UNIVERSITY OF KWAZULU-NATAL

Key performance indicators for container ports: A case of Weighted Efficiency Gains from Operations (WEGO) in South Africa.

by

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DECLARATION

I, **Mwezi Terrence Dlamuka**, declare that

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LIST OF ABBREVIATIONS

AWT	Average Waiting Time
BUR	Berth Utilisation Rate
BOR	Berth Occupancy Rate
CTCT	Cape Town Container Terminal
DCT	Durban Container Terminal
DEA	Data Envelopment Analysis
ETA	Estimated Time of Arrival
GCH	Gross Crane Hour
GDP	Gross Domestic Product
ICT	Information Communications Technology
KPI	Key Performance Indicator
LOA	Length Overall
LTPF	Transnet Long Term Planning Framework
MSC	Mediterranean Shipping Company
MOPS	Marine Operating Performance Standards
NCPP	National Commercial Port Policy
NCT	Ngqura Container Terminal
NPA	National Ports Authority
PCC	Port Consultative Committee
PE	Port Elizabeth
PRSA	Ports Regulator of South Africa
PWC	Price Water Coopers
RR	Required Revenue
SADC	Southern African Development Community
STS	Ship Turnaround Time
SWH	Ship Working Hour
TFP	Total Factor Productivity
TEU	Twenty-foot equivalent unit
TOPS	Terminal Operating Performance Standards
TNPA	Transnet National Ports Authority

TPT	Transnet Port Terminals
ULCS	Ultra-Large Container Ship
UNCTAD	United Nations Conference on Trade and Development
VLCS	Very Large Container Ship
WEGO	Weighted Efficiency Gains from Operations

ABSTRACT

South Africa is a developing country, within which the volume of exports and imports plays a significant role in the local economy, and therefore ports are critical gateways to support international trade, which ensures uninterrupted movement of goods in the global supply chain. Transnet National Ports Authority (TNPA) in South Africa acts as the ports' landlord. The institution is responsible for the funding and administration of local ports. Various authorities including businesses raise concerns about inefficiencies in South African ports. The dominant factors are poor performance and high tariffs. These factors have been explored by previous studies and benchmark studies that were conducted by Ports Regulator of South Africa (PRSA). Durban container port is characterised with poor performance particular for container handling and high tariffs for specific port users. The Ports Regulator of South Africa responded to this concern of high tariffs and poor performance by establishing a new element into tariff Methodology called Weighted Efficiency Gains from Operations (WEGO). This is a tool aimed to improve port operational performance, applying to all South African ports. This study aims to assess and explore Key Performance Indicators (KPIs) selected to determine WEGO. TNPA intends to link performance gains for operations to the tariff methodology (Required Revenue). TNPA published port operational performance for 2017/2018 and 2018/2019 financial periods. The ports' operational performance data assisted PRSA to select performance indicators to be considered for efficiency gains and the Ports Regulator published the first WEGO performance results in 2018/2019 financial period. The study applied both quantitative and qualitative research methods to analyse WEGO performance results. This study relies on secondary data published by PRSA. The author only focused to containers and Durban as the main container port of the country. This data shows performance scores for each KPI selected and the aim is to observe changes to performance and seek understanding behind improved or declined operational performance. However, there will be no specific statistical or mathematical models utilised. In conclusion, this research also offered recommendations on what TNPA and TPT can do to improve their performance and efficiency in order to be on par with their global counterparts.

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CHAPTER ONE

INTRODUCTION

1.1 Background and Context

The success of international trade relies on cost-effective modes of transport, an adequate logistics' infrastructure, and a well-synchronised network to connect the different economic hubs. Universally, carriage of goods by sea is the most preferred mode of transport by cargo owners to move cargo across the international supply chain due to its economic advantages. The maritime transport sector, including seaports, enables other industries and regions to physically exchange goods in a global landscape. Seaports are the critical nodal points for the movement of goods in the global supply chain. Therefore, efficient port systems are critical for economic growth. These port systems must ensure a seamless flow of goods from shipper to consignee. To promote this system, port services must be offered at a competitive rate to support trade.

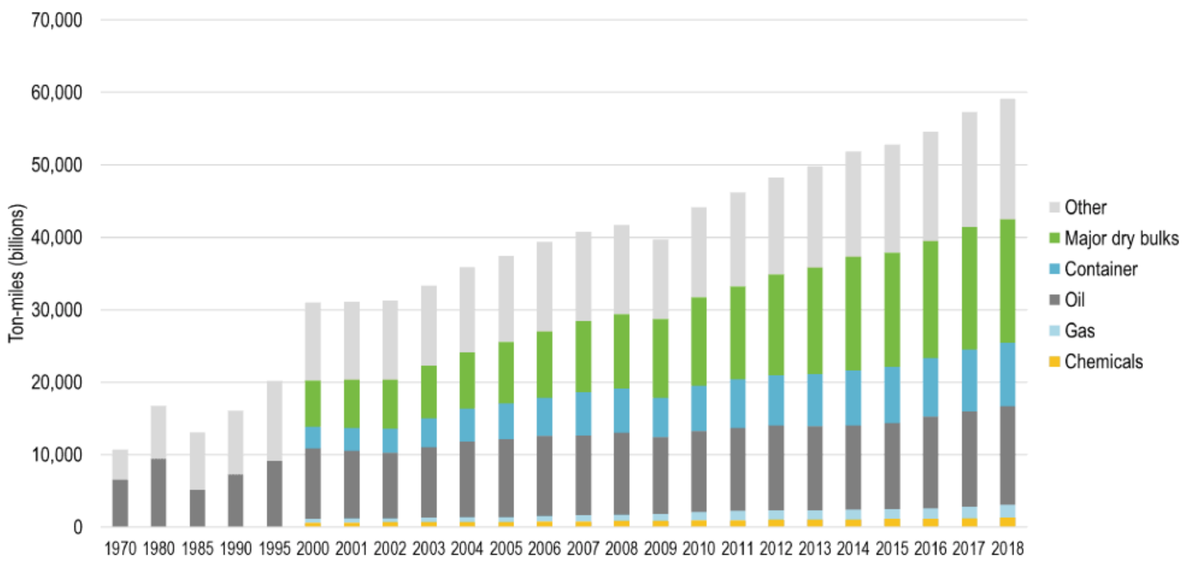
In terms of tonnage across the world, more than 80% of traded goods are carried by commercial vessels (LTPF, 2016). It is not surprising that South Africa (SA) only shares 3.5% of seaborne trade in terms of cargo volume (Meyiwa, 2016). The geographical position of South Africa holds an advantage for vessels sailing in the Southern Hemisphere. South African ports are the critical nodal points for vessels passing through or calling to its shores, whether it be for port services or calling for cargo work (LTPF, 2016).

It is the responsibility of the National Ports Authority (NPA) to ensure an uninterrupted flow of goods within the ports' value chain and through the hinterlands. In the South African context, in line with the National Ports Act, 12 of 2005, Transnet National Port Authority (TNPA) is responsible for the management, administration, and control of all eight commercial ports in the country. This legislation, and the National Commercial Port Policy (NCPP) of 2002 in South Africa, aim to enhance the effectiveness and efficiency of local ports so that they remain competitive in the regional and global communities.

Besides the TNPA, port operators (in both the public and private sectors) and the Ports Regulator of South Africa (PRSA) are the key role players that ensure efficient cargo handling and economic regulation of TNPA's functions (Transnet, 2012).

Transnet Port Terminals (TPT) is a state-owned entity that is permitted by the National Ports Act to offer cargo-handling services within automotive and container terminals. TPT also handles other bulk and breakbulk cargoes, although not exclusively. In terms of the National Port's Act of 2005, it is mandatory for management to provide a degree of satisfaction to its port users and to offer satisfactory services. The Ports Regulator of South Africa (PRSA) is enabled by the National Ports Act to promote fair access to the South African port infrastructure and it ensures that TNPA adheres to directives and regulations that are stipulated by the legal regimes governing the SA port system.

Figure 1: World Seaborne Trade by Cargo Type



Source: UNCTAD (2018)

Figure 1 above indicates the evolution of global seaborne trade by cargo type. According to UNCTAD (2018: 16), "seaborne trade is measured in ton-miles to reflect the distance travelled and the employment of ship capacity". Figure 1 also reflects the on-going evolution of maritime trade per commodity type over the years, from 1970 to 2018. In the context of ton-miles, the figure 1 projects an upward trend. Across all segments, major dry-bulk cargo records higher ton-miles over other cargo types. Oil cargoes also contribute very substantially to maritime trade.

TNPA must take cognisance of the fact that world seaborne trade has been increasing over the years. This, in turn, has exerted a pressure on the port system to handle more cargoes.

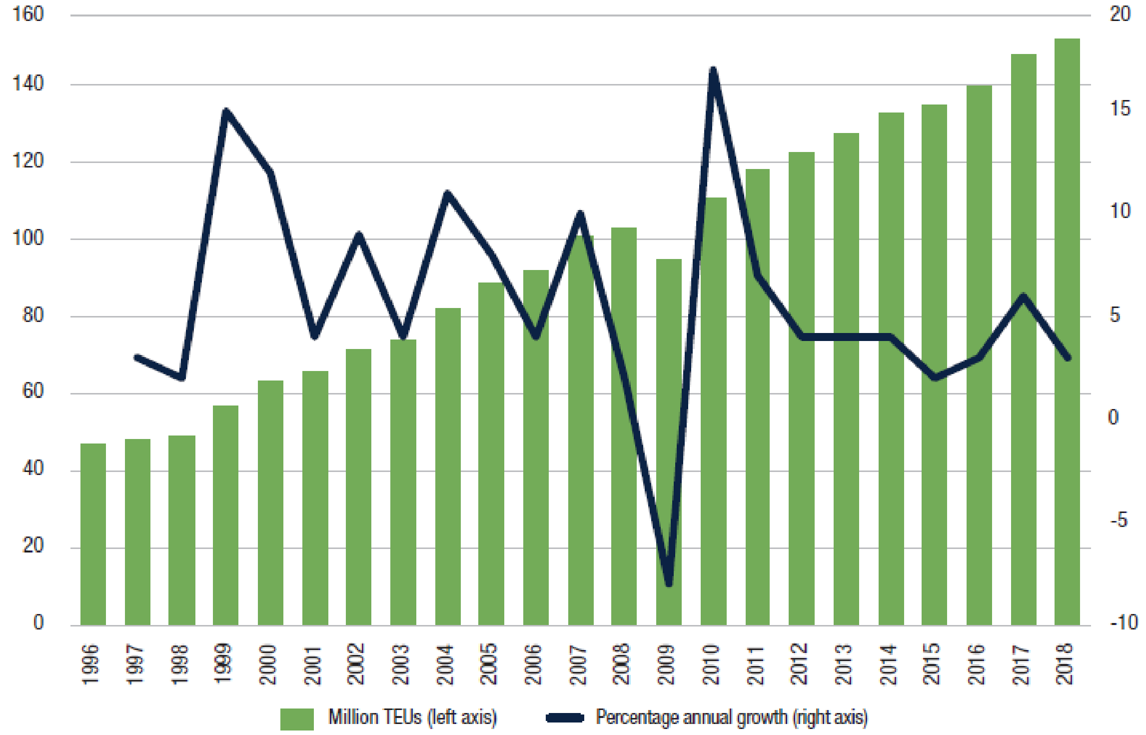
Both developing and developed economies have contributed significantly to the growth of the world seaborne trade (UNCTAD, 2018).

The Asian markets have gathered momentum and are increasing rapidly. The growth of these markets has accounted for their being the largest contributor to global trade (UNCTAD, 2018).

Developing nations such as South Africa, Brazil and Australia remain centres of growth in international maritime trade, most notably in respect of the dry-bulk exports which they produced, and which contribute the largest component of seaborne trade. This is followed in turn by oil, which is supplied from sources in the Middle East and in other oil-producing regions, and by the container trades (UNCTAD, 2018). Furthermore, it is important to highlight that the container trades are also the fastest growing throughout the world, as well as in South African sea trade. With this background, it may be construed that the success of international trade relies on an efficient and effective port system. Since the volumes of exports and imports are increasing, TPNA is expected to accommodate this extra cargo volume through its local ports.

The global containerised trade in Figure 2 below shows that the number of Twenty-foot Equivalent Units (TEUs) has increased on a sustained basis since 1996, except for 2009 (UNCTAD, 2019) due to the world economic slowdown. A variety of factors have led to increased globalisation of the international trading community. This globalisation has been an enabling force for the growth of the sea freight industry, and containerisation has been identified as one of the factors responsible for enhancing globalisation. The United Nations Conference on Trade and Development (UNCTAD, 2018) indicated trends that showed increased container world trade, and certainly UNCTAD and others also show quite convincingly that the container trades have been growing faster than any other major component of seaborne commerce. Apart from these factors, the growth in global Gross Domestic Product (GDP) has increased the demand for container services. In the South African context, the container trade is also increasing. Partel (2015), reported that container terminals are operating close to maximum capacity.

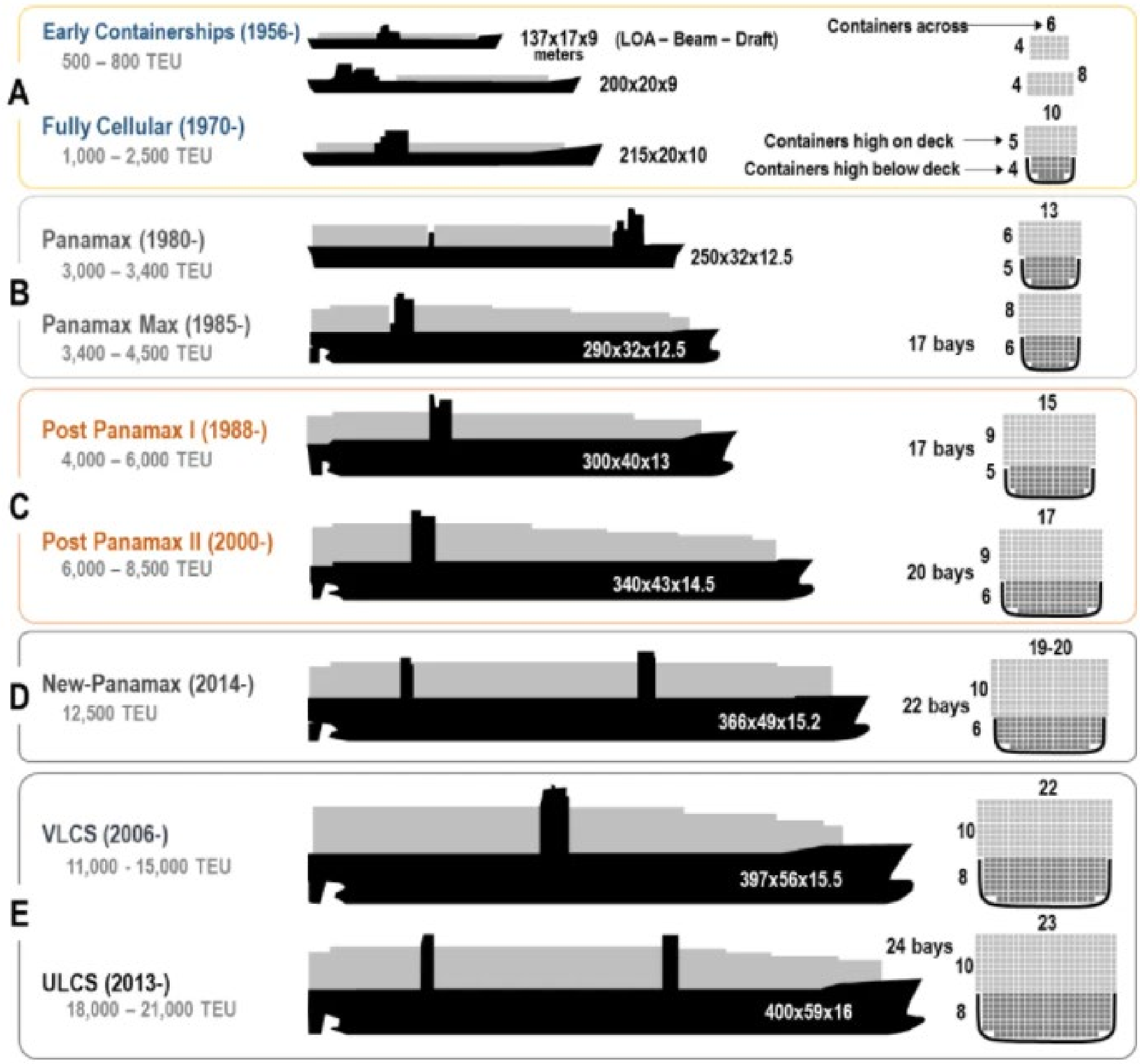
Figure 2: Global Containerised Trade



Source: UNCTAD (2019)

Ship owners have responded in various ways to market changes observed in international seaborne trade. To match growing demand and to accommodate an ever-increasing pace of containerisation, they introduced larger containerships. The container shipping industry is supported by multi-faceted players, acting in different roles to support a global network of container movement. Figure 3 below reflects the evolution of vessel sizes from the first development of container ships in 1956 until the recent deployment of container ships with capacity in excess of 20,000 TEU. These Ultra-Large Container Ships (ULCS) and Very Large Container Ships (VLCS) operate on the busiest trade routes with the highest volume of container trade, such as between Europe and the Far East. This deployment has displaced other larger containerships such as new-Panamax, through the cascading of tonnage, to thinner trading routes in the Southern Hemisphere. Some of those vessels are operating in South Africa and others are received by the Brazilian container ports. It is believed that ship owners deploy larger containerships to explore economies of scale associated with vessel size, and falling operational costs.

Figure 3: Evolution of Container Ships



Source: The Geography of Transport System, Jean-Paul Rodrigue (5th Edition)

However, Malchow (2017) argued that the need to create greater economies of scale seems to be not an endless process, but that from the perspective of ports, ever larger containerships may not always generate lower unit of costs. Recently, the Durban container port in South Africa has recorded a decline in the number of container callers due to the fact that the port received larger containerships that were capable of working more boxes per port call. Therefore, bigger ships are slowly replacing the smaller ships. With these vessel traffic changes, the container terminals have not always been able to handle these ships in terms of terminal productivity and overall port efficiency. In most ports around the world, the larger containerships increased the pressure on both Port Authorities and Terminal Operators to strive for optimum port performance and terminals productivity.

For instance, ports would increase the water depth to accommodate bigger vessels, and terminal operators are expected to invest in superstructure to boost the container-handling process. The larger ships are established on the basis that they offer falling costs per TEU per ton-mile of real transport activity, minimum port stay and are fuel efficient. In that light, this study is also concerned about the impact of bigger vessels on ports, in the way of port efficiency and terminal productivity.

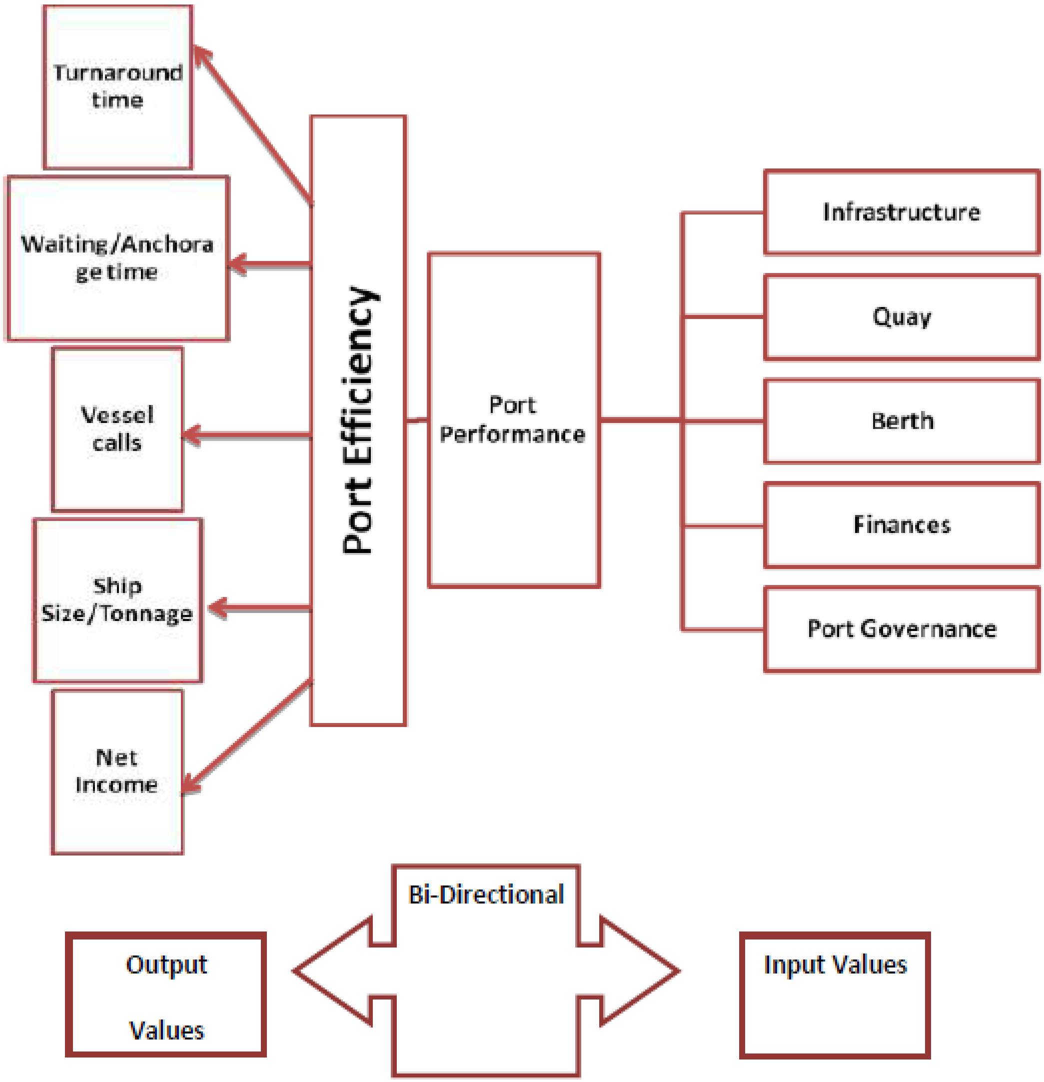
There has been a concern from different maritime stakeholders, including cargo-owning industries, about the efficiency levels in container terminals where shipping lines face high tariffs in comparison to their counterparts across the world and poor performance within container terminals. In addition, the shipping lines also experience poor productivity in terms of cargo handling. The shipping lines calling to South Africa have complained about the hours spent by vessels at anchor awaiting berths, low levels of containers worked per Ship Working Hours (SWH) and prolonged total port turnaround time (PRSA, 2019).

Basic port infrastructure and superstructure have been identified as key factors that contribute to inefficient quayside operations. Additionally, inefficient customs procedures create clearance anomalies which end up causing bottlenecks along stacking yards. On the other hand, these port inefficiencies undermine the core principles of setting an optimum fee for port services and functions, such as the principles of equity, strategy and efficiency. Consequently, these factors impede the competitiveness of local ports to attract additional vessel calls and also impede the movement of additional cargo through South African waters. The competitiveness of the South African ports has a great influence on the performance of local economy and markets. The container ports are the catalyst to attract more trade to a region and to improve the overall economic performance of a specific country. The weaknesses and poor conditions within container ports or terminals, such as poor performance and imbalanced port prices, result in increased total shipping costs and poor port development.

1.2 Scope of the Proposed Research Work

The principal focus of this dissertation is on the performance metrics used in the determination of container port efficiency and terminal productivity. Figure 4 below indicates the paramount performance indicators used expressly in port efficiency and terminal productivity. Babounia and Imran (2018) grouped the parameters into input variables and output variables. Input variables include port governance, number of berths, port infrastructure, and finances. Output values include ship turnaround time, anchorage waiting times, vessel calls, and ship size.

Figure 4: A Hypothetical Model for Port Efficiency



Source: Babounia and Imran (2018)

The fact that Babounia and Imran (2018) looked at the finances as input and net incomes as output, suggests that the authors looked at both operational indicators and financial indicators. This dissertation proposes to assess port performance by visiting the operational key performance indicators only.

In the South African context, TNPA as the port landlord, TPT as the container terminal operator and cargo owners play a significant role to promote port efficiency and terminal productivity. The terminal operator manages and controls port superstructures to render shipping services to container carrying lines. Assessing port performance is critical for them to identify areas where they are lacking or under-performing. That exercise is conducted to enhance terminal productivity. Therefore, the operators prioritise quick vessel turnaround time in an efficient manner through the deployment of sufficient port assets, optimally utilising the quay, efficiently operating the landside, and efficiently utilising the labour that is available (Motau, 2015).

The shipping lines have prioritised to utilise all available cranes deployed to support cargo work operations efficiently. Their target is to reduce port costs and give consideration to optimum terminal productivity which will result in quicker vessel turnaround time and the accommodation of larger vessels without berth complexity (Motau, 2015). TNPA generates port income through port tariffs by providing basic marine infrastructure and marine services. Efficient container terminals will attract more vessels calling into a port, and more cargo, thereby increasing revenue from cargo dues that remains the principal source of TNPA revenue. So, if the vessel traffic increases, the Authority will generate more income. From the cargo owner's perspective, the container ports have a direct link with the hinterland; cargo owners use cargo dwell time as a measure of container port efficiency. It is desirable that imports and exports spend minimum hours or days waiting in the terminal area (Motau, 2015).

In terms of the National Ports Act, the TPNA is mandated for the provision of marine services and infrastructure to shipping lines, tenants and cargo owners. This Act enables TNPA to generate revenue which is collected through the port tariff, and this income is used to maintain the existing port infrastructure, and to ensure that port users receive affordable and efficient port services and the maintenance of an efficient marine service fleet (Transnet, 2012). South African ports operate within a complementary port system.

TNPA as the landlord, offers similar port services across all eight commercial ports of the country. The local port Authority uses a uniform pricing system, meaning that there is a single tariff book that consists of set prices for different functions of a port and is applicable to the different ports. Some port prices are, however, differentiated, notably in respect of marine services that are sensitive to port layout and physical port characteristics, but a uniform pricing system is applicable to infrastructure provision, where the landlord collects both port dues and cargo dues, respectively. It is argued that system-wide pricing enables cross-subsidisation for ports, whereby certain port functions are funded by other port users (PRSA, 2015). PRSA favours tariff simplicity, but not “one price fits all”, irrespective of underlying costs.

Far more significantly, complementary port systems stifle inter-port competition that would be in place when two or more ports serving common hinterlands are able to compete for the business of competing carrying lines. For instance, appropriate and fair tariffs designed for a particular port can promote inter-port competitiveness. Getting tariffs wrong can destroy the whole trade function between ports.

As much as the tariff structure, tariff methodology and port governance are not the principal problems in this research, the study proposes to interrogate elements of both port governance and tariff methodology to understand some of inefficiencies present within SA container ports. However, the tariff structure looks more at the allocation of tariff items across categories of port users, as well as the problem with the structure, the lack of clarity as to who should pay for what, and how much they should pay. The Regulator has sought to fashion a more equitable tariff distribution amongst port users. The tariff structure was dealt with in some considerable detail in the period up to 2015. The Tariff Strategy for the ports system aims to correct the historic anomalies and imbalances present in the port tariff structure. The Tariff Strategy, published in July 2015 and revised in March 2020, seeks to establish cost-effective tariffs in the SA port system over ten years and to eliminate inequitable cross-subsidies progressively over this time. The specific treatment of container cargoes or any other category is a matter of the tariff strategy.

In South Africa, PRSA has conducted benchmark studies previously to evaluate the efficiency, productivity and pricing within the SA container ports and terminals (PRSA, 2020). The benchmark exercise is effective if the ports show common characteristics or features. PRSA undertook benchmark studies to gain more insight on how other global counterpart ports examine port performance – are South African ports on par with international standards or are there gaps which exist to collect information and insights to address issues on hand?

1.3 Problem Statement

The Port Operator (TPT) and Landlord (TNPA) have received constant criticism from various port stakeholders about poor container terminal performance, until these entities established a comprehensive approach to monitor and assess port performance. The performance of South African ports is currently monitored and assessed through Marine Operation's Performance Standard (MOPS) and Terminal Operation's Performance Standard (TOPS). From the performance point of view, "the National Ports Authority seeks to create sustained economic value as per its policy mandate, through its strategic role as the national provider of port infrastructure capacity and its efficient and competitive port services" (TNPA, 2019:3).

TNPA introduced the TOPS and MOPS across all eight South African ports as part of its licensing conditions (Transnet, 2015). TNPA imposed performance standards on TPT to ensure that a reasonable level of service is achieved and improved productivity is maintained within local terminals. The Landlord is also interested in monitoring other dimensions of operations not under the control of TPT. Such monitoring can be used for benchmarking against prior years' performance or best practice operators in other ports, in order to improve terminal productivity, while TPT employs TOPS to ensure equipment readiness to carry a container and real time tracking of each container's position in the terminal. In this way, containers and equipment are optimally staged, reducing idle time of both equipment and containers. TNPA and TPT identified key performance areas and indicators to evaluate performance from South African port systems, namely, anchorage waiting time, average ship turnaround time, berth occupancy, berth utilisation, container dwell time, moves per gross crane hour, container moves per ship working hour, train turnaround, truck turnaround time and loading rate (TPT and TNPA, 2019).

The Ports Regulator of South Africa exercises economic regulation over the National Ports Authority and also deals with complaints against the entity. The container shipping lines and cargo owners are not satisfied with the service level received from domestic container terminals. Port users believe that performance issues are related to equipment problems encountered from container terminals.

The study targeted the Port of Durban as the busiest container terminal in the country since it handles more container traffic if compared to other domestic container terminals. The port users identified long waiting periods to berths and berth time delays as key operational challenges affecting Durban Container Terminals. The operator is mindful that the reliability and availability of equipment makes a phenomenal difference in terms of overall operational performance.

Therefore, PRSA came up with a systematic approach to performance assessment, that is distinct across all South African ports and terminals. This is called Weighted Efficiency Gains from Operations (WEGO), which is a tool aimed to motivate better operational performance and improved port tariffs. WEGO is an incentives-based element that has been inserted in the local tariff methodology (Required Revenue) to offer discounts on operational performance and to impose penalties of deficient performance. The performance scores are generated through TOPS, after which PRSA applied mathematical and accounting systems for calculations to determine improved or poor performance. The shipping lines and cargo owners are concerned about the determination of terminals' operational efficiency incentives in the form of WEGO. Port stakeholders and port users are not convinced by the direction followed by PRSA in an attempt to resolve performance issues within container terminals. On the basis of from the roadshows conducted by PRSA, the perception of port users is that the existing KPIs selected for WEGO do not capture the performance issues of domestic ports sufficiently comprehensively.

The Port Consultative Committee (PCC) and TNPA embarked on a process to select the most appropriate Key Performance Indicators (KPIs) to be considered in determining the WEGO and to assign relevant weights that best match the status quo of domestic ports. During this process of efficiency determination, PRSA is tasked to advise TNPA, as well as to verify and review the entire process to ensure that the port tariff maintains the requirements of legal provisions as stipulated in the National Ports Act of 2005. In that sense, PRSA published the first WEGO performance results for the 2017/18 and 2018/19 financial years.

The main issue identified by this study is the selection and nomination of KPIs used to generate WEGO scores. Therefore, the objective is to explore KPIs that are commonly associated with container terminal operations, in order to draw a meaningful assessment of performance or quantify performance levels to ports' stakeholders. In the meantime, WEGO has relied on the following indicators: ship turnaround time, berth productivity, ship working hour, anchorage waiting time and ship productivity indicator (PRSA, 2019). These indicators are readily applied to container operations and other non-containerised operations, regardless of the fact that each port or terminal has its own unique characteristics and performance level. Therefore, there is a need to develop indicators after considering the real factors which match the regulatory framework and administration of local ports. The study further aims to review the indicators that are likely to be included in the WEGO, which are able to address the performance and capacity issues.

1.4 Research Objectives and Questions

1.4.1 Research Objectives

Researchers undertake a research study to meet certain objectives and aims. These objectives and aims refer to the desired outcomes of the research. The research objectives paint a clear picture of the scope of a study. The principal objectives of this study are:

- Assessing critically the KPIs used to measure container port performance, productivity and efficiency;
- Examining the selection and nomination of KPIs used to generate WEGO performance scores; and
- Examining critically the factors affecting Durban Container Terminals performance by performing a detailed analysis to TOPS and WEGO secondary data.

1.4.2 Research Questions

The literature reviewed and data analysis were guided by a number of research questions, informed by the study objectives. These principal research questions are:

- Which port performance indicators and metrics are relevant to South Africa to demonstrate the value of services offered?
- Which performance KPIs can be selected or eliminated from the WEGO KPIs basket?
- Which factors are affecting the Durban Container Terminals performance?

1.5 Research Methodology

This dissertation relies on both a quantitative and a qualitative research method as the mechanisms to meet the objectives of this study. This research study mainly focuses on the estimated and actual performance scores for the Durban, Cape Town, Port Elizabeth and Ngqura container terminals. Since a form of comparative analysis is undertaken, container efficiency scores will be collected from both TNPA and TPT to express the performance capabilities of the South African container terminals. This will be a desktop study in which the secondary data will be relevant to quantify the results. PRSA annually publishes the Terminal Operator's Performance Standard (TOPS) data, Marine Operator's Performance Standard (MOPS) data and WEGO performance results. This data will be collected to observe operational performance within South African ports. Furthermore, TNPA, TPT, and port statistics of African ports will be instrumental to supply numerical secondary data for analysis.

1.6 Study Overview

This dissertation consists of five chapters.

Chapter One has provided a brief overview and introduction to the research background and problem statement which clearly outlines a motive for the researcher to undertake this research study. It has set out the research questions, research objectives and aims which guide the research study throughout. The research methods, the data collection technique, and data analysis are identified.

Chapter Two analyses received literature to interrogate container port terminals' efficiency and productivity and related performance indicators in greater detail. Theoretical frameworks related to container port performance are analysed and the ports' performance is reviewed to explore the WEGO approach followed by South Africa and performance indicators selected. Chapter two further provides a comprehensive overview of South African container terminals.

The functions and role of port authorities are discussed, together with the structure and ownership of container terminal operations.

Chapter Three presents the research methodology and sets out the research methods, techniques used to collect data, and approaches to analyse data. This chapter summarises the choice of both quantitative and qualitative research approaches. The consistency of findings against those cited in the literature review, is explored.

Chapter four presents a fuller outline of container port performance indicators, with a focus on relevant comparator ports, to gain more insight into evaluation of port performance and the most appropriate port performance metrics. Further, it interrogates South African container ports in respect of container terminal efficiency in recent years, and seeks to collect and interpret these data, with an aim to track relevant observed changes. Such analysis will help inform this study as to which areas needs attention by TNPA and TPT to enhance port efficiency and terminal productivity.

Chapter five provides a summary of the whole study, and it sets out the research conclusion and recommendations, as well as recommendations for future research.

CHAPTER TWO

LITERATURE REVIEW

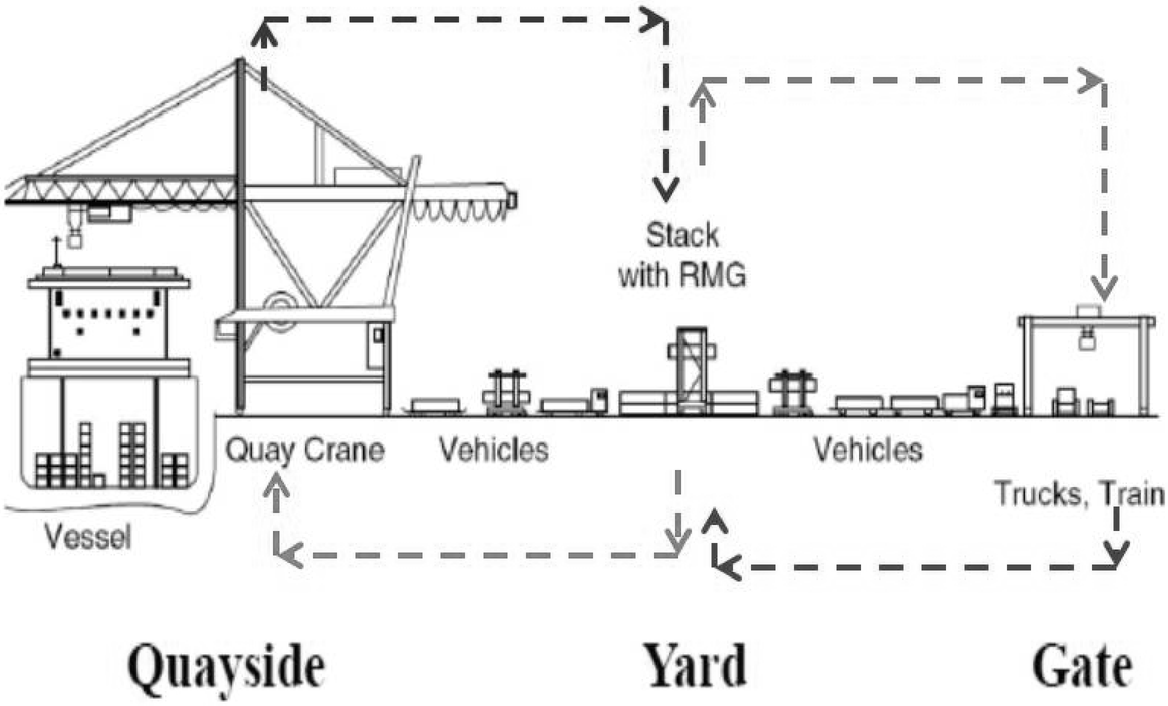
2.1 Introduction

Port performance and productivity are the concepts utilised to express the value and quality of port services rendered by the different players in the port sector. This chapter explores the common Key Performance Indicators (KPIs) that are widely explored by different scholars to express port performance and productivity, particularly for container ports and terminals. The discussions will be informed by the analysis of received literature in order to interrogate container port terminal efficiency and productivity in greater detail. The theoretical framework related to container port performance is analysed and port performance is reviewed to explore the WEGO approach that is followed in South Africa. TNPA monitors port performance and productivity, to link port performance to tariffs determination through WEGO for optimum port pricing. Optimum port pricing is not merely about generating enough port income, but it should support better utilisation of the port assets and infrastructure, it should decrease the average cost of doing business with a port and it should bring about new ways of attracting more trade into a particular region, as well as to provide the right allocative signals for investments and for users. Furthermore, this chapter outlines the fundamentals of the South African port sector from administration to ownership structure of domestic ports.

2.2 The Fundamentals of Container Ports and Terminals

Container terminals are defined as complex facilities that involve a variety of different parts and processes, which consist of berths for ships, cranes for transferring containers between the terminal and the ship, yards for the storage of containers, gates for the entrance and exit, and several other subdivisions for equipment and administration (Scholtz, 2017). The schematic representation of a container terminal in Figure 5 overleaf, encapsulates the prominent terminal activities that make up the entire operations of the container terminals.

Figure 5: Skeleton of Container Terminal Operations



Source: Abdel-Fattah, El-Tawil, and Harraz (2013)

These activities include quayside activities, yard activities and gate activities. The process unfolds in this fashion: the containership waits outside the port, waiting to be escorted by a pilot and tug to the designated berth. All these terminal processes commence after a vessel is moored (safe berthing) and agents board the vessel for the necessary documentation that is required by the Authority. Once all the inspections and clearances are finished, cargo work or operation proceeds by transferring cargo to/from an apron area using gantry cranes. The apron is the area set aside for discharging and loading of containers to and from the vessel. The apron is connected to the terminal stacking area, which is the temporary place used as a container storage, whilst the container is inside the terminal precinct, and then through the terminal gates to the port hinterland, comprising areas that are located inland from the maritime ports (Scholtz, 2017).

For all of the terminal operations stated above, there are key roles players in the South African context for each stage, namely terminal operators (TPT), shipping lines, cargo owners, stevedores, customs authorities and the Port Authority (TNPA). The various role players that are involved in the terminal's operations are responsible for making sure that the container operations are carried out on time and in a cost-effective manner through the ports' network.

In the same manner, PRSA ensures that TNPA and TPT operate within the National Ports' Act framework. TNPA as the port authority, acts as the landlord, providing marine services, such as tug operations, and also providing basic marine infrastructure like turning basins and the berths themselves. TPT as the terminal operator plays a distinct role in the port environment. TPT provides the superstructure like gantry cranes and cargo-handling services.

TNPA owns and controls eight commercial ports of South Africa. Out of the eight, four ports have special facilities for container handling. The following section outlines the characteristics and important features of these container ports.

2.2.1 Durban Container Terminals (DCT)

The port of Durban has the characteristics of a hub port. It handles mixed cargoes like automobiles, break-bulk, liquid bulk and containers. The port acts as a trans-shipment port for cargoes in transit. The KwaZulu-Natal Province is active in local trade whilst Gauteng Province is the epicentre of the country's economic activity. Both of these provinces are served through the port of Durban. The port of Durban is also connected to a wider Southern African regional hinterland (Partel, 2015). The Port has a railway infrastructure that connects Durban and Gauteng Province, and also has a direct link to road infrastructure.

Its primary responsibility is to facilitate domestic trade, but it also serves the trading needs of landlocked countries in the SADC region like Zimbabwe, Lesotho and Botswana. Not only does the SADC region benefit from the port of Durban, but the eThekwini Municipality and the wider metropolitan economy, as the host region of Durban port, also benefit from this.

It contributes some 20% towards the city's Gross Domestic Product (GDP) (Zangwa, 2018). This gives the port a wide scope of operations. With this background, the port is being labelled as the busiest and premier port in the whole of the African region. Unfortunately, the port is characterised by poor container-handling performance. It is not easy for regular callers to deviate from this trade because of the very limited competitor ports.

For that reason, the South African container importers and exporters do not have economically sound alternate ports of call.

The Durban Container Terminal (DCT) is one of the largest in the continent. In the African region, the port of Durban is characterised by high liner shipping connectivity. The Durban Container Terminal (DCT) is subdivided into DCT Pier 1 and Pier 2. These are the leading container terminals in the country having a designed capacity of 700 000 TEUs and 2 400 000 TEUs, respectively. The port approach channels, fairways and the entrance channel are already dredged to a minimum of 16 metres, which is sufficient for port entry by new-Post Panamax container ships. However, water depth alongside berths is a constraint for larger, fully-laden containerships. Overall, Durban has 59 berths and 19 terminals that serve different ships calling to the port (TNPA, 2020). The dimensions for container berths are distributed as follows, DCT Pier 1 has only 2 berths, so approximately 750-800 metres of quaywall (berths 105 and 107). DCT Pier 2 is greater in length than Pier 1, has 6 berths which total to 2150 metres of length (TNPA, 2020).

2.2.2 Cape Town Container Terminals (CTCT)

The Cape Town container terminal is ranked as the second-busiest container terminal in the country with a designated annual capacity of 900 000 TEUs. This port also handles other types of commodities besides fresh produce and fruit, for example, liquid bulk and breakbulk cargoes. The terminals have a total of 5,250 ground slots for general containers and 1,500 for integrals. This port is well connected to the deep-sea trade routes which are connected to the European markets and West Africa. In terms of superstructure, the Port of Cape Town has four specialised berths for containers (PRSA, 2019). The port also has 15,5 metres of water depth, which is sufficient for post-Panamax vessels visiting the port. Berth length is 1,137 metres. The facility uses 10 straddle carriers and 28 Rubber-Tyred Gantries (RTGs) to move and handle containers (TNPA Annual Report, 2020). Finally, it employs 8 ship-to-shore gantry cranes to support quayside cargo-handling operations.

2.2.3 Ngqura Container Terminals (NCT) and Port Elizabeth Container Terminals (PECT)

The port of Ngqura is the most recently-developed port that is located in the Eastern Cape Province, 19 kms north-east of Port Elizabeth (PE). It is the second largest port in the province. Both the PE and Ngqura ports have specialised container facilities. Ngqura is the deepest container port in the country and features 16.5m of water depth and primarily attracts containerships that are moving trans-shipment containers (PRSA, 2019). The port has a capacity in excess of 1,300,000 TEUs and handles larger container vessels beyond 12 000 TEU which frequently call in South Africa. At this port, TPT employs 10 mega-max ship-to-shore gantries for container operations. The port has a total of 1,300 metres of berth length (TNPA, 2020).

PE is a less busy and is the smallest container port in South Africa having a capacity of 375,000 TEUs, 11.2 metres water depth, and three berths totalling 925 metres. Besides containers, the port also handles Ro-Ros and breakbulk cargoes. TPT utilises five shoreside gantry cranes to service containerships. Since the terminal services carriers with refrigerated containers, it is equipped with 212 reefer slots, and 5,400 ground slots (TNPA, 2020).

The depressed economic conditions around the Eastern Cape Province and the poor connectivity with the industrial areas, affect the ports' hinterland and thus the container traffic. The close proximity between the ports of Port Elizabeth and Ngqura has an effect on the vessel calls to Port Elizabeth, especially with Ngqura being a deep-water port, which can attract larger vessels which would not be able to call at the port of Port Elizabeth (PRSA, 2019).

2.3 Port Performance and Productivity

Seaports operate in a competitive global trading environment. The ability of a port or a country to attract additional cargo owners or carriers is central to positive port performance, terminals productivity and overall port efficiency. There are various ways to measure and evaluate port performance, but time and cost dimensions are commonplace. Port customers are not only concerned with costs incurred for transferring a cargo through the port facility, but the waiting time for a cargo to reach its desired destination is also a factor.

Port performance is a broad concept that covers almost any objective of operational management and competitive excellence of a port and its activities. Notteboom (2020) refers to port performance as the execution of port activities in a way that accomplishes the set targets by owners and service providers, and it fulfils the promises or requests of the port customer. The study done by Price Water Coopers (PWC) (2018) considers performance as a product of connected activities for the efficient transfer of goods. For example, high quay productivity does not mean much when ships have to wait at anchorage, while cargo delivery processes are slow and inland transportation networks are poor.

Technically, the port performance is viewed from different angles rather than by the factors which describe the port performance and how it is captured (PWC, 2018).

Commercial ports are recognised as engines of economic growth, thereby allowing different states to exchange goods. Their performance results communicate a crucial message to the various stakeholders from both private and public sectors, who have an interest in the operations and management of the ports. This includes the policy makers, the Ports Regulator, maritime clusters, and ship owners' associations, to mention a few. Port users, that is the shipping lines, tenants, and cargo owners, are concerned about the value and satisfaction of services rendered by the port. A general value proposition of container ports is derived from an adequate infrastructure to support cargo operations, a reduction in excessive turnaround time, better utilisation of port assets, as well as port efficiency and productivity (Notteboom, 2020).

From an academic perspective, port efficiency and productivity are the fundamental concepts that are indicative of a port's performance. Port productivity is usually defined as the combined measure of the results pertaining to available resource utilisation as inputs to be transformed into outputs, while efficiency can be defined as relative productivity necessary to achieve a desired output over a period of time or space (Motau, 2015).

In the case of ports, based on the complexity of the contemporary port product, each actor, the authorities, operators, and stakeholders, all have to apply multi-faceted examinations of the different performance components (Zangwa, 2019). Port performance is expressed in the similar way as in the efficiency and productivity, except that port performance is assessed in a broader context.

The port authorities need to define a robust process in an efficient and effective way in tracking and measuring port performance, which will adhere to the provisions of the legal framework regulating the port sector. In the meantime, the Authority has relied on TOPS and MOPS to evaluate the overall port operational performance (PRSA, 2015). Port managers set performance targets as the level of performance which managers strive to achieve, and measured against the recorded performance (Notteboom, 2020).

In order to fulfil the objectives, the assessor is advised to establish KPIs to measure port performance. The objectives prescribe that in the context of their performance, local ports should register performance that best matches international standards. A better understanding of the KPIs can indicate whether or not a port is able to constantly satisfy port users with the infrastructure and services needed. The Authority must continuously search for combinations that yield better services to shipping lines. Port authorities and terminal operators use performance results as a feedback tool to express whether or not these entities do meet the desired strategic objectives. These performance measurements are the best way to capture the value of port services received by the port users.

Port performance can be assessed in various forms. UNCTAD publishes internationally-recognised measures of port performance indicators to strive for uniform procedures ports can consider to establish performance indicators. Table 1 below outlines the operational port performance indicators and financial performance indicators which serve as a reference tool or yardsticks for performance assessors (Ducruet et al, 2014).

Table 1: Port Performance Indicators Proposed by UNCTAD.

Financial indicators	Operational indicators
Tonnage worked	Arrival date
Berth occupancy revenue per ton of cargo	Waiting time
Cargo handling revenue per ton of cargo	Service time
Labour expenditure	***Turn-around time***
Capital equipment expenditure per ton of cargo	Tonnage per ship
Contribution per ton of cargo	Fraction of time berthed ships worked
Total contribution	Number of gangs employed per ship per shift
	Tons per ship-hour in port
	Tons per ship hour at berth
	Tons per gang hours
	Fraction of time gangs idle

Source: Ducruet, Itoh, and Olaf Merk (2014)

The financial indicators are the most important indicators for terminal operators and port authorities to track ports' financial streams and expenditures. Port authorities collect revenue through tariffs; financial indicators are critical factors in determining and administering port pricing. The financial indicators include total contributions, labour expenditure, revenue and expenditure per ton of cargo. El Imran and Babounia (2018) argued that these indicators are difficult to measure and compare because of the diversity of activities involved. Gumede (2012) agreed, and further highlighted that there is no uniform approach to collect port tariffs.

Partel (2015) links operational performance indicators into operational efficiency and productivity. Operational efficiency refers to the operational performance of the ports, and in particular, the maximisation of the produced output with given resources, or the production of a given output with the use of limited possible resources (Pallis, 2020).

Operational port performance tracks the utilisation of port resources and assets. In a container port, the terminals are the main drivers of operational performance. For example, efficient cargo handling can assist in minimising ship turnaround time. With regards to yard operations, the fast movement of containers from the yard area will also help carriers to reduce ship waiting time. Port operators will benefit from maximising berth facilities which will result in high cargo throughput (El Imran, and Babounia, 2018).

This research accepts that there is no universal or unique approach that can be followed by port managers or scholars in selecting and defining KPIs that are used to evaluate port performance or specific container terminal operations. Normally, operational performance indicators are tied to the activities that occur within the port logistics chain (USAID, 2018). Furthermore, the selection of container ports is generally derived from the various activities that occur between the port's entrance buoy and the port (or terminal) gate, which constitute the port logistics chain. However, it is important to highlight that some indicators are germane, which means that those container port KPIs that are relevant to other ports, can also be recommended or useful for those ports as well. In most cases, the choice of KPIs is influenced by the availability of data. Each data variable deals with a particular aspect of whole performance problem, for example, port efficiency and port productivity, and many of these instruments are limited to 'measurable' data for port management and operations.

2.4 Container Ports and Terminals Key Performance Indicators

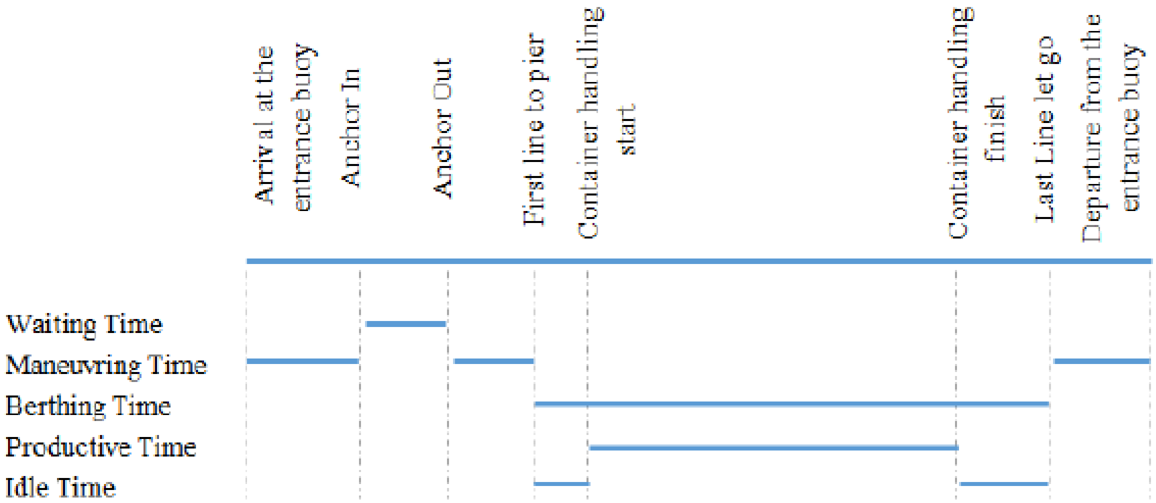
The following section explores and interrogates the different KPIs used to determine port performance and productivity, particularly for container ports and terminals, and with a principal focus on the fundamentals of operational performance indicators. De Monie (1987) set out to measure and evaluate port performance and productivity, indicating that these partial indicators are useful to evaluate and measure port performance, namely, the measure of berth occupancy, the total tonnage handled per port call and the duration a vessel spends at port.

2.4.1 Ship Turnaround Time

Ship Turnaround Time (STT) is a key indicator used by shipping lines to determine time efficiency for container ports. Therefore, the major international carriers consider ship turnaround time as a means to select their choice of port of call.

A better understanding and meaningful assessment of ship turnaround time involves the breakdown of vessel activities from the moment a vessel arrives at the port anchorage until it departs. Premathilaka (2018) used Figure 6 below to illustrate the breakdown of ship activities and specific time intervals. Ship turnaround time is a product of waiting time, berthing time, idle time, manoeuvring time and productive time (Premathilaka, 2018). Figure 6 shows that a ship is expected to stay longer along terminal quayside, but De Monie, (1987) believed that the real value of ship turnaround time must also reflect the total tonnage handled or number of boxes transferred. Furthermore, De Monie (1987) performed a scenario defining a relationship between the ship turnaround time and cost, taking into account cost related to cargo handling and total tonnage carried. This exercise shows that ports with high berth occupancy rates generate inefficient anchorage waiting time.

Figure 6: A Breakdown of Ship Turnaround Time Intervals and Vessel Activities



Source: Premathilaka (2018)

Within the category of berthing time, any event which prevents a ship to resume cargo-handling operations is referred to as idle time. Examples include unexpected stoppages, shift changes or equipment breakdown. Consequently, idle time affects ship turnaround time negatively, by extending port stay for ships. Reductions to these time components assist vessels to receive shorter ship turnaround time, thus mitigating port congestion. Far more important is that terminal operators drive the quayside operations; therefore, they have a significant impact to reduce turnaround time.

Premathilaka (2018) examined berth occupancy and waiting time to highlight the efficiency of quayside operations, and showed that if the berth occupancy is high in a particular port, the ship waiting time by anchorage will also increase.

The author took cognisance of the fact that various factors can affect the ship turnaround time, like weather conditions, labour strikes, technical skills and availability of equipment.

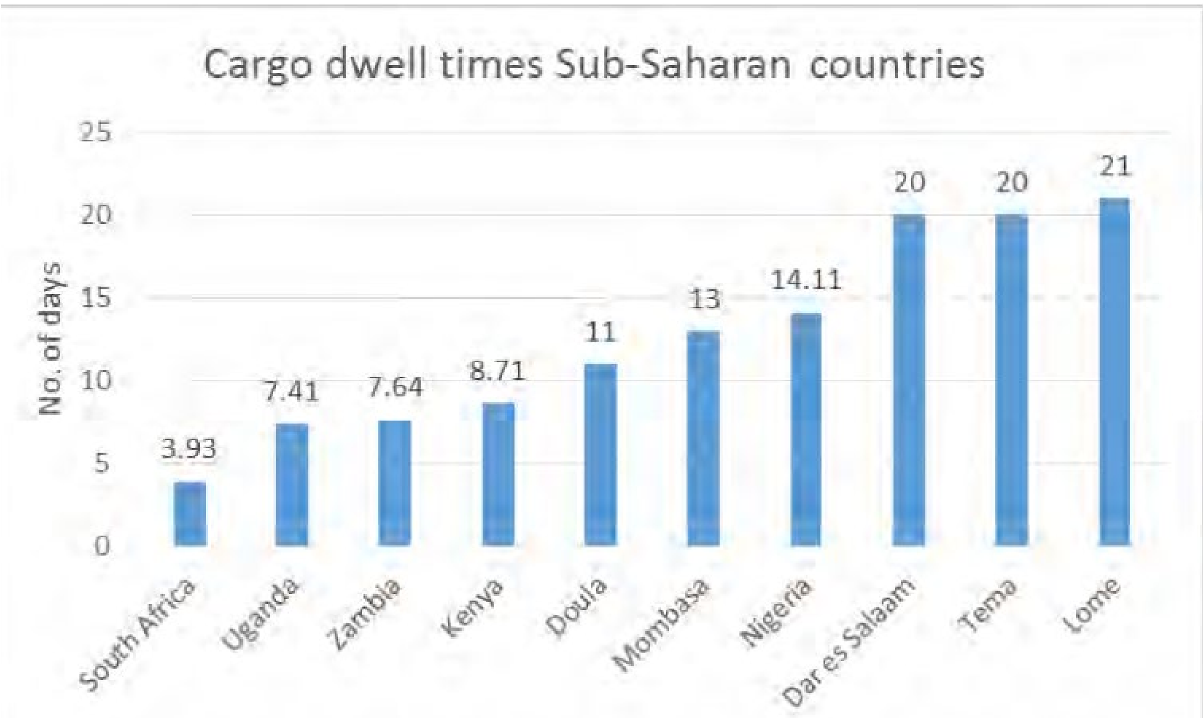
Local and international, the seaports operate under different environments. El Imrani & Babounia (2018) highlighted that since the ports operate under unique environments, the ship turnaround time hugely influenced by the volume containers or tonnage of cargo worked per port of call; if a ship is working more cargo per port call, this implies that the same ship will need to stay longer in a port, *ceteris paribus*. Ducruet, Itoh, and Olaf Merk (2014), further reported that ship turnaround time is also affected by traffic size as it stated in the previous statement, inefficient quayside operations and to some extent, by the average age of vessels. Infrastructural solutions that may reduce ship turnaround time include locating sufficient handling and moving equipment within the staking area, and increasing the number of gantry cranes available for quay side handling operations.

2.4.2 Average Dwell Time

The average dwell time is another factor which affects the port performance and productivity. The average dwell time is separated into two categories, cargo dwell time and port dwell time. Both carriers and cargo owners are affected by delays from ports. The port dwell time refers to the time spent by ships waiting within the port or an area of port extension, whereas cargo dwell time refers to the time between vessel arrival and container exit from the port facilities (El Imran and Babounia, 2018).

Generally, ports operate with fixed assets, like a fixed number of berths. A high average dwell time may be associated with a slow overall movement of containers within a port's facilities, which add strain to fixed port capacity, such that operators end up functioning too close to maximum capacity. Hence, faster cargo handling within the berth facilities, will ensure carriers are able to leave ports at scheduled times. This will increase the number of ships that are able to access berth facilities. Therefore, efforts to reduce overall dwell times are key elements in reducing logistics costs along the port supply chain. Figure 7 overleaf indicates the average cargo dwell time in Sub-Saharan countries. PRSA (2016: 18) benchmark studies argue that “dwell times in South African terminals are considered a good benchmark for ports in Sub-Saharan Africa as significant improvements have been made in reducing dwell times to between three and five days for imports and exports respectively, and ten days for transhipment”. Figure 7 reflects South African terminals with better cargo dwell time against other African ports, with Lome as an upside outlier. Cargo dwell time is negatively affected by delays arising from customs administration, terminal capacity and ships missing their schedules.

Figure 7: : Cargo Dwell Times Sub-Saharan Countries



Source: PRSA (2016)

2.4.3 Ship Anchorage Waiting Time

Port Anchorage Waiting Time (AWT) is defined as a measured amount of time in hours that a vessel waits outside a port before it is allowed to come into a berth to commence cargo work (PRSA, 2019). Container ships wait outside the port for various reasons, as set out in Table 2, overleaf. In a nutshell, the ship anchorage waiting time is an indicator of port congestion. Port congestion is not similar to port waiting time. As shown in Table 2, below, PRSA (2016) collected data to indicate the frequency of and reasons for occurrences where ships wait by the anchorage before berthing. As Table 2 indicates, in most cases ships wait because of no immediate berth availability. This accounts for the largest proportion of hours a ship waits at the anchorage, followed by terminal-related factors.

Furthermore, Motau (2015) highlighted that sometimes the longer anchorage waiting time is linked to the carriers' behaviour. Unprecedented events from the carrier's obligations, such as unfavourable weather conditions, can force the ship's master to reduce sailing speed, which may result in the vessel missing the estimated time of arrival.

Table 2: Reasons for Container Ships Delays at Anchorage

Reason for delay	No of Vessels delayed	Total anchorage time (Hours)
Tugs	-	-
Pilot	2	3.4
Repairs	4	807.85
Weather	53	769.23
Orders	290	20 861.97
Cargo	21	1 170.62
Berth	780	33 623.04
Terminal	657	22 361.77
Total	**1 807**	**79 597.87**

Source: PRSA (2016)

Moreover, deliberate instruction of the carrier may result in a longer waiting time. The vessels are sailing against the perils of the sea. Ships utilise precautionary measures to ensure and maintain navigational safety. Also, a vessel may slow-steam to reduce fuel consumption. These strategies can lead to a vessel missing the estimated time of arrival. Finally, the circumstances in previous ports of call may also have a knock-on effect, and may result in ships missing their scheduled arrival and berthing windows.

The anchorage waiting time for container callers is one of the most important factors considered to determine the container port efficiency and a terminal's productivity. In light of port competitiveness, if the port shows minimum characteristics of anchorage waiting time, it is expected to attract more carriers into a port, where inter-port competition exists.

2.4.4 Berth Occupancy Rate (BOR)

According to Zangwa (2018: 51), "the berth occupancy rate indicates the total occupation time of the berthing facilities. it is calculated as the total time of vessel at berth divided by the total berth hours available". Partel (2015: 25) contends that “an optimal berth occupancy ratio for a container terminal is 65% because once the congestion point of a terminal is reached, queuing of vessels increases and service quality drops”. De Monie (1987) agreed, and states that berth occupancies of 70% or more are indicative of congestion.

In the South African context, the landlord estimates berth occupancy between 55% and 85%, which is within the parameters of 65 % optimal berth occupancy for containers mentioned by Partel. Berth occupancy is a useful source of information to the landlord; the analysis of this indicator can also reveal whether the berths are under-utilised or over-utilised (Partel, 2015). Based on this viewpoint, under-utilised berth facilities create undesirable conditions for both terminal operators and port landlords, as it would be associated with excess, unutilised capacity. Improved terminal operations aid port authorities to maintain optimum berth occupancy, and increased container throughput.

2.4.5 Berth Productivity and Average Moves per Ship Working Hour

PRSA (2016) classified the moves per ship working hour (SWH) as the principal measure of berth productivity. Berth productivity measures are defined as the rate at which cargo is handled at a particular berth (Motau, 2015). But a more comprehensive definition is cited by the PRSA (2019), when it states that berth productivity indicates how productively a berth is used by dividing the number of container units handled per annum over the berth length in metres. Motau (2015) notes that berth productivity indicates the number of container moves which cranes are working over the quay. The type of superstructure, port facilities and equipment are highlighted as the factors affecting berth productivity. However, the traffic composition, ship size and call size are also primary factors driving berth productivity.

Beskovnik, Twrdy and Bauk (2019) assessed the significance of proper stowage planning to enhance berth productivity. Stowage planning is the responsibility of carriers, and carriers also consider stability of a ship. The terminal operator has the direct link with port superstructures and procedures and is thus also responsible for berth productivity.

PRSA (2020) emphasises the difference between berth productivity and berth throughput, by stating that berth throughput measures the total tonnage of cargo handled at berth in a stated period, and it is only an indicator of the facility activity, not of efficiency. Port Authorities consider berth productivity as a useful indicator to determine which berths are over-occupied or under-utilised. In addition, it is a valuable indicator for asset utilisation such as gantry cranes, straddle carriers and terminal yards. Fairly accepted productivity means that berths are operating in an efficient and economic manner, which means that the requirements of the throughput match the available resources at the port. Anything sub-standard creates yard abnormalities, port congestion and longer ship turnaround time (Motau, 2015).

The Ship Working Hour (SWH) metric refers to the number of container units handled in an hour across the vessel, from the time the vessel commences cargo operations to the time the vessel completes cargo operations (Motau, 2015). In short, the SWH indicator examines the function of the terminal operators in the container-handling activity, either in the loading, discharging or repositioning of containers. According to Bocanete and Dragomir (2011), the SWH includes productive time when operations are performed, including the container-handling operation itself, the booming up and down of quay cranes, moving of hatch covers and the travelling of quay cranes between bays. The SWH measure considers all variables involved in the process of discharging and loading containers. These variables include the number of gantry cranes deployed, call size, types of handling gear and quay lengths. The equipment, such as the number of Straddle Carriers, Rubber-Tyred Gantries (RTGs), or haulers, are key resources in supporting cargo- handling operations.

Under normal circumstances, a non-prime berth has a designed capacity to make 60 moves per hour, whereas a prime berth (which refers to the ability to deploy more gantries on a particular vessel call) should achieve 90 moves per hour (UNCTAD, 2019), thereby increasing the number of moves per hour that the ship is worked on. That means that the vessel is able to do more moves per port call, per unit of time. Moreover, the productivity of terminal operations will mean the terminal operators are satisfying the carriers with expected level of port services.

2.5 Approaches to Evaluate Container Terminal Efficiency and Productivity

The concepts, “container port efficiency and terminal productivity” have gained popularity in the academic world. Wisnicki, Chybowski and Czarnecki (2017) grouped methods to assess productivity and efficiency into non-parametric and parametric methods. The Least Squares, Stochastic Frontier and Deterministic Frontier are the fundamental examples of non-parametric methods. Previously Zangwa (2018), Wisnicki (2017), and de Langen and Helminen (2015) used a parametric approach to evaluate efficiency and productivity.

The parametric approach is sub-divided into Total Factor Productivity (TFP) and Data Envelopment Analysis (DEA). In relation to container terminal efficiency and productivity, the parametric technique was popular. This approach was applied due to its effectiveness in measuring input parameters against output parameters. Different studies applied different parameters to express efficiency and productivity. Since each port is unique it is acknowledged that there is no common standard to assess port performance. Nevertheless, there are criteria that they have used to assess the port efficiency and terminal productivity.

This section briefly explores the parametric techniques only; a detailed discussion is beyond the scope of this study. Zangwa (2018), used the Total Productivity Indicator (TPI) in the study titled “A total factor productivity analysis of a container terminal, Durban, South Africa”. Wisnicki (2017), applied a Data Envelopment Analysis technique to analyse the efficiency of container port terminals in Europe to evaluate container terminal productivity and efficiency.

The combination of parameters (inputs versus outputs) is influenced by the scope of work or the objectives any study wishes to fulfil. In the case of terminal efficiency and productivity, parameters such as throughput per hour, call size, and berth length were utilised in many of the publications consulted. With regards to Partial Factor Productivity (PFP), the authors only focus on “a subset of outputs to a subset of inputs when multiple outputs and inputs are involved” (de Langen and Helminen, 2015: 7), while TFP “combines multiple inputs and outputs into port performance measurement by using an aggregate index or using indices estimated from cost or production functions” (Zangwa, 2018:23).

Where there are multiple inputs and outputs involved, Partial Factor Productivity (PFP) indicators compare a subset of outputs to a subset of inputs. For example, Motau (2015), assessed the productivity of South African container terminals.

The study looked at a number of parameters, but the analysis focused on port terminal operations, Ship Working Hour (SWH) and Gross Crane Hour (GCH) as the subsets of output, benchmarking actual scores and target scores of actual data to express crane throughput per hour. The study also addressed dwell time and ship turnaround time.

The choice of partial measures such as number of moves per crane per hour is influenced by the size of containerships, vessel stowage plans, and availability of equipment. It does not require statistical estimation from operations or production. In the absence of such data, an estimation of the weights from operations or econometric models may be used as an estimate. The main advantage of TFP measurements is that the overall impact of the changes in multiple inputs against total outputs is shown.

However, the results of TFP would depend largely on the definition of weights and the technique used to estimate the weights. It is the primary role of TPT to achieve optimum container productivity and satisfactory cargo-handling services. This role of TPT enables the operators to monitor and measure a terminal’s performance. In relation to that, Zangwa (2018) assessed the productivity of Durban Container Terminals, and in the study, selected berth length in metres, service time, waiting time, TEU per hectare, labour productivity and the number of quay cranes as the parameters of container terminal productivity. For Zangwe, productivity is the ratio of outputs over inputs, and is often used to benchmark the performance of a port by examining how well the inputs are used to produce its outputs.

Furthermore, one of the commonly applied non-parametric techniques is Data Envelopment Analysis (DEA). Wisnicki, Chybowski and Czarnecki (2017) applied this method to evaluate the efficiency of terminal production if operators utilise technological capabilities to increase productivity. The study was based around European ports, where ports offer similar container-handling services, but where they have distinctive features relative to water and land infrastructure and superstructure, and are also distinctive in respect of features such as water depth, terminal capacity and access for connectors. The study assessed the adoption of technological solutions to enhance terminal productivity.

The DEA method was effective to compare inputs against output parameters. Automated ship-to-shore gantry cranes and automated stacking cranes were some of the key functional areas to inspect and monitor efficiency.

Therefore, DEA approaches are suitable for measuring the efficiency of observing multiple inputs and outputs. It is also suitable for providing information on the sources of the relative efficiency. However, de Langen and Helminen (2015) show that there are shortcomings associated with this method. It does not incorporate the negative effects of highly-utilised terminals on waiting times. On the other hand, it may show that a port is very productive when the waiting times for shipping lines are at a minimum.

2.6 Weighted Efficiency Gains from Operations (WEGO)

TNPA took a decision to move towards establishing a more efficient port pricing system and in applying a performance-based pricing system. The performance-based approach refers to a pricing mechanism that is aimed to promote better utilisation of port assets. This element encourages more efficient behaviour of the port service providers like terminal operators, which can be achieved by using facilities optimally, by taking into account both the time a facility is used and the time of users waiting in line to use it. It requires a calculation of the optimum level for the ports' assets, and when the level of utilisation is below the optimum, the tariff is decreased, and only increased once the level of utilisation is above the optimum level (Mchizwa, 2014).

The efficiency levels in container handling remain a concern but are an area of focus for the current implementation of the Weighted Efficiency Gains from Operations (WEGO) that incentivises or penalises the TNPA based on operational efficiencies, starting in 2018/19. The final WEGO KPIs were published towards the end of the 2017/18 tariff year and operational efficiency improvements should in part at least offset the expected dollar losses facing shipping due to the strengthening South African Rand at the time (PRSA, 2019). PRSA approved the ship turnaround time, anchorage waiting time, ship productivity indicators, berth productivity and container moves per ship working hour (*Ibid.*)

The TNPA published the second multi-year tariff methodology that is applicable for 2018/19-2020/21 tariff period (PRSA, 2018). In the recent tariff methodology that still adheres to the principles of a Revenue Required approach, the TNPA introduced a new component to the formula called WEGO to mitigate the absence of any incentivisation elements in the methodology (*Ibid.*). PRSA is able to regulate and monitor TNPA through port tariffs. As result the WEGO was built into these port tariffs. This is a tool or instrument proposed by PRSA to improve operational port performance. In that note, PRSA is limited to prescribe what can be done by the Authority to improve operational port performance. Through roadshows, PRSA gathered comments from port users about how the Authority performed in certain areas. Basically, WEGO allows up to 5% additional profit to the National Ports for a 10% increase in year-on-year improvements on a basket of key performance indicators (KPIs) if the Authority was able to improve performance in certain areas, thereby building a reward into the RR methodology. Similarly, PRSA builds non-performance penalties into the RR tariff methodology by imposing up to a 5% decrease in profit for a 10% decline in performance, thereby generating savings for port users (*Ibid.*).

According to PRSA (2018:5) “the Regulator set up a Key Performance Indicators sub-committee that will report to Port Consultative Committee (PCC). The PCC is a consultative mechanism under the Regulator and DoT, although its scope sometimes overlaps with the TNPA operations. The KPIs committee seeks to address the issue of setting and selecting KPIs for each port”. The entire process is a collective effort of TNPA, approved by the Regulator and with the nomination of ship turnaround time, berth productivity, ship working hours, ship productivity indicators and vessel delay at anchorage, as the price-sensitive performance indicators through the PCC.

The Authority is mindful that these are early stages of WEGO and that common errors might occur. However, the Ports Regulator conducts roadshows on an annual basis with an aim to improve the WEGO process. During meetings across the eight commercial ports of South Africa, port stakeholders have an opportunity to make inputs, such as how the development of KPIs can be included into WEGO in future for each port (PRSA, 2018). It is argued that to some extent, these meetings can influence the existing KPIs for WEGO since it creates a platform where the port users air their concerns pertaining to the methodology and port performance. On the other hand, some port users do not welcome WEGO as an essential to address performance issues for container port and terminals. Poor port performance within container terminals is attributed to inadequate infrastructure and superstructure to support the cargo-handling operations.

2.6.1 Assigning Weights to KPIs

The process of selecting ship turnaround time, berth productivity, ship working hours, ship productivity indicators and vessel delays at anchorage as the KPIs for WEGO, involve the TNPA and the PPC to select five KPIs from the basket of KPIs. The TNPA is cautioned about port differences. Therefore, greater attention is given to specific port efficiencies or inefficiencies, and the port's strengths or weaknesses (PRSA, 2018). Each of these five KPIs has been assigned a weighting of 20%, which add up to a total of 100%. The Ports Regulator had a different approach to assign the weighting, opposing the 20% that is allocated to each KPI. Instead, in areas where the performance is slackening, according to the study, the Authority should have assigned a higher weighting to motivate better performance.

Furthermore, the better performing areas or KPIs should be assigned lower weighting to cap or discourage declining performance.

In sum, this suggests that the TNPA still had a challenge in allocating a weighting to KPIs. The KPIs that fall outside the scope of operations are not included. Nevertheless, according to the Regulator, KPIs that are likely to compromise the safety of operations (NPA manoeuvring time and pilotage) are excluded (*Ibid.*). The KPIs selected cover the entire value chain of ports, including the landside and marine performance indicators. WEGO used the TOPS data as the track tool and inputs for calculations; the MOPS data is excluded since there operational safety issues related to provision of marine services.

According to the Ports Regulator, the Authority uses the previous performance scores as the baseline for discounts and incentives to pricing (*Ibid.*). According to port users profiling the scores using the previous year's performance record, will pose a challenge to certain groups of port users. For example, "the performance in 2017/18 will be the starting baseline. An increase or decrease in performance in 2018/19 will determine the WEGO profit or loss multiplier for 2019/20" (*Ibid,16.*).

Initially, from the benchmark studies, the analysis on cargo differentiation has shown that containers and automobiles face high port costs and poor performance. The Landlord should assess whether it is necessary for bulkers to be added to the scheme of WEGO beneficiaries. This comes after discounting their port costs and positive terminals performance. The challenge to this thought is that the TNPA uses a uniform tariff methodology. As it stands, the

WEGO applies across a whole spectrum of commodities and to all South African ports, excluding Mossel Bay. The Regulator and port stakeholders are mindful that the TNPA is implementing WEGO for the first time. The process should be monitored closely, so as to enable the Authority to identify any downside immediately before its effects can spread throughout the port network.

2.7 Functional Port Authority Models

Basically, there are three different functional port authority models, which constitute the responsibilities of private and public sector involvement in port functions. Essentially, these are landlord, tool and operating port models. Table 3 below, captures the control by Port Authority over port infrastructure, port superstructure and cargo handling services.

Table 3: Traditional Port Types and their Characteristics

	Control by Port Authority over		
	Port Infrastructure	**Port Super-structure**	**Cargo Handling Services**
Landlord	**Yes**	**No**	**No**
Tool	**Yes**	**Yes**	**No**
Operating/Comprehensive	**Yes**	**Yes**	**Yes**

Source: Jones (2016)

TNPA is a state-owned entity but is self-funded and does not receive funding from the National Government. Havenga and Simpson (2016) examined the overall architecture of TNPA, and considered the landlord port model as the most favoured type that is pursued by self-funded ports. Partel (2015) classified three popular port authority models which are captured by Table 3 above, in some greater detail.

2.7.1 Landlord Port Model

This is a typical governance structure characterised by a mixture of both private and public sector participation in port operations (Partel, 2015), but principally where the cargo operations are mostly leased out to private entities, usually for a long period of time. As Table 3 shows, under this model the Authority is responsible for control and management of port infrastructure. The role of private entities is to maintain their own superstructures and acquire new additional superstructures where necessary, as a response to demand for efficient cargo-handling services. The Authority is excluded from cargo-handling processes and stevedoring.

Within the terminals, private entities use their cargo-handling equipment to support the operations. In a landlord port model, the port authority retains all the regulatory functions, and owns and controls the basic infrastructure of the port (Jones, 2016). Ports from Europe like Rotterdam and Antwerp are classical examples of landlord ports. Other than European ports, New York and Singapore port authorities have also followed the landlord port type model. It is noted that these ports are ranked high in terms of container throughput in the world (Partel, 2015).

South African container terminals constitute an exception to the landlord style. As a public entity, TPT is responsible for container handling, automotive RoRos and most break-bulk and some dry-bulk commodities. According to norms of landlord model, it supposed to be private entities involved instead of TPT. Consequently, this makes this country a poor candidate to be viewed as a landlord port authority.

2.7.2 Tool Port Model

Table 3 reflects that in tool port model, the responsibilities of the Authority are extended from the provision of port infrastructure to the provision of superstructure (refers to all facilities and assets utilised in handling of cargoes). Under this model, the Authority retains the ownership of all port structures and land involved in the movement of cargoes and ships. This model allows the port Authority to lease cargo-handling operations and management to private entities. The services are supplied by private entities in a tool port, but using authority equipment Gumede (2012). The Port of Chittagong in Bangladesh and the larger French ports (the so-called “ports autonome”) are examples of Tool ports (Partel, 2015).

2.7.3 Operating Port Model

Under this model, the port Authority is responsible for the entire port value chain. For example, the Authority is responsible for management and maintenance of port infrastructure and superstructures. The responsibility is extended to all commercial activities related to cargo handling, that includes stevedoring. The role of the Authority is to control every operating asset found within the port or terminal. An example of this type of model is the Port of Mombasa in Kenya, which is owned and managed by the Kenyan Port Authority (Partel, 2015).

The framework of port operations presented in Table 4, below, provides a useful insight into the spread of terminal operations and ownership in the South African ports system. The port terminal operators are regarded as the businesses of ports operations. They are responsible for cargo handling or any other cargo-related services (TPT, 2019). The framework of port operations in Table 4 captures the proportion or composite of each entity in the spectrum of port operations. As shown, TNPA is the landlord and the sole provider of marine services, hence its 100% ownership. The port operations are either executed by private players or Transnet Port Terminals (TPT, 2019).

Table 4: South African Port Operations Split

		Port operations	
Service	TNPA	TPT	Private sector
Marine services	100%		
Bulk cargo handling		52%	48%
Break-bulk cargo handling		69%	31%
Container handling		98%	2%
Automotive (Ro-Ro)		100%	

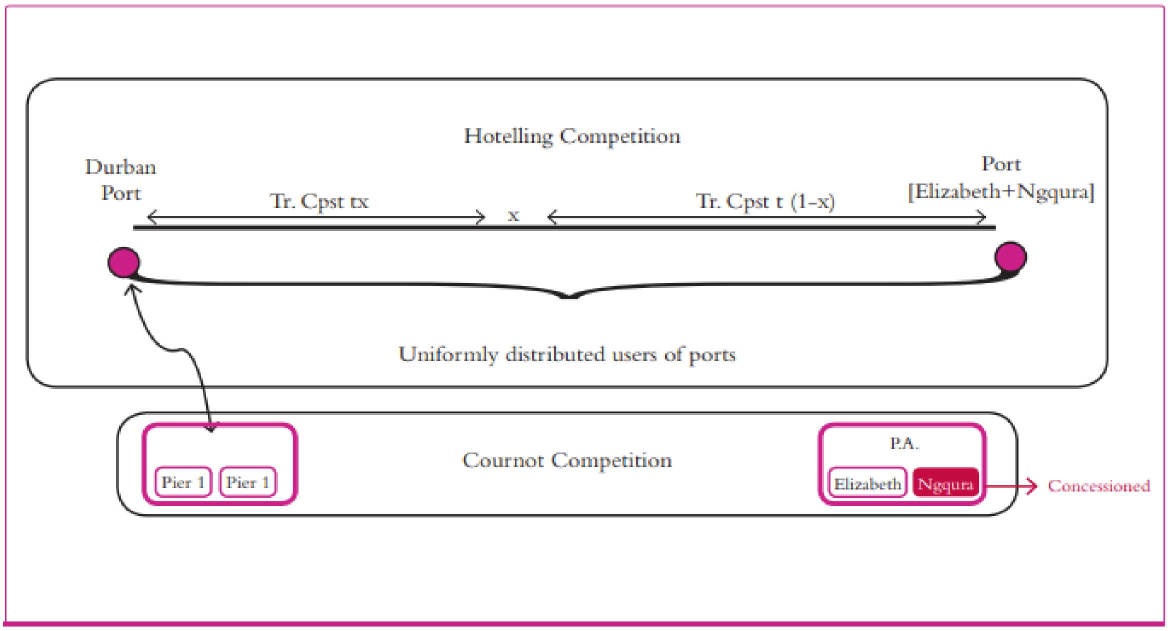
Source: Havenga and Simpson (2016)

2.8 The Public and Private Sector Interface in the South African Port Sector.

TPT is a sub-division of the Transnet group that is exclusively responsible for cargo-handling services within South African ports controlling 98% and 100% of the market share in the automotive and container businesses, respectively (Transnet, 2019). The present structure of SA ports excludes private players from making a significant impact in the container cargo-handling business, but with a greater presence in bulk arena, where TPT is also present.

Havenga and Simpson (2016) provided a useful insight into the privatisation of some SA container terminals. Figure 8, overleaf, illustrates a scenario where game theory is applied to explain terminals' competition and possible effects if TNPA decides to open container terminal operations to private entities. A linear market area of unit length is assumed, with identical consumers. To fulfil the hypothetical simulation, Havenga and Simpson (2016) selected three South African container ports, Port Elizabeth, Ngqura, and Pier 1 and Pier 2 terminals from the port of Durban. The scenario assumed that TPT continued to operate as the sole provider of cargo handling services in Durban for Pier 1 and Pier 2 and that Ngqura followed the landlord port governance style and leased terminals operations to private terminal operators. This allowed private terminal operators to take over in cargo handling services whilst Port Elizabeth remained under TPT operations.

Figure 8: The Linear City Model under the Cournot Model



Source: Kaselimi and Notteboom (2020)

The distance between Ngqura and Port Elizabeth is no more than 19 km. Hypothetically speaking, the container terminals from these ports are treated as if they are competing from one port. The case study viewed terminals competition under the Cournot model, which is an economic model in which competing firms choose a quantity to produce independently and simultaneously. The model applies when firms produce identical or standardised goods, and it is assumed they cannot collude or form a cartel (Lie, 2014). Quantity competition is perceived as a choice of scale that determines the firm's cost functions and thus determines the conditions of price competition (Kaselimi and Notteboom, 2020). Although a few port economists have questioned the validity of the hypotheses by Kaselimi and Notteboom (2020), it was later expected that some competition elements will appear. However, no port competition was detected, but the general observation was that the competition model is inevitable between Port Elizabeth, Ngqura, and Pier 1 and Pier 2 terminals from the port of Durban (*Ibid*.). Creating a space for private terminals at Ngqura would will add value to port operations. Facilities from this port are under-utilised. Private entities will more likely to maximise the capacity of a port and extended services to hinterlands as was reported by (UNCTAD, 2019).

The terminal behaviour will change, since this will induce intra-port competition. For example, the Port Authority in Brazil transformed the interface of container operators. The Authority allowed private terminal operators to be in charge in the container terminals operations business. The BTP (APM) and DP World started port operations in that country. Due to the arrivals of new container terminal operators, they were able to increase the technical efficiency and productivity in their space. It exposed the public operators Pecem and Vila do Conde to intra-competition (Lopez-Bermudez, Freire-Seoane and Gonzalez-Laxe, 2018). With regards to Durban Pier 1 and Pier 2, if one terminal is leased or auctioned to private terminals, that will induce intra-competition. The same behaviour is also observed in Barcelona port, which is comparable in size to Durban, in terms of volume. APM Terminal has been previously producing positive terminal productivity, but the newer and larger terminal Hutchison BEST Terminal, outperforms the APM Terminal.

2.9 Conclusion

Based on the information reviewed, the operational performance indicators were seen as the most effective tools to assess port performance and terminals' productivity. In that regard, the literature review has analysed and mapped backgrounds of port performance and productivity, in relation to container ports and terminals. However, an overall assessment of port performance also includes financial performance indicators. WEGO is strongly linked to operational performance of domestic ports, therefore, it seems to be beyond the scope of this research to include a full discussion of financial indicators. The financial indicators are of course relevant to indicate the investment returns on ports' assets or the total cost incurred to handle the tonnage through the facility. From the opinions collected and analysed, it was found that there is no single approach to port performance assessment, but the literature review offered a more comprehensive view of different approaches to assess productivity or efficiency. The chapter also outlined the key configurations of a basic container terminal including the key activities undertaken. Moreover, it provided an additional insight to each container terminal of the country. It is noted that WEGO is not well covered, and the study took cognisance that WEGO is under development. This chapter also looked at the general overview of the South African port sector, supplementing the discussions by highlighting the key role players, functional port authority models and finally the interface of public and private sectors involvement.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

Research methodology is perceived as a mechanism or systematic approach pursued by a researcher to meet the objectives and aims of any particular study, thereby identifying a research problem, and proposing a solution to the problem. The role of research methodology defines the procedures and techniques that are applicable to the problem. Furthermore, research methodology is a plan of action that articulates the research methods, the data collection tools, and the procedures to interpret and analyse data. This research study proposes to assess the KPIs for container ports in the context of WEGO; that is, to assess the performance-sensitive KPIs, which are ship turnaround time, anchorage waiting time, berth productivity, and containers worked per ship working hour, in a context of efficiency and productivity.

The researcher chose to apply the principles of a comparative study of these KPIs between the ports of Cape Town, Port Elizabeth, Ngqura and Durban. Considering this fact, the analysis and comparative exercise will be further extended to review contemporary studies which discuss container ports efficiency but with reference to other international ports. The aim will be to explore approaches and parameters selected by those ports in determining or assessing port efficiency and productivity. This chapter first outlines quantitative and qualitative research methods. This will be a desktop study, without recourse to fieldwork. It then sets out the data collection techniques to be used, which comprise a review of the common variables (input versus output parameters) commonly used to evaluate port efficiency and terminal productivity.

3.2 Research Methods

Mokone (2016) identified three research methods: qualitative methods, quantitative methods and mixed method approaches. According to Mokone (2016:39), "a quantitative approach involves compiling statistics, opinion surveys and questionnaires, then examining the results to produce data-driven analysis and a qualitative approach in a process that enables a researcher to gain an understanding of underlying reasons, opinions, and motivations of the study". A quantitative approach refers to a collection of numerical data to which mathematical and statistical programmes are applied to quantify research results.

A qualitative approach is based on the object and opinion to quantify the research results. A mixed method approach combines both the qualitative method and quantitative method.

The research methodology will interrogate the efficiency and productivity of container ports, including the operational nature and content of KPIs that will be sufficient to address the research question and to draw a meaningful conclusion based on comparison between local container ports and international ports. The assessment of productivity and efficiency will seek to reveal the capabilities of the South African container sector wherein both TNPA and TPT can invest to improve operational performance, thus benefiting containerships calling at South African ports (Motau, 2015).

This dissertation applies principles of both qualitative and quantitative research methods, on the basis that this study will collect and analyse the actual efficiency and performance data from the sample selected and then match this against the baseline data estimated in order to conduct a comprehensive review. Measuring container port performance is critical for the planning and organising of port infrastructure and the utilisation of port capacity. Additionally, it is an important indicator for future port investments.

A mixed approach is systematically linked to operational port performance. A quantitative approach collects and analyses WEGO performance scores, while a qualitative approach searches for reasons for observed performance fluctuations, backed up by reviewing scholarly publications to justify and defend the reasons. This dissertation used numerical data to present the observed trends from the WEGO performance results. This research intends to draw a relationship and observe the trend in performance between the KPIs selected to express efficiency and productivity of South African container ports.

In terms of sampling the data, the study will examine container information only, thus excluding dry-bulk, liquid-bulk, automotive and break-bulk cargoes, as presented in the WEGO performance results. KwaZulu-Natal and the Port of Durban will be the general site of research focus, although no specific survey work will be conducted at any specific site.

Due to ethical consideration and the confidentiality of primary data, this dissertation relied on secondary data to fulfil the objectives of this study.

Data availability imposes limitations on the success of a research study. Besides the availability of data, the authenticity of presented data is still a challenge. This study sought to secure data related to ship turnaround time, berth productivity and anchorage waiting time from comparator ports.

3.3 Data Collection Technique

This is a desktop research study, which means that it is a data collection approach, and is specific to secondary data, whereby a researcher sources data without visiting a field. Desktop research collects secondary data from internal sources, the internet, libraries, trade associations, government agencies, books and published reports. This dissertation relied upon online available ports information such as vessel traffic statistics, productivity and efficiency scores, which are published through academic journals or ports authorities' websites.

Information on the chosen ports (Durban, Ngqura, Port Elizabeth and Cape Town) and comparator ports was publicly available and additional information was obtainable from the relevant ports' authorities. TNPA, TPT, the Africaports.co.za website, and PRSA all play a critical role in generating secondary data for this study. Both TNPA and TPT publish conventional annual reports. These reports contain sufficient information about the organisations' annual performance, strategies, achievements, and targets, and will be used as such here. TNPA and TPT financial statements are also available in the public domain, although the focus of this research is on operational performance indicators, and not on financial indicators.

PRSA published WEGO performance results for the 2018/2019 financial periods. This information, which is drawn from PRSA's publications, is used to review and interpret container ports efficiency scores. The WEGO performance results for the years 2017, 2018 and 2019 will be collected and analysed without using any mathematical and statistical modelling techniques. Since WEGO is still under construction, the researcher took cognisance of the gaps in the data collected on KPIs. The secondary information was gathered with the aim of exploring gaps observed in each domestic container port, with reviewing the deployment of resources, and identifying the variables or factors that lead to an inefficient and unproductive port system.

3.4 Study limitations

WEGO is a tool established by the Ports Regulator. This research noted that there are few ports around the world that have port regulators. There is no single approach to assessing port performance. Likewise, there is no single approach to enhance port efficiency and terminal productivity. Ports pursue different channels to improve port performance. For a variety of reasons, there was no data available similar to WEGO. The inability to acquire such information limited the author to carry out a more comprehensive comparative analysis with other international ports.

The benchmark exercise will be useful to PRSA and TNPA to expose gaps, if they exist, or to gain more insight into performance-based port pricing. The study will obtain WEGO performance scores for 2017/2018-2018/2019 financial periods. For more robust analysis, any performance trend is best interpreted from multiple years, hence 2017/2018-2018/2019 performance scores are not sufficient to express Durban (or other SA port) performance trends fully and the study will be limited to examine the consistency of KPIs. UNCTAD prescribed financial and operational performance indicators, but this research will be limited to containers handled per SWH, anchorage waiting time, berth productivity and ship turnaround time. Therefore, the analysis will be limited to these KPIs.

3.5 Variables (Input and Output Parameters)

The literature review highlighted non-parametric and parametric variables as the systematic approach to evaluate port performance. The research methodology outlines the common variables considered in measuring performance, which is expected to add value to this study. According to De Langen and Helminen (2015), a productivity indicator or efficiency determinant would have to measure a certain input in relation to a certain output. Table 5 overleaf depicts the output and input parameters which are employed in assessing port performance. The volume of containers that pass through the facility and vessel traffic are considered to be output parameters, while duration of berth occupation, number of quay cranes available, berth length and terminal size are classified as input parameters. The analysis carried out will be informed by the distinctive features of South Africa container ports, such as cranes' capabilities, berth lengths, and terminal capacity.

Hinterlands and trade connectivity have an influence on call size, vessel traffic and container volume. All these inputs and outputs will be featured in WEGO performance analysis.

De Langen and Helminen (2015) further note that "an indicator could either focus on a broad picture per port, be specific for a specific type of terminal (e.g. container terminal) or even a specific measure per ship". Performance can be viewed at disaggregated levels, as shown in Table 5. It could be the vessel traffic calling to a particular port, performance of the entire port or assessment of productivity at a specific terminal. In order to minimise the variation in performance indicator results, the study must select a general focus. This research will be inclined to focus on Durban container terminal productivity and efficiency. A broader assessment of all KPIs and different type of cargoes is beyond the scope of this study.

Table 5: Potential operational indicators

	Outputs	**Input**
Port level	Throughput volume Ship calls	Length of quays number of berthing places. Size of land for terminal activities Size of the port area (land + water). Number of employees
Terminal level	Throughput volume	Quay length Size (m2) of terminal Number of employees
Ship visit	Volume loaded and unloaded	Time at berth

Source: De Langen and Helminen (2015).

It is imperative to mention that the choice of variables selected is backed by the availability of data, such as port statistics and the records of infrastructure to a limited scale. With reference to gantry cranes and container throughput, the data tables presented in subsequent chapters will show the number of TEU handled per crane per hour, and in light of the volume of containers, the tables will indicate TEUs handled per hour.

3.6 Conclusion

This chapter has set out the research methods, data collection tools, consideration of variables, and options to synthesise information collected in order to generate results. The success of a research study lies upon the availability of data. Although there were restrictions in sourcing secondary data, this study embodies both a qualitative and a quantitative research approach. This is a comparative study, benchmarking local ports with internationally-recognised ports. The availability of information from foreign ports remained an issue due to the confidentiality and competition regulation. The information that was available directly from port authorities was intended for marketing purposes and takes the form of reports to various ports stakeholders. However, the academic papers and publications fill that gap by sourcing primary material pertaining to port performance.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Introduction

Measuring port performance is not a simple task for Port Authorities across the world, including the Transnet National Ports Authority (TNPA) in South Africa. Many entities or organisations, including seaports, possess unique characteristics to also operate under dynamic and complex eco-systems. But that does not limit the responsibility of authorities to evaluate the ports' performance and to report to the port stakeholders as well as to port users. Moreover, each port is different because of its internal and external characteristics. To name a few, these could be the position of the infrastructure, port administration, port pricing, and last but not least, the volume and composition of trade that affects a particular port.

These port differences require the authorities to find an efficient and consistent manner to evaluate overall port performance. In the South African context, TNPA, which is the landlord, acknowledges that there is no single measure that encapsulates all the important aspects in reviewing port efficiency and terminal productivity. Nevertheless, the lack of uniformity motivated the establishment of the Terminal Operators Performance Standards (TOPS) and the Marine Operator Performance Standards (MOPS) by the TNPA. Prior to the establishment of these instruments, the authorities had neither been instrumental, nor pro-active, in measuring the ports' efficiency and productivity.

The introduction of the Ports Regulator of South Africa (PRSA) in 2007, helped the Authority to monitor and benchmark port performances, while striving to enhance productivity and to reduce high port tariffs for particular port users. Recently, the TNPA and PRSA have systematically started monitoring the performance of all South African ports, including the container terminals, in a process whereby port performance is evaluated against measures that have been consulted on, and agreed upon, by the relevant stakeholders.

The aim of this study is to analyse the commonly-used parameters to assess productivity and efficiency within container ports. There are two broad categories of performance indicators recognised by this study, namely, operational performance indicators, and financial performance indicators. The greater emphasis of this research will be on operational key performance indicators.

TNPA published the Key Performance Areas and indicators for the 2017, 2018, and 2019 financial periods, as well as an estimation for the 2020 financial period. The study engages with a previous exercise started by PRSA and TNPA by reviewing the key performance indicators nominated for a Weighted Efficiency Gains from Operations (WEGO) process, such as ship turnaround time, berth productivity, performance per ship working hour, ship productivity indicators and the extent of vessel delay at anchorage, relating to South African container ports and terminals from Durban, Port Elizabeth (PE), Ngqura and Cape Town. Additionally, a comprehensive analysis of performance trends using the available secondary information supplied by PRSA, TNPA and TPT, presents and seeks to interpret the variations between estimated and actual performance.

This study analyses the key performance indicators in respect of container port and terminal efficiency and productivity as one of the principal objectives of this study. The author addresses the concepts of 'efficiency and productivity' in the context of container ports and terminals. The author recognises that it is imperative, and it will add value, to examine the components which influence the ports' efficiency and productivity. Moreover, this research summarises components such as the utilisation of assets and infrastructure, berth availability or productivity, and the quality of services provided by both TNPA and TPT to ensure better terminal productivity and port efficiency. Other factors outside the jurisdiction of the TNPA and terminal operators are also included in the discussion, and pertain to efficiency and productivity.

The Durban container port is the main container-handling facility in the country. The study assesses Durban Port's performance against those of Ngqura, Port Elizabeth and Cape Town. The availability of the KPI scores motivated the study to observe a performance pattern between South African container ports, and the overall performance whereby the actual data is assessed against targeted scores. The detailed analysis is limited only to South African ports.

4.2 The Evolution of WEGO

The port inefficiencies and competition issues around the South African port sector prompted the establishment of the Ports Regulator of South Africa (PRSA) in 2007. The primary role of PRSA is to administer and oversee the economic regulation of TNPA's functions. By definition, economic regulation aims generally to address market failures or monopoly behaviour where there are no effective competitive conditions to set efficient prices in the provision and maintenance of infrastructure (Havenga and Simpson, 2016).

Prior to the establishment of the Ports Regulator, TNPA had little incentive to turn around any of the principal functions of a port, or to uplift the standard of port services and improve overall operational performance of the South African ports. There was hardly any competition between ports or within ports, as well as inadequate port infrastructure, digital infrastructure and superstructure. The South African port system is characterised with high tariffs for particular cargoes and poor terminal activities. PRSA and TPNA are working together to overcome these shortcomings. The institutions are moving towards better port pricing thus promoting incentives for port efficiency. PRSA runs roadshows to engage with port users and different stakeholders on issues pertaining to port pricing.

PRSA is empowered by the National Ports Act of 2005, to regulate and administer port pricing. In response to the demands of port users, PRSA established the Weighted Efficiency Gains from Operations (WEGO) as an instrument aimed to improve ports' operational performance. WEGO is incorporated into the tariff methodology (Required Revenue) used to collect revenue from port users. According to PRSA (2020: 19), "WEGO allows up to 5% additional profit to the National Ports Authority (the NPA) for a 10% increase in year-on-year improvements on a basket of key performance indicators (KPIs), and similarly up to 5% decrease in profit for a 10% decline in performance".

The process to arrive at performance incentives or disincentives is a joint decision between relevant authorities and stakeholders. The process for arriving at final WEGO incentives or disincentives may be illustrated by citing the process applied in 2018/2019, and applicable to the next tariff year. The process is illustrated as follows:

- In April/May of 2020, NPA submits the full performance data of the preceding periods, 2018 and 2019.

- The Regulator will publish the results and make a call for comments/inputs from port users,
- In case(s) where performance is contested by a port user or a port user segment, verifiable data must be provided and/or Ports Regulator and/or KPI subcommittee must be provided with access to such information.
- May-June 2020: consultations will be held with port users through PCC KPI subcommittees (including the NPA) to interrogate and verify performance data.
- 1 August 2020: NPA submits its tariff application for 2021/22 including WEGO incentive/disincentive based on performance in 2018/19 and 2019/20.
- PCC and/or individual port users comment on WEGO as part of written submissions to the Regulator on the NPAs tariff application.
- 01 December 2020: Ports Regulator WEGO decision as part of tariff determination ROD (**PRSA Record of Decision: WEGO KPI and Weights 2020/21, pp 5-7**)

4.3 Assessment of WEGO Performance Results for 2017/18 - 2018/19 Financial Years

Table 6 overleaf shows all five KPIs which are selected for WEGO, together with a description of each KPI, its method of calculation and its weight in the overall instrument. As Table 6 shows, each KPI is assigned a weight of 20%. Furthermore, Table 6 outlines the distinctive features PRSA considers to evaluate port performance. PRSA expressed anchorage waiting time in percentage terms, whereas TNPA expressed anchorage time in hours. PRSA explained that anchorage waiting time is supposed to measure the number of vessels serviced on time as requested against the total number of vessels called, which is the reason PRSA used percentage terms to express this KPI. Nevertheless, PRSA revised this KPI, and it will be replaced by vessel service delay which basically measures average delays to vessels as the direct result of the terminal, so in future this KPI will be expressed in the form of hours. PRSA adheres to standard norms in other areas, such that ship turnaround time is expressed in hours, whilst berth productivity, ship working hour, and ship productivity indicators are all expressed in terms of the number of containers a terminal or ship handles per hour.

Table 6: Key Performance Indicators for WEGO 2018/2019

No.	Key Performance Indicator	Description	Calculation	Approved Weight
1.	Ship Turnaround Time	"Total hours' vessels stay in port (breakwater-in to breakwater-out) divided by total number of vessels." Excludes: *force majeure* (weather delays), surge, under currents, and external power supply failures.	STT = ∑ (BWO – BWI)/ (∑ vessels). *Where:* STT= Ship Turn Around Time BWO = Breakwater Out BWI = Breakwater In	20%
2.	Ship Productivity Indicator	Total number of TEU (for containers) or tons handled (for breakbulk and bulk cargoes) divided by total hours in port.	SPI = ∑ (Vol/ STT) *Where* SPI = Ship Productivity Indicator Vol = Volume STT = Ship Turn Around Time	20%
3.	Vessel Delay at Anchorage	The average delay to vessels as a direct result of X (terminal, marine services). Total of all (vessel actual berthing time - vessel planned berthing) / total number of vessels delayed. Excludes: *force majeure* (weather delays), surge, under currents, and external power supply failures.	VDx = ABT – PBT/ No. of VD *Where* X is the type of delay (terminal, tug, pilotage, shipping line). ABT = Actual Berthing Time PBT = Planned Berthing Time. VD= number of vessels delayed	20%
4.	Berth Productivity	Total number of TEUs (for containers), tons handled (for breakbulk and bulk cargoes), kilolitres (for liquid bulk) and number of units (for Auto/RORO) divided by Total time of ships alongside.	BP=∑ (Vol/ (LLU –FLT)) *Where* LLU =Last Line Untied FLT= First Line Tied	20%
5.	Ship Working Hour	Total volume handled during the total productive working hours for the vessel. Total volume for a given period, number of moves (for containers) tons handled (for breakbulk and bulk cargoes), kilolitres (for liquid bulk) and number of units (for Auto/RORO) divided by Total vessel productive time i.e. (Sum for all vessels during the month (last swing) – (first swing). Excludes: *force majeure* (weather delays), surge, under currents, and external power supply failures.	SWH= ∑ (Vol/ (LL – FL)) *Where* LL = Last lift FL= First Lift	20%

Source: PRSA, Record of Decision Weighted Efficiency Gains from Operations, 2018.

The process allows PRSA to use the previous years' performance results as the baseline to generate WEGO performance scores for the current year. Therefore, PRSA relied on 2017/2018 and 2018/2019 operational performance scores which are supplied by TNPA as the baseline. The KPI tables below (from Table 7 to Table 13) will reflect the 2017/2018 and

2018/2019 operational performance. The operational performance scores will be interpreted to capture changes observed between the 2017/2018 and 2018/2019 financial periods. The analysis will also seek to understand factors influencing each KPI. Changes observed from performance levels will be supplemented using South African port information, which will suggest reasons for the improvement on previous years' performance or the possible explanation for a decline from the previous years' performance.

TNPA assesses port performance in the context of MOPS and TOPS with an aim to improve operational efficiency and productivity levels. PRSA further synthesises the information collected from TOPS to quantify the WEGO performance results. WEGO and TOPS used similar performance indicators to express operational performance levels observed or experienced by port users.

However, the objective of the study is to quantify and evaluate the container port performance indicators by tracking the effectiveness of an indicator to measure container port efficiency as well as to critique the level of services received by port users relating to the terminal size, storage capacity and finally, to measure the extent to which port resources and facilities are utilised.

Although PRSA previously conducted a benchmark study on South African ports capacity, the study will also seek to provide a useful insight to particular container indicators on other terminal operators worldwide to achieve acceptable performance levels.

The respective Key Performance Indicators will now be presented and assessed in turn, in sections 4.3.1 to 4.3.4 that follow.

4.3.1 Ship Turnaround Time

Ship turnaround time is a performance indicator that expresses the total time spent by a ship in a seaport. Usually, it commences the moment the vessel reports its arrival at a port's limits, then proceeds to its working berth, and is further calculated until the ship leaves port premises or limits. With respect to Durban Container Terminals, the indicator includes the following parameters: container handling hours, the total time a ship is alongside at a berth, hours a ship waits to berth, ship size and berth throughput.

Table 7: Ship Turnaround Time (hours) at South African Container Terminals 2017/2018-2018/2019

2018/2019 WEGO PERFORMANCE RESULTS			
Container Ports	**2017/2018 (hours)**	**2018/2019 (hours)**	**Performance Changes (Gain or Loss)**
Durban	70,0	69,0	1,4%
Cape Town	32,0	30,8	3,6%
Ngqura	38,0	30,2	20,5%
Port Elizabeth	20,0	19,0	5,0%

Source: PRSA, Notice on WEGO Performance 2018/2019

In terms of ship turnaround time, the port of Durban improved slightly from 2017/2018 to 2018/2019. PRSA recorded an improvement to 69 hours in 2018/2019 from 70 hours in 2017/2018, or a small performance gain of 1.4%. Durban is the largest container port of the country and handles more cargo volume per annum as reflected in Table 8, overleaf. This higher level of cargo activity is largely responsible for the higher ship turnaround times in Durban, as reflected in Table 7, above.

Ngqura recorded the second-highest ship turnaround time, after Durban. The port recorded an average of 38,0 hours in 2017/2018 and 30,2 hours in 2018/2019, across all container callers, such that Ngqura achieved a significant reduction in time by some 20,5%. This indicates that the port performance has improved from the 2017/2018 to 2018/2019 financial periods. In that context, Ngqura container terminals set a low container volume of 774 899 TEUs during 2017/2018 calendar year and volumes reached 829 813 TEUs in the 2018/2019 financial year (TPT, 2019). Transhipment traffic plays a critical role to generate more containers passing through the facility.

Table 8 overleaf shows the number of containers handled in Durban per annum and the vessel traffic of all seagoing ships that visited the port of Durban per annum, between 2009 and 2019. The table does not reflect the productivity of a port but it reflects the vessel and container cargo activity passing through all port facilities. The port has recorded an increase in the container throughput since 2009, but the number of ships (all ships, not only container ships) visiting the port has decreased over most annual periods from 2009 to 2019, falling from 4702 callers in 2009 to 3253 in 2019, or by some 31 percent. The implication is that fewer, larger containerships are calling to Durban and have been working more containers per port call.

The shipping activities coincide directly with developments occurring as a result of international trade. The increase in container throughput locally and internationally is enabled by the growth in global gross domestic product, as well as by globalisation and other macro-economic and micro-economic variables (UNCTAD, 2020).

Table 8: Number of TEUs handled and Vessel calls in Durban, 2009-2019

Year	Total Number of TEUs Handled Per Annum	Vessel Calls Per Annum
2009	2 395 000	4702
2010	2 529 209	4633
2011	2 720 915	4273
2012	2 568 124	4157
2013	2 660 146	3958
2014	2 664 330	3963
2015	2 770 335	3875
2016	2 630 000	3754
2017	2 690 000	3325
2018	2 950 000	3061
2019	2 844 000	3253

Source: www.Africaports.co.za, 2009-2019 and Scholtz (2017)

In the local context, both TNPA and TPT have a direct influence over the ship turnaround time. This underscores the fact that these entities can control each component of ship turnaround time, like waiting time or berthing time, such that the carriers can enjoy minimum vessel turnaround time. As noted in Table 6 above, PRSA has excluded weather delays (associated with *force majeure*) and other exogenous factors in the determination of ship turnaround time in the context of WEGO. These factors do have an impact on ship turnaround time, although they may be deemed to be outside the control of the terminals themselves (PRSA, 2019). Premathilaka (2018) identified the following key factors as affecting the operational performance in Durban Port: the number of quay cranes, number of container moves, berth productivity, gross crane productivity and ship turnaround time.

Indeed, the ship turnaround time is primarily affected by the number of containers handled in a typical port call, which in turn is a function of the throughput that passes through the port facilities per annum. Table 8 indicates that the container volumes dropped in Durban in 2019 to 2,844 000 TEUs from 2,950,000 TEUs in 2018. In the same period, Durban also had a positive gain of 1,4% in ship turnaround time.

It can be expected that if the number of boxes handled across the ship to shore side is increased, this will require the ships to extend their port stay, thereby increasing the turnaround time. This could be tested by comparing the number of boxes handled against the total time spent by a ship in a port or berth. As the container throughput increases in Durban, it is expected that ships will stay a bit longer in port whilst working on more containers per call.

The throughput statistics show that the container volumes were high during 2017/2018 financial period compared to 2018/2019 financial period, but WEGO performance results for 2018/2019 reported that during the same period ship turnaround time improved. The ship turnaround time indicator does not capture the actual performance of Durban. This is considering that the ship turnaround time has been difficult to analyse in detail. A meaningful assessment of this indicator involves the breakdown of ship activities from the moment a ship arrives at the port anchorage until a ship departs.

Terminal or berth productivity is the core function of ship turnaround time. The number of boxes a particular ship or berth handles per hour will be fully explored in the following sections (i.e. berth productivity and containers handled per ship working hour).

Motau (2015) links operational performance inconsistency in Durban to infrastructural challenges, like berth unavailability, and a breakdown of cargo-handling equipment. Any increase in anchorage waiting time also contributes to vessel delays and consequently increases vessel turnaround time. In the case of a vessel missing the Expected Time of Arrival (ETA), this ends up increasing the pressure on TPT to strive for optimum cargo-handling productivity to maintain a targeted vessel turnaround time, so that a vessel can depart as per schedule.

According to TNPA and TPT, it is impossible for these institutions to change any major infrastructure in the short run. However, the configuration around yard operations can improve quayside operations. Earlier, Scholtz (2017), commented about yard operations in Durban. Scholtz was concerned with the clearance efficiency from yard to gates; containers were moving slowly within terminals, which ends up creating constraints for stacking capacity, which, in turn, hinders quayside operations. The author identifies factors affecting quayside operations as emanating from poor management that is observed from yard operations, and contends that yard operations are integral for productive container-handling processes.

Smooth terminal operation is supported by the availability of basic infrastructure and superstructure. This refers to all handling and moving equipment within the stacking area, to the availability of the number and length of berths, and to the number of gantry cranes per running metre of quay wall.

The high container volume handled in Durban (up to 2.95 million TEU per annum) requires smooth yard operations. These entail proper container stacking, the avoidance of unnecessary container movement, and the management of the effective flow of information using Information Communication Technology (ICT) tools. As alluded to before, the bottlenecks within the yard operations result in a longer vessel turnaround time. At least TPT, as the terminal operator, can have an influence on yard operations.

Vessel size affects the turnaround time in various ways. It is obviously affected by the volume of containers handled per typical port call. Vessel size may certainly influence turnaround times, as is fairly commonplace in Durban, if vessel movements are constrained to tidal windows. The issue of weather is uncontrollable and inevitable to TPT. The essence here is that the draft of larger vessels may limit their movements to tidal windows, so effectively, the vessels cannot arrive or depart except in time periods around high water (high tides).

In order to enhance operational performance, TPT must prevent equipment breakdown by frequently and regularly maintaining the handling gear because unexpected equipment failure negatively affects the ship turnaround time.

Vessel dimensions can affect the productivity of the bigger ships, many of which cannot access the port of Durban in a laden condition (because they are too deep for the berths), and of course this can have a knock-on effect on other vessels waiting to use particular berths. The port of Durban would have the potential to accommodate larger vessels of neo-Panamax dimensions in laden condition only if the TNPA can increase the water depth alongside container berths.

4.3.2 Berth Productivity

Berth productivity is a performance indicator that demonstrates the number of container moves per-vessel per-hour or per running metre of quay. Each container port in the country has distinctive factors affecting berth productivity. This includes the number of gantry cranes deployed, the average size of ships calling into a port, total berth length in metres, and finally whether the port is a transshipment port or is a gateway port. The Port of Durban attracts larger ships and has high container volumes as depicted in Table 8. Durban is the main gateway port of Southern Africa, but also attracts transshipment containers to boost overall activity.

Table 9: Berth Productivity (in TEUs per hour) of SA Container Ports (2017/2018-2018/2019)

2018/2019 WEGO PERFORMANCE RESULTS			
Container Ports	**2017/2018 (TEUs per Hour)**	**2018/2019 (TEUs per Hour)**	**Performance Changes (Gain or Loss)**
Durban	42,5	49,7	16,9%
Cape Town	30,0	33,1	10.3%
Ngqura	38,8	37,0	-4,6%
Port Elizabeth	28,0	25,1	-10,3%

Source: PRSA, Notice on WEGO Performance 2018/2019

By comparison, of the four ports under review, and as presented in Table 9 above, the port of Durban yielded the highest number of containers handled per hour of 49,7 TEUs in 2018/2019 and 42,5 TEUs per hour in 2017/2018. The ports of Durban and Cape Town both improved their berth productivity for the financial periods from 2017/2018 to 2018/2019, with gains of 10,3% and 16,9%, respectively. Berth productivity did not improve in Port Elizabeth. This port recorded a negative performance of 10,3% between 2017/2018 and 2018/2019. A similar situation of poor berth productivity can be seen in Ngqura with a negative performance of 4,6%.

The container volumes that a particular port handles remain the critical driver of berth throughput or berth productivity. The berth productivity is interlinked with terminal activity which coincides with the volume of container traffic that Durban handles.

As depicted in Table 8 above, container throughput in Durban in 2019 was not as high as in 2018. This left Durban with a decreased throughput per annum. But according to WEGO, the performance results in Durban improved because of the number in the boxes handled per hour in 2019. The terminals with a lower yearly container throughput achieve lower berth productivity. Other things remain equal, higher berth productivity is favoured by large container volumes that permit multiple cranes to work on large ships.

In terms of asset and port facilities utilisation, this indicator is deemed to be insufficient to measure the extent to which facilities are utilised. The WEGO values do not capture the real situation about berth and crane capacity.

This underscores the fact that WEGO is still a new tool to monitor and track port performance and terminal productivity. Despite the progress made by the port in handling larger containership and higher container volumes, productivity issues stagnated over the previous years. The year-on-year comparison over 2017/2018 and 2018/2019 is not sufficient for PRSA to determine the progress made by the operators and TNPA to improve port performance.

Meaningful assessment of berth productivity comes down to crane density and crane productivity. Table 6 above does not clearly show the approach followed by WEGO to arrive at berth productivity scores. For TPT, in order to fully understand productivity of cranes, assessment should consider moves per hour handled by a single crane versus the number of cranes employed across the full vessel.

High crane density is meaningless if individual cranes make few moves per hour. For example, it is preferable to operate with 3 to 5 cranes achieving 40 moves per berth hour rather than working with 5 to 7 cranes but achieving 35 moves per berth hour. Assuming that a ship is working on a full load, the number of cranes assigned to a ship partially depends on overall vessel length. Durban is receiving ships ranging between 300m to 366m in length and the average number of cranes can be applied to these vessels is 5. Accommodating larger containerships does not increase berth productivity, but makes for fuller use of terminal facilities. The unproductive time is lower with larger ships because these ships assure the terminal operator a continuous operation of quay cranes. For available quay cranes, the terminal operator can be able to perform same time cargo handling operations other than moving individual cranes along bays.

Total moves per port call is determined by the characteristics of particular ships and berths. The port of Durban has a berth length totalling 3576 metres. There are 24 gantry cranes available in Durban for container handling operations, 7 gantries at Pier 1 and 17 gantries at Pier 2.

Unfortunately, Table 9 does not represent the performance of TEUs handled per running metre of quay. From the superstructure or infrastructure point of view, increasing the number of cranes surely will, *ceteris paribus*, increase TEUs worked per running metre of quay, provided that berths remain occupied.

The study extracted Berth Occupancy Rate (BOR) as indicated in Table 10. This represents "the percentage of the total available time that berths are occupied by ships" (Motau, 2015). BOR is discussed as the useful indicator of berth productivity and as a measure of berth capacity.

Table 10: Container Terminals Berth Occupancy Rate (2017-2019)

Key performance area and indicator	**Unit of measure**	**Actual**	**Actual**	**Target**	**Actual**	**Target**
Berth Occupancy Ratio	**Percentages**	**2017**	**2018**	**2019**	**2019**	**2020**
DCT (Pier 1)		61	64	60-70	69	65-75
DCT (Pier 2)		61	69	65-75	69	65-75
CTCT		73	64	65-75	61	60-70
Port Elizabeth		50	48	55-65	46	55-65
Ngqura		40	68	70-80	60	70-80

Source: TNPA (2019)

Between 2018 and 2019, the BOR for Pier 2 remains the same at 69%, whilst, BOR for Pier 2 increased from 64% in 2018 to 69% in 2019. In that regard, TNPA estimated BOR to be between 60-70 % for Pier 1 and 65-75% for Pier 2. So far, Durban has shown a balanced BOR.

BOR coincides directly with the number of boxes handled over a running quay metre. A low BOR in Durban will result in minimum number of moves per running metre of quay. The decrease in the volume of containers in Durban in the year 2019 had a considerable effect on terminal performance, but container volumes are pivotal factors to lower berth productivity. Productivity is linked to infrastructure capabilities.

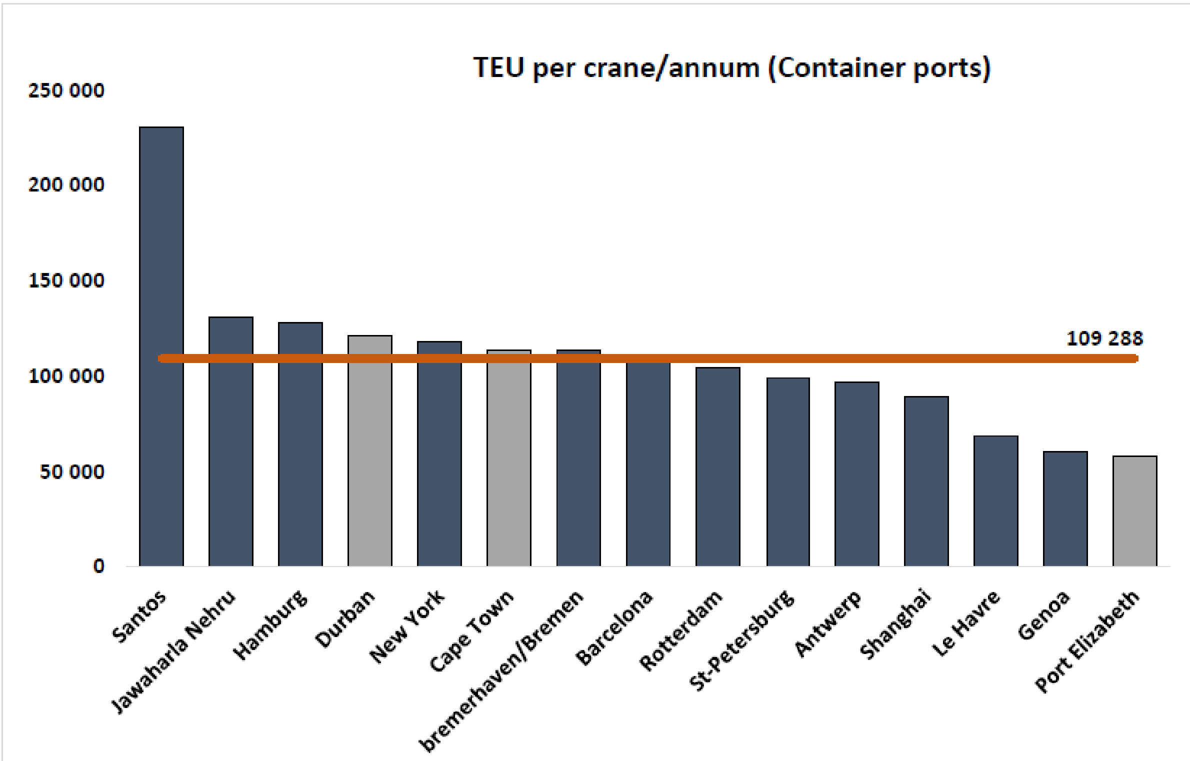
According to WEGO performance results, ship turnaround time improved from 2017/2018 to 2018/2019 calendar years. During the same period 2017/2018, the number of containers handled per running metre of quay was higher reaching (2 950 000 TEUs/3576m) = 824,94 TEUs compared to (2 844 000 TEUs/3576m) = 795,302 TEUs in the 2018/2019 financial period.

Durban container terminals have the potential to maximise the number of moves per hour per ship call, thus increasing berth productivity. DCT is operating on a 24 hour, 7 days a week and 3 shifts per 24 hours for crane operators and other supporting staff. During shift changes some operations remains idle. Such unproductive time increases ship turnaround time. TPT must make sure that no time is wasted during operational changes. Working on a 3 eight-hour shift per day basis enables the ship to handle more boxes as opposed to two eight hour shifts per day (TPT, 2020).

Operational issues interrupt the flow of containers from quay side to container yard. Operational issues usually emanate from poor planning by TPT and poor coordination of working resources between quay side and container yard. This has an effect on crane operation. At times in Durban, there are delays in the movement of containers within the terminal due the delay in the container clearance. This is caused by inadequate management as well as unavailability of moving equipment. In view of this, crane operators end up working fewer boxes per hour.

In the context of berth productivity, the number of crane moves per hour or per annum is a useful indicator for utilisation of quayside cranes, ship-to-shore cranes, or mobile harbour cranes. PRSA (2015) performed a benchmark exercise indicating TEUs handled per crane per annum. Figure 9 overleaf shows crane productivity at South African container ports, against international ports. This data was published during the 2015/2016 financial year.

Figure 9: TEU per crane/annum of International ports (2015-2016)



Source: PRSA Bechmarking Report: SA Port Terminals (2015/16)

In terms of crane productivity, Durban is slightly above the global average of 109 288 TEUs. Durban is operating with 24 gantry cranes altogether and handled 2 844000 TEUs in 2019 and 2 950 000 in 2018. Considering output per crane per annum of 118 500 TEUs in 2019 and 122 917 TEUs in 2018, the 16,9% performance gain of WEGO does not express the value of asset utilisation. Although terminal assets may be available, PRSA should be mindful of the fact that sometimes terminal operations or efficiency may decline because of a loss of market share or lower overall demand, which might be the case in Durban.

4.3.3 Vessel delay at anchorage

The Anchorage Waiting Time (AWT) is defined as a measured amount of time in hours that a vessel waits outside a port before it is allowed to come into a berth to commence cargo work (PRSA, 2019). The anchorage waiting time for container callers is one of the most important factors considered in determining the container port efficiency and a terminal's productivity. In light of port competitiveness, if the port shows minimum characteristics of anchorage waiting time, it is expected to attract more carriers into a port, in cases where inter-port competition exists.

Table 11: Anchorage Waiting Time (hours) in South African container terminals, 2017-2020

Key performance area and indicator	Unit of measure	Actual	Actual	Target	Actual	Target
Anchorage waiting time	**Averages hours**	**2017**	**2018**	**2019**	**2019**	**2020**
DCT (Pier 1)		26	42	≤ 30	25	≤ 25
DCT (Pier 2)		30	79	≤ 40	36	≤ 30
CTCT		25	34	≤ 28	34	≤ 25
Port Elizabeth		30	33	≤ 30	22	≤ 35
Ngqura		16	42	≤ 28	29	≤ 28

Source: TNPA (2019)

Earlier, the study commented that the anchorage waiting time is usually expressed in hours instead of percentage terms. Percentages are a poor measurement of anchorage waiting time and performance. AWT is supposed to measure the time in hours of ships waiting for available berths. TNPA also assesses the ship waiting time as reflected in Table 11, and hours are being used to measure waiting time. These are an average of the actual times and performance targets estimated by the landlord and the operator.

In that light, PRSA collects performance data from TNPA or TPT to generate WEGO performance results. Percentage terms limit comparative analysis. Therefore, the two cannot be compared because two different measures are being used. Normally, percentages are calculated from original data. Without the original data the percentages cannot be calculated. Calculations transform inputs into results but the inputs must be like-for-like to make a comparison. The information available does not show how PRSA arrived at the percentages. Due to the fact that Durban welcomes different types of vessels, percentage terms do not reveal the real performance challenges of Durban.

According to Table 11, in 2019, the actual performance scores of Ngqura and PE were close to their performance targets of 22 hours and 29 hours respectively. WEGO produced results that show that the anchorage waiting time improved in Durban, whereas Durban produces AWT above the global average hours mentioned in chapter 2.

Table 11 indicates that container vessels had to lie at anchor for 42 to 79 hours in Durban during the 2018 financial year, whilst waiting for available berths at Pier 1 and Pier 2, respectively.

Table 12: Anchorage Waiting Time (Percentage Terms) in South African container terminals, 2017-2019

2018/2019 WEGO PERFORMANCE RESULTS			
Container Ports	**2017/2018**	**2018/2019**	**Performance Changes (Gain or Loss)**
Durban	22%	7,0%	88,2%
Cape Town	9,0%	3,0%	66,7%
Ngqura	5,0%	5.1%	-2,0%
Port Elizabeth	3,0%	2,4%	19,7%

Source: PRSA, Notice on WEGO Performance 2018/2019

This paragraph highlights WEGO performance results as reflected in Table 12 above. This is an imperfect measure of performance and productivity and there is still uncertainty as to how the Regulator arrived at the following percentage terms: the port of Durban gained a 88,2% reduction after the performance improved in 2017/2018 from 22% to 7,0% in 2018/2019. During the period under review, 2018/2019, only the port of Ngqura showed a loss of 2%, whereas, Cape Town and Port Elizabeth also recorded an improved operational performance with regards to anchorage waiting time. Cape Town recorded a gain of 66,7% and Port Elizabeth recorded a gain of 19,7%. AWT was supposed to measure the service time for ships, which is expressed in hours. Percentage terms do not capture the delays at Durban accordingly. It is not clear as to exactly what they do measure. Nevertheless, this indicator is under review by the Regulator.

As per the data analysis, this study rejects that AWT improved in Durban during the 2019 period as WEGO suggested. Anchorage waiting time correlates directly with terminal activities. Presumably, improved anchorage time would mean there is less port congestion and the operators are producing higher terminal productivity. During 2019, the trend has been downward in Durban for containership callers as reflected by Table 8 earlier. The performance had not necessarily improved due to poor berth productivity.

Although, it might be a minor aspect, presumably, AWT improved due to the reduced ship traffic particular container callers and decreasing container throughput.

This research found that some vessels from MSC omit berthing in Durban and discharge cargoes in PE or Cape Town. Thereafter, the cargoes destined for Durban are transhipped through the mentioned ports (MSC, 2020). Container callers cited high anchorage waiting time as the reason for reducing Durban calls or abandoning Durban as a port of call.

It was not easy for both TNPA and the Regulator to identify issues attributed to longer anchorage waiting time for DCT (Pier 1) and DCT (Pier 2) during the 2018 financial year. Generally, Durban is not constrained by the availability of marine services. The inefficiencies are linked to poor terminal productivity and high ship turnaround time. High berth occupancy, will mean more ships must wait for available berths. The study has mentioned technical delays as the common challenge for Durban. The unproductive labour force, delays during shifts, poor terminal activities, and equipment breakdown has been mentioned repeatedly as the pivotal issues contributing to lower berth productivity.

The National Ports' Act holds both TNPA and TPT accountable for delays in the South African ports, except for the factors that are not under their control. TNPA provides marine services such as pilotage and berth planning, while TPT is responsible for terminal capacity and performance.

Another factor is that there has been no tangible infrastructure development like ICT for capacity planning that has been achieved in the recent years as opposed to additional superstructures. The study commented on this matter under berth productivity. Newly deployed quay cranes do not match the new capacity due to lack of infrastructure and other essential equipment.

Cape Town for example, had improved significantly in the reduction of time spent by this category of vessels at the anchorage. This was influenced by the increased number of gantry cranes. PRSA should be mindful that AWT is not a useful measure of terminal productivity or efficiency. However, the measurement of terminal efficiency or productivity is more useful through moves per Ship Working Hour (SWH) or per running metre of quay. Section 4.3.4, which follows, will explore SWH in greater detail.

Other things being equal, a reduced number of callers as depicted in Table 8 might not necessarily reduce anchorage waiting time. It is noted that the cargo throughput has been increasing due to larger containerships calling into the port. If containerships all worked more cargo per port call, they will occupy berth for a longer period of time leaving other ships to wait outside.

Motau (2015) suggests that sometimes a container ship anchors at the port limits because it missed the booked time window or for other reasons related to liner scheduling. A longer vessel waiting time around anchorage, may, however, also be associated with inefficiencies arising from quayside and landside due to poor container activity alignments.

Furthermore, Motau (2015) highlighted that sometimes the longer anchorage waiting time is linked to the carrier's behaviour. Unprecedented events from the carrier's obligations, such as unfavourable weather conditions, can force the ship's Master to reduce the sailing speed, which may result in the vessel missing the estimated time of arrival. Moreover, the deliberate instruction of the carrier may result in a longer waiting time. The vessels are sailing against the perils of the sea. Ships utilise precautionary measures to ensure and maintain navigational safety. Also, a vessel may employ a slow-steaming strategy to reduce fuel consumption. These strategies can lead to a vessel missing the estimated time of arrival. Finally, the circumstances in previous ports of call may also have a knock-on effect, and may result in ships missing their scheduled arrival and berthing windows.

4.3.4 Containers handled per Ship Working Hour (SWH)

The Ship Working Hour (SWH) metric refers to the number of container units handled in an hour across the vessel, across all container gantries assigned to the vessel, from the time the vessel commences cargo operations to the time the vessel completes cargo operations (Motau, 2015). In short, this indicator, SWH, examines the function of the terminal operators in the container handling activity, either in the loading, discharging or repositioning of containers.

Table 13: Containers Moves Per Ship Working Hour (2017/2018-2018/2019)

2018/2019 WEGO PERFORMANCE RESULTS			
Container Ports	**2017/2018 (TEUs/Hour)**	**2018/2019 (TEUs/Hour)**	**Performance Changes (Gain or Loss)**
Durban	49	55	11,7%
Cape Town	44,5	47,5	6,6%
Ngqura	46,1	42,9	-6,8%
Port Elizabeth	36,5	33,0	-9,7%

Source: PRSA, Notice on WEGO Performance 2018/2019

In the 2018/2019 period, the port of Durban improved the number of containers handled per hour to 55 TEUs per hour from 49 TEUs handled in 2017/2018. As Table 13 shows, the change was above 10 % as the requirement stipulated by PRSA. The ports of Durban and Cape Town recorded gains of 11,7% and 6.6% respectively, whereas Port Elizabeth and Ngqura recorded losses of 9.7% and 6.8%, respectively.

At the Durban container port, the SWH was lower in 2017/2018 when compared to the 2018/2019 baseline assessments. The lower SWH in the earlier period was attributed to unmatched landside and quayside equipment for particular berths not the terminal as a whole. The terminal crane capacity was increased at berths 203-205, however the supporting landside fleet and labour capacity was not adjusted. This stretched the limited resources to service the operations. Increasing the number of cranes available per vessel call was also expected to increase the number of boxes handled per hour. Motau (2015) suggested that if TPT increases capacity on the quayside, the operator must also increase land fleet to match the new capacity. Terminal inefficiencies trade off the benefits of additional working cranes thus reducing potential maximum SWH.

The Port of Durban has high container volumes. In order to maintain minimum ship working hours, Pier 2 acquired additional tandem ship-to-shore (STS) cranes. Furthermore, TPT is not hesitant to address the problem of poor yard management and inefficiencies arising from the stacking area.

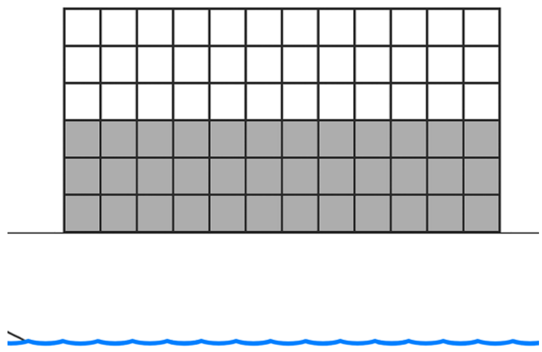
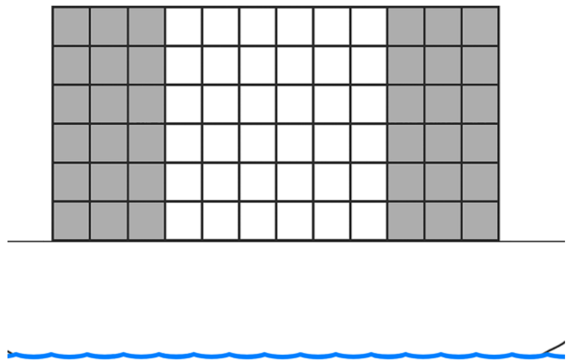
TPT acquired additional haulers that were worth 23.4 million rands for DCT pier 1. TPT believed that improvements to operational assets would aid the operator to eliminate bottlenecks that affect the stacking area, which was reported by Scholtz (2017) earlier.

Cargo-handling techniques and strategies help international container terminals to eliminate time consuming factors. The implementation of dual-cycling operation of the quay cranes paid off for international terminal operators, reducing the ship turnaround time while improving berth productivity (Bocanete and Dragomir, 2011). Under this technique, the cranes are able to load and discharge containers simultaneously. With reference to the call size, the single-cycle method is not feasible in a port that is working high volumes of containers. But in Durban, few, if any, berths operate with a single-cycle operation. This implies that the port operates on a dual-cycle operation. It is very rare, if it ever happens, for a port with high throughput to operate on a single-cycle operation (Bocanete and Dragomir, 2011). A decade ago, TPT implemented this system (dual cycle) in Cape Town to improve SWH, and this system presented the port with a 41% increase in crane productivity and SWH.

Indirectly, the carriers have an impact on the number of boxes that can be handled per vessel call. A vessel stowage plan indicates the distribution of containers on board a ship. Container carrying lines share stowage plans with TPT, the terminal operator, which then allocates containers to specific bay positions based on the stowage plan provided by the company. TPT planning entails allocating resources to support the entire handling operations. If the targeted SWH is not maintained, this could, in part, be attributed to the stowage plans of the carriers. Therefore, it is the responsibility of both operators and carriers to maximise the number of boxes handled per SWH. The ship stability and port rotation are critical drivers for a stowage plan.

Proper stowage allows crane operators to work on more containers per period of time. This study examines a Manhattan stowage arrangement and a layer-by-layer plan, as depicted in Figure 10 overleaf.

Figure 10: Container Deck Stowage Arrangements

Layer-by-Layer	Manhattan Stowage
	

Source: Drotz and Johansson (2016)

The discussion starts with a clear exposition of the differences between the two arrangements. The boxes are demonstrated using two different colours, white and grey. As seen in Figure 10, the layer-by-layer stowage arrangement enables the carrier to place white containers on top of grey containers. In terms of Drotz and Johansson, 2016:35 "the white containers for discharge in the first port are placed on top of the grey containers remaining on board for discharge in a later port. In Manhattan Stowage, the containers have been placed in stacks and are accessible regardless of which port are called first, divided on each side and some cargo operations will be made between these stacks".

Planners consider Manhattan Stowage as the better plan to avoid containers for a later drop-off to be placed on top of containers that are to be offloaded at an earlier port. In Figure 10 above, the plan allows containers to be stacked high, and the layer-by-layer plan shows that containers are evenly stacked.

In light of Manhattan Stowage, crane operators experience difficulties in accessing containers from the other side, and anything that obstructs the view of crane operators reduces crane productivity. Allowing stacks that are too high stacks results in intermediate spaces to have empty cells with a minimum number of containers. Crane operators will spend more time working on re-stows, thus reducing SHW. Moving up containers along the stack, increases the frame of the crane, while cargo operations are reduced.

The layer-by-layer stowage plan is a possible alternative solution to Manhattan Stowage. The containers are evenly distributed. Crane operators have a clear view and this results in minimum container re-stows. However, there are shortcomings with regards to the layer-by-layer arrangement. Ships with high port rotation, visiting a number of ports, would have difficulties in accessing containers for discharge. The terminal operators witnessed that anything that obstructed the view of crane operators resulted in unnecessary delays.

A practical problem encountered by a container vessel sometimes emanates from the stowage plan, which determines the exact positioning of containers in a vessel. Unnecessary moves should be avoided by placing containers designated for a terminal visited earlier during the journey, on top of containers designated for the later visited terminals within constraints of ship stability. In order to save time, it is important to limit the number of re-stows.

The Port of Durban is working on “shipped, transhipped, and landed” containers and the re-stows in the port affect all types of containers handled, as other containers sometimes have to be moved to access boxes. In terms of volume, in 2018, Durban handled a total of 1 460 804 landed TEUs (including 172 537 TEUs transhipped) and total of 1 495 866 shipped TEUs (including 176 377 transhipped) (TNPA, 2019). In all categories, sometimes the shipping lines may also request the terminals to shift containers that are to remain on board to new locations in the same bay or to restore them to another bay. Re-stows have the potential to lower the maximum number of boxes crane operators can exchange between ships and quayside. Containers on the top of a stack may need to be moved in order to access a container at a bottom position. According to de Langen and Helminen (2015: 17), “Crane operations are easier when a huge number of containers have to be loaded in the same section of the ship, without a need for moving the cranes”. The optimum stowage plan assists to minimize unnecessary container shifts.

To streamline effective planning between the container shipping companies and operators, crane efficiency on the landside can be improved with proper training of the crane operators and improvement on crane intensity. This will mean more gantry cranes per berth (Zangwa, 2019). Generally, three cranes can be applied instead of two, to increase crane intensity. The crane intensity will result into quicker vessel turnaround time and achieve a high container loading and off-loading rate.

4.4 Conclusion

Measuring container port and terminal productivity and efficiency is an important exercise for port stakeholders. After assessing DCT operational performance, this research noted that it is not easy for an Authority and Ports Regulator to arrive at meaningful performance results. Various container ports across the world use unique performance indicators to measure productivity or efficiency. The study set out to show that a meaningful assessment is derived from a combination of performance indicators that will suit all dimensions of DCT and seek to address time and operational efficiencies.

South African ports have distinctive features which ultimately have an effect on performance outcomes. This refers to the annual container throughput, port infrastructure and superstructures, and ship sizes which are among the critical drivers of container port efficiency and terminal productivity. The port of Durban is working on larger container ships, but not necessarily larger than Ngqura. However, the volume of containers worked per port call in Durban remains the critical driver. Information gathered indicated that DCT is still deemed to be inefficient due to the inability to utilise port assets efficiently. The inefficiencies might result in ship-owners reducing or abandoning calls to Durban.

The study recognised the berth throughput, which measures the total number of boxes handled at a berth in a stipulated period of time, berth productivity, which is the rate at which containers are handled to and from a ship docked along quayside, and crane productivity as essential types of output indicators that demonstrate port efficiency and productivity. WEGO identified ship turnaround time and anchorage waiting time (AWT) as two of the five indicators used to determine performance values. This study critiqued ship turnaround time and AWT. These two indicators are not in themselves particularly useful measurement tools to capture the level of services rendered by both TPT and TNPA. The percentage approach of the PRSA is clearly less useful than measuring waiting time in hours. It would seem better for PRSA to assign more weight to berth productivity and containers handled per SWH, as the more useful indicators to reflect container port performance. Some ports will use service time, which is usually the total actual time the vessel is berthed, while other ports may consider only working time. The study lacked comparative analysis, due to unavailability of pricing tools similar to WEGO from other countries. Nevertheless, the level of productivity in a port is acceptable when the Authority is able to compare its performance against certain standard benchmarks achieved by its counterparts.

PRSA introduced WEGO to effect changes into tariff methodology and to promote better utilisation of port assets. PRSA relies on previous years' operational performance to arrive at WEGO incentives or disincentives. Using previous performance scores is of limited value for Durban. The study noted that poor terminal performance is not always linked to inefficiencies of the operator, but poor container throughputs can be attributed to depressed economic conditions in a port. The indicator may decline in value as a result of market-related conditions such as lower overall demand or a loss of market share. WEGO performance results show that operational performance increased in the year 2019, although the availability of performance data for only two years is also a limitation. The performance values do not really capture real terminal activities and productivity. Durban experiences challenges such as equipment breakdown, terminal area operational issues and under-utilisation of port infrastructure and superstructure. Deployed cranes are working on lower moves per hour than targets. Taking that into account, Durban is still lacking optimal utilisation of port assets. This means that TPT must focus on the employment of cranes and berths. Container throughput has increased in Durban from 2009 to 2019, although not always evenly across year-on-year intervals.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

The main purpose of undertaking this research was to examine and interpret operational KPIs which were selected for Weighted Efficiency Gains from Operations (WEGO). The port of Durban is a critical nodal point in the South African economy which supports domestic and international trade. The container shipping industry is facing a new trend, whereby ship owners are deploying larger containerships into different primary trading routes. Usually, bigger containerships bring more containers into a port. Increasing vessel size has an influence on port and terminal operations. Port users expect port authorities and terminal operators to render port services at lower costs which are reasonable and, at the same time, to yield high port performance. Therefore, it has become urgent for terminal operators and port authorities to invest in new infrastructure and technologies to achieve optimum port efficiency and terminal productivity.

In 2018, DCT was leading in the country in terms of container throughput, reaching a maximum of 2,9 million TEUs per annum. The port welcomes ships having a carrying capacity of 10 000 TEUs and above, although port entry of the part of 15 000-TEU vessels in laden condition is restricted by water depth alongside container berths. Due to operational challenges, infrastructural issues and other factors, DCT has produced unsatisfactory operational performance to container-carrying lines and cargo owners. Poor port performance is at odds with the provisions of the National Ports Acts and NCPP since it affects the entire port network and trade negatively. PRSA, TNPA, and TPT are the key role players in the domestic port sector and are working on solutions to enhance overall port performance.

TNPA as the landlord, monitors and evaluates port performance using KPIs that best match the distinctive background of South African ports. Furthermore, the study explored the KPIs used to measure the performance capabilities of South African container port and terminal productivity.

TNPA designed the tariff methodology (Required Revenue) which is used to collect port income from tenants, shipping lines and cargo owners. TNPA and PRSA introduced a new element to tariff methodology called WEGO. This instrument was introduced to promote better port performance and asset utilisation.

The literature review gathered opinions and views on port performance and terminal productivity from the perspectives of different scholars. The section outlined the landscape and management of South African ports, which included the main characteristics of DCT, CTCT, NCT and PECT. The literature review also explored the public and private sector interface, and noted that the container handling business is 100% operated by TPT, which is a public entity. Chapter Two sought to set out the basic constituent assets and operations that may be associated with the configuration of modern container terminals, and highlighted the gate operations, yard operations and quayside operations as the paramount terminal activities.

It appeared from the same section that measuring and monitoring port performance is a complex exercise. For more insights, the literature review listed the operational KPIs recognised by UNCTAD with an aim to explore factors that influence port performance. Collective views and opinions support the view cited that a majority of scholars employed a combination of both parametric and non-parametric approaches to evaluate port performance. The new element to tariff methodology, WEGO, was also explained under the literature review section.

A desktop research approach was carried out to identify the factors which influence each KPI under investigation. The success of the study relied on the secondary data available in the public domain that was supplied mainly by TPNA, TPT and PRSA through their performance reports and annual publications that were available online. The Africa Ports website provided an important link to understand the volume of container throughput and vessel traffic. An analysis revealed that container throughput in Durban increased over the observed 10-year period, whilst this increased traffic was sustained by fewer vessel calls, but by larger container ships working more cargo per port call.

A mixed approach of quantitative and qualitative research methods was used to quantify and gain more insight into port performance and terminal productivity. Of the four container ports under review, Durban was selected as the sample of the study. The research scope was limited to South African parameters, since comparator ports do not employ a tariff system similar to

WEGO. However, a benchmark exercise would have provided TNPA and TPT with useful information on how to yield higher port productivity. WEGO performance results were analysed over two financial periods, 2017/2018-2018/2019. Chapter Four had shown that this did limit the analysis, as the short time period was deemed insufficient to show the consistency of KPIs.

5.1 Principal findings

The analysis and findings of WEGO performance results were carried out in Chapter Four. First and foremost, this coverage demonstrated the application of WEGO and how PRSA arrived at performance incentives and disincentives. PRSA published WEGO performance results for the 2017/2018 to 2018/2019 financial periods. The ship turnaround time, berth productivity, SWH and anchorage waiting time were KPIs under review to explore the performance levels within container terminals.

WEGO performance scores indicated that overall performance increased in Durban from 2017/2018-2018/2019, and the same port performs better if compared to other domestic container terminals. Between 2017/2018 to 2018/2019, the KPIs had shown gains in performance. The ship turnaround time improved from 70 hours to 69 hours, the anchorage ship waiting time improved from 22% to 7.0%, the berth productivity improved from 42,5 TEUs to 49,7 TEUs per hour and finally, containers worked per SWH increased from 49 TEUs to 55 TEUs.

The study found that, according to WEGO, the operations show positive signs of performance, whereas, in practical terms, Durban still achieved actual performance lower than performance targets estimated by TNPA. TPT has been delivering poor performance for berth productivity and SWH. The lower productivity has been attributed to poor equipment maintenance, ships missing schedules, improper yard management, lack of ICT infrastructure, port administrative issues, inadequate quayside operations and poor terminal capacity planning. Some performance issues are outside the control of TNPA and TPT. It was found that late arrivals, and improper stowage plans, are the responsibility of the container shipping lines, and not the ports. With all these performance issues on hand, WEGO recorded an improvement from previous year performance (2017/2018) compared to 2018/2019 financial year, however, the analysis revealed performance is still below the benchmark set of KPIs.

Each KPI is assigned a weight of 20%. The analysis pointed out that the ship turnaround time and anchorage waiting time are deemed to be less effective in expressing the value of services rendered in domestic ports. Berth productivity and SWH metrics are far more appropriate and compelling indicators to measure infrastructure capabilities of Durban. The container-handling operations require intensive facilities and superstructures. With that view in mind, berth productivity and SWH may more reasonably be allocated weights above 20%. The study further highlighted the inappropriateness of PRSA to express anchorage waiting time in percentage terms.

WEGO applies similar KPIs across containers, break-bulk, roro, and bulk cargoes. Future research must explore which indicators are most relevant to containers, and whether year-on-year performance analysis is still feasible to arrive at incentives. Further research may try to integrate other classic indicators of terminal handling facilities, although they are often difficult to collect and compare on a large scale.

5.2 Study Recommendations

The number of boxes handled per hour per working vessel is the key determinant of berth productivity and SWH. Increasing the number of moves per hour assists TPT to reduce the substantial hours spent by a ship that occupies a berth, thus reducing vessel turnaround time, making more berths available for ships waiting at anchor. High anchorage waiting time was linked to berth problems more than to any other factor. Therefore, the creation of dedicated terminals with tightly-scheduled ship arrivals can achieve higher berth occupancy levels without congestion.

In order to achieve high berth productivity, TPT is recommended to achieve high crane output. In a practical situation, the high quay crane output will be possible when TPT implements a maintenance plan which will ensure minimum down time. Crane productivity is also influenced by the crane operator's skill, which determines how many boxes a quay crane can handle in a certain period of time. TPT must systematically train the crane drivers and keep the workforce motivated to achieve performance targets placed by TPT.

Table 8 in Chapter Four, above, had shown that on a yearly basis, container throughput in the port of Durban increased in the last 10 years observed. TPT must make sure that in order to enhance terminal productivity, installed capacity should ideally be increased at a higher rate than container throughput increases, such that supply growth more than matches demand growth. Consequently, the average terminal productivity per crane will also increase, while berth utilisation remains at the same level.

In order to overcome this challenge, the operator must improve the terminal surface for fast movement of straddle carriers and acquire additional moving equipment to match the capacity of newly-deployed tandem lift ship-to-shore cranes. The previous chapter also promoted the dual-cycling method as a viable alternative to increase the number of boxes handled per hour. The concept of crane intensity is also promoted. For ships working larger numbers of containers and having LOA above 300m, the operator must make sure more quay cranes are available across the ship. This will increase crane productivity, thereby improving SWH.

Simultaneously, improved container-handling operations enable operators to make more moves per hour per vessel call. This function is possible if containers are evenly distributed on board for easy accessibility, and re-stows and un-productive container movements are minimised. It must be borne in mind that the number of quay cranes available along quayside can limit the number of boxes ships and cranes are able to handle. For ships carrying more containers and which have high LOA, TPT must make sure that sufficient cranes are available to support the operations.

Terminal productivity places a shared responsibility between terminal operators and container carrying lines. Stowage plans are produced by the carrier, and are important tools for operators in terminal planning. The synchronisation of systems will enable operators and ships to streamline activities, whereby the operators will receive information instantly, or within 24 hours.

Reshuffling containers and removing the hatch cover also takes time and reduces productivity of a quay crane. With the increasing vessel size, the ship must make sure that no time is wasted during container lashing that places quay cranes idle. Unproductive time affects ship turnaround time.

Another option to unlock the full potential of DCT productivity is to optimise yard management. Proper yard management entails the provision of enough stacking area, and sufficient capacity to handle the volume of containers from gate that pass through the facility, until it lands on board a vessel. When the terminal operates smoothly, this ensures that time is not wasted by quay cranes waiting for the containers to arrive. Productive time ensures that quay cranes operate at their full capacity. Crane productivity is largely influenced by proper planning which emanates from the stacking area. Meanwhile, a poorly organised stacking area allows for mistakes, reshuffling and unnecessary waiting. Nevertheless, the availability of latest technologies plays a crucial role to fast track the movement of containers within the port network. This research also accepts the recommendations made by Scholtz. Re-configuring the terminal layout can aid Durban to increase terminal capacity. Hence, this will open more space for keeping of containers temporarily and enough space for moving equipment.

In the long run, more comprehensive maritime port policy reforms can be harnessed to boost port performance, other than influencing the tariff methodology. Opening terminal business to private terminal operators can induce intra-port competition which will result in higher port performance, thereby benefiting port users. NCPP and the National Ports' Act does make provision for potential privatisation within the terminals. This issue remains with the licence-holding company (Transnet), which exclusively monopolises the business, by offering licenses only to TPT, which is a public entity also owned by Transnet.

The study supports the inclusion of private operators, since they are likely to be more efficient and productive in handling containers. This direction will be supported by the recent decision to create more independence for TNPA. TNPA is permitted by Section 57 of the National Ports' Act to venture into business partnerships with the private sector.

Both TNPA and TPT are a subdivision of the Transet group, and TPT leases terminals from TNPA. In order to ensure the integration of performance assessment, separation is required in terms of National Ports' Act. In that regard, TNPA will act in good faith in terms of assessment, and design policies, and plans that will allow different entities to increase container terminal efficiency, productivity and capacity. It is not clear how performance is being monitored since they belong one company. This study recommends that they should be separated, with TNPA performing the duties of the landlord and TPT as the independent terminal operator. At present, by contrast, TPT is the sole provider of cargo handling services within container terminals across all container ports of the country.

5.3 Conclusion

Containerised sea trade is growing faster than any other part of seaborne commerce, and it is therefore no surprise that containerships are also increasing in size to a greater extent than any other vessel types, as ship owners pursue further benefits of economies of scale. If the local and international trade volume increases, the obvious outcome is that the South African ports will have to be able to handle more cargoes, and in larger vessels. Container traffic growth and increased ship size will have a wide impact on both ports' operations and productivity. In order to accommodate these changes, the port authorities and terminal operators must acquire additional port infrastructure and increase current port capacity. The introduction of WEGO may assist to enhance port performance and efficiency in South Africa, to meet the expectations of port users. A greater refinement of WEGO, and its better application, could serve to improve productivity of the DCT, with better asset utilisation, higher berth productivity and improved cargo-handling activity per Ship Working Hour, which this research identifies as the most robust of the standard productivity metrics.

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