 as both terminals have implemented different types of equipment from quay to stack areas.

4.5. Port of Durban ranked globally

SA was in disbelief when the World Bank conducted a review of the best and worst performing ports. A total of four SA ports ranked at the bottom of the list with Port of Durban performing the worst rated in the bottom 3 out of a total of 351 container handling ports around the world (see table 4.3) (World Bank Group, 2020). The other ports were Ngqura, Port Elizabeth and Cape Town. The analysis was conducted using two approaches, the administrative and the statistical approach. The administrative approach involves considering the experience and knowledge of industry experts and when applied Durban was ranked last on the list at 351, Marseille at 350, Ngqura at 349, Port Elizabeth at 348 and Cape Town at 347 (World Bank Group, 2020).

Table 4.3: World Bank Global Ranking of Container Ports, 2020

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
CAPE TOWN	347	6.528	CAPE TOWN	347	-177
PORT ELIZABETH	348	7.659	PORT ELIZABETH	348	-183
DURBAN	349	8.082	NGQURA	349	-190
LUANDA	350	8.383	MARSEILLE	350	-238
NGQURA	351	8.401	DURBAN	351	-255

Source: (World Bank Group 2020:14)

The statistical approach evaluates current infrastructure and operations and the outcome when analysed resulted in Ngqura being ranked last at 351, Luanda at 350 and Durban was listed at 349 (World Bank Group, 2020). Port Elizabeth was348 on the list while Cape Town ranked 347. The requirements for the ranking were, that ports needed to accommodate at least 10 vessels over a six-month period and ports that did not meet these criteria was excluded (World Bank Group, 2020).

The ports that were leading the ranking list were Yokohama port in Japan, followed by King Abdullah Port situated in Saudi Arabia (World Bank Group, 2020). Appendix 3 presents all 351 rankings. Under the administrative approach, Djibouti ranked 93 and outperformed all ports in Africa, while other ports such as Mombasa and Maputo were ahead of SA ports (World Bank Group, 2020). The Port of Mombasa was ranked 43rd in the global sample for their technical efficiency. Dar es Salaam and Durban ranked number 64th and 70th respectively in the technical efficiency ranking. The main criteria for the analysis were representation of at least one expert operator at the terminal, transhipment traffic and decreased time spend at berthsn (World Bank Group, 2020).

According to Master mariner Malcolm Hartwell, numerous activities such as process changes, technological upgrade were implemented, however the performance of the Port of Durban deteriorated (Mchunu, 2021). Some of the issues identified as contributing factors towards the Port of Durban's poor performance were the on-going equipment breakdowns, failure to adopt new technologies and lack of collaboration between Transnet and stakeholders (Mchunu, 2021).

According to Transnet they have advised that the analysis by the World Bank was conducted during the lockdown period and the data presented was not accurate (Mchunu, 2021). These claims may be valid, however, further analysis in this study shows poor performance in the last 5 years (Transnet Port Terminals, 2019).

Transnet is claiming that SA ports invested a lot in infrastructure development, more than other African countries, although some of these countries like Djibouti, were ranked higher by the World Bank (Mchunu, 2021). Transnet further explained that initiatives such as appointment of a Decongestion Team in Durban, Truck Booking Systems and soon to come, the launch of a digital platform to allow cargo movers to monitor movement of goods called Cargo connect, were instituted to ease congestion and to improve performance (Mchunu, 2021). These initiatives will then be duplicated across all SA ports.

The SA president, Mr Cyril Ramaphosa, expressed his concern over the ranking and has declared that the state intends to make Transnet National Ports Authority an independent business as a measure to improve future rankings and to close the gaps that are affecting performance. This strategy will allow TNPA to use revenue generated toward upgrading of port infrastructure and facilities. (Chambers, 2021).

Figure 4.6 extracted from the 2020 World Bank Report, measures port performance by using stochastic frontier (World Bank Group, 2020). The frontier indicates the maximum outputs that can be achieved by using various inputs. The frontier will calculate the efficiency at ports by differentiating between observed production and theoretical production (World Bank Group, 2020). The theoretical production is centred on best practice by the ports that are performing better outputs and have similar characteristics (World Bank Group, 2020).

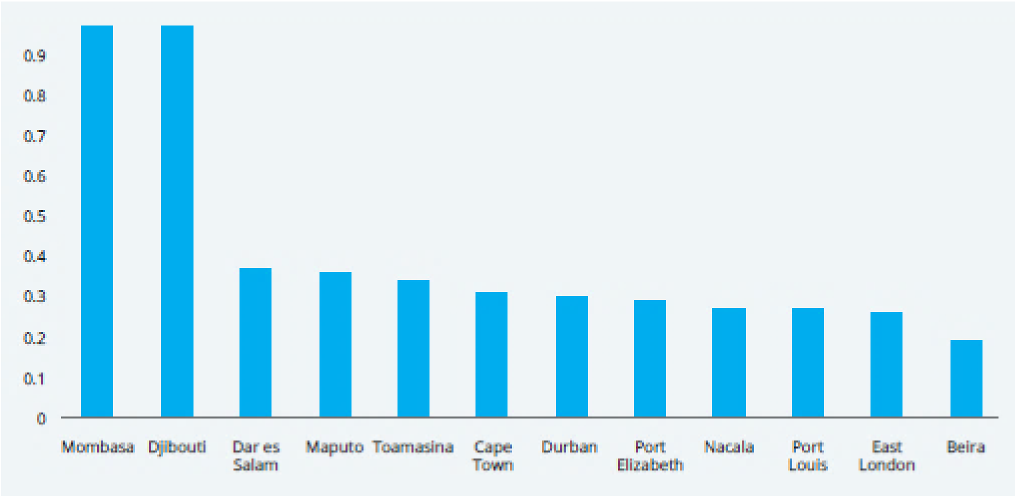


Figure 4.6: Port of Durban's World Bank ranking compared to other African countries

Source: (World Bank Group 2020:38)

The purpose of using similar ports is because larger ports will attain efficiency levels that will not be reached by the sizes of African ports. This analysis included three important inputs: the addition of the container length and berths at the port, the square meterage of the container yard and capacity of the container port equipment (World Bank Group, 2020).

The other variables that were considered in the analysis were dummy variables for private terminals, railway access and a connectivity index. The time trend reflected changes in technology (World Bank Group, 2020). Based on this data analysis, Mombasa was the most technically efficient port in the Eastern region of Africa and ranked 43rd for the most efficient port globally. Durban and Dar es Salaam were rated 64th and 70th in these areas (World Bank Group, 2020). It was interested to note that the analysis identified that the critical factors that contributed toward better efficiency in operations were the existence of a specialised operator at the terminal, the inclusion of railway connections to the terminal, transshipment traffic and reduced dwelling time at the berth (World Bank Group, 2020).

4.6. Performance of the DCT in comparison to other ports

The following figure 4.7, compares the total average minutes it takes per container moves for the various vessel call sizes by the DCT as compared to Cape Town, Ngqura, Port Elizabeth and Mombasa Container Terminals. Mombasa port has outperformed almost all SA ports within all call size groups (see figure 4.7). On average, Durban container terminals spend around 11 minutes per container move to service feeder vessels (call size less than 500). Cape Town container terminal spends 8.1 minutes, Port Elizabeth 6.1 minutes and Ngqura the least amount of time in SA at 4.6 minutes. On the other hand, the Mombasa container terminal spends only 3.2 minutes per container move within this call size group.

Thus, Durban and Cape Town container terminals spend a longer time per container moving across all call size groups. This situation could be a sign showing increased volumes handled and poor crane performance, and especially for Cape Town, where bad weather halts loading and offloading operations frequently. On the other hand, the Ngqura container terminal performs better than almost all other South African container terminals.

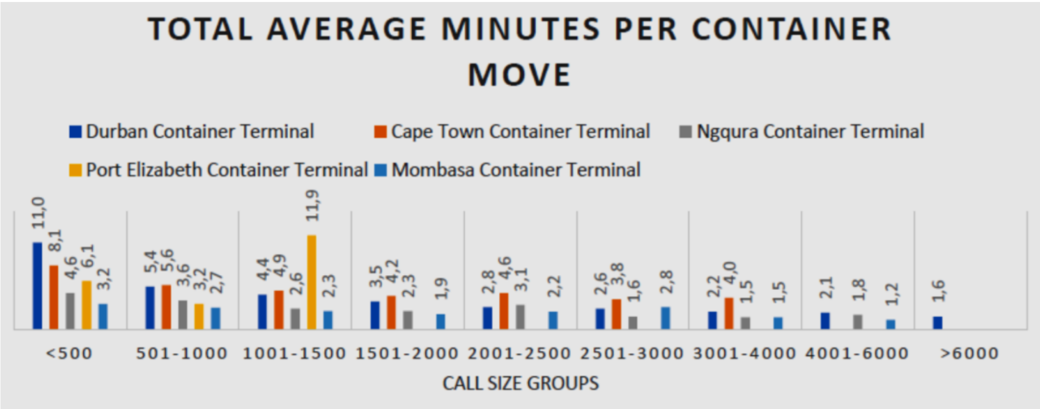


Figure 4.7: Minutes per move for various call sizes

Source: (Coetsee 2021:42)

SA ports struggle with the arrival process for vessels (Business Insider SA, 2021). Vessels calling at Durban container terminal and Cape Town container terminal spend the most time at the arrival and cargo operations processes (Business Insider SA, 2021). Time spent during the arrival process is considered ‘time-wasted’ and should be as little as possible (Melanie, 2017). On the other hand, container vessels calling at Mombasa port spend on average only 2 to 2.2 hours within the arrival process. Strikingly, the DCT (Pier 2) spends 74.5 hours during cargo operations which is the worst compared to all other terminals above. One also needs to consider the increased volumes handled at Durban terminal Pier 2 compared to the other terminals as shown in figure 4.8. Nevertheless, figure 4.8, clearly shows that most of a vessel's time spent in port is during port operations and, therefore, these operations need to improve.

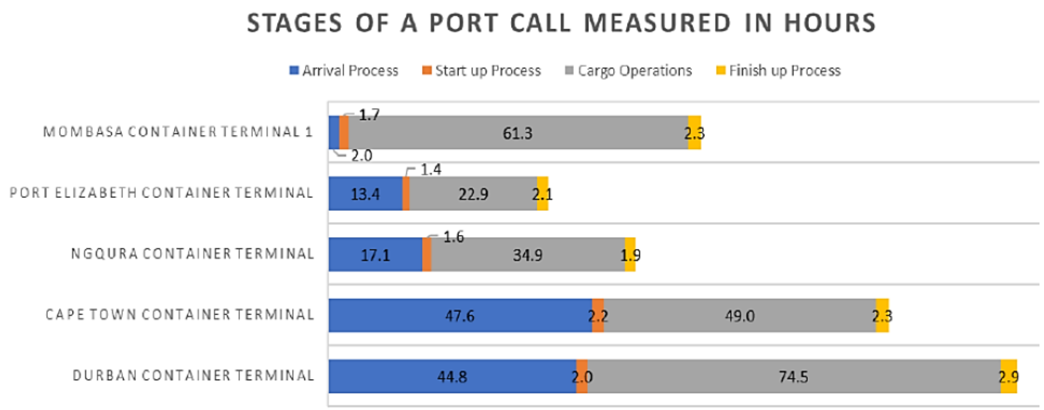


Figure 4.8: State of port calls

Source: (Coetsee 2021:43)

4.7. Container handling equipment between the quay and stack area

The capacity of a port is the maximum limit a port can manage over a period and is measured in TEUs. The maximum throughput is determined by the physical and economic conditions. According to table 4.4, the capacity of DCT Pier 1 is 700 000 TEUs and Pier 2 can handle 2.9 million TEUs per annum (Transnet Port Terminals, 2021). The terminal capacity is determined by examining factors such as channels and waterways, berths and berth length, loading and unloading equipment, operations, yard storage and weather conditions (Statistics, 2017).

Table 4.4: The DCT Terminal Capacity

Containers		
	Pier 1	Pier 2
Capacity	0.7 TEU	2.9 TEU
Berths	2	6
Draft	12.5m	12.2m

Source: (Transnet Port Terminals, 2021)

4.7.1. Pier 1: RTG operation

Pier 1 operations are based on a RTG system (World Port Source, 2021). A typical RTG-TTU system of operations is shown below (see figure 4.9 and 4.10). The Ship-to-Shore (STS) gantry crane places the containers on TTUs. The TTUs then handover the containers to the stacking yard by positioning itself under the RTG. The RTG then removes the container from the TTU and places the containers in blocks called block stacking (see Figure 4.10). An RTG can either be used in conjunction with TTUs or road trucks. The port terminals will decide on the specifications of the RTG based on the requirements. Reinforced concrete paving is necessary to support the wheel loading. Steel pads allow the RTG to turn and travel along storage spaces to perform operations (Böse, 2011). RTGs are smaller than RMGs and are more suitable on reclaimed land as they do not require reinforced piling (Brinkmann, 2011). The current terminal capacity is provided as 770,000 TEU (see table 4.4) (Transnet Port Terminals, 2021). Pier 1 has a fleet of 18 Kalmar RTGs (Kalmar, 2008).

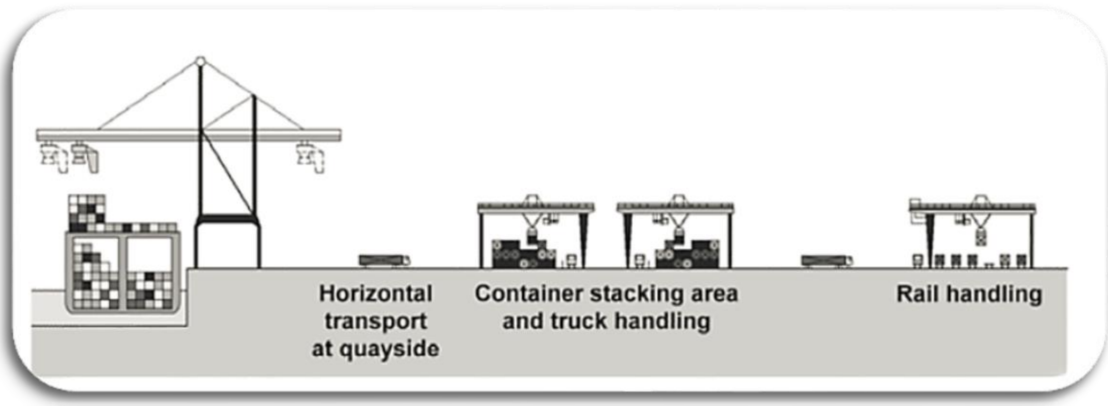


Figure 4.9: A typical layout of an RTG-TTU system

Source: (Brinkmann, 2011:136)

Figure 4.10: RTG operation at the DCT Pier 1

Source: (Kosal, 2021)

Brinkman (2011) lists the following system advantages:

- The stacking yard is utilised effectively as it has the ability to stack 8 high and there is no requirement for travel lanes. Efficient planning in the yard is required to avoid reshuffling of containers.
- This equipment is extremely flexible as it can be utilised in other storage areas with minimum disruption.
- The capital expenses on the equipment is medium.
- RTGs can manage a high number of containers due to their ability to lift, lower and stack efficiently.
- Cross-block operations allow greater space consumption.

Brinkman (2011) lists the following system disadvantages:

- There are two handover requirements when moving containers from the quay crane to the RTG.
- RTG consumes fuel heavily and this could lead to exorbitant operation costs.
- Emissions from exhausts and noises can lead to environmental concerns.

Production of RTGs

RTG-TTU moves per hour at the DCT Pier 1 are shown below (see table 4.5). The data was sourced from TPT website, Terminal updates for 31 August 2019 at 5:51AM. There were 17 RTGs that were analysed for a single shift. Due to the flexibility and speed of the RTG-TTU combination, the performance is efficient. The maximum number of boxes moved per shift is 125. Each shift is 7.75 hours excluding breaks and therefore the total number of boxes moved per hour is approximately 17 boxes. The average RTG crane moves per hour in general is 10.14 (Scroder, 2013), therefore this is an indication that Pier RTGs are suitable for conditions expereinced at the DCT. The statistics shown below show outputs that far exceed the benchmark. A point worth noting is the RTG-TTU double handles containers between the quay and stack, however performance is exceptional. If a comparison is done with the data collected in figure 4.12 and 4.13 it is clear that the rate of production for RTGs far exceeds that of SCs (Transnet Port Terminals, 2021). One of the main focus areas in any port is KPIs, and from the data collected it is evident that the DCT should adopt a complete RTG system of operation. A point to note is that these readings have been collected for a single shift. Further related studied may use multiple readings under various weather conditions to obtain a stronger or more accurate result.

Table 4.5: RTG statistics report

Moves by CHE and Hour of Day (ALL)

che	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	ttl	m/hr	adj m/hr
RTG1	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	8	6	18	3.0	-
RTG10	4	6	1	3	8	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	6	52	6.5	-
RTG11	-	-	5	12	1	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	8	7	43	6.1	-
RTG12	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	10	26	8.7	-
RTG14	2	8	3	2	9	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	4	11	7	49	4.9	-
RTG15	13	-	4	10	6	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	8	45	6.4	-
RTG17	11	4	6	9	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	9	4	49	5.4	-
RTG18	1	2	-	3	5	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	12	11	48	6.0	-
RTG19	5	9	11	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	35	7.0	-
RTG2	7	4	6	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	11	42	7.0	-
RTG20	15	12	19	12	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	7	87	12.4	-
RTG21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	9	19	9.5	-
RTG22	14	-	7	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	7.3	-
RTG4	9	14	5	14	10	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	27	4	97	10.8	-
RTG5	9	14	9	5	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	12	63	7.9	-
RTG8	26	17	25	17	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	16	19	125	13.9	-
RTG9	5	5	2	1	17	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	11	4	61	6.8	-

RTG-TTU moves per shift divide by 7.75

Source: (Transnet Port Terminals, 2021)

4.7.2. Pier 2: SC operation

A typical layout of a pure SC system which Pier 2 has adopted is shown below (see figure 4.11). When this system is adopted, it is simpler to alter the terminal layout due to the flexibility of this type of equipment (Brinkmann, 2011). Since this layout is suitable for medium to large terminals, the DCT, Pier 2 has implemented this system. The STS crane would generally require approximately 5 straddles per shift. One of the advantages of the SC is that it can be offloaded at the required location without delaying (Brinkmann, 2011).

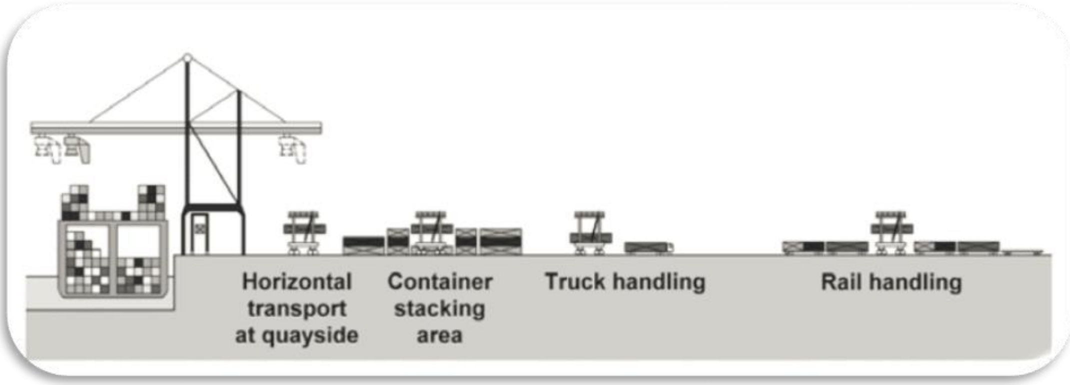


Figure 4.11: Typical layout of a pure straddle carrier system

Source: (Brinkmann, 2011:149)

Brinkman (2011) lists the following SC system advantages:

- The land is used efficiently as they can stack up to 3 high and sometimes up to 4 high depending on the weather conditions at the port. Ports that experience extreme weather generally stack up to 3 high.
- This type of equipment requires few staff to move containers from quay to stack as compared to other equipment.
- The SCs have smaller wheel loads, therefore less damage to the pavement occurs.
- SCs are able to manoeuvre better than most port equipment and operations are simpler.

Brinkman (2011) lists the following SC system disadvantages:

- SCs sometimes clash with other moving port equipment or damage terminal property due to poor visibility.
- The occurrence of breakdowns happens often and therefore this results in high maintenance costs.
- Parking areas that are designated for SC end up with oil and grease on the floor due to leaks and this becomes an environmental issue.
- Stacking heights are lower than other equipment such as RTGs and therefore more yard space will be required. This is not an ideal option as the terminal has land constraints.
- Workshops are required to repair SC. This would use unnecessary space and the cost of maintenance would be higher due to repairs at the workshop.

Production of SCs at Pier 2

SC production rates were extracted from the terminal updates website for August 2019 at Pier 2 (Transnet Port Terminals, 2021). Appendix 1 has the original raw data, however the time wasted, and total movements outputs were summarised and plotted on the graph below (see figure 4.12 and 4.13).

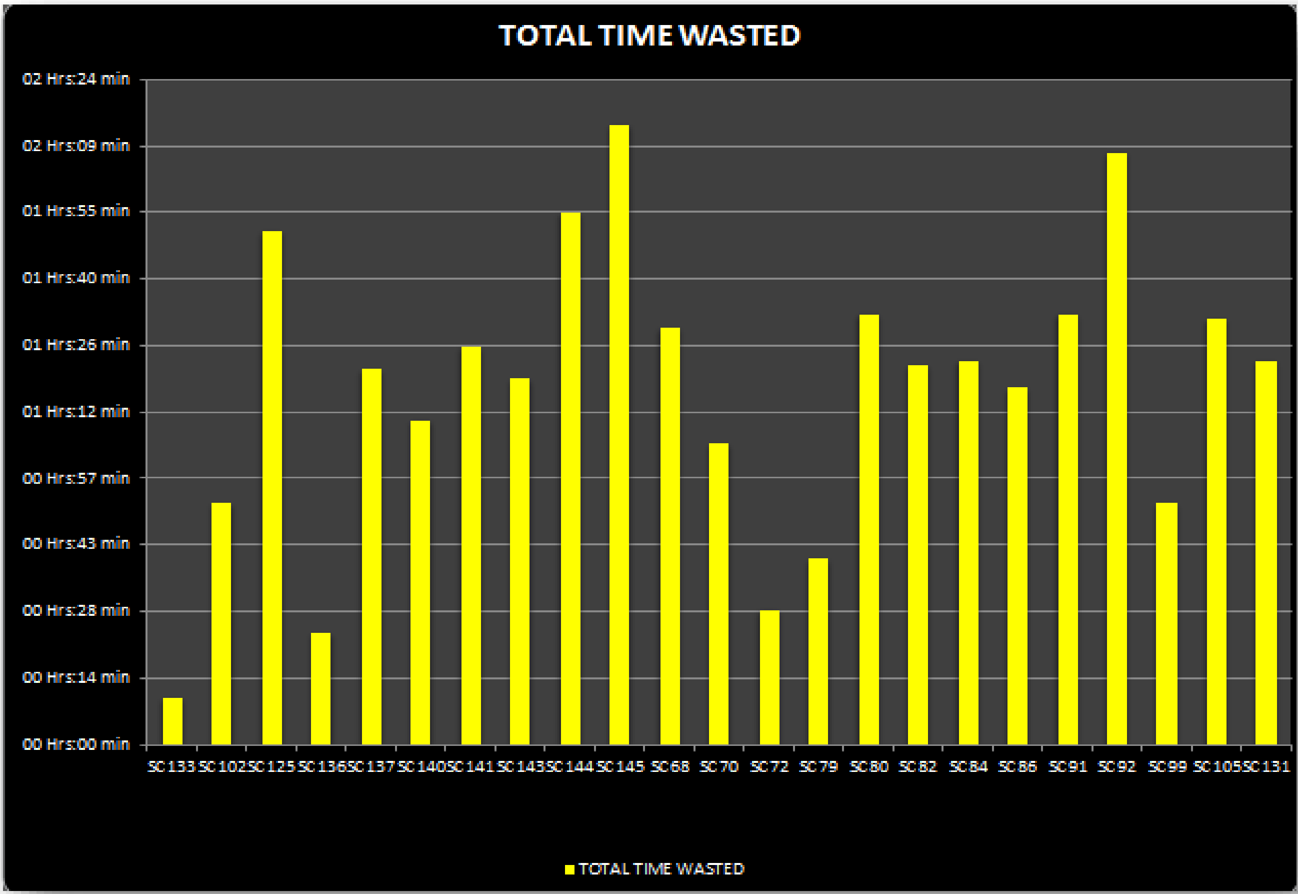


Figure 4.12: Total time wasted per straddle at DCT for a single shift

Source: (Transnet Port Terminals, 2021)

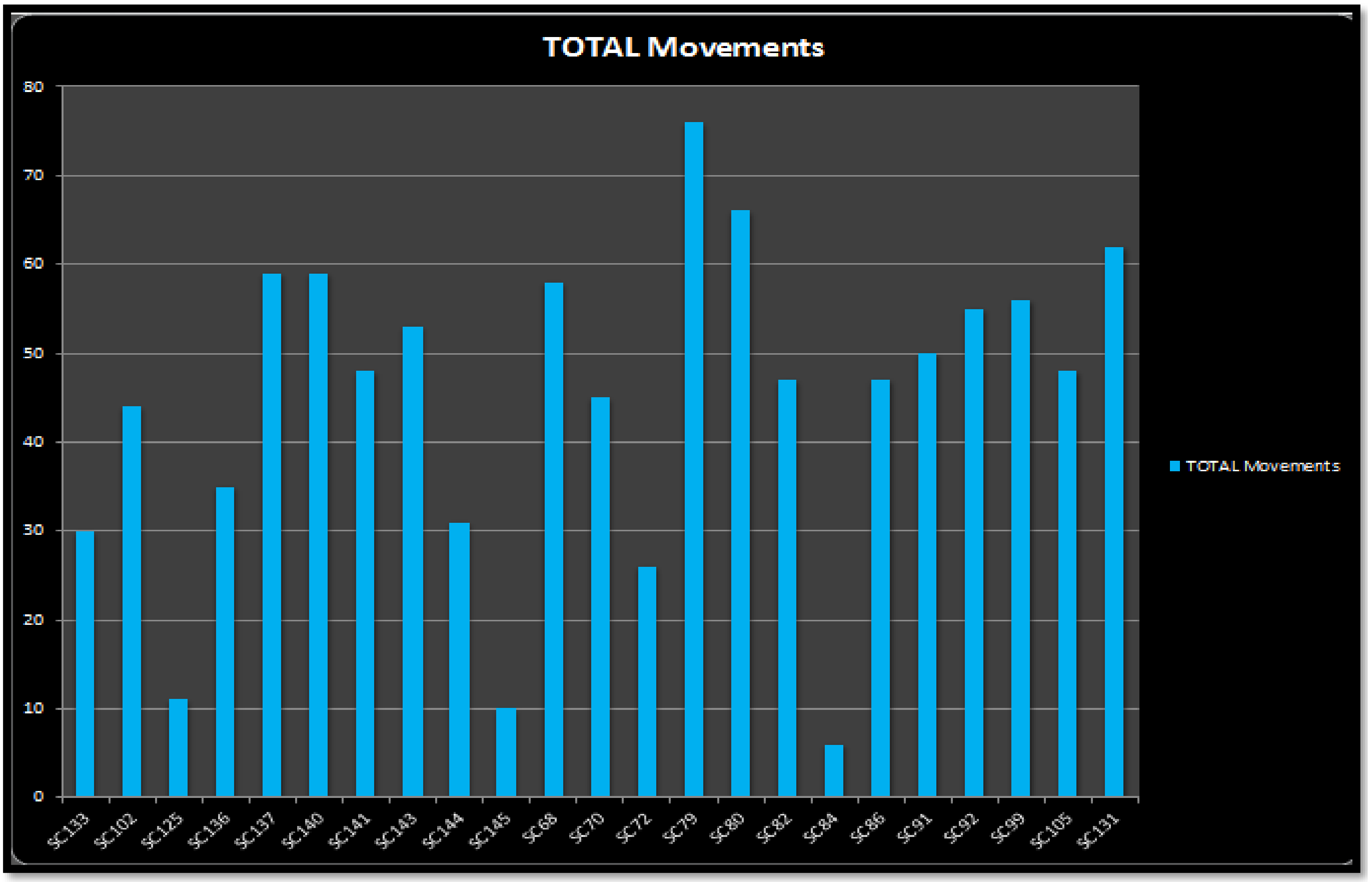


Figure 4.13: Total moves per straddle at the DCT for a single shift

Source: (Transnet Port Terminals, 2021).

The time wastage seems significantly higher than total movements (figure 4.12). The time wastage was monitored by a Transnet tracking system and possible reasons could be waiting for the STS to offload, breakdowns or just time wasting. Other factors could be damaged pavement or fatigue (Transnet Port Terminals, 2021). The introduction of target bonuses may be used to address the issues regarding wastage time. The maximum number of boxes moved per shift is 76 (figure 4.13). Each shift is 7.75 hours excluding breaks and therefore the total number of boxes moved per hour is approximately 10 moves. The results for each straddle are diverse.

It is clear operations and port management needs to develop strategies to mitigate time wastage and to improve performance. The seven tandem lift ZPMC ship-to-shore cranes have the capability of offloading two 40 foot (12 meter) containers, or four 20 foot (6 meter)containers simultaneously, however with the rate of production the container traffic would cause major congestion, as the STS rates would not coincide with SCs movement rates (Bigala, 2012).

4.8. Cost analysis of purchasing and maintaining RTGs and SCs

The purpose of this section is to provide an estimate of possible cost scenarios for labour, purchasing and maintenance costs for SCs and RTGs, using data obtained from 2012. This data was then converted to the closest approximation into today's currency by applying the compound interest formulae and cross checking with an inflation calculator. Unfortunately, the only available information that could be sourced from the public domain pertaining to Transnet's operational costs was published by Urban-Econ in 2012 and is shown below (see table 4.6, 4.7 and 4.8).

Table 4.6: Labour costs 2012

	Manning per equipment hour	Labour costs provided per hour (ZAR)
Quay Crane (STS)	2.28 (2)	116.9 (Pier 2)
SC (1 over 3)	2.36 (2)	103.4 (Pier 2)
RTG (eco)	2.36 (2)	149.8 (Pier 1)

Source: (Urban-Econ (PTY) Ltd, 2012)

Table 4.7: Purchasing costs 2012

	Purchase costs provided by Transnet		International benchmark	relative difference
	(ZAR)	(euro)	(euro)	(%)
STS – single hoist	75,000,000	6,250,000	6,250,000	0%
STS – tandem hoist	100,000,000	8,300,000	8,300,000	0%
SC (1 over 3)	9,500,000	790,000	750,000	5%
RTG (eco)	17,000,000	1,400,000	1,350,000	4%

Source: (Urban-Econ (PTY) Ltd, 2012)

Table 4.8: Maintenance costs 2012

	Maintenance costs provided by Transnet		International benchmark	relative difference	Maintenance costs assumed for Transnet situation	
	(ZAR/hr)	(euro/hr)	(euro/hr)	(%)	(euro)	(ZAR)
Quay crane (STS)	1,280	106.7	95	4%	106.7	1,280
SC (1 over 3)					31.1	373
RTG (eco)	215	17.9	16	7%	17.9	215

Source: (Urban-Econ (PTY) Ltd, 2012)

The latest costs of such equipment could have been sourced from suppliers, but these costs would then have excluded Transnet's overhead costs and therefore this section will only consider and convert the original values in the 2012 data. The latest Transnet overhead costs were not made available to the public as this is company sensitive information.

This data provides labour costs for two operators per item of equipment, purchase costs for SCs and RTGs, maintenance costs to properly run the equipment and a comparison of all these costs to the international norm. These tables make reference to costs estimated under normal operating conditions (maintenance costs for Transnet's situation) that excludes any force majeure or unusual and out of the norm operational circumstances (see table 4.6, 4.7 and 4.8). The data also stipulates costs for Quay Cranes however these costs were not included in this analysis as the focus for this study was the use of SCs or RTGs for improving performance and efficiencies between the quay and stack area in the DCT.

The values were converted from the original amounts on 1 January 2012 to the latest possible values dated 1 September 2021 using the compound interest formulae and cross checking with inflation calculator for the Rands and Euro conversion. The Rand and Euro online inflation rate tool was used to determine the average inflation rate values of 4.8% (divide by 100=0.048) and 0.8% (divide by 100=0.0081) for the rand and euro values respectively. The average inflation rate was then used in the compound interest formulae to convert the values into today's currency. The formulae FV = PV (1 + i) formula was used and when cross-checked with the online inflation tool convertor there was a slight difference in the results. Therefore, for this analysis and for the most accurate comparison, the online inflation tool result was captured in the summary table (see table 4.9). The abbreviations in the formulae mean the following:

FV: Future Value
PV: Present Value
i: Interest rate (inflation)
n: Number of times the interest is compounded (i.e. # of years)

4.8.1. Rand Conversion

Using the formulae FV = PV (1 + i) the Rand conversion results were as follows:

Labour costs:

- **FV = PV $(1 + i)^9$ = R103.40 * $(1 + 0.048)^9$= R157.17 (SC)**
- **FV = PV $(1 + i)^9$ = R149.80 * $(1 + 0.048)^9$= R227.70 (RTG)**

Purchase costs:

- **FV = PV $(1 + i)^9$ = R9,500,000.00 * $(1 + 0.048)^9$= R 14, 440,000 (SC)**
- **FV = PV $(1 + i)^9$ = R17,000,000.00 * $(1 + 0.048)^9$= R 25,840,000.00 (RTG)**

Maintenance costs:

- **FV = PV $(1 + i)^9$ = R373.00 * $(1 + 0.048)^9$= R 566.96**
- **FV = PV $(1 + i)^9$ = R215.00 * $(1 + 0.048)^9$= R 326.80**

Using the online inflation convertor, the Rand conversion results were as follows:
(SA Inflation Calculator, 2021)

Labour costs
R 103.40 from January 2012 would be worth **R 166.14** in September 2021.
R 149.80 from January 2012 would be worth **R 240.70** in September 2021.

Purchase costs
R 9,500,000.00 from January 2012 would be worth **R 15,264,744.43** in September 2021.
R 17,000,000.00 from January 2012 would be worth **R 27,315,858.45** in September 2021.
Maintenance costs
R 373.00 from January 2012 would be worth **R 599.34** in September 2021.
R 215.00 from January 2012 would be worth **R 345.47** in September 2021.

4.8.2. Euro Conversion

Using the formulae FV = PV (1 + i), the Euro conversion results were as follows:

International benchmark for purchase costs:

- **FV = PV $(1 + i)^9$ = €790000 * $(1 + 0.0018)^9$= € 849,492.65**
- **FV = PV $(1 + i)^9$= €1400000 * $(1 + 0.0018)^9$= € 1,505,430.01**
- **FV = PV $(1 + i)^9$ = €750000 * $(1 + 0.0018)^9$= € 806,480.36**
- **FV = PV $(1 + i)^9$= €1350000 * $(1 + 0.0018)^9$= € 1,451,664.65**

International benchmark for purchase costs:

- **FV = PV** $(\mathbf{1}+\boldsymbol{i})^{\mathbf{9}}$ **= €31 *** $(\mathbf{1}+\mathbf{0.0018})^{9}$**= €33.33**
- **FV = PV** $(\mathbf{1}+\boldsymbol{i})^{\mathbf{9}}$ **= €18 *** $(\mathbf{1}+\mathbf{0.0018})^{9}$**= €19.35**
- **FV = PV** $(\mathbf{1}+\boldsymbol{i})^{\mathbf{9}}$ **= €16 *** $(\mathbf{1}+\mathbf{0.0018})^{9}$**= €17.20**

Using the online inflation convertor, the Euro conversion results were as follows:
(Euro Inflation Tool, 2021)

International benchmark for purchase costs:
€790000 from January 2012 would be worth **€856,571.57** in September 2021.
€1400000 from January 2012 would be worth **€1,517,974.94** in September 2021.
€750000 from January 2012 would be worth **€813,200.86** in September 2021.
€1350000 from January 2012 would be worth **€1,463,761.55** in September 2021.

International benchmark for purchase costs:
€31 from January 2012 would be worth **€33.61** in September 2021.
€18 from January 2012 would be worth **€19.52** in September 2021.
€16 from January 2012 would be worth **€17.35** in September 2021.

4.8.3. Summary table for Rand and Euro conversion

The results for the conversions are summarized in table 4.9 below. There are slight variances in the cost comparisons. When the compound interest formulae were applied for the rand conversion, the results were much lower than when using the online inflation calculator, however when the euro conversion is analysed, the compound interest formulae values are higher. The closest and most accurate value would be the online inflation calculator. There are various reasons for this such as elimination of human error and the online inflation calculator takes into account the Consumer Price Index (CPI) formula and values are calculated on a yearly basis for the last 9 years to obtain the most accurate result. It is for this reason the data obtained from the online inflation calculator will be used in the final summary. The original data is shown in Appendix 2.

Table 4.9: Summary table for rand and euro conversion

	Compound interest formulae	Online inflation calculator
	Rands	Rands
Labour costs (SC)	R157,17	R166,14
Labour costs (RTG)	R227,70	R240,70
Purchase costs (SC)	R14,440,000.00	R15,264,744.43
Purchase costs (RTG)	R25,840,000.00	R27,315,858.45
Maintenance costs (SC)	R566.96	R599.34
Maintenance costs (RTG)	R326.80	R345.47
	Euros	Euros
International benchmark for purchase cost (SC)	€ 849,492.65	€856,571.57
International benchmark for purchase cost (RTG)	€1,505,430.01	€1,517,974.94
International benchmark for purchase cost (SC)	€806,480.36	€813,200.86
International benchmark for purchase cost (RTG)	€1,451,664.65	€1,463,761.55
International benchmark for purchase and maintenance costs (SC)	€33.33	€33.61
International benchmark for purchase and maintenance costs (RTG)	€19.35	€19.52
International benchmark for purchase and maintenance costs (RTG)	€17.20	€17.35

4.8.4. Final Summary of costs of purchasing and maintaining RTGs and SCs

An estimate of the cost to operate SCs and RTGs per hour is shown below (see table 4.10). You will notice the cost to operate the RTG is slightly higher than a SC however the outputs in adopting the RTG system is much more efficient as discussed in section 4.7. The main reason is the operator cost for RTG rates will be higher as more skills are required to operate an RTG since it is a little more complex and not as straight forward as the SC. The other reason is SC requires a single driver and a standby driver whereas RTGs requires a TTU driver together with an RTG operator.

Table 4.11 shows an approximate cost of purchasing a RTG as compared to a SC. Although the purchase costs for an RTG is higher, the maintenance cost for a SC is quite substantial compared to an RTG (see table 4.12). As discussed earlier, according to Ports Regulator of South Africa (2020), on average, from 2015-2020, ZAR86 million was spent on port asset maintenance at the DCT. A steep increase since 2015 was shown, indicating port equipment costs, SCs in particular (Ports Regulator of South Africa, 2020).

Table 4.10: Labour costs

Equipment	Manning per equipment hour	Pier	Current labour costs per hour ZAR (2021)	
			2012	2021
SC (1 over 3)	2.36 (2)	2	103.4	166.14
RTG	2.36 (2)	1	149.8	240.7

Source: (Urban-Econ (PTY) Ltd, 2012) and (SA Inflation Calculator, 2021)

Table 4.11: Purchase cost

Equipment	Purchase costs provided by Transnet				International benchmark		relative difference (2021)	
	(ZAR) 2012	(ZAR) 2021	(euro) 2012	(euro) 2021	(euro) 2012	(euro) 2021	(%) 2012	(%) 2021
SC (1 over 3)	9,500,000	15,264,744.43	790000	856,571.57	750000	813,200.86	5%	5%
RTG	17,000,000	27,315,858.45	1,400,000	1,517,974.94	1,350,000	1,463,761.55	4%	4%

Source: (Urban-Econ (PTY) Ltd, 2012), (SA Inflation Calculator, 2021) and (Euro Inflation Tool, 2021)

Table 4.12: Maintenance cost

Equipment	Maintenance costs provided by Transnet				International benchmark		Relative difference		Maintenance costs assumed for Transnet			
	(ZAR/hr) 2012	(ZAR/hr)2021	(euro/hr) 2012	(euro/hr) 2021	(euro/hr) 2012	(euro/hr) 2021	2012%	2021%	(euro) 2012	(euro) 2021	(ZAR) 2012	(ZAR) 2021
SC (1 over 3)									31.1	33.61	373	599.34
RTG	215	345.47	17.9	19.52	16	17.35	7%	7%	17,9	19.52	215	345.47

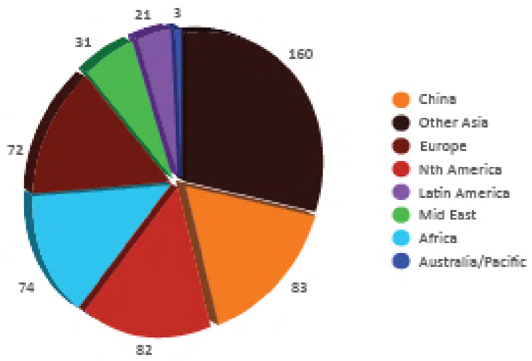
Source: (Urban-Econ (PTY) Ltd, 2012), (SA Inflation Calculator, 2021) and (Euro Inflation Tool, 2021)

The next section studies the number and type of port equipment purchased in 2018 and 2019. This section will validate that RTGs have now become the preferred method of operation in ports globally as there was a significant increase in RTG purchases as compared to RMGs and SCs combined in 2019.

4.9. Total number of container handling equipment purchased globally in 2018 & 2019

Figure 4.14 and Figure 4.15 below indicate a total of 670 container yard cranes delivered around the globe as compared to 636 in 2018 (Port Equipment Manufacturers Association, 2020). To be precise, there were 526 RTGs and 133 RMG and SCs combined delivered worldwide. If one compares deliveries in 2018, there were 393 RTGs and 243 RMGs and SCs combined delivered (Port Equipment Manufacturers Association, 2020). There was a 34 per cent increase in RTG deliveries in 2019 around the world. Surprisingly, the number of RMGs and SCs declined by 40 per cent from 243 delivered in 2018 to 144 in 2019 (Port Equipment Manufacturers Association, 2020).

China	83	16%
Other Asia	160	30%
Europe	72	14%
Nth America	82	16%
Latin America	21	4%
Mid. East	31	6%
Africa	74	14%
Australasia	3	0%
Total	526	100%



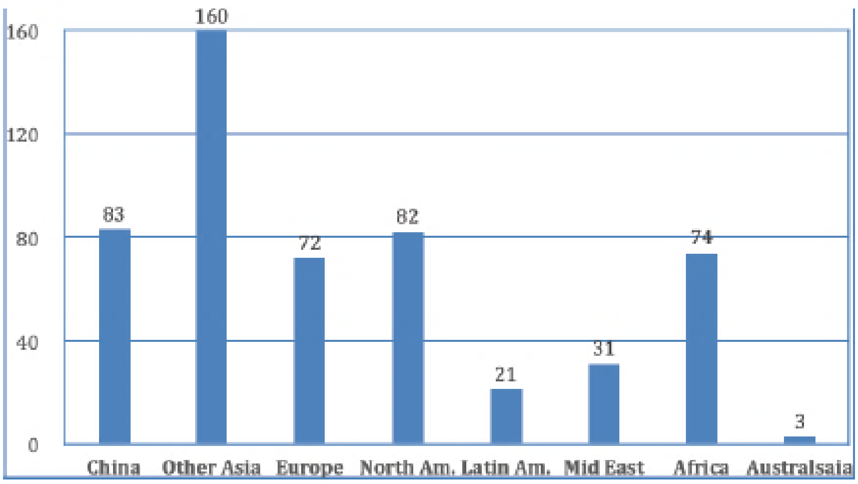
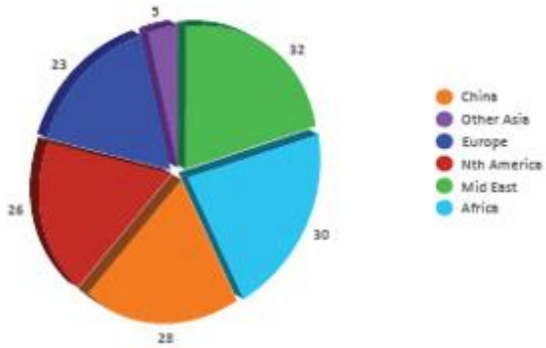


Figure 4.14: Global RTG deliveries 2019 by Geographic Region

Source: (Port Equipment Manufacturers Association 2020:9)

China	28	19%
Other Asia	5	3%
Europe	23	16%
Nth America	26	18%
Latin America	0	0%
Mid. East	32	22%
Africa	30	21%
Australasia	0	0%
Total	144	100%



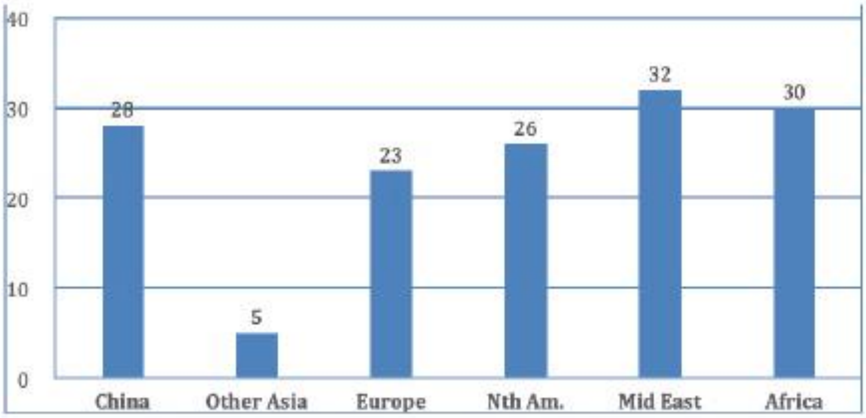


Figure 4.15: Global RMG deliveries 2019 by Geographic Region, Including Straddle Carriers

Source: (Port Equipment Manufacturers Association 2020:10)

The data above was collected from container equipment suppliers globally and published (Port Equipment Manufacturers Association, 2020). The information was gathered between February and March 2020. Ports around the world are starting to adopt RTG as their preferred equipment to improve efficiencies and to reduce port congestion due to its flexibility and modern equipment such as positioning systems, auto steering systems and camera monitors (Cederqvist & Holmgren, 2020). These latest enhancements would be extremely beneficial to the `DCT if it adopts the RTG operating system. RMGs are too costly and are not as flexible as RTGs due to it being fixed on crane rails and beams (Mohseni, 2011). As discussed in section 4.7, SC are too costly to maintain due to frequent breakdowns and can only stack up to 3 high which results in the inefficient use of the container yard (Brinkmann, 2011). Asian countries such as the Port of Yokohama have adopted RTGs and according to the data in figure 4.14, Asian countries have purchased 160 RTGs in 2019 (Port Equipment Manufacturers Association, 2020). The SA government are planning to invest ZAR100 billion in port infrastructure and RTG should form part of the equipment upgrade plan (Magubane, 2021). The conversion will utilise the limited yard space at the DCT efficiently due to its high stacking ability.

4.10. Infrastructure used by Port of Yokohama- Japan and King Abdullah Port

According to the World Bank, as shown in table 4.13, Port of Yokohama- Japan and King Abdullah Port ranked first and second place respectively (World Port Source, 2021). The ranking is based on port hours per vessel and time taken for vessels to enter, exchange cargo and exit and containers moves per call. The study indicates Port of Yokohama takes 1.1 minutes to load or offload cargo (Asia Shipping Media, 2021). King Abdullah Port ensured uninterrupted round-the-clock operations and launched smart processes for safe and easy operations during the Covid-19 pandemic (King Abdullah Port, 2021). King Abdullah Port is owned by the private sector and is a fast-growing port (King Abdullah Port, 2021).

Table 4.13: World Bank Ranking: Port of Yokohama- Japan and King Abdullah Port

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
YOKOHAMA	1	-5.995	YOKOHAMA	1	130
KING ABDULLAH PORT	2	-5.684	KING ABDULLAH PORT	2	114

Source: (World Bank Group, 2020)

The following table 4.14 shows the characteristics of the Port of Yokohama and King Abdullah Port. Since these ports were ranked as the leading ports for the year 2020 by the World Bank, it will be interesting to understand what port equipment is being used and what measures are in place to reduce port congestion.

Table 4.14: Characteristics of the Port of Yokohama and King Abdullah Port

	Port of Yokohama- Japan	King Abdullah Port (National Container Terminal)
Throughput	2.4 million TEUs	2.3 million TEUs
Berth draft	20m	18m
Measures to reduce port congestion	Customer notification system, vessel schedules and gate cameras, extended free storage and gate opening times	Port Community System, the Smart Gate System
No of container berths	14	6
Terminal area	85.4ha	120 ha
Type of vessels berthing	ultra-mega vessels (up to 18,000 TEUs)	ultra-mega vessels (over 23,500 TEUs)
Type of port handling equipment	RTGS, TTU & STS	RTGS, TTU & STS

Source: (Yokohama Port Corporation, 2020) & (King Abdullah Port, 2021)

4.10.1. Port of Yokohama- Japan

The Port of Yokohama is recognised as a port of global strategic importance (APM Terminals Japan, 2021). All berths have seismic technology installed to resist the impact of adverse weather conditions. It has the deepest waters leading to the berth vicinity with a length of 1600 meters with a 20-meter draft and the quay is earthquake resistant (APM Terminals Japan, 2021). The STS crane is very advanced with an outreach of approximately 24 rows. The port land area is a total of 7,315.9ha and has a capacity of 2.4 million TEUs per annum. The terminal has plans to expand the capacity into adjacent land (see figure 4.16) (APM Terminals Japan, 2021).

Figure 4.16: Port of Yokohama

Source: (Yokohama Port Corporation, 2020)

The port can handle ultra large vessels up to 18000 TEUs and operation is based on a RTG system. The port introduced a container loading and offloading advanced reservation system called CONPAS. Truck waiting areas are also available to reduce port congestion (APM Terminals Japan, 2021).

The port of Yokohoma has also introduced a customer notification system that updates customers on the latest information regarding port disruptions such as labour issues, adverse weather conditions delaying operations, congestion and customs issues (Yokohama Port Corporation, 2020). The terminal also provides time estimates for resolution to allow customers to plan accordingly.

The terminal also has accessible gate cameras and a schedule for vessels is readily available to the customers (Yokohama Port Corporation, 2020). Some alternative resolutions they are implementing to manage the impacts are extended free storage and gate opening times (Yokohama Port Corporation, 2020).

4.10.2. King Abdullah Port - National Container Terminals

National Container Terminals (NCT), port container terminal operator for King Abdullah Port in Saudi Arabia (see figure 4.17). This terminal has become the second largest container operating facility in the world. (King Abdullah Port, 2021).

Figure 4.17: King Abdullah Port - National Container Terminals

Source: (Albilad, 2020)

The terminal caters for multiple services and is located in a strategic position (King Abdullah Port, 2021). NCT has 6 fully operational berths spanning over 18 meters and has a draught of 18 meters. The terminal land area is over 1.2 million square meters and is able to accommodate 2500 refrigerated containers (King Abdullah Port, 2021). The port's throughput has risen from 1.7 million TEUs in 2017 to 2.3 million TEUs in 2018 (Albilad, 2020).

Figure 4.18 indicates the type and number of container handling equipment that the port uses. It is worth nothing that this leading port that has been ranked second by the World Bank is operating with RTG-TTU combination. There are a total of 60 RTGs and 153 TTUs amongst other equipment (King Abdullah Port, 2021).

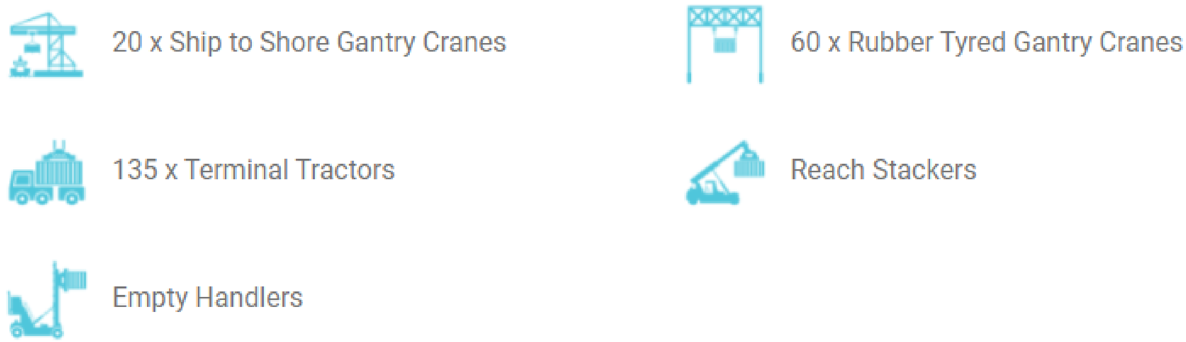


Figure 4.18: King Abdullah Port Handling Equipment

Source: (King Abdullah Port, 2021)

NCT have introduced modern container scanning systems and advances planning systems for vessels and yards. The Smart Gate System is incorporated with the port communications systems and the terminal gate systems to ensure all key stakeholders stay up to date on the latest at the port (King Abdullah Port, 2021). This system has security characteristics that allows port authorities to retrieve important information regarding the truck, cargo and driver. This automated system eliminates time wastage by excluding human interference. It also improves the turnaround time at the ports and only admits vehicles that make an advanced appointment. (King Abdullah Port, 2021). The terminal is able to plan more efficiently due to the advanced booking system. The STS cranes have an outreach of 25 TEUs and are the largest cranes in the world. Ultra-mega vessels that carry up to 23 500 TEUs can be accommodated by the Port (King Abdullah Port, 2021).

4.11 Chapter summary

This chapter, in section 4.2, highlighted the importance of selecting the most efficient container handing equipment for ports and for the DCT in particular. This section outlined how globally trading has evolved, and sea trade demand has increased rapidly. It is therefore critical for port operators to ensure the most efficient port equipment has been installed to produce the best results.

The chapter then began analysing the current state of the DCT, in section 4.3, in terms of performance as compared to the rest of the world. TPTs KPIs between 2017 to 2020 were examined to identify the current state of the port. It was identified that TPT performed poorly during this period for reasons such as outdated and old port equipment and adverse weather conditions (Transnet Port Terminals, 2019). Although the DCT Pier 1 has increased SWH results from 46 to 48 moves in 2019 while Pier 2 has just surpassed its target from 53 to 54 SWH, the GCH suffered a sharp decline from 25 moves in 2018 to 22 moves in 2019. According to TPT, they have committed to try and improve the performance outputs by purchasing 10 empty container handlers for DCT Pier 2, 18 haulers for DCT Pier, improvement of gangs and support equipment (Transnet Port Terminals, 2019).

Once it was established that the DCT was performing poorly, section 4.4 then began examining the infrastructure used at the Port of Durban as well as, container volumes handled, vessel calls, capex allocation and the maintenance budget. This analysis proved that although Durban was managing the bulk of containers in SA, there was a decrease in capex expenditure and an increase in maintenance costs. Critical expansion projects were not executed for unknown reasons which worsened the state of the DCT. The maintenance costs increased tremendously from 2015 to 2020 and an approximate average value of ZAR 86 million was spent on asset maintenance (Ports Regulator of South Africa, 2020).

SA ports were examined from a global perspective in section 4.5 and 4.6 and specific reference was made to the recent World Bank Report (World Bank Group, 2020). This report ranked SA ports in the bottom five out of 351 container handling ports worldwide, with the Port of Durban being the last when ranked with an administrative approach and third from the bottom when the statistical approach was applied (World Bank Group, 2020). When SA was compared to Port of Mombasa in Kenya it was clear that the DCT was no longer a leading port in Africa and an in-depth study of the current container equipment was required to improve the performance of the DCT.

Section 4.7 and 4.8 then assessed the container handling infrastructure currently used at the Port of Durban between the quay and stack area in Pier 1 and Pier 2. Due to the fact both these Piers adopted a different method of operation, it made for an interesting comparison. The results that were extracted from Transnet websites were analysed for both SCs (Pier 2) and RTGs (Pier 1) The results were chosen on a normal shift without any port disruptions or adverse weather conditions. A total of 23 SCs outputs for a shift were examined and the total number of moves per shift approximated to 76 moves which equals approximately 10 moves per hour. When the outputs of the RTGs were examined, it was interesting to note that the results were much higher, (approx. 126 moves). It was on this basis RTGs became the preferred choice of equipment for container moves. To further enhance the RTG proposition, the advantages and disadvantages were studied. Although flexibility was one of the key takeaways for SCs as an advantage, it was identified that breakdowns, environmental issues and accidents were a few of the disadvantages that SCs carry. RTGs on the other hand have fewer breakdowns, less environmental issues and few port accidents. Another great advantage is the ability of RTGs to stack up to 8 high, SC can only stack up to 3 high. The outputs and advantages of RTGs make it an ideal choice for the DCT Pier 2 to adopt.

In section 4.9, a cost effectiveness analysis was carried out by using Transnet's 2012 cost data and converting the values into today's currency by using the compound interest formula and online inflation calculators. The labour, purchase and maintenance costs were converted and analysed to determine the most feasible option to adopt between SCs and RTGs. The values using both compound interest formula and online inflation calculators were not far off, however the value obtained using online inflation calculators were used due to accuracy and the use of Consumer Price Index (CPI) formula on a yearly basis. The compound interest formulae were used to ensure the values were close to accurate. Once the tables were summarised the results were then analysed. Although the cost to operate and purchase the RTG is slightly higher than SCs, cost to maintain SCs far outweighs RTGs.

In section 4.10 the total number of most popular container handling equipment purchased between 2018 and 2019 were discussed and it was identified that the number of RTGs purchased in 2019 internationally far outweighed RMGs and SCs purchases combined. There was a 34 per cent increase in RTG deliveries in 2019 around the world and the number of RMGs and SCs declined by 40 per cent from 243 delivered in 2018 to 144 in 2019 (Port Equipment Manufacturers Association, 2020). The result indicates that RTGs are a popular piece of equipment used by leading and modern ports globally. Section 4.11 then compared the Port of Yokohama- Japan and King Abdullah Port since they were the leading ports ranked first and second place according to the World Bank Report (World Bank Group, 2020). It was identified that both these cutting-edge ports use the RTG system to produce the superb results that ranked them 1st and 2nd in the World Bank Report. The current technology was studied, and recommendations based on this is made in the recommendations section.

Further analysis can be carried out to discuss other equipment such as RMGs in future studies, however, the focus for this study was SC and RTGs due to the restrictions and high costs related to RMGs. It is a point worth noting that RMGs are in fact RTGs on rail tracks. Further, the comparison with available data for the Pier 1 and Pier 2 made a stronger argument that RTGs are a better choice.

On site performance monitoring of port equipment may be an approach that future research can adopt rather than using available data. This would provide an opportunity to identity other opportunities to improve port performance by conducting equipment load calculations and state of current pavement conditions.

There are also opportunities to discuss automation. Many ports are adopting this type of technology to improve performance. This topic was too vast to be covered in the timeframe required for this dissertation.

Opportunities to expand the cost analysis exist as only two options in this study were explored. If recent data is obtained it would provide more accurate results and could present stronger substance to the recommendation.

The study focusses mostly on data just before Covid-19 as the idea was to examine data under normal operating conditions. However, there is opportunity for future research to study the impact of Covid-19 on operations at the Port of Durban.

The analysis in this chapter presents a strong argument that RTGs would the ideal method of operation for the DCT. The data presented in this chapter suggests that RTGs are the better performers both short term and long term and moreover most of the leading ports are turning toward this mode of operation. In this section the ports container handling equipment, throughputs and current technology adopted were discussed to justify the port equipment recommendation made for the DCT.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

The purpose of this fifth chapter is to provide the conclusions and recommendations drawn from this research and to provide suggestions for forthcoming studies.

The intent of this study was to establish the most suitable container handling equipment that should be implemented at the DCT to reduce port congestion. This desktop study was used to analyse the current state of the DCT and to provide recommendations of improvement to the current container handling equipment to reduce port congestion.

5.2. Summary of the Findings

The study contributed to the objectives as follows:

5.2.1. Objective one: to examine the productivity of the DCT in comparison to other ports nationally and internationally

The first objective was to examine the productivity of the DCT in comparison to other ports nationally and internationally. The study revealed that the KPIs that were analysed from 2017 to 2020 indicated a significantly poor performance by the DCT. It was identified that TPT performed poorly during this period for reasons such as outdated and old port equipment and adverse weather conditions (Transnet Port Terminals, 2019). The operation performance volumes for containerised goods decreased by 2 per cent in 2019 when compared to 2018. The results in 2018 indicate a decline in comparison to previous years. Transnet have attributed the poor performance to prolonged cargo dwelling time, port equipment challenges and forced cancellations by shipping lines.

Although the DCT Pier 1 has increased SWH results from 46 to 48 moves in 2019 while Pier 2 has just surpassed its target from 53 to 54 SWH, the GCH suffered a sharp decline from 25 moves in 2018 to 22 moves in 2019. According to TPT, they have committed to try and improve the performance outputs by purchasing 10 empty container handlers for DCT Pier 2, 18 haulers for DCT Pier, improvement of gangs and support equipment (Transnet Port Terminals, 2019).

Once it was established that the DCT was performing poorly, the infrastructure, container volumes handled, vessels calls, capex allocation and maintenance budget were then analysed. This analysis proved that although Durban was managing the bulk of containers in SA, there was a decrease in capex expenditure and increase in maintenance costs. Critical expansion projects were not executed for unknown reasons which worsened the state of the DCT. The maintenance costs had increased tremendously from 2015 to 2020 and an approximate average value of ZAR 86 million was spent on asset maintenance (Ports Regulator of South Africa, 2020).

The study analysed the World Bank Report and established that a total of four SA ports ranked at the bottom of the list with Port of Durban performing the worst rated in the bottom 3 out of a total of 351 container handling ports around the world when the administrative and statistical approach was applied (see table 4.3) (World Bank Group, 2020). The other ports were Ngqura, Port Elizabeth and Cape Town.

The Port of Mombasa was ranked 43rd in the World Bank Report for their technical efficiency. On average, Durban container terminals spend around 11 minutes per container move to service feeder vessels (call size less than 500). Cape Town container terminal spends 8.1 minutes, Port Elizabeth 6.1 minutes and Ngqura the least amount of time in SA at 4.6 minutes. On the other hand, the Mombasa container terminal spends only 3.2 minutes per container move within this call size group. Durban and Cape Town container terminals spend a longer time per container moving across all call size groups. Ngqura container terminal performs better than almost all other South African container terminals. It was established that the Port of Mombasa outperformed the DCT in all KPIs and outperformed almost all SA ports within all call size groups.

Some of the issues identified as a contributing factor towards the Port of Durban's poor performance is the on-going equipment breakdown, failure to adopt new technologies and lack of collaboration between Transnet and stakeholders (Mchunu, 2021).

According to Transnet they have advised that the analysis by the World Bank was conducted during the lockdown period and the data presented was not accurate (Mchunu, 2021). These claims may be valid, however, further analysis in this study shows poor performance in the last 5 years (Transnet Port Terminals, 2019).

It was evident in the study that the DCT has been performing poorly over the last 5 years. The constant breakdown of port equipment due to it being old and outdated seems to be the common problem. This allowed the preceding chapters to flow seamlessly as the focus was selecting the most appropriate container handling equipment to increase productivity.

5.2.2. Objective two: To examine the performance of current container handling equipment used at the Durban Container Terminal.

The second objective was to study the current container equipment used in the DCT's Pier 1 and Pier 2 and to compare performance data for the equipment to identify which of the two are the better performers. Pier 1 and Pier 2 use RTGs and SCs respectively and therefore in figure 5.1, RTG represents Pier 1 operations and SC represents Pier 2 operations. It was established in terms of performance that RTGs far outperform SCs. Performance data available for DCT Pier 1 and Pier 2 was extracted from the Transnet website and compared to identify if the RTGs or SC were performing better. The highest RTG moves per hour in Pier 1 was 125 and SC moves per hour in Pier 2 was 76 (see figure 5.1).

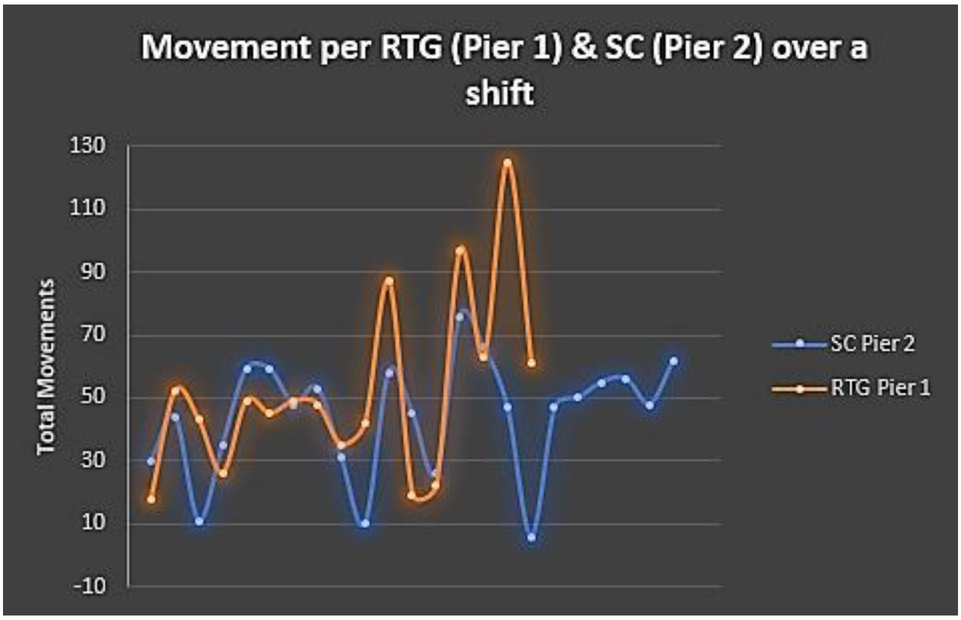


Figure 5.1: Summary of production outputs of RTGs and SCs

Advantages and disadvantages were discussed, and a cost analysis was conducted to further support the recommendation. RTGs have the ability to stack higher than SC, which is a huge advantage especially when the yard space is limited or if there are tight budget constraints in the face of impeding port expansions. Safety is one of the key focus areas in ports, however SCs are more prone to accidents due to constant movement from quay to stack and the poor visibility conditions. SC breakdowns are more frequent than RTG breakdowns which means that maintenance costs for SCs would be higher. Again, RTGs were the preferred option as the advantages outweighed the disadvantages (see table 5.1).

Table 5.1: Summary of RTG and SC advantages and disadvantages

	RTG	SC
Stacking height	8	3
Flexibilty	Flexible	Flexible
Capital expenses	Medium	High
Accidents	Low	High
Breakdowns	Low	High
Repair workshops	Not required	Required

Further research was conducted to identify which type of equipment was the preferred option by ports by analysing which equipment had the highest number of sales globally. There was a 34 per cent increase in RTG deliveries in 2019 around the world and the number of RMGs and SCs declined by 40 per cent from 243 delivered in 2018 to 144 in 2019 (Port Equipment Manufacturers Association, 2020). The result indicates that RTGs are a popular piece of equipment used by leading and modern ports globally.

The World Bank (2020) ranked Port of Yokohama- Japan and King Abdullah Port first and second place in their list of best performing container ports globally in 2020. When the infrastructure used by these ports were examined it was noted that both of these ports use RTGs systems.

The results drawn indicate that RTGs produce better production outputs when compared to SCs. They are more efficient with fewer breakdowns. Leadings ports globally are adopting the RTG operations due to the many benefits. To further substantiate the recommendation a cost comparison was conducted. Section 5.2.3 summarises the outcome of this analysis.

5.2.3 Objective three: to examine and compare the costs of using a Rubber Tyred Gantry system versus Straddle Carrier system at the Durban Container Terminal

The third objective was to examine and compare the costs of operating, purchasing and maintaining the Rubber Tyred Gantry system versus the Straddle Carrier system at the Durban Container Terminal. Available cost data was sourced from 2012 and converted into current currency values using compound interest formulae and cross checking with an inflation calculator. There are slight variances in the cost comparisons. When the compound interest formulae was applied for the rand conversion, the results were much lower than using the online inflation calculator, however when the euro conversion is analysed, the compound interest formulae values are higher. The closest and most accurate value would be the online inflation calculator. It is for this reason the data obtained from the online inflation calculator was used in the final summary. Although the cost to operate the RTG is slightly higher than the SC because of the combined use of TTUs, the outputs in adopting the RTG system is much more efficient. Although the purchase costs for an RTG is higher, the maintenance cost for a SC is quite substantial compared to an RTG (see table 5.2). One of the issues Transnet is facing is the huge maintenance costs (Ports Regulator of South Africa, 2020).

Table 5.2: Summary of cost comparisons-RTG versus SC

Equipment	Labour costs (ZAR)	Purchase costs (ZAR)	Maintenance costs (ZAR)
SC (1 over 3)	166.14	15,264,744.43	599,34
RTG	240.7	27,315,858.45	345,47

5.3. Recommendations

The following recommendations are made as a result of the study.

5.3.1. Adopt a complete RTG system for the DCT

The study fully substantiates the recommendation of the DCT, Pier 2 adopting an RTG system to boost performance and to reduce port congestion. This is just a preliminary investigation and other reasons for port congestion do exist, however this study was limited to port equipment at the DCT.

5.3.2. Fully utilise the Ship-to-Shore Cranes

In order for the port to achieve maximum efficiency levels, all supporting infrastructure, including the ZPMC STS cranes need to be fully operational at all times. Terminal operators will need to ensure measures are in place to alleviate downtime and manage maintenance plans accordingly. In the DCT the tandem lift ZPMC STS cranes have the ability to lift two 40-foot or four 20-foot containers simultaneously, however this benefit will need to be fully exploited to achieve maximum crane outputs. When staff are fully trained and equipped with the skills to operate the STS cranes larger vessels can be offloaded quicker and the dwelling time will be significantly reduced.

5.3.3. Customer notification system

The port of Yokohoma introduced a customer notification system that updates customers on the latest information regarding port disruptions such as labour issues, adverse weather conditions delaying operations, congestion and customs issues (Yokohama Port Corporation, 2020). A similar system, adapted for the DCT, will allow time estimates for resolution to allow customers to plan accordingly and allow the port to cope with the upsurge in container movement and sudden interruptions.

5.4. Recommendations for Future Studies

5.4.1. Redesigning the terminal layout

An alternative to upgrading the port is to redesign it. This option is less costly and if designed correctly, will maximise terminal capacity. Redesigning the terminal will assist in increasing terminal capacity and reducing cargo dwell time at the port. Yard space will then be used efficiently, eliminating the constant need to reshuffle containers. A further study is required in this area as there is opportunity to improve productivity through redesigning.

5.4.2. Wind mitigation measures

Wind mitigation seemed to be the most common theme that was highlighted when it came to poor results and TPT should investigate the use of anti-sway and far-reaching technology for larger vessels. When cranes experience adverse weather conditions they are forced to shut down as it poses a safety risk and this results in inefficiencies. The anti-sway system will eliminate this problem.

5.4.3. Back of port container warehousing- Extended gate concept

This is a concept where the terminal strategically extends its hinterland services beyond its gate. It adopts a horizontal and vertical integration for services outside the port's gates. The purpose of this concept is to ease port congestion, noise, and air pollution whilst at the same time improve customer experience (Notteboom, et al., 2021).

5.4.4. Automation of the DCT

Modern ports are seizing opportunities to automate ports either partially or in their entire operation to increase performance and to ensure they remain competitive. Automation will reduce operating costs and increase production outputs. Safety is another benefit that will result from automating terminals (Alho, et al., 2012). Terminals that are automated can operate unmanned all day and all year in almost any weather condition and will increase revenue and smoother operations (Alho, et al., 2012).

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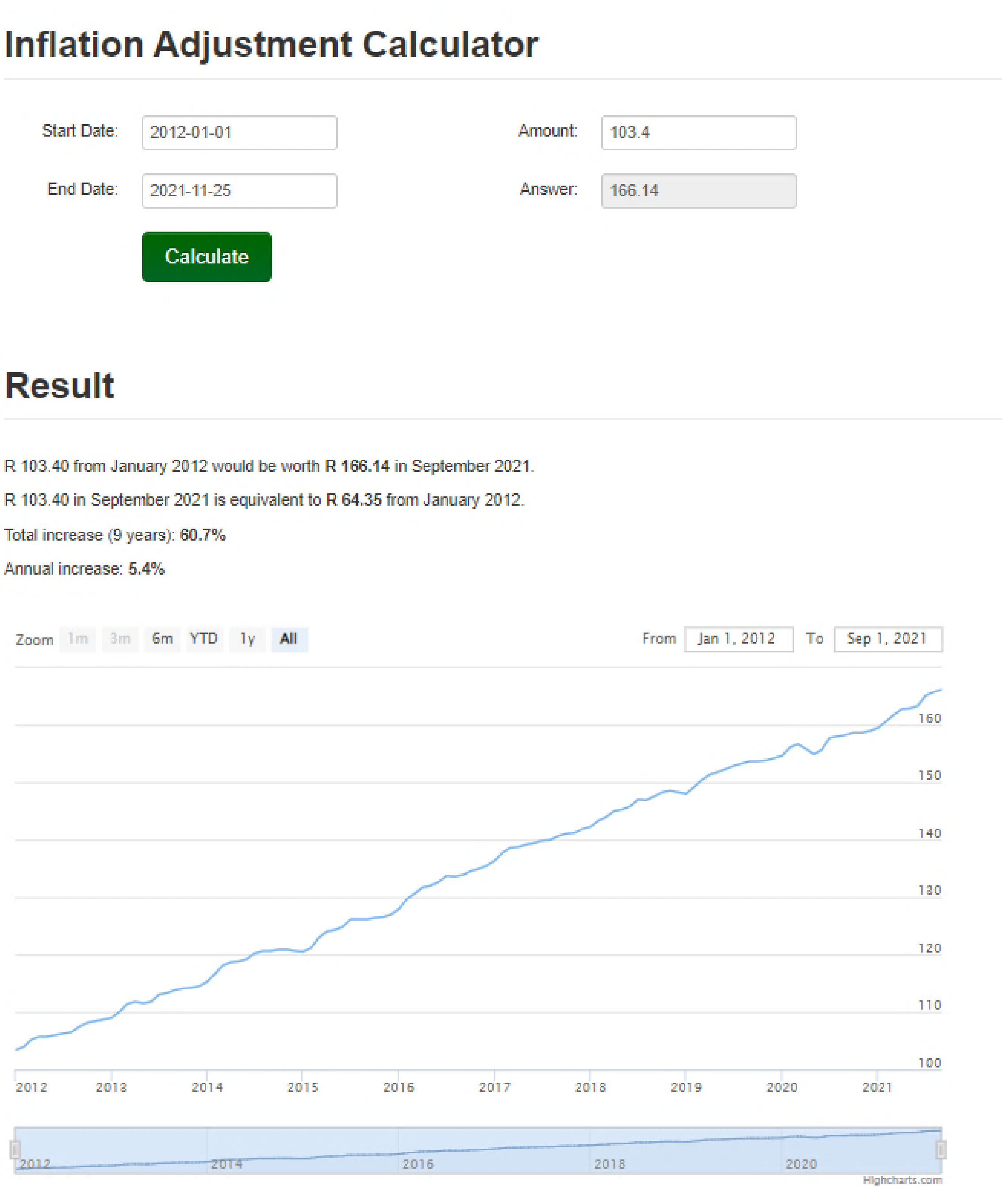
APPENDIX 1: SC CONTAINER MOVEMENT DATA

SC Name	Total Time Wasted	SC Name	Total Movements/7.75hrs	First Lift
SC133	00 Hrs:10 min	SC133	30	2019/08/28 16:52
SC102	00 Hrs:52 min	SC102	44	2019/08/28 14:42
SC125	01 Hrs:51 min	SC125	11	2019/08/28 17:10
SC136	00 Hrs:24 min	SC136	35	2019/08/28 16:08
SC137	01 Hrs:21 min	SC137	59	2019/08/28 14:53
SC140	01 Hrs:10 min	SC140	59	2019/08/28 14:47
SC141	01 Hrs:26 min	SC141	48	2019/08/28 14:42
SC143	01 Hrs:19 min	SC143	53	2019/08/28 14:59
SC144	01 Hrs:55 min	SC144	31	2019/08/28 17:24
SC145	02 Hrs:14 min	SC145	10	2019/08/28 14:48
SC68	01 Hrs:30 min	SC68	58	2019/08/28 14:50
SC70	01 Hrs:05 min	SC70	45	2019/08/28 14:43
SC72	00 Hrs:29 min	SC72	26	2019/08/28 18:07
SC79	00 Hrs:40 min	SC79	76	2019/08/28 14:47
SC80	01 Hrs:33 min	SC80	66	2019/08/28 14:33

SC82	**01 Hrs:22 min**	**SC82**	**47**	2019/08/28 14:41
SC84	**01 Hrs:23 min**	**SC84**	**6**	2019/08/28 15:14
SC86	**01 Hrs:17 min**	**SC86**	**47**	2019/08/28 14:39
SC91	**01 Hrs:33 min**	**SC91**	**50**	2019/08/28 14:52
SC92	**02 Hrs:08 min**	**SC92**	**55**	2019/08/28 15:21
SC99	**00 Hrs:52 min**	**SC99**	**56**	2019/08/28 14:41
SC105	**01 Hrs:32 min**	**SC105**	**48**	2019/08/28 15:14
SC131	**01 Hrs:23 min**	**SC131**	**62**	2019/08/28 14:35

Source: (Transnet Port Terminals, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS



Source: (SA Inflation Calculator, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)

Inflation Adjustment Calculator

Start Date: 2012-01-01

Amount: 149.8

End Date: 2021-11-25

Answer: 240.70

Calculate

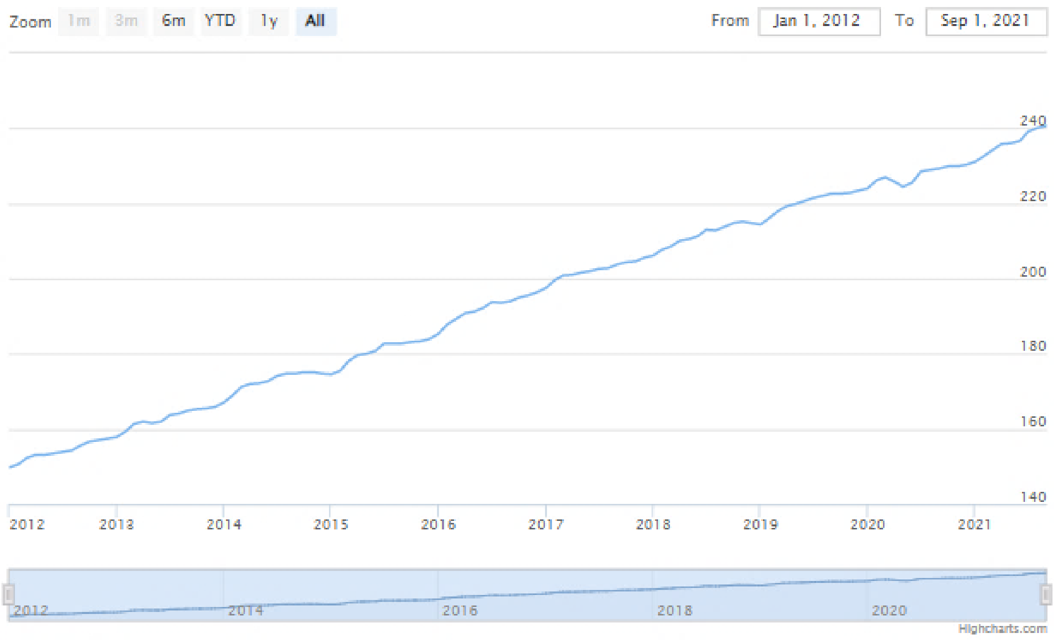
Result

R 149.80 from January 2012 would be worth **R 240.70** in September 2021.

R 149.80 in September 2021 is equivalent to **R 93.23** from January 2012.

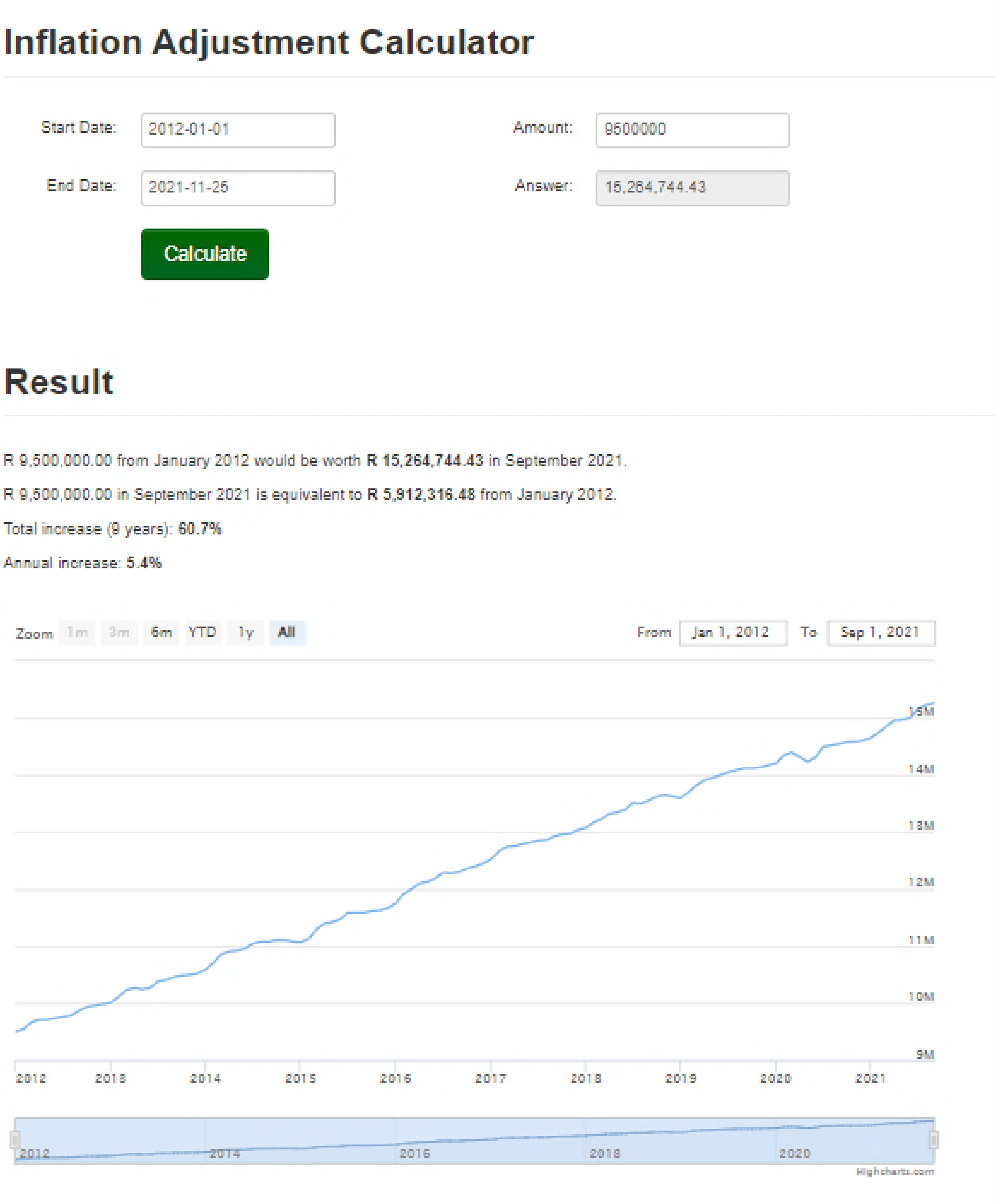
Total increase (9 years): **60.7%**

Annual increase: **5.4%**



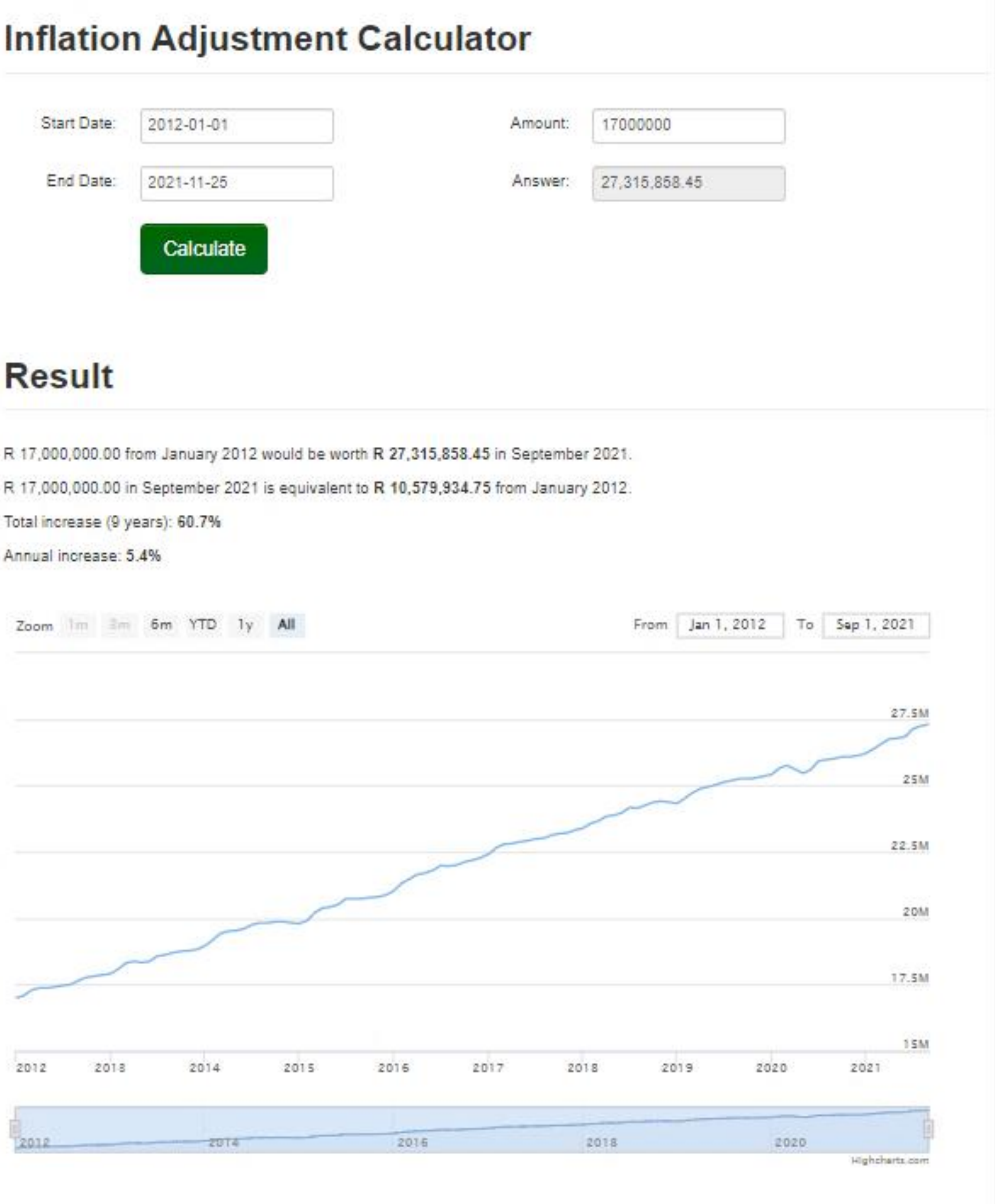
Source: (SA Inflation Calculator, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)



Source: (SA Inflation Calculator, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)



Source: (SA Inflation Calculator, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)

11/25/21, 8:17 PM Value of 2012 Euro today - Inflation calculator

INFLATIONTOOL

Value of 2012 Euro today

Calculator

Standard mode | Advanced mode

Amount (€)

790000

Start year

2012

End year

2021

Calculate

€790,000 in 2012

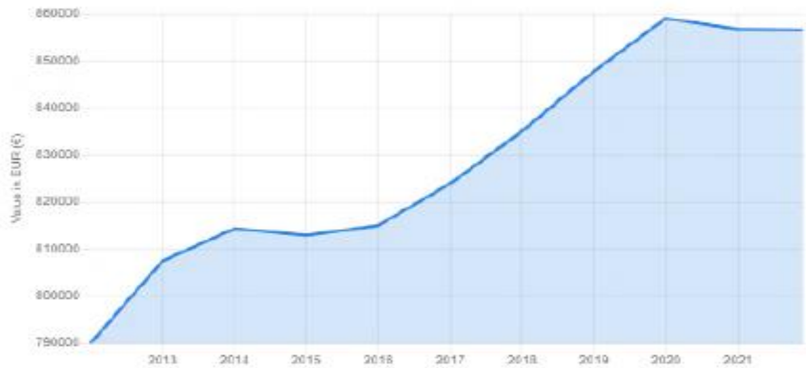
⬇

€856,571.57 in 2021

The inflation rate in the eurozone between 2012 and today has been 8.43%, which translates into a total increase of €66,571.57. This means that **790,000 euro in 2012 are equivalent to 856,571.57 euro in 2021**. In other words, the purchasing power of €790,000 in 2012 equals €856,571.57 today. The average annual inflation rate has been 0.81%.

Inflation timeline in the eurozone (2012-2021)

The following chart depicts the equivalence of €790,000 throughout the years due to inflation and CPI changes. All values are equivalent in terms of purchasing power, which means that for each year the same goods or services could be bought with the indicated amount of money.



Source: (Tool, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)

11/25/21, 8:25 PM — Value of 2012 Euro today - Inflation calculator

INFLATIONTOOL

Value of 2012 Euro today

Calculator

Standard mode | Advanced mode

Amount (€)

1400000

Start year

2012

End year

2021

Calculate

€1,400,000 in 2012

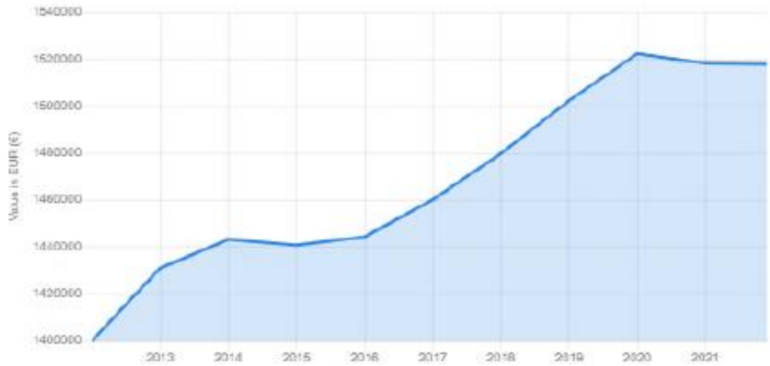
⬇

€1,517,974.94 in 2021

The inflation rate in the eurozone between 2012 and today has been 8.43%, which translates into a total increase of €117,974.94. This means that **1,400,000 euro in 2012 are equivalent to 1,517,974.94 euro in 2021**. In other words, the purchasing power of €1,400,000 in 2012 equals €1,517,974.94 today. The average annual inflation rate has been 0.81%.

Inflation timeline in the eurozone (2012-2021)

The following chart depicts the equivalence of €1,400,000 throughout the years due to inflation and CPI changes. All values are equivalent in terms of purchasing power, which means that for each year the same goods or services could be bought with the indicated amount of money.



Source: (Tool, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)

11/25/21, 8:20 PM Value of 2012 Euro today - Inflation calculator

INFLATIONTOOL

Value of 2012 Euro today

Calculator

Standard mode | Advanced mode

Amount (€)

750000

Start year

2012

End year

2021

Calculate

€750,000 in 2012

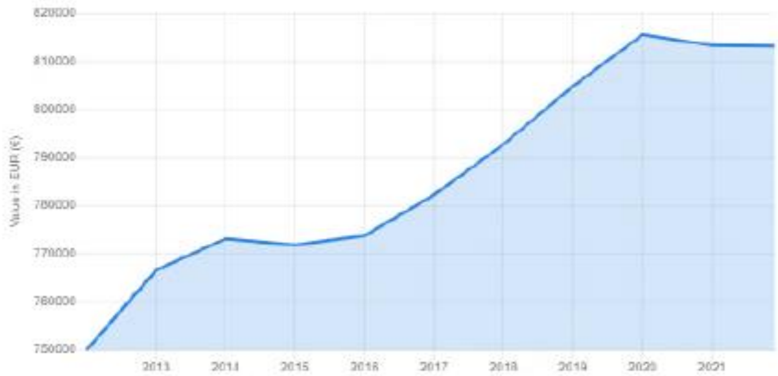
↓

€813,200.86 in 2021

The inflation rate in the eurozone between 2012 and today has been 8.43%, which translates into a total increase of €63,200.86. This means that **750,000 euro in 2012 are equivalent to 813,200.86 euro in 2021**. In other words, the purchasing power of €750,000 in 2012 equals €813,200.86 today. The average annual inflation rate has been 0.81%.

Inflation timeline in the eurozone (2012-2021)

The following chart depicts the equivalence of €750,000 throughout the years due to inflation and CPI changes. All values are equivalent in terms of purchasing power, which means that for each year the same goods or services could be bought with the indicated amount of money.



Source: (Tool, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)

11/25/21, 8:27 PM Value of 2012 Euro today - Inflation calculator

INFLATIONTOOL

Value of 2012 Euro today

Calculator

Standard mode | Advanced mode

Amount (€)

1350000

Start year

2012

End year

2021

Calculate

€1,350,000 in 2012

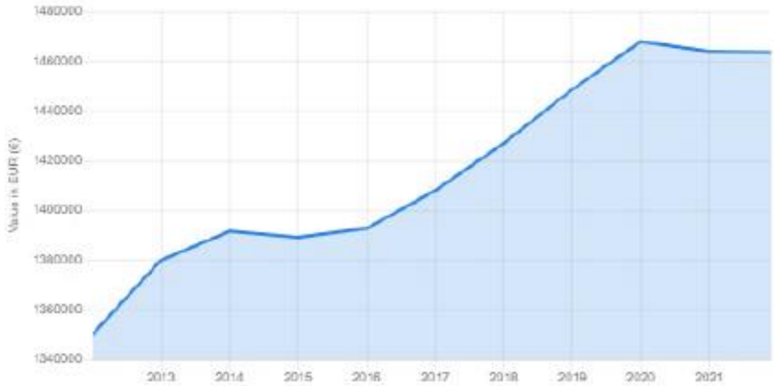
⬇

€1,463,761.55 in 2021

The inflation rate in the eurozone between 2012 and today has been 8.43%, which translates into a total increase of €113,761.55. This means that **1,350,000 euro in 2012 are equivalent to 1,463,761.55 euro in 2021**. In other words, the purchasing power of €1,350,000 in 2012 equals €1,463,761.55 today. The average annual inflation rate has been 0.81%.

Inflation timeline in the eurozone (2012-2021)

The following chart depicts the equivalence of €1,350,000 throughout the years due to inflation and CPI changes. All values are equivalent in terms of purchasing power, which means that for each year the same goods or services could be bought with the indicated amount of money.



Source: (Tool, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)

Inflation Adjustment Calculator

Start Date: 2012-01-01

Amount: 373

End Date: 2021-11-25

Answer: 599.34

Calculate

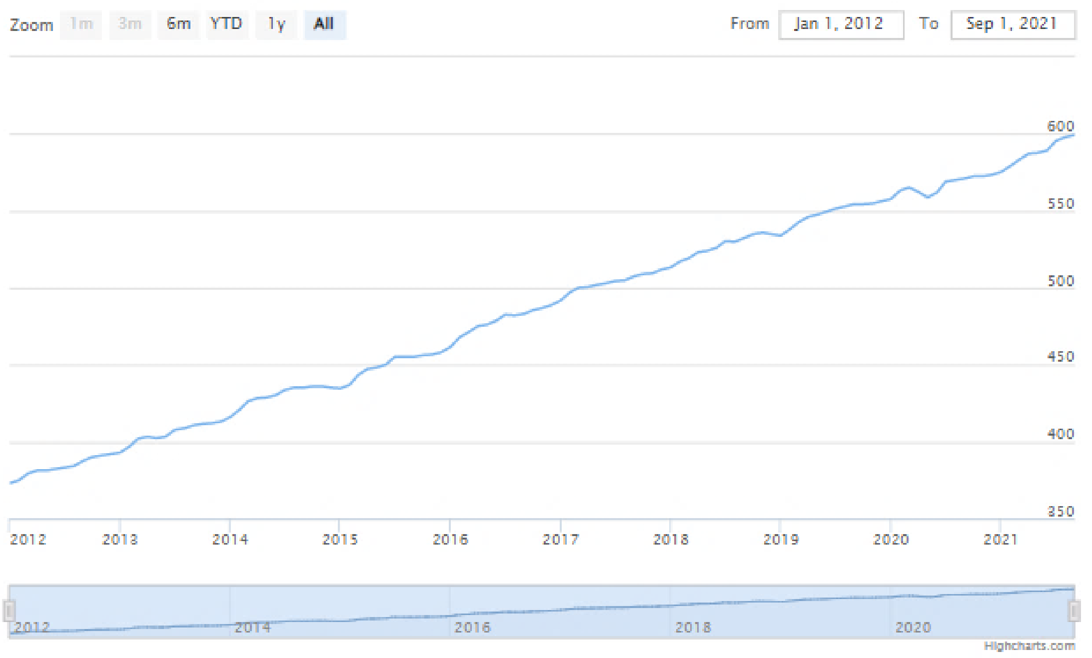
Result

R 373.00 from January 2012 would be worth **R 599.34** in September 2021.

R 373.00 in September 2021 is equivalent to **R 232.14** from January 2012.

Total increase (9 years): **60.7%**

Annual increase: **5.4%**



Source: (Tool, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)

Inflation Adjustment Calculator

Start Date: 2012-01-01

Amount: 215

End Date: 2021-11-25

Answer: 345.47

Calculate

Result

R 215.00 from January 2012 would be worth **R 345.47** in September 2021.

R 215.00 in September 2021 is equivalent to **R 133.81** from January 2012.

Total increase (9 years): **60.7%**

Annual increase: **5.4%**

Source: (Tool, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)

11/25/21, 8:40 PM Value of 2012 Euro today - Inflation calculator

INFLATIONTOOL

Value of 2012 Euro today

Calculator

Standard mode | Advanced mode

Amount (€)

31

Start year

2012

End year

2021

Calculate

€31 in 2012

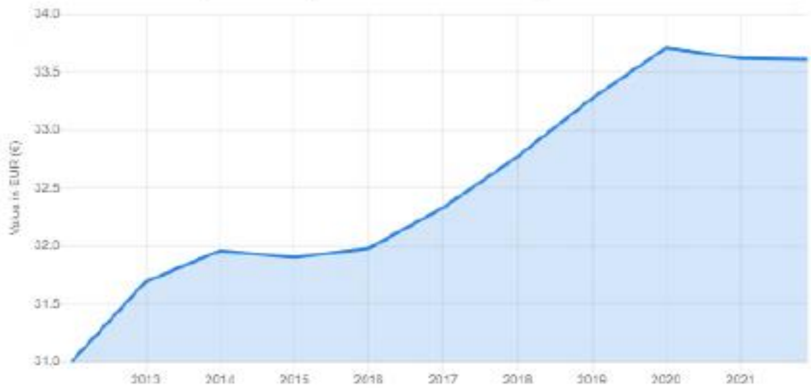
⬇

€33.61 in 2021

The inflation rate in the eurozone between 2012 and today has been 8.43%, which translates into a total increase of €2.61. This means that **31 euro in 2012 are equivalent to 33.61 euro in 2021**. In other words, the purchasing power of €31 in 2012 equals €33.61 today. The average annual inflation rate has been 0.81%.

Inflation timeline in the eurozone (2012-2021)

The following chart depicts the equivalence of €31 throughout the years due to inflation and CPI changes. All values are equivalent in terms of purchasing power, which means that for each year the same goods or services could be bought with the indicated amount of money.



Source: (Tool, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)

11/25/21, 6:39 PM Value of 2012 Euro today - Inflation calculator

INFLATIONTOOL

Value of 2012 Euro today

Calculator

Standard mode | Advanced mode

Amount (€)

18

Start year

2012

End year

2021

Calculate

€18 in 2012

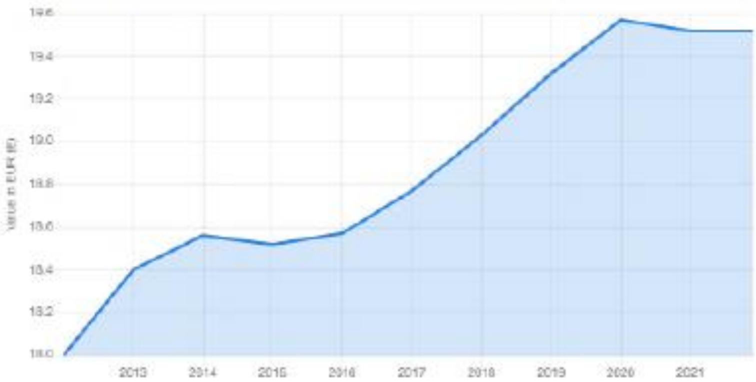
⬇

€19.52 in 2021

The inflation rate in the eurozone between 2012 and today has been 8.43%, which translates into a total increase of €1.52. This means that **18 euro in 2012 are equivalent to 19.52 euro in 2021**. In other words, the purchasing power of €18 in 2012 equals €19.52 today. The average annual inflation rate has been 0.81%.

Inflation timeline in the eurozone (2012-2021)

The following chart depicts the equivalence of €18 throughout the years due to inflation and CPI changes. All values are equivalent in terms of purchasing power, which means that for each year the same goods or services could be bought with the indicated amount of money.



Source: (Tool, 2021)

APPENDIX 2: INFLATION CALCULATOR RESULTS (continued)

11/25/21, 8:41 PM Value of 2012 Euro today - Inflation calculator

INFLATIONTOOL

Value of 2012 Euro today

Calculator

Standard mode | Advanced mode

Amount (€)

16

Start year

2012

End year

2021

Calculate

€16 in 2012

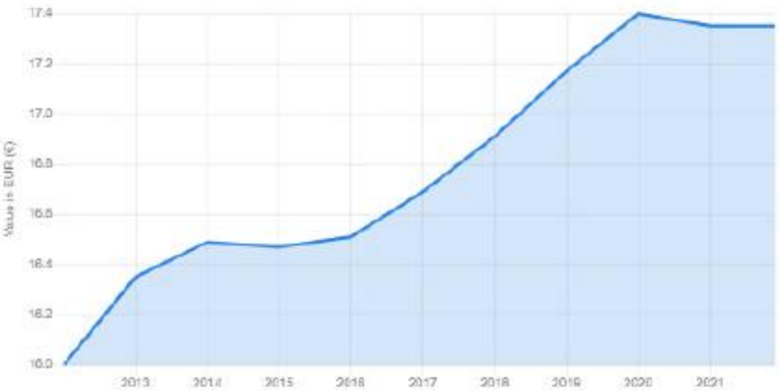
⬇

€17.35 in 2021

The inflation rate in the eurozone between 2012 and today has been 8.43%, which translates into a total increase of €1.35. This means that **16 euro in 2012 are equivalent to 17.35 euro in 2021**. In other words, the purchasing power of €16 in 2012 equals €17.35 today. The average annual inflation rate has been 0.81%.

Inflation timeline in the eurozone (2012-2021)

The following chart depicts the equivalence of €16 throughout the years due to inflation and CPI changes. All values are equivalent in terms of purchasing power, which means that for each year the same goods or services could be bought with the indicated amount of money.



Source: (Tool, 2021)

APPENDIX 3: WORLD BANK REPORT

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
YOKOHAMA	1	-5.995	YOKOHAMA	1	130
KING ABDULLAH PORT	2	-5.684	KING ABDULLAH PORT	2	114
CHIWAN	3	-5.202	QINGDAO	3	102
GUANGZHOU	4	-5.162	KAOHSIUNG	4	99
KAOHSIUNG	5	-4.669	SHEKOU	5	94
SALALAH	6	-4.531	GUANGZHOU	6	92
HONG KONG, HONG KONG SAR, CHINA	7	-4.276	HONG KONG, HONG KONG SAR, CHINA	7	89
QINGDAO	8	-3.860	ZHOUSHAN	8	88
SHEKOU	9	-3.726	SALALAH	9	87
ALGECIRAS	10	-3.597	YANGSHAN	10	87
BEIRUT	11	-3.378	TANJUNG PELEPAS	11	86
SHIMIZU	12	-3.361	SINGAPORE	12	83
TANJUNG PELEPAS	13	-3.342	NINGBO	13	83
PORT KLANG	14	-3.334	PORT KLANG	14	78
SINGAPORE	15	-3.279	TANGER MEDITERRANEAN	15	76
NAGOYA	16	-3.251	TAIPEI, TAIWAN, CHINA	16	75
COLOMBO	17	-3.209	YANTIAN	17	73
SINES	18	-3.183	CAI MEP	18	68
KOBE	19	-3.127	DALIAN	19	66
ZHOUSHAN	20	-2.963	TIANJIN	20	64
JUBAIL	21	-2.898	FUZHOU	21	61
YEOSU	22	-2.831	KHALIFA PORT	22	60
FUZHOU	23	-2.829	LAZARO CARDENAS	23	60
NINGBO	24	-2.805	SHIMIZU	24	59
LAZARO CARDENAS	25	-2.798	HALIFAX	25	59
KHALIFA PORT	26	-2.795	XIAMEN	26	58
TANGER MEDITERRANEAN	27	-2.769	CHIWAN	27	58
YANGSHAN	28	-2.733	SINES	28	56

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
YANTIAN	29	−2.724	MAWAN	29	56
TAIPEI, TAIWAN, CHINA	30	−2.681	AGUADULCE (COLOMBIA)	30	56
DA CHAN BAY TERMINAL ONE	31	−2.588	LIANYUNGANG	31	54
MAWAN	32	−2.557	ALGECIRAS	32	53
DALIAN	33	−2.506	COLOMBO	33	53
INCHEON	34	−2.422	CARTAGENA (COLOMBIA)	34	52
TOKYO	35	−2.418	DA CHAN BAY TERMINAL ONE	35	52
HAMAD PORT	36	−2.411	BUSAN	36	51
LIANYUNGANG	37	−2.375	INCHEON	37	51
PIPAVAV	38	−2.371	HAMAD PORT	38	51
HALIFAX	39	−2.365	PIPAVAV	39	48
CAUCEDO	40	−2.355	YEOSU	40	48
BREMERHAVEN	41	−2.265	AQABA	41	47
CARTAGENA (COLOMBIA)	42	−2.185	JEDDAH	42	46
SALVADOR	43	−2.051	AARHUS	43	43
AARHUS	44	−2.036	MUNDRA	44	43
AGUADULCE (COLOMBIA)	45	−2.035	MAGDALLA	45	42
CAI LAN	46	−1.991	BARCELONA	46	42
HAIPHONG	47	−1.953	RIO GRANDE (BRAZIL)	47	42
MAGDALLA	48	−1.943	NAGOYA	48	41
CAI MEP	49	−1.932	SHANGHAI	49	41
MUNDRA	50	−1.902	KOBE	50	39
GEMLIK	51	−1.892	LAEM CHABANG	51	39
BUSAN	52	−1.887	WILHELMSHAVEN	52	39
JEDDAH	53	−1.862	CHARLESTON	53	38
DILISKELESI	54	−1.842	TOKYO	54	38
LAEM CHABANG	55	−1.807	SALVADOR	55	35
JAWAHARLAL NEHRU PORT	56	−1.786	CALLAO	56	34
AMBARLI	57	−1.783	JUBAIL	57	33
PORT SAID	58	−1.652	YARIMCA	58	33

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
PECEM	59	-1.647	JEBEL ALI	59	33
AQABA	60	-1.594	HAIPHONG	60	33
DJIBOUTI	61	-1.590	AMBARLI	61	32
XIAMEN	62	-1.541	BEIRUT	62	32
SHANGHAI	63	-1.532	JAWAHARLAL NEHRU PORT	63	31
TANJUNG PRIOK	64	-1.521	KEELUNG	64	31
KEELUNG	65	-1.509	ANTWERP	65	31
TRIPOLI (LEBANON)	66	-1.497	TANJUNG PRIOK	66	31
OSAKA	67	-1.440	WILMINGTON (NORTH CAROLINA, USA)	67	30
YARIMCA	68	-1.393	CAUCEDO	68	30
ITAPOA	*69	-1.376	SOHAR	69	29
SANTOS	70	-1.376	PORT SAID	70	29
SOHAR	71	-1.375	BUENAVENTURA	71	29
BUENAVENTURA	72	-1.353	SANTOS	72	28
SEPETIBA	73	-1.338	BOSTON (USA)	73	27
RIO GRANDE (BRAZIL)	74	-1.332	CAI LAN	74	27
KARACHI	75	-1.292	DILISKELESI	75	27
BARCELONA	76	-1.224	TRIPOLI (LEBANON)	76	27
POSORJA	77	-1.192	OSAKA	77	27
OSLO	78	-1.192	BALBOA	78	27
QUY NHON	79	-1.163	GEMLIK	79	26
CAT LAI	80	-1.149	KARACHI	80	26
SUAPE	81	-1.129	YOKKAICHI	81	26
LONDON	82	-1.117	COLON	82	25
PHILADELPHIA	83	-1.080	MERSIN	83	25
DANANG	84	-1.053	SEPETIBA	84	24
PORT OF VIRGINIA	85	-1.044	BREMERHAVEN	85	24
ANTWERP	86	-1.011	PECEM	86	23
ZEEBRUGGE	87	-0.988	PHILADELPHIA	87	23
SANTA CRUZ DE TENERIFE	88	-0.970	ITAPOA	88	23

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
NEW YORK & NEW JERSEY	89	−0.969	PIRAEUS	89	23
GDYNIA	90	−0.942	ROTTERDAM	90	22
SHANTOU	91	−0.935	OSLO	91	20
NAHA	92	−0.883	DAMMAM	92	20
PIRAEUS	93	−0.859	DJIBOUTI	93	19
PUERTO LIMON	94	−0.858	PAITA	94	19
CHARLESTON	95	−0.820	SANTA CRUZ DE TENERIFE	95	19
PORT AKDENIZ	96	−0.820	SAVANNAH	96	18
TAICHUNG	97	−0.814	VERACRUZ	97	18
ULSAN	98	−0.811	ALTAMIRA	98	17
HAKATA	99	−0.758	JACKSONVILLE	99	17
COLON	100	−0.752	TAURANGA	100	17
MOBILE	101	−0.745	MARSAXLOKK	101	16
DAMMAM	102	−0.737	VALPARAISO	102	16
PUERTO BARRIOS	103	−0.731	GDYNIA	103	16
NOUMEA	104	−0.721	QUY NHON	104	16
PAITA	105	−0.705	ITAJAI	105	16
MARSAXLOKK	106	−0.698	PUERTO LIMON	106	16
YOKKAICHI	107	−0.692	PARANAGUA	107	16
MALAGA	108	−0.690	JOHOR	108	15
OMAEZAKI	109	−0.680	CAT LAI	109	15
JOHOR	110	−0.669	PORT OF VIRGINIA	110	15
MOJI	111	−0.663	NAHA	111	15
BATANGAS	112	−0.663	FORT-DE-FRANCE	112	15
BOSTON (USA)	113	−0.631	POINTE-A-PITRE	113	14
BALBOA	114	−0.625	MIAMI	114	14
SIAM SEAPORT	115	−0.613	DANANG	115	13
ROTTERDAM	116	−0.611	HAKATA	116	12
BURGAS	117	−0.611	SHANTOU	117	12
DUNKIRK	118	−0.611	AUCKLAND	118	12

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
WILHELMSHAVEN	119	-0.598	BALTIMORE (USA)	119	12
SANTA MARTA	120	-0.589	DAKAR	120	12
TARRAGONA	121	-0.588	OMAEZAKI	121	11
CAGAYAN DE ORO	122	-0.582	PUERTO BARRIOS	122	11
AUCKLAND	123	-0.562	MOJI	123	11
NORRKOPING	124	-0.553	NOUMEA	124	11
FORT-DE-FRANCE	125	-0.543	ENSENADA	125	11
GUSTAVIA	126	-0.528	POSORJA	126	10
QINZHOU	127	-0.523	NEW YORK & NEW JERSEY	127	10
FREDERICIA	128	-0.493	CAGAYAN DE ORO	128	10
COPENHAGEN	129	-0.471	MALAGA	129	10
TUTICORIN	130	-0.469	SUAPE	130	10
PUERTO CORTES	131	-0.468	GDANSK	131	10
PORT BRONKA	132	-0.454	MOBILE	132	10
TANJUNG EMAS	133	-0.433	BURGAS	133	9
CHIBA	134	-0.418	TARRAGONA	134	9
SHIBUSHI	135	-0.382	NORRKOPING	135	9
ENSENADA	136	-0.378	SIAM SEAPORT	136	9
SAIGON	137	-0.375	SANTA MARTA	137	9
BALTIMORE (USA)	138	-0.368	FREDERICIA	138	9
PENANG	139	-0.367	TUTICORIN	139	8
KHALIFA BIN SALMAN	140	-0.356	CEBU	140	8
PUERTO BOLIVAR (ECUADOR)	141	-0.347	WELLINGTON	141	8
GIOIA TAURO	142	-0.344	COPENHAGEN	142	8
DAVAO	143	-0.341	TANJUNG EMAS	143	8
CASTELLON	144	-0.339	BATANGAS	144	8
ALTAMIRA	145	-0.324	MANZANILLO (MEXICO)	145	8
RIO HAINA	146	-0.322	TAICHUNG	146	8
POINTE-A-PITRE	147	-0.319	PORT EVERGLADES	147	8

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
SAN JUAN	148	−0.303	QINZHOU	148	8
SHUAIBA	149	−0.301	PUERTO CORTES	149	7
NAPLES	150	−0.280	CHIBA	150	7
CEBU	151	−0.275	SAIGON	151	7
FREEPORT (BAHAMAS)	152	−0.271	PORT BRONKA	152	7
TANJUNG PERAK	153	−0.269	HAIFA	153	6
PUERTO QUETZAL	154	−0.269	PORT AKDENIZ	154	6
WILMINGTON (NORTH CAROLINA, USA)	155	−0.237	PUERTO BOLIVAR (ECUADOR)	155	6
VIGO	156	−0.233	DAVAO	156	6
PAPEETE	157	−0.227	CASTELLON	157	6
VERACRUZ	158	−0.219	CORONEL	158	6
SAN ANTONIO	159	−0.218	VIGO	159	5
SHUWAIKH	160	−0.216	RIO HAINA	160	5
JACKSONVILLE	161	−0.215	GUSTAVIA	161	5
CALDERA (COSTA RICA)	162	−0.206	KHALIFA BIN SALMAN	162	5
BELL BAY	163	−0.205	BELL BAY	163	5
HELSINGBORG	164	−0.196	SAN JUAN	164	5
POINT LISAS PORTS	165	−0.182	CALDERA (COSTA RICA)	165	4
BORUSAN	166	−0.163	SHIBUSHI	166	4
KALININGRAD	167	−0.159	PAPEETE	167	4
CARTAGENA (SPAIN)	168	−0.153	SALERNO	168	3
BARRANQUILLA	169	−0.137	BARRANQUILLA	169	3
CRISTOBAL	170	−0.135	YUZHNY	170	3
LATAKIA	171	−0.135	HELSINGBORG	171	3
PALERMO	172	−0.125	TANJUNG PERAK	172	3
NASSAU	173	−0.109	SAN ANTONIO	173	3
SALERNO	174	−0.080	PUERTO QUETZAL	174	2
CIVITAVECCHIA	175	−0.072	ULSAN	175	2
WELLINGTON	176	−0.049	RAVENNA	176	2

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
DAKAR	177	−0.031	POINT LISAS PORTS	177	2
HERAKLION	178	−0.030	LIMASSOL	178	1
RAVENNA	179	−0.025	CARTAGENA (SPAIN)	179	1
CATANIA	180	−0.021	LONDON	180	1
LARVIK	181	−0.015	CIVITAVECCHIA	181	1
PORT FREEPORT	182	−0.008	PALERMO	182	1
VILA DO CONDE	183	0.000	ANCONA	183	0
VITORIA	183	0.000	LARVIK	184	0
OITA	185	0.004	HERAKLION	185	0
KRISTIANSAND	186	0.008	LYTTELTON	186	0
GIJON	187	0.013	LATAKIA	187	0
LYTTELTON	188	0.034	OITA	188	0
ODESSA	189	0.046	NASSAU	189	0
DURRES	190	0.057	CATANIA	190	0
MARIEL	191	0.057	HAMBURG	191	0
LIMASSOL	192	0.063	PHILIPSBURG	192	0
ANCONA	193	0.067	PORT FREEPORT	193	0
PHILIPSBURG	194	0.090	KRISTIANSAND	194	−1
MUUGA—PORT OF TALLINN	195	0.092	BORUSAN	195	−1
VARNA	196	0.094	GIJON	196	−1
BELAWAN	197	0.104	MARIEL	197	−1
YUZHNY	198	0.105	MUUGA—PORT OF TALLINN	198	−1
RIO DE JANEIRO	199	0.126	SHUWAIKH	199	−1
MIAMI	200	0.149	TAMPA	200	−1
BARI	201	0.167	SANTO TOMAS DE CASTILLA	201	−2
VLADIVOSTOK	202	0.182	BELAWAN	202	−2
SANTO TOMAS DE CASTILLA	203	0.185	BARI	203	−2
VOSTOCHNY	204	0.192	TOMAKOMAI	204	−2
TOMAKOMAI	205	0.194	MATADI	205	−2

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
LEIXOES	206	0.201	NELSON	206	-2
ARICA	207	0.211	NAPLES	207	-2
PORT EVERGLADES	208	0.213	RAUMA	208	-3
MATADI	209	0.238	POTI	209	-3
NELSON	210	0.240	LEIXOES	210	-3
SAINT JOHN	211	0.241	PORT MORESBY	211	-4
TRIESTE	212	0.241	GIOIA TAURO	212	-4
GAVLE	213	0.242	VARNA	213	-4
MERSIN	214	0.275	GAVLE	214	-4
POTI	215	0.278	NEW MANGALORE	215	-4
TEESPORT	216	0.303	FREETOWN	216	-5
PORT MORESBY	217	0.307	ABIDJAN	217	-5
TIANJIN	218	0.310	VITORIA	218	-5
TAURANGA	219	0.333	TOAMASINA	219	-5
FREETOWN	220	0.350	KALININGRAD	220	-5
SAN VICENTE	221	0.361	ALEXANDRIA (EGYPT)	221	-5
VALPARAISO	222	0.365	GRANGEMOUTH	222	-6
BERBERA	223	0.368	RIGA	223	-6
BILBAO	224	0.384	FREEPORT (BAHAMAS)	224	-6
HAIFA	225	0.384	ZEEBRUGGE	225	-6
TAMPA	226	0.411	SAN VICENTE	226	-7
TOAMASINA	227	0.433	PENANG	227	-7
ABIDJAN	228	0.439	SHUAIBA	228	-7
RAUMA	229	0.439	PANJANG	229	-7
CHORNOMORSK	230	0.449	KOPER	230	-7
CALLAO	231	0.450	DURRES	231	-7
NEW MANGALORE	232	0.451	APRA HARBOR	232	-7
UMM QASR	233	0.452	COTONOU	233	-8
ALEXANDRIA (EGYPT)	234	0.482	BRISBANE	234	-8

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
RIGA	235	0.482	TAKORADI	235	−8
SEATTLE	236	0.487	PUERTO PROGRESO	236	−8
VANCOUVER (CANADA)	237	0.499	NEW ORLEANS	237	−9
CONAKRY	238	0.505	TEESPORT	238	−9
EL DEKHEILA	239	0.509	BLUFF	239	−9
NAPIER	240	0.513	VLADIVOSTOK	240	−9
LA SPEZIA	241	0.548	VILA DO CONDE	241	−9
KOTKA	242	0.558	HOUSTON	242	−9
GRANGEMOUTH	243	0.560	BILBAO	243	−10
COTONOU	244	0.562	KOTKA	244	−10
OWENDO	245	0.563	BERBERA	245	−10
BRISBANE	246	0.569	NANTES-ST NAZAIRE	246	−10
PANJANG	247	0.573	ARICA	247	−11
APRA HARBOR	248	0.610	PORT OF SPAIN	248	−11
ACAJUTLA	249	0.640	ACAJUTLA	249	−11
DAMIETTA	250	0.650	CONAKRY	250	−11
LIVORNO	251	0.658	SAINT JOHN	251	−12
PARANAGUA	252	0.659	DUBLIN	252	−12
CONSTANTZA	253	0.660	STOCKHOLM	253	−13
TAKORADI	254	0.683	MALABO	254	−14
NANTES-ST NAZAIRE	255	0.693	VOSTOCHNY	255	−14
LIRQUEN	256	0.708	EL DEKHEILA	256	−14
BLUFF	257	0.731	CRISTOBAL	257	−14
LE HAVRE	258	0.746	ST PETERSBURG	258	−14
PUERTO PROGRESO	259	0.750	BANGKOK	259	−15
PORT OF SPAIN	260	0.775	MOGADISCIO	260	−15
TEMA	261	0.782	NAPIER	261	−15
DUBLIN	262	0.839	LIRQUEN	262	−15
MALABO	263	0.859	SEATTLE	263	−16

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
HUENEME	264	0.862	TRIESTE	264	-16
NEW ORLEANS	265	0.865	ODESSA	265	-17
HOUSTON	266	0.878	KLAIPEDA	266	-17
STOCKHOLM	267	0.915	AGADIR	267	-17
BEIRA	268	0.919	CASABLANCA	268	-17
MANAUS	269	0.967	IZMIR	269	-18
ONNE	270	0.994	MANAUS	270	-18
BANGKOK	271	1.024	OWENDO	271	-18
ISKENDERUN	272	1.024	ISKENDERUN	272	-18
MONTEVIDEO	273	1.033	HUENEME	273	-19
VENICE	274	1.042	CHORNOMORSK	274	-19
MANZANILLO (MEXICO)	275	1.070	BATUMI	275	-19
AGADIR	276	1.122	MANILA	276	-19
IZMIR	277	1.136	BRISTOL	277	-19
GENERAL SANTOS	278	1.148	LAE	278	-19
SAVANNAH	279	1.158	RIJEKA	279	-20
HAMBURG	280	1.176	SAMSUN	280	-20
MOGADISCIO	281	1.194	BEIRA	281	-21
CORONEL	282	1.203	GENERAL SANTOS	282	-21
VALENCIA	283	1.211	MONTREAL	283	-22
THESSALONIKI	284	1.229	THESSALONIKI	284	-22
MONTREAL	285	1.231	CONSTANTZA	285	-22
KINGSTON (JAMAICA)	286	1.283	KINGSTON (JAMAICA)	286	-23
LAE	287	1.314	KRIBI DEEP SEA PORT	287	-24
LOME	288	1.332	OTAGO HARBOUR	288	-24
MEJILLONES	289	1.381	LA SPEZIA	289	-24
SOUTHAMPTON	290	1.404	LIVORNO	290	-24
CASABLANCA	291	1.442	ONNE	291	-25
PORT VICTORIA	292	1.457	NOUAKCHOTT	292	-25

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
SOKHNA	293	1.459	SAN PEDRO (COTE D'IVOIRE)	293	-27
BRISTOL	294	1.462	UMM QASR	294	-27
NOUAKCHOTT	295	1.475	VENICE	295	-27
MUHAMMAD BIN QASIM	296	1.499	LA GUAIRA	296	-28
SAMSUN	297	1.502	DAMIETTA	297	-28
DOUALA	298	1.510	CHATTOGRAM	298	-28
MAPUTO	299	1.533	PORT VICTORIA	299	-28
NOVOROSSIYSK	300	1.626	LE HAVRE	300	-30
KLAIPEDA	301	1.635	NOVOROSSIYSK	301	-30
MELBOURNE	302	1.676	DOUALA	302	-31
KRIBI DEEP SEA PORT	303	1.701	VANCOUVER (CANADA)	303	-31
ST PETERSBURG	304	1.719	TIMARU	304	-32
LA GUAIRA	305	1.737	DUNKIRK	305	-33
CHATTOGRAM	306	1.809	MAPUTO	306	-33
WALVIS BAY	307	1.819	PUERTO CABELLO	307	-34
ITAJAI	308	1.828	VALENCIA	308	-34
PUERTO CABELLO	309	1.829	RIO DE JANEIRO	309	-35
SAVONA-VADO	310	1.897	BUENOS AIRES	310	-37
GDANSK	311	1.944	MEJILLONES	311	-38
RIJEKA	312	1.974	TEMA	312	-40
FELIXSTOWE	313	2.006	MELBOURNE	313	-40
OTAGO HARBOUR	314	2.023	SAVONA-VADO	314	-40
ALGIERS	315	2.076	ASHDOD	315	-42
BATUMI	316	2.175	MUHAMMAD BIN QASIM	316	-42
TIMARU	317	2.225	SOUTHAMPTON	317	-45
KOPER	318	2.237	ALGIERS	318	-49
SAN PEDRO (COTE D'IVOIRE)	319	2.267	FREMANTLE	319	-49
BUENOS AIRES	320	2.391	IQUIQUE	320	-54
GENOA	321	2.420	SOKHNA	321	-55
MANILA	322	2.445	FELIXSTOWE	322	-55

APPENDIX 3: WORLD BANK REPORT (continued)

Statistical approach			Administrative approach		
Port name	Rank	Total score	Port name	Rank	Index points
JEBEL ALI	323	2.482	PRINCE RUPERT	323	-56
DAR ES SALAAM	324	2.561	DAR ES SALAAM	324	-58
DUTCH HARBOR	325	2.591	DUTCH HARBOR	325	-60
FREMANTLE	326	2.716	NEMRUT BAY	326	-61
ASHDOD	327	2.797	PORT BOTANY	327	-63
LOS ANGELES	328	2.899	MONTEVIDEO	328	-65
NEMRUT BAY	329	2.970	TACOMA	329	-66
PRINCE RUPERT	330	2.979	BEJAIA	330	-72
MOMBASA	331	3.140	GENOA	331	-74
OAKLAND	332	3.163	LOME	332	-77
LONG BEACH	333	3.175	ADELAIDE	333	-78
PORT REUNION	334	3.302	OAKLAND	334	-79
TACOMA	335	3.628	MOMBASA	335	-79
GUAYAQUIL	336	3.647	WALVIS BAY	336	-80
PORT BOTANY	337	3.907	LOS ANGELES	337	-82
BEJAIA	338	4.054	GUAYAQUIL	338	-84
ADELAIDE	339	4.546	GOTHENBURG	339	-87
LAGOS (NIGERIA)	340	4.646	PORT REUNION	340	-89
GOTHENBURG	341	4.653	LONG BEACH	341	-96
IQUIQUE	342	4.766	LAGOS (NIGERIA)	342	-114
TIN CAN ISLAND	343	4.789	LUANDA	343	-115
PORT LOUIS	344	5.501	TIN CAN ISLAND	344	-118
MARSEILLE	345	5.696	POINTE-NOIRE	345	-128
POINTE-NOIRE	346	5.832	PORT LOUIS	346	-175
CAPE TOWN	347	6.528	CAPE TOWN	347	-177
PORT ELIZABETH	348	7.659	PORT ELIZABETH	348	-183
DURBAN	349	8.082	NGQURA	349	-190
LUANDA	350	8.383	MARSEILLE	350	-238
NGQURA	351	8.401	DURBAN	351	-255

Source: (World Bank Group, 2020)

APPENDIX 4: ETHICS CLEARANCE CERTIFICATE

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

21 December 2021

Rowen Naicker (219035344)
Grad School Of Bus & Leadership
Westville Campus

Dear R Naicker,

Protocol reference number: HSSREC/00003510/2021
Project title: Examining container handling equipment to reduce port congestion at Durban Container Terminal
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 01 October 2021 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted FULL APPROVAL.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 21 December 2022.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee
Postal Address: Private Bag X54001, Durban, 4000, South Africa
Telephone: +27 (0)31 260 8350/4557/3587 **Email:** hssrec@ukzn.ac.za **Website:** http://research.ukzn.ac.za/Research-Ethics

Founding Campuses: Edgewood | Howard College | Medical School | Pietermaritzburg | Westville

INSPIRING GREATNESS

APPENDIX 5: TURNITIN REPORT

Rowen Naicker Dissertation

ORIGINALITY REPORT

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APPENDIX 6: EDITING CERTIFICATION

ASOKA ENGLISH LANGUAGE EDITING
35 Arcadia, 1 Peacehaven Pl, Grosvenor, Bluff, 4052. South Africa

CELL NO.: 0836507817

DECLARATION

THIS IS TO CERTIFY THAT THE DISSERTATION ENTITLED

Examining container handling equipment to reduce port congestion at Durban Container Terminal

Candidate: Naicker R

HAS BEEN ENGLISH LANGUAGE EDITED.

[redacted]

DISCLAIMER
Whilst the English language editor has used electronic track changes to facilitate corrections and has inserted comments and queries in a right-hand column, the responsibility for effecting changes in the final, submitted document, remains the responsibility of the client and the editor cannot be held responsible for the quality of English Language expression used in corrections or additions effected subsequent to the transmission of this certificate on 11/01/2021.

Prof. Dennis Schauffer, M.A.(Leeds), PhD, KwaZulu (Natal), TEFL(London), TITC Business English, Emeritus Professor UKZN. Univ. Cambridge Accreditation: IGCSE Drama. Hon. Research Fellow, DUT. Durban University of Technology.