*Center for Maritime Economics and Logistics*
*Erasmus University Rotterdam*

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# Benchmarking the operational efficiency of Africa container terminal: A case study of Sogester

by

Kiende Alfredo Caumba

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**Abstract**

According to the World Bank, the economy of the African continent is growing and expanding rapidly. The GDP of the continent increased by 3,8% in 2022, and the demand for containerized cargo also increased and reached a level of 37 million TEU. Hence, it is necessary for African container terminals to continuously evaluate their level of efficiency to optimize resource utilization and maximize throughput.

In this research, the main goal was to investigate the efficiency of the Sogester container terminal in comparison to other terminals in the same region. For the quantitative analysis, the Data Envelopment Analysis (DEA) method and Key Performance Indicators (KPI) were employed to evaluate the level of efficiency of the terminal. DEA evaluates the relation between input variables (quay length, number of cranes, terminal area, and yard equipment) and output variables (throughput). Additionally, the KPI analysis evaluates the relation between the variables such as TEU per crane, TEU per area, TEU per yard equipment, and TEU per quay length. Finally, an online questionnaire was conducted at the Sogester container terminal with employees with a response rate of 100%.

The results of this study revealed that the Sogester terminal has the second-lowest efficiency among the benchmarked terminals. These outcomes show that the terminal is currently operating at 48% of its efficiency in comparison with 100% of some of its competitors. The sensitivity analysis presents that to achieve maximum efficiency and get full use out of the present resources, the Sogester container terminal should increase the terminal throughput by at least half a million TEU. The DEA result is supported by the KPI analysis showing that to operate efficiently the terminal should at least reach 1000 TEU per meter quay length, 80000 TEU per crane, 20000 TEU per hectare, and 17000 TEU per yard equipment.

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## List of Abbreviations

BCC…………… Banker, Charnes, and Cooper

BOR…………… Berth occupancy ratio

CCR…………… Charnes, Cooper, and Rhodes

CRS…………… Constant return to scale

DEA…………..... Data Envelopment Analysis

DMU………….. Decision make unit

GDP…………… Gross domestic product

Ha……………… Hectare

KPI……………. Key Performance Indicator

M2……………… Meter square

RTG …………… Rubber tired gantry

TEU…………….. Twenty equivalent unity

UNCTAD……….. United Nations Conference on Trade and Development

# 1 Chapter - Introduction

## 1.1 Background

Shipping trade is a vital part of the global economy since it transports goods and raw materials between different countries and regions. Global value chains, which have gained importance over the past few decades, are supported because they enable businesses to obtain supplies and sell products in distant markets. Delays in container terminals and shipping lanes restrict individuals in need from obtaining medicine, energy, food, and other supplies because over 80% of world trade is carried out by ships (UNCTAD, 2022). Global seaborne trade increased to 1,4% in 2022, and according to UNCTAD's Review of Maritime Transport 2022, it is expected to stay at that level in 2023.

Containerized cargos are a key component of global seaborne trade because they allow cost-effective and efficient transport of goods in standardized units (Humphreys, 2023). The global container throughput has increased from 690 million TEUs in 2000 to 828 million TEUs in 2010, and then 880 million TEUs in 2022 (Clarkson Research, 2023). Additionally, according to Clarkson Research's (2023) forecast, approximately 869 and 895 million TEUs will be shipped globally in 2023 and 2024. According to the World Bank (2022), the economy of the African continent is expanding quickly, and the GDP of the continent in 2022 experienced an increase of 3,8%. Ross and Kelly (2019), mention that an increase in GDP leads to increases in the level of seaborne trade in the region. The African container terminal market is facing a continuous increase in the demand for containerized cargo, and according to Clarson's research (2023), the container throughput of the region in 2022 was approximately 37 million TEU. The 26000 kilometers of coastline on the African continent have more than 100 ports, harbors, and terminals. However, only a few can handle significant amounts of container traffic volumes (Ahmed, 2022). So, it is necessary for African container terminal to continuously evaluate their level of efficiency to ensure that they can optimize resource utilization and maximize throughput (Mlambo, 2021).

The Sogester container terminal is located within the Port of Luanda, Angola, and serves as a vital gateway for trade in the region and neighboring countries (Ahmed, 2022). This terminal is the biggest and busiest container terminal in Angola and handles a significant amount of volume of cargo, supporting the local economic growth and neighboring countries (Maritimafrica, 2022). The Sogester container terminal is a consortium managed by Sociedade Gestora de Terminal and APM terminals since 2007, in a 20-year concession (APM terminals, 2020). The container terminal has been experiencing a constant increase in container traffic during the years with an increase of 24% in 2021 and an increase of 6,8% in 2022 (Sogester, 2023). To control this level of growth, keep a competitive edge, and adjust to quickly changing global trade dynamics, the Sogester terminal should pinpoint the causes of inefficiency and consider available technical remedies to operate with efficiency and avoid operating at capacity. Additionally, the Sogester container terminal should assess the productivity and performance efficiency of the terminal infrastructure, equipment, and facilities due to the rapid development of container traffic flow that it is facing. The level of efficiency of the terminal efficiency can be evaluated by benchmarking it with other container terminals in the same region to find opportunities to optimize processes and operations. Benchmarking container terminals is a worldwide and crucial practice in the maritime industry, allowing a comprehensive evaluation of their operational efficiency and competitiveness (Fallon, 2023).

## 1.2 Research question and Sub research question

The main research question that this research will be focussed to answer is:

**How does the operational efficiency of the Sogester Container Terminal compare to its direct competitors in the same region?**

The research question seeks to identify the factors that are affecting the operational efficiency of the Sogester container terminal and how the terminal is performing compared with others in the same region. To adequately address the above main research question, several sub-research questions need to be investigated:

1- What is the current level of operational efficiency of the Sogester container terminal in comparison to its direct competitors?
2- What are the key reasons behind the differences in operational efficiency among the container terminals under analysis?
3- How can the Sogester container terminal capitalize on its strengths, improve its weaknesses, and gain a unique edge over its direct competitors in the container terminal market?
4- Which research model is the most suitable for addressing the research question, and how does it work?

## 1.3 Thesis scope and limitation

The scope and delimitation of the thesis are:

- Data for the thesis were collected from available reports and information about the chosen benchmark terminals. However, limitations in data availability might impact the depth and thoroughness of the analysis.
- The findings and recommendations of the thesis applied specifically to the chosen benchmarked terminals. It might not be feasible to extend these results to other container terminals due to variations in operations, infrastructure, market conditions, and other factors.
- The efficiency of terminal operations can be influenced by external factors such as economic conditions, regulatory changes, labor disputes, and natural disasters. These external factors can impact the analysis and limit

the extent to which the thesis can attribute efficiency solely to terminal operations.

- The investigation is only concentrated on the operational performance factors, avoiding a thorough examination of the financial, commercial, or legal aspects of the container terminal's operations.

## 1.4 Research design and methodology

This thesis employs qualitative and quantitative approaches to obtain reliable results and appropriate conclusions about the operational performance of the Sogester container terminal.

In terms of literature, the theoretical framework of port revolutionaries changes, the emergence of containerization and mega vessels, the role of container terminals in worldwide trade, and the analysis of container terminals in Africa were investigated and followed up.

Data were collected through terminal review reports and websites. DEA is the model used to properly answer the research question regarding the level of efficiency of the container terminal. The DEA analysis aims to identify the optimal combination of inputs that can produce the maximum level of output. A key performance indicator analysis of the six benchmarked terminals is carried out to evaluate the operational efficiency. Additionally, it was conducted an online questionnaire at the Sogester terminal to evaluate the level of operational performance according to the view of employees.

## 1.5 Thesis structure

Chapter 2: This chapter began with the theoretical framework of port revolutionaries changes, the role of container terminals in worldwide trade, and the analysis of the container terminals market in Africa. Moreover, it presented the key concepts of operational performance in container terminals and the determinants of key performance indicators.

Chapter 3: Outlines and describes in depth the quantitative and qualitative methodological approach implemented for the research, DEA method, and KPIs, jointly with the online questionnaire at the Sogester container terminal.

Chapter 4: Includes an analysis of the results achieved from the implementation of the DEA model, the results of KPI comparison, and findings from the qualitative research (online questionnaire) utilized for processing information.

Chapter 5: This chapter summarises the main findings and results of the research, focussing on the level of operational performance of the Sogester container terminal in comparison to other terminals in the same region. Additionally, it presents suggestions of areas for further research.

# 2 Chapter - Literature Review

This chapter begins with the theoretical framework of the port business environment, evolutions in port, the emergence of containerization and mega vessels, and the African container terminal market. Moreover, it presents key concepts in benchmarking container terminals and the KPIs used to evaluate the level of operational efficiency at container terminals.

## 2.1 Port evolutionary changes

Ports have been historically seen as straightforward transshipment facilities where goods are unloaded and loaded from/onto the ship and land vehicles, and the port functions, locations, and methods of utilization of ports have changed over time (Notteboom et al., 2020). To survive in instances of intense competition, ports have continuously adjusted to changing circumstances. Supply chain integration, customer-focused practices, port sustainability, and value-added operations are other port evolution developments that have taken place (Woo et al., 2013). Ports eventually fell into one of three generations depending on development strategy, policy, and attitude. First-generation vehicles were solitary and offered straightforward cargo transit or switching between maritime and land vehicles. Second-generation ports are recognized as being important commercial, industrial, and transportation centers that offer added-value services and support the growth of the port's surrounding area. Third-generation ports link moving points in the intricate global manufacturing and distribution network as well as integrated transport and logistics platforms for global trade. General cargo was almost fully unitized and ship sizes increased in the 2000s. While the number of workers has decreased, cargo handling operations have become more automated and mechanical. Processes and methods for supporting cargo have multiplied. Ports were forced to invest less in commercial return assets due to safety and environmental concerns, which led to a decrease in accidents, absenteeism, and the creation of quality-assured environmental management systems. Humphreys (2023) asserts that ports, which serve as an integrated transportation hub and logistics platform for international trade, are essential components of the supply chain. A port supply chain can be thought of as an integrated platform for processes where several port stakeholders collaborate closely to run cargo, ships, and other modes of transportation. A bilateral convergence and divergence of the flows of goods, modes of transportation, and information - both physical and non-physical - distinguishes this network.

## 2.2 The emergence of containerization and mega vessels

Containerization is one of the outstanding breakthroughs in the maritime transportation industry because it resulted in, speed, high-quality, and low-cost transportation (Rodrigue, 2023). This faster transportation and distribution of goods improved the global supply chains, which established a single market with a global base (Ha, 2016). Containers have been transported since the mid-1950s when the Sea Land-owned converted tanker Ideal X made its debut voyage between New York and Houston carrying 58 containers (World Bank, 2023). The first container ship was launched in 1969, and the subsequent generation of containerships was built with quay cranes in mind to increase cargo handling productivity and the number of containers that could be carried (World Bank, 2023). Since the containerization revolution, there has unavoidably been a significant capital investment in port infrastructure and vessel construction, but the advantages, such as a significant decrease in transportation costs and an increase in transport efficiency due to economies of scale, have been distributed throughout the supply chains (Slack, 2001). Since then, global container volumes have increased noticeably, and containership capacity has grown dramatically (Notteboom et al., 2020). Containerization has had a direct impact on the port business, necessitating large investments in port infrastructure, superstructures, and machinery. Purchasing container cranes and yard equipment, extending terminal locations and storage spaces, and optimizing berth-yard-gate processes are a few of the investments mentioned above. Ships spend less time in port as a result, and operational productivity at the terminal increases. Due to ports' inventive adaptations, shipping businesses now have access to a wider variety of ports (Akyar, 2019). The types of ships and typical sizes of containerships are also changed by containerization. Tanker ships and dry cargo ships with a capacity of fewer than 1000 TEU were converted and equipped with onboard cranes to transport containers in the early years of container shipping between U.S. ports (World Bank, 2023).

### 2.3 The role of container terminals in international trade

More than 80% of the volume of goods internationally traded between nations and more than 70% of trade values, is carried out by sea (UNCTAD, 2019). It is impossible to overstate how crucial imports and exports are to the economy. An important factor in calculating a country's trade balance is its exports and imports. It is well known that because of their capacity to affect economic growth and the eradication of poverty, exports are viewed as a catalyst for social and economic development. Global GDP increased by 3,1% in 2022 and the seaborne trade grew by 1,4% in the same period ( UNCTAD, 2022)

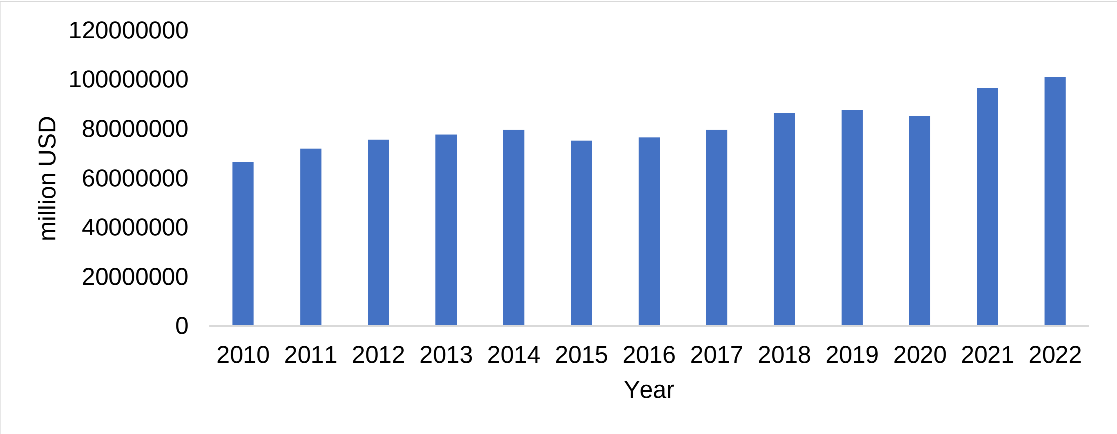


**Figure 1: GDP of the World**

Source: Author based on World Bank, 2022

Seaborne trade is directly and indirectly impacted by GDP. According to Ross and Kelly (2019), the GDP affects the level and type of seaborne commerce by having an impact on the demand for goods, trade balances, and general economic stability of a country. Additionally, an increased seaborne trade often follows an expanding and stable GDP, but economic downturns or instability have the reverse impact. Generally, the main operations in a container terminal involve the processing of cargo, and the transfer or transit of cargo from the terminal to ships or other means of transportation (Ha, 2016). In 2022, an astounding 880 million TEUs were transported globally, an increase from the years before (Clarkson research, 2023).

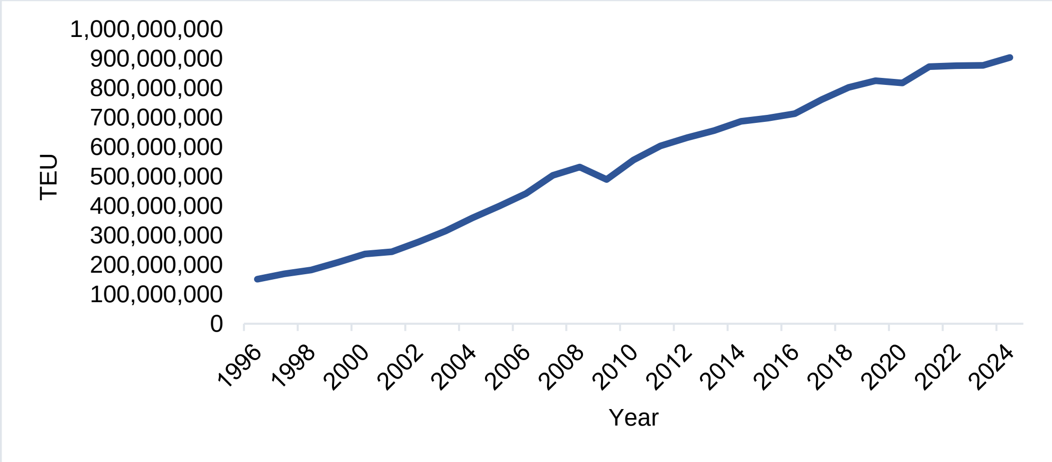


**Figure 2: World container throughput**

Source: Author based on Clarkson research database, 2023

## 2.4 Situational analyses of container terminals in Africa

Container terminals in Africa have developed into important hubs in the global maritime trade network, enabling the passage of goods and fostering local economic growth (Ahmed, 2022). These container terminals serve as key points for African nations into national markets and promote trade expansion, regional integration, and the development of vital industries. These container terminals have multiple factors influencing their operations and have a unique business environment characterized by a mix of challenges and opportunities (Olukoju, 2020). Trade is stimulated by this economic growth, which has an impact on the volume of containers moving through African ports. According to the World Bank (2022), the GDP of the African continent in 2022 increased by 3,7%.

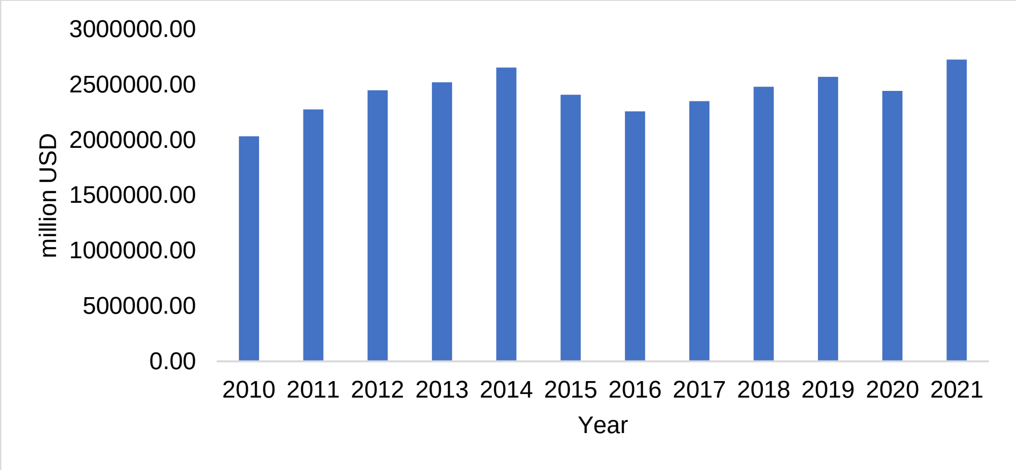


**Figure 3: GDP of Africa**

Source: Author based on World Bank, 2022

The increase in container throughput in Africa over the past few years is an indication of the continent's expanding role in global trade and economic expansion (World Bank, 2020). Even though the volume of containerized trade in Africa is still lower compared to other continents, there has been a positive trend toward increased container throughput, suggesting space for future expansion and development. According to Clarkson research (2023), the overall container throughput for Africa in 2022 was approximately 37 million TEUs.

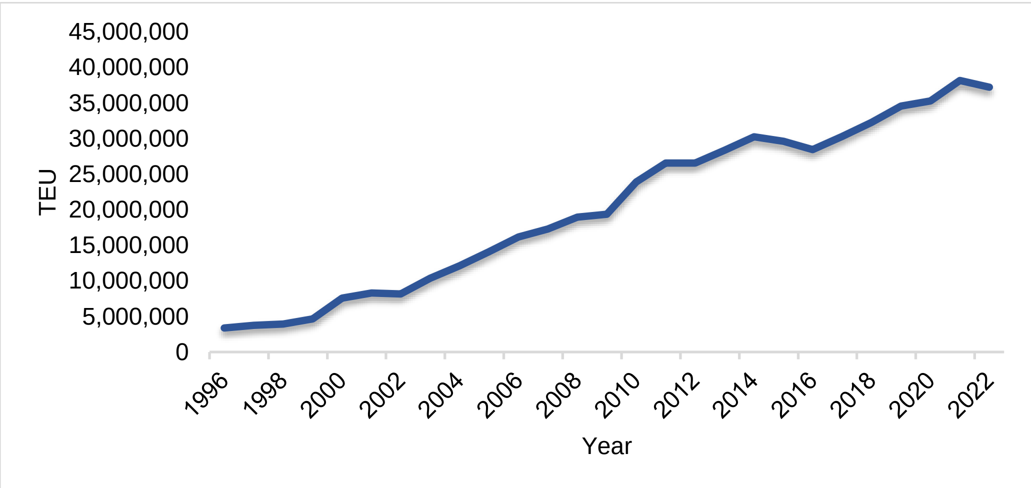


**Figure 4: Africa container throughput**

Source: Author based on Clark research database, 2023

The African continent has over 26000 kilometers of coastline and has more than 100 ports, harbors, and terminals but only a few can handle significant amounts of container traffic volumes (Ahmed, 2022). Container terminals such as Sogester, Mombasa, Dar es Salaam, Maputo, Walvis Bay, and Durban Pier 2 are extremely significant for regional and international trade in Africa due to their advantageous location on the coast, as shown in Figure 5. These terminals are crucial entry and exit locations for cargo traveling between continents and are strategically positioned along important shipping lanes, they serve as important regional and international commerce hubs due to their proximity to important trade networks (AICD, 2008). Furthermore, the terminals of this region play a critical role in facilitating intra-African trade. They encourage industrialization, increase the effectiveness of logistics, connect Africa to international markets, and boost economic progress.


**Figure 5: Container terminals in Africa**

Source: Author based on Google Maps, 2023

The flow of commodities both inside Africa and to the rest of the globe is made easier by these container terminals, which serve as important commerce hubs. They are critical for fostering imports of basic commodities and raw materials and supporting export-oriented companies as trade gateways. These container terminals serve as a conduit between African producers and global customers, promoting the export of produced commodities and raw resources while permitting imports of necessary items and technologies. The GDP of these areas is approximately 26% of Africa's GDP and 28,5% of Africa's container throughput. Each of the aforementioned container terminals shown on the map has also undergone a thorough situational study.

### 2.4.1 Walvis Bay Container Terminal

An essential facility for container handling and maritime trade in the area is the Walvis Bay Container Terminal, which is situated in the port city of Walvis Bay, Namibia (Namport, 2022). Namibia is the driest nation in Sub-Saharan Africa, with a population of only 2,53 million and a coastline extending about 1500 kilometers along the South Atlantic (World Bank, 2022). It shares borders with Angola, Botswana, South Africa, and Zambia. According to the African Development Bank (2023), Namibia's GDP growth grew to 4,6% in 2022, while inflation increased to an average of 6,1% in 2022.

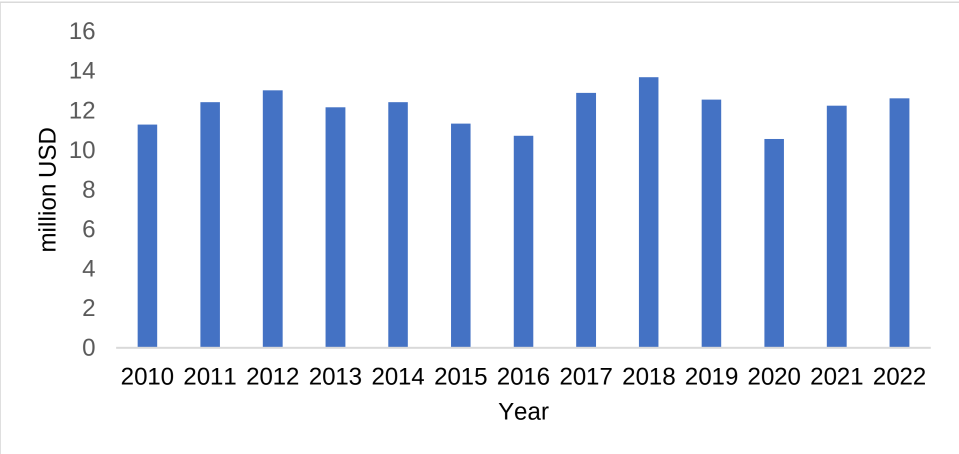


**Figure 6: GDP of Namibia**

Source: World Bank 2022

The terminal is ideally situated on the west coast of southern Africa, offering easy access to important shipping lanes and acting as a crossing point for trade between Europe, Asia, and Africa (Namport, 2019).


**Figure 7: Location map of Walvis Bay container terminal**

Source: Google Maps, 2023

The Namibia Ports Authority, or Namport for short, runs the Walvis Bay container terminal. The terminal is important for facilitating imports and exports for Namibia and acts as a transshipment hub for surrounding landlocked nations (Namport, 2022). Table 1 presents the specifications of the Walvis Bay container terminal.

**Table 1: Walvis Bay container terminal specifications**

| Walvis Bay Container Terminal | |
|---|---|
| Capacity (million TEU) | 0,75 |
| Draft (m) | 12,8 |
| Quay length (m) | 600 |
| Number of ship-to-shore cranes | 4 |
| Reach stacker (unit) | 15 |
| Forklift (unit) | 26 |
| Empty handlers (unit) | 2 |
| RTG (unit) | 6 |
| Area (ha) | 18 |

Source: Walvis Bay container terminal database

The container throughput at Walvis Bay Container Terminal has been increasing over the years and it increased by 9% in 2022 (Namport 2022).

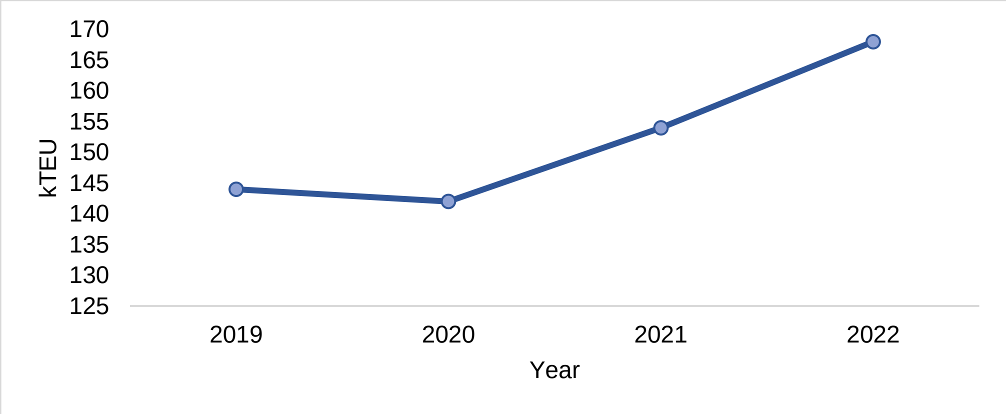


**Figure 8: Walvis Bay container terminal Throughput**

Source: Walvis Bay container terminal database

### 2.4.2 Dar es Salaam container terminal

The Dar es Salaam Container Terminal, located in Tanzania, is a key maritime facility that has a significant impact on regional trade and business in East Africa (Maneno, 2019). Tanzania has a population of around 62 million and is bordered by Uganda and Kenya, the Indian Ocean Mozambique, Malawi, and Zambia, and by Burundi and Rwanda. Inflation climbed to 4,3% in 2022, while Tanzania's real GDP growth slowed to 4,7% (African Development Bank, 2023).

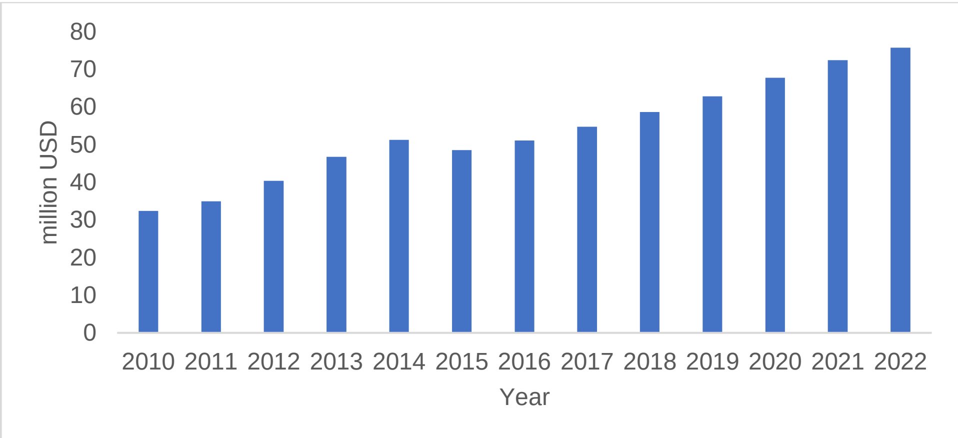


**Figure 9: GDP of Tanzania**

Source: World Bank 2022

As a major entry point for imports and exports, the Dar es Salaam container terminal represents the region's economic vigor and trade integration efforts (TPA Handbook, 2020). The Dar es Salaam Container Terminal takes advantage of its geographic advantage by being tucked away along Africa's eastern coast, overlooking the great expanse of the Indian Ocean, Figure 10. This allows for seamless connectivity to key shipping routes and unmatched access to global markets.


**Figure 10: Location map of Dar es Salaam container terminal**

Source: Google Maps, 2023

In a joint venture with Tanzania International Container Port Service Limited (TICTS), the private operator Hutchison Port Holding manages the Dar es Salaam container terminal (Tanzania Port Authority, 2022). More than 85% of Tanzania's maritime containerized traffic is handled by the Dar es Salam container terminal, which also acts as a key gateway for supplies to and from Tanzania and the landlocked nations of Eastern, Central, and Southern Africa (World Bank, 2019). Table 2 presents the specifications of the Dar es Salaam container terminal.

**Table 2: Dar es Salaam container terminal specifications**

| Dar es Salaam Container Terminal | |
|---|---|
| Capacity (million TEU) | 1,05 |
| Draft (m) | 12,2 |
| Quay length (m) | 1282 |
| Number of ship-to-shore cranes (unit) | 15 |
| Reach stacker (unit) | 8 |
| Forklift (unit) | 21 |
| Empty handlers (unit) | 7 |
| RTG | 17 |
| Area (ha) | 26 |

Source: Dar es Salaam container terminal database

The volume of containers passing through the Dar es Salaam container terminal is yearly rising. The container throughput at the container terminal increased by 4,8% between 2021 and 2022 (UNCTAD, 2022).

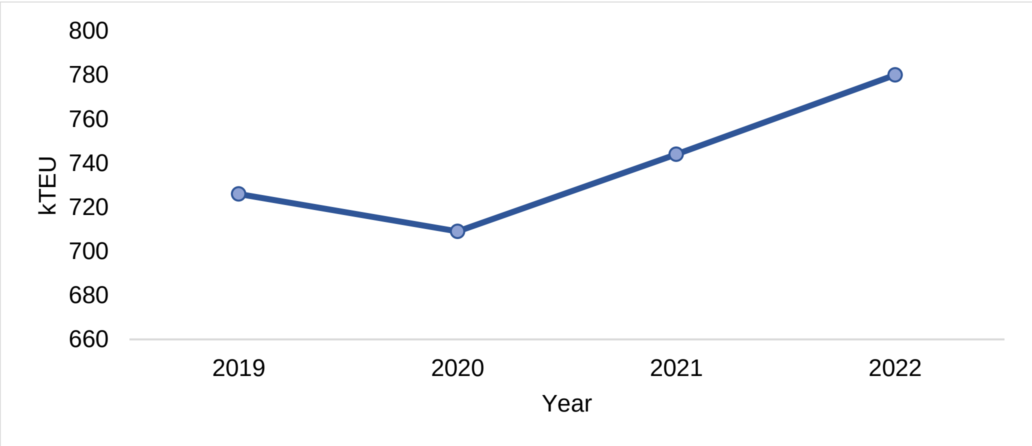


**Figure 11: Dar es Salaam container terminal throughput**

Source: Dar es Salaam container terminal database

### 2.4.3 Durban Pier 2 container terminal

The largest container terminal in sub-Saharan Africa is the Durban Container Terminal, which is part of the Port of Durban on the eastern coast of South Africa (Humphreys et al., 2019). Durban Pier 2 container is a prominent container terminal of enormous significance for the country. South Africa has a population of approximately 60,6 million and is surrounded by Mozambique, Namibia, and Botswana (Wikipedia, 2023). The GPD of South Africa decreased from 4,9% in 2021 to 2% in 2022, (World Bank, 2023).

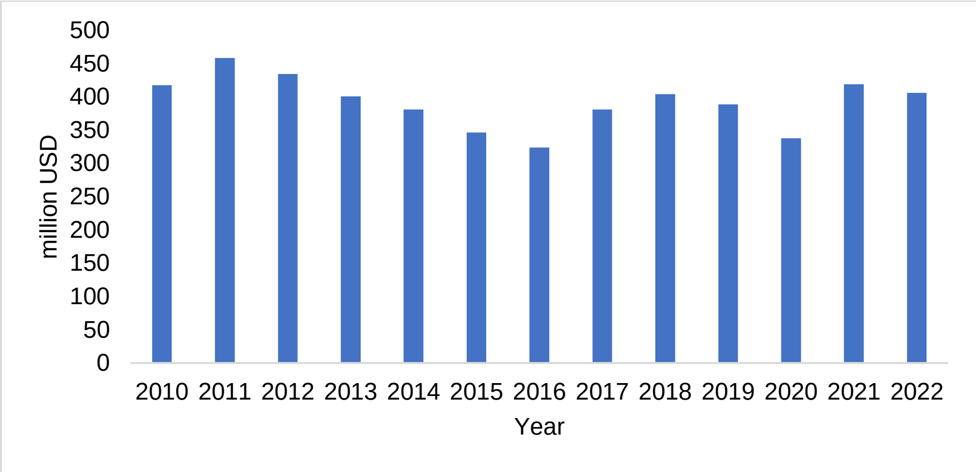


**Figure 12: GDP of South Africa**

Source: World Bank, 2023

The Durban container terminal, which is managed by Transnet Port Terminals (TPT), a branch of Transnet SOC Ltd., is a crucial hub for regional logistics and facilitates international trade (Transnet, 2019). It is perfectly situated to act as a hub for containerized freight coming from Australia, the Middle East, the Far East, and the Indian Ocean Islands.


**Figure 13: Location map of Durban Pier 2 container terminal**

Source: Google Maps, 2023

The Durban container terminal has two terminals Durban Pier 1 and Durban Pier 2, and both handle more than 65% of South Africa's container throughput. In this research, only Durban Pier 2 is analyzed and Table 3 presents its specifications.

**Table 3: Durban Pier 2 container terminal specifications**

| **Durban Pier 2 Container terminal** | |
|---|---|
| Capacity (million TEU) | 2,9 |
| Draft (m) | 12,2 |
| Quay length (m) | 1538 |
| Number of ship-to-shore cranes (unit) | 22 |
| Reach stacker (unit) | 3 |
| Forklift (unit) | 7 |
| Empty handlers (unit) | 13 |
| RTG | 53 |
| Area (ha) | 109 |

Source: Durban Pier 2 container terminal database

Between 2019 and 2022, there were noticeable changes in the container throughput at Durban Pier 2 Container Terminal. This variance is linked to a wide range of variables, including the current state of the global economy, changes in trade patterns, and supply chain interruptions, particularly those brought on by the widespread COVID-19 epidemic (Transnet, 2019). The container throughput increased from 1671 kTEU to 1838 kTEU in the years 2021 to 2022, reversing the previous trend, a percentage increase of 10% (UNCTAD, 2022).

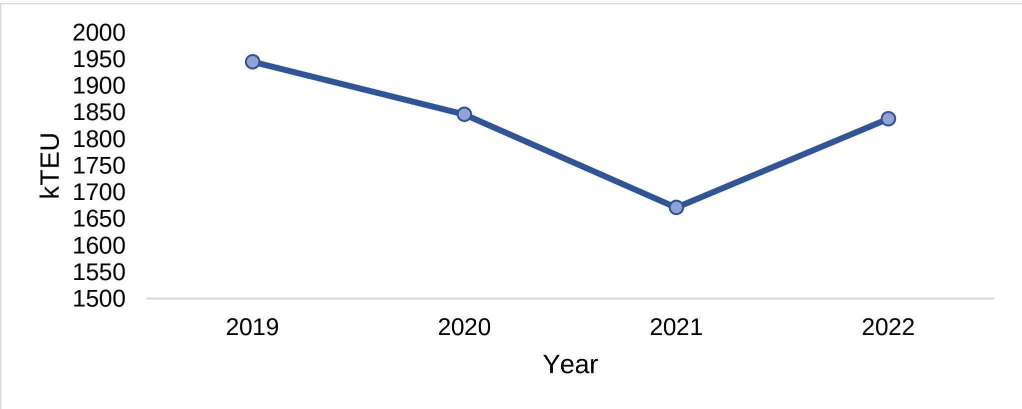


**Figure 14: Durban Pier 2 container terminal throughput**

Source: Durban Pier 2 container terminal database

### 2.4.4 Mombasa container terminal

Mombasa container terminal is the largest terminal in the country and is located in the south of Kenya. With a population of more than 47,6 million, Kenya is a nation in East Africa and is bordered by Tanzania in the south, Uganda in the west, South Sudan in the northwest, Ethiopia in the north, and Somalia in the east (Wikipedia, 2023). Real GDP growth in Kenya nation dropped to 5,5% in 2022 from 7,5% the year before, and inflation increased to 7,6% in 2022 from 6,1% in 2021 (Africa Development Bank, 2023).

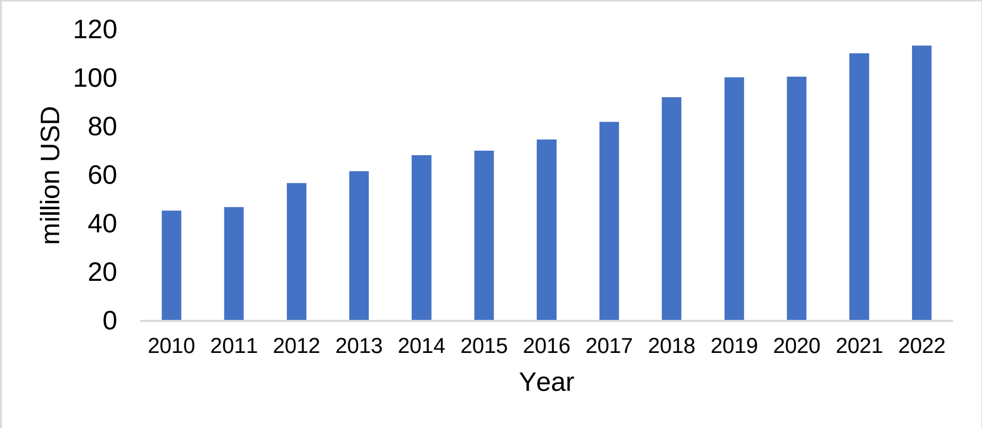


**Figure 15: GDP of Kenya**

Source: World Bank, 2023

The Mombasa container terminal, managed by the Kenya Ports Authority (KPA), is a cornerstone of marine operations, acts as a key entry point for imports and exports, and contributes significantly to the growth of the local economy. The Mombasa Container Terminal takes advantage of its favorable location along the eastern coast of Africa, Figure 16, overlooking the great expanse of the Indian Ocean, by offering seamless connectivity to important shipping routes and giving unrestricted access to worldwide markets (KPA, 2023).


**Figure 16: Location map of Mombasa container terminal**

Source: Google Maps, 2023

The economy of Kenya greatly depends on the import and export of containerized cargo through the Mombasa container terminal (MILU, 2018). Two container terminals can be found at the Mombasa port: the Mombasa Container Terminal and the recently built Kipevu Container Terminal, which was opened in April 2016 and has a Phase I annual handling capacity of 550000 TEU (KPA, 2023). Table 4 presents the overall specification of the Mombasa container terminal.

**Table 4: Mombasa container terminal specifications**

| Mombasa Container Terminal | |
|---|---|
| Capacity (million TEU) | 1,65 |
| Draft (m) | 12,5 |
| Quay length (m) | 1400 |
| Number of ship-to-shore (unit) | 13 |
| Reach stacker (unit) | 16 |
| Forklift (unit) | 26 |
| Empty handlers (unit) | 3 |
| RTG (unit) | 80 |
| Area (ha) | 40 |

Source: Mombasa container terminal database

The throughput of the Mombasa terminal has been increasing over the years. In 2022 reached 1535000 TEUs, a growth rate of 6,9% (UNCTAD, 2022).

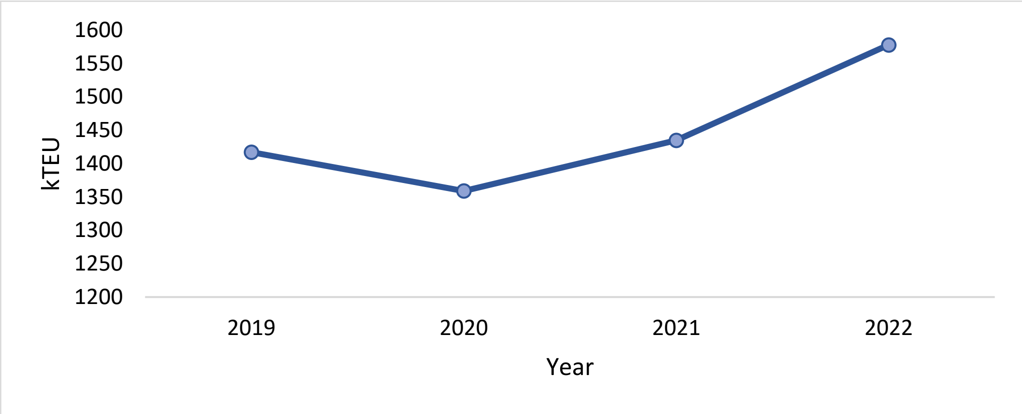


**Figure 17: Mombasa container terminal throughput**

Source: Mombasa container terminal database

### 2.4.5 Sogester Container Terminal

The Sogester container terminal is situated within the Port of Luanda, Angola. This container terminal is the biggest and busiest container terminal in the country and manages a sizable volume of goods from different shipping lines (Sogester, 2023). Angola is the seventh-largest nation in Africa, located on the west coast of southern Africa and surrounded by Namibia, the Democratic Republic of the Congo, Zambia, and the Atlantic Ocean to the west (Wikipedia, 2023). Real GDP growth in Angola increased to 3% in 2022 (African Development Bank, 2023).

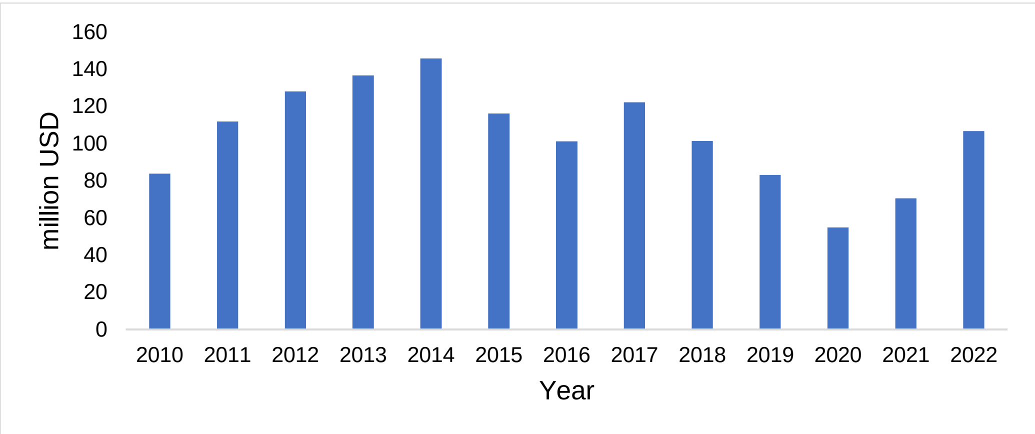


**Figure 18: GDP of Angola**

Source: World Bank, 2023

Sogester, which is located on Angola's western coast and has direct access to maritime shipping lanes, makes it easy to transfer commodities quickly to and from foreign markets, Figure 19. In addition to aiding trade and commerce in Angola, the Sogester Container Terminal also contributes significantly to the nation's economic growth (António Bengue, 2022 ).


**Figure 19: Location map of Sogester container terminal**

Source: Google Maps, 2023

Sociedade Gestora de Fundos (49%) and APM Terminals (51%), are the two shareholders companies in the consortium, which was established in 2007 to manage the container terminal under a 20-year concession (APM Terminals, 2022). Table 5 shows the specifications of the container terminal.

**Table 5: Sogester container terminal specifications**

| Sogester Container Terminal | |
|---|---|
| Capacity (million TEU) | 0,82 |
| Draft (m) | 12,5 |
| Quay length (m) | 545 |
| Number of ship-to-shore cranes (unit) | 8 |
| Reach stacker (unit) | 18 |
| Forklift (unit) | 8 |
| Empty handlers (unit) | 7 |
| Area (ha) | 14 |

Source: Sogester container terminal database

Container throughput at the Sogester container terminal shows a fluctuating trend. The Sogester container terminal faced an increase in container throughput from 247 to 264 in 2022, amounting 6,8% increase (Sogester, 2023).

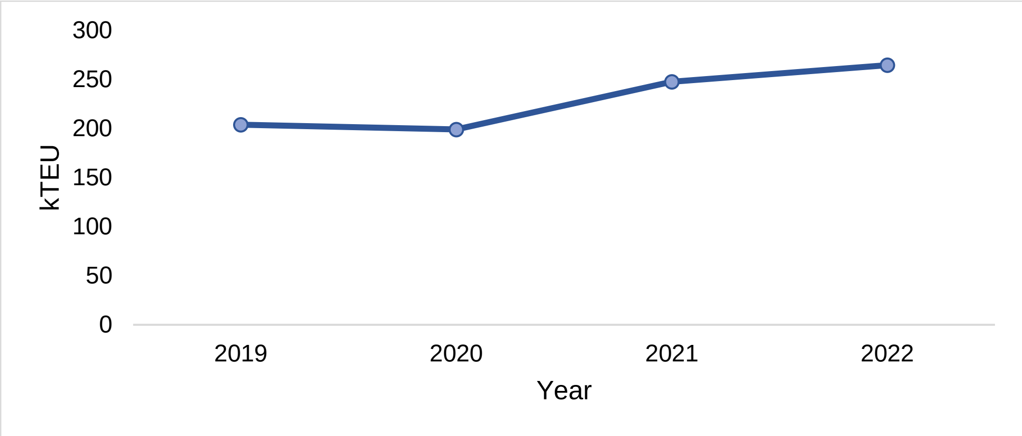


**Figure 20: Sogester container terminal throughput**

Source: Sogester container terminal database

### 2.4.6 Maputo Container Terminal

The Maputo container terminal is located in the Port of Maputo, Mozambique. According to the World Bank (2022), Mozambique country has a population of about 33 million people and is bordered by Tanzania, Malawi, Zambia, Zimbabwe, South Africa, and Eswatini. Real GDP growth in the nation increased by 3,8% in 2022, and inflation increased by 10,3% in 2022 (Africa Development Bank, 2023).

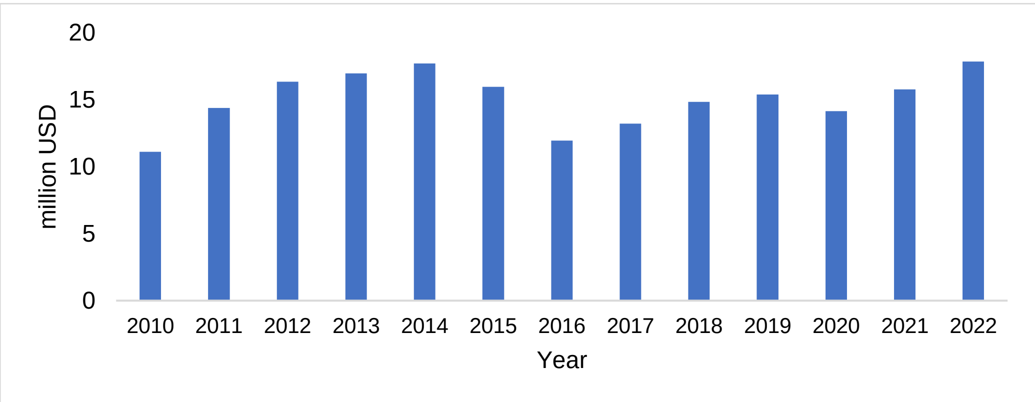


**Figure 21: GDP of Mozambique**

Source: World Bank, 2023

The Maputo container terminal is situated close to the Indian Ocean on Mozambique's southeast coast, Figure 22. According to Humphreys et al. (2019), Maputo benefits from its proximity to important global shipping lanes, particularly the east-west commerce lanes linking Asia, Africa, Europe, and the Americas.


**Figure 22: Location map of Maputo container terminal**

Source: Google Maps, 2023

MIPS was renamed DP World Maputo in 2008 when DP World acquired P&O in 2006. The Maputo container terminal is managed, developed, and operated by DP World Maputo under a concession that is valid until 2043 (Porto de Maputo, 2023). Table 6 shows the specifications of the Maputo container terminal.

**Table 6: Maputo container terminal specifications**

| Maputo Container Terminal | |
|---|---|
| Capacity (million TEU) | 0,35 |
| Draft (m) | 12,5 |
| Quay length (m) | 308 |
| Number of ship-to-shore cranes (unit) | 3 |
| Reach stacker (unit) | 15 |
| Forklift (unit) | 23 |
| RTG (unit) | 6 |
| Area (ha) | 17 |

Source: Maputo container terminal database

The container throughput at Maputo Container Terminal consistently increased. The positive percentage fluctuations seen annually point to a gradual rise in container handling, and in 2022 this container terminal experienced an increase of 15,2% (UNCTAD, 2022).

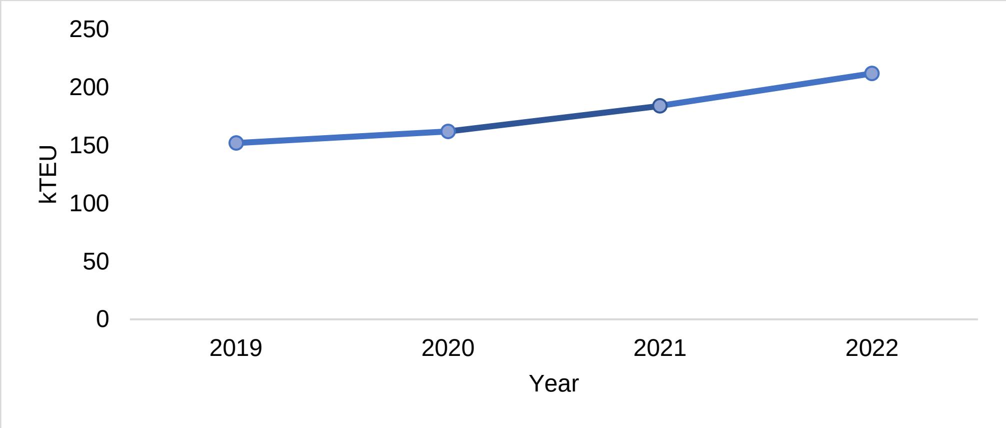


**Figure 23: Maputo container throughput**

Source: Maputo container terminal database

## 2.5 Benchmarking container terminals

Benchmarking is a technique for establishing the foundation for inventive breakthroughs instead of just comparison, imitation, or theft, and this concept was motivated by the Japanese concept of dantotsu, which means to aim to be the best of the best (Castro et al., 2013). Benchmarking consists of finding the best practice, which means achieving the highest standard of excellence for goods, services, or processes and then implementing those standards (Akyar, 2019). The best practices should be ingrained into an organization's culture rather than being imposed to improve performance or achieve business excellence. According to Ha (2016), the four subcategories of benchmarking are internal benchmarking, external or competitive benchmarking, functional or sectorial benchmarking, and process or generic benchmarking. The following is a list of each benchmarking type's definitions:

- Internal benchmarking: to establish internal performance standards, and analyze the performance of comparable business units or business processes within a company.

- Competitive benchmarking: which compares an organization's performance to that of its direct rivals, and typically concentrates on certain goods, services, or processes, as well as work processes and administrative procedures.
- Functional benchmarking: which focuses on a specific function in two or more organizations, and compares an organization's performance to that of an industry leader or the best functional operations of particular firms.
- Generic benchmarking: is a method for applying the best work process benchmarking that contrasts similar operations and processes in two or more different firms.

## 2.6 Key performance indicators (KPI) in container terminal

Key performance indicators are simply measures of various aspects of container terminal operations and they should be easy to calculate and simple to understand (Esmer, 2008). KPIs are used to compare the performance with a target and observe trends in the performance level (Varma, 2018). One of the earliest studies on port performance was created by UNCTAD (1976) using 18 measures split into two major categories: financial (7 indicators) and operational (11 indicators). The operational performance indicators are related to the container terminal activities and facilities (Mwasenga, 2012). According to Yu et al. (2022), excellent terminal performance shows that the terminal can provide its users with high-quality service. When evaluating a container terminal's operational performance, it is important to consider several factors, such as waiting time, throughput per crane, and so on (Tongzon, 2002). Mwasenga (2012) mentions that good operational performance indicators should measure the quality of service provided to customers, and the level of activity of the business in a period, and additionally should measure how intensely the terminal facilities are used. The main operational key performance indicators metrics are described below:

### 2.6.1 Container Traffic

Container traffic is the volume of containers that are moving through a terminal at any given time, which is measured in TEUs on a daily, weekly, monthly, and annual basis (Varma, 2018). Container traffic is a metric used to determine how many containers were imported, exported, or transshipped through a terminal in a given year. This KPI provides an essential evaluation of the operational activity and capability of the terminal for efficient cargo handling. Higher container traffic volumes suggest a busy and active container and tell us how effectively the terminal is utilizing its capacity (Chibuzo Mbanefo, 2020). A high throughput denotes effective utilization of infrastructure and resources, whereas a low throughput indicates potential room for expansion.

### 2.6.2 Vessel turnaround time

Vessel turnaround time tracks how long it takes a container ship to complete a full cycle of port calls at a terminal (Poel, 2023). This metric starts from the ship's arrival at the berth for cargo operations and its departure after completing the necessary activities, such as loading and unloading. The vessel turnaround time is a crucial metric for assessing terminal performance because it directly shows how quickly a terminal runs its cargo operations, and vessel handling procedure. According to Chibuzo Mbanefo (2020), a shorter turnaround time indicates more effective processes. Effective vessel turnaround times enable more vessels to be accommodated at the terminal in a given period, increasing berth utilization and operating capacity.

### 2.6.3 Vessel waiting time

Vessel waiting time is the amount of time a ship must remain at anchor or in a designated waiting area before it can berth and begin cargo operations at a terminal (Poel, 2023). This KPI provides data on the efficiency of port berth allocation, scheduling, and operational management in general. During the waiting time, the vessel is not actively participating in cargo handling operations at the port due to berth availability, traffic, scheduling conflicts, or other operational constraints. It starts when the ship arrives at the port and ends when it is assigned a berth and permitted to begin loading goods. The vessel waiting time is a direct indicator of how well the berth allocation and scheduling activities are working, and an effective vessel waiting time reduces the idle time for vessels and increases total operating capacity by ensuring that berth space is used to the utmost (Varma, 2018). Reduced wait times are a symptom of better operational planning.

### 2.6.4 Container dwell time

According to Chibuzo Mbanefo (2020), container dwell time is the amount of time containers spend at a terminal before being picked up or transferred to their final destination. This KPI gives information on the efficiency of operating procedures as well as the efficiency of cargo movement within the terminal. The container dwell time includes the time needed for operations like customs clearance, document verification, storage, and other operational tasks before the container is released for further travel. A shorter dwell time indicates fewer delays and better workflow. Vessels can turn around more rapidly if dwell time is effectively decreased, allowing them to leave the port earlier and lessening congestion. The total flow of commodities through the terminal is impacted by container dwell time, which can also limit the terminal's capacity to handle higher quantities or meet peak demand.

### 2.6.5 Berth utilization

The productivity of a container terminal's operations is determined by the amount of cargo handled relative to the length of the available quay (Chibuzo Mbanefo, 2020). In simple words, berth productivity is the container throughput obtained per unit of quay length. The more productive a berth is, the more effectively the terminal uses its quay length to handle containers. A rise in berth productivity indicates that the terminal is managing its operations well and cutting down on vessel turnaround times. This KPI metric helps the terminal managers evaluate how well they are using the quay space and other resources, such as cranes, handling equipment, and people, to boost cargo throughput (Mwasenga, 2012). By tracking berth productivity over time and contrasting it with industry averages, terminal operators can monitor their performance, set goals for improvement, and identify opportunities for operational improvements.

### 2.6.6 Berth occupancy rate

The berth occupancy rate quantifies how much berth space was used over a specific time (Chibuzo Mbanefo, 2020). It displays the percentage of a vessel's total available time during a given period that is spent using a berth, whether for loading, unloading, or other operational activities. This KPI provides data on how well a container terminal is managing its berths and operational capacity. The berth occupancy rate is the proportion of berths used for vessel operations. The times when berths are actively processing freight and when they are empty are both considered. According to Mwasenga (2012), berth occupancy rates between 60%-80% are desirable, while berth occupancy below 50% indicates underutilization, and berth occupancy above 90% indicates congestion.

### 2.6.7 Quay crane productivity

The productivity of the quay is a key indicator of how well a container terminal employs its quay cranes to move cargo (Varma, 2018). This KPI determines the typical amount of cargo that a quay crane can move in a time. It demonstrates how well containers are loaded and discharged from ships utilizing the quay cranes at the terminal. This KPI demonstrates how effectively the terminal operates its quay cranes. A higher production rate demonstrates that the terminal is handling the cargo, effectively using the cranes, and reducing downtime (Metalla et al., 2015). Additionally, by utilizing productivity data from quay cranes, terminal managers can efficiently assign quay cranes based on demand. It helps prevent the wasteful or excessive use of crane resources.

### 2.6.8 Terminal productivity

Terminal productivity is used to assess the efficacy and efficiency of cargo handling operations at a container terminal. It gauges the hourly average speed at which containers are loaded and unloaded from ships. This important performance indicator provides information about the terminal's operating performance as well as its ability to handle products quickly and efficiently. Additionally, terminal productivity refers to the quantity of container handling operations (loading and unloading) carried out by terminal machinery, such as cranes and handling equipment, in a single hour (Chibuzo Mbanefo, 2020). The productivity of the terminal is directly correlated with how efficiently cargo is carried across the facility. Faster moves per hour imply easier procedures and faster wait times. A more productive terminal results in quicker turnaround times for ships, shorter berthing periods, and better shipping operations overall.

# 3 Chapter - Research Methodology and Data

This chapter discusses what model and methodological strategy would work best to support this research. In section 3.1, we first assess and compare various modeling approaches that may be used to examine the operational performance of the container terminal, choosing the most relevant. This research uses the model's data analysis envelopment to produce accurate operational performance findings, discussed in Section 3.2. In section 3.3.2, we analyze how the data were selected and how the model included them. Additionally, the quantitive analysis also includes the evaluation of KPI, presented in section 3.3.3. Moreover, it discussed the qualitative method used to obtain information regarding the operational performance of the Sogester container terminal from their employees.

## 3.1 Selecting the appropriate quantitative model

To be able to quantify, comprehend, analyze, and provide strategies, a model is used in this research. This allows us to properly assess the factors that affect the operational performance of the Sogester container terminal and what strategies can be used to improve that operational performance. Data envelopment analysis (DEA) and Stochastic frontier analysis (SFA) are two of the various models used to evaluate the level of efficiency of the operational performance of a container terminal (Deazone, 2018).

Data Envelopment Analysis (DEA): a non-parametric technique for assessing the relative effectiveness of DMUs that use numerous inputs to generate multiple outputs. DEA can be used to compare how well container terminals performance operationally to other terminals in the same region, pinpoint best practices, and point out areas for development.

Stochastic Frontier Analysis (SFA): a parametric technique to evaluate the production process's technical efficacy. SFA can be used to analyze container terminals to find inefficiencies and suggest ways to improve them.

The main differences between the different models can be summarised as follows:

**Table 8: Different models to evaluate operational efficiency**

| Method | Key Features | Advantages | Disadvantages |
|---|---|---|---|
| **Data Envelopment Analysis (DEA)** | Non-parametric method | Handle multiple inputs and outputs; handle different-sized decision-making units | Assumes inputs and outputs are measured without error; sensitive to outliers; |
| **Stochastic Frontier Analysis (SFA)** | Parametric method | Handle measurement errors; estimate technical efficiency and scale efficiency separately; | Assumes functional form of the production function; sensitive to outliers; |

Source: Author based on various sources

The DEA model is a great option for evaluating the performance of container terminals because of its non-parametric structure, flexibility to handle numerous inputs and outputs, capacity to find inefficiencies and draw comparisons with benchmarking, and reliance on actual data. Stakeholders can increase productivity and efficiency by using DEA to have a better understanding of how the terminal operates. For the aforementioned reasons, the DEA model will be used in this research to evaluate the level of efficiency of the operational performance of the Sogester container terminal

### 3.2 Data envelopment Analysis model – DEA model

Abraham Charnes, William W. Cooper, and Edwardo L. Rhodes created the non-parametric mathematical technique known as Data Envelopment Analysis (DEA) in the late 1970s (Efecan and Temiz, 2020). For assessing the relative effectiveness and productivity of DMUs within a group of companies or entities, this influential technique has become a well-known instrument in operations research and management science (Koster and Balk, 2014).

DEA is based on the core premise that DMUs transform a variety of inputs into a variety of outputs, and its main goal is to evaluate how well each DMU uses its inputs to produce outputs. DEA uses linear programming approaches to assess efficiency rather than explicit functional forms or production technology assumptions (Cooper et al., 2007). Due to this characteristic, DEA is especially well suited for situations in which input-output relationships are ill-defined or when comparing units with various input-output combinations. The ability of the DEA to evaluate efficiency while simultaneously taking into account many inputs and outputs is its defining characteristic. Using observed data to build an efficiency frontier or production possibility set, DEA determines the upper limit of achievable output levels for a given set of inputs. The relative efficiency of each DMU is then determined by contrasting its actual performance with this frontier. By helping to identify underperforming DMUs, DEA offers prescriptive insights into potential adjustments that could be made to help them reach greater efficiency levels.

Manufacturing, healthcare, banking, education, transportation, and public services are just a few of the areas and industries where DEA has been widely used. Its uses include policy formulation, resource allocation, benchmarking, and performance evaluation. DEA enables decision-makers to highlight areas for improvement, establish best practices, create objectives, and optimize resource allocation. It is important to keep in mind that although DEA is a useful tool, its results depend on the choices made for the inputs, outputs, and underlying assumptions (Koster and Balk, 2014). The accuracy and validity of DEA analyses depend heavily on the prudent assessment of pertinent variables and the cautious interpretation of findings.

### 3.2.1 The mathematical expression of the DEA model

Without knowing in advance which inputs and outputs will be most crucial in calculating an efficiency measure, DEA is intended to identify the best practice DMU and determine the degree of inefficiency for all other DMUs that are not thought to be the best practice DMUs (Panayides et al., 2009). The Linear Programming solution to a DEA problem does not create any standard errors and does not allow for hypothesis testing because it is non-statistical. Random shocks are not allowed in DEA since any departure from the frontier is viewed as inefficient (Panayides et al., 2009). The model below demonstrates how the DMU's relative efficiency score is determined, according to Charnes et al.'s (1978) proposal, which was based on the seminar paper of Farrell (1957). For calculating the relative efficiency score of a particular DMUj among comparable n entities being evaluated, they suggested the mathematical programming listed below.

$$\mathrm{DMU_j} = \frac{U_1Y_{1j}+U_2Y_{2j}+\cdots+U_rY_{rj}}{V_1X_{1j}+V_2X_{2j}+\cdots+V_iX_{ij}} = \frac{\sum_{r=1}^{s} U_rY_{rj}}{\sum_{i=1}^{m} V_iX_{ij}} \leq 1, j = 1, \dots, n \qquad (1)$$

$U_r, \dots \ , U_s > 0$ and $V_i, \dots \ , V_m \geq 0\ ; r = 1, \dots \ , s;\ \ i = 1, \dots \ , m$

Where:

$Y_{rj}$ = Amount of output r produced by $\mathrm{DMU_j}$

$X_{ij}$ = Amount of input i utilized by $\mathrm{DMU_j}$

r = Number of output generated by the DMUs

i = Number of input used by the DMUs

$U_r$ = weight is given by DEA to output r

$V_i$ = weight given by DEA to input i

Converting the equations above to linear programming model (LPM1):

$$\max \sum_{r=1}^{s} U_rY_{r0} \qquad (2)$$

Subject to $\sum_{r=1}^{s} U_rY_{rj} - \sum_{i=1}^{m} V_iX_{ij} \leq 0, j = 1, \dots \ , n$ (3)

$$\max \sum_{i=1}^{m} V_iX_{ij} = 1$$

$U_r, V_i \geq 0$

The above equations also known as the CCR ratio, can be simplified and converted to the linear programming model (LPM2), as shown by Panayides et al. (2009). The formulation of the DEA model (LPM2) is as follows

$$\mathrm{Max}\ \theta_p(U_r, V_i) = \sum_{r=1}^{s} U_rY_{rp} \qquad (4)$$

Subject to $\sum_{i=1}^{m} V_iX_{ip} = 1$ (5)

$$\sum_{r=1}^{s} U_rY_{rj} - \sum_{i=1}^{m} V_iX_{ij} \leq 0; j = 1, \dots \ , n$$

$$U_r \geq \varepsilon; i = 1, \dots \ , s$$

$V_i \geq \varepsilon; i = 1, \dots , m$

Where $\theta_p$ is the relative efficiency of $p^{th}$ DMU

The DEA-Charnes, Cooper, and Rhode (CCR) and DEA-Banker, Charnes, and Cooper (BCC) models are created by combining the two models (LPM1 and LPM2) with DEA-CCR assuming a constant return to scale and DEA-BCC using variable return to scale. The efficiency of the DMU is maximized by solving the aforementioned equations, subject to the efficiencies of all other DMUs in the set, with an upper bound of 1. To find the relative effectiveness of each DMU, the aforementioned model is solved n times. The weights U_r and V_i are treated as unknowable variables, and the most effective way to discover their values is to maximize the effectiveness of the targeted DMU. According to Panayides et al. (2009), a DMU with an efficiency score of 1 is considered to be efficient when compared to other DMUs, whereas DMUs with a score below 1 are considered to be inefficient.

In a larger sense, DEA transforms each DMU's numerous, inputs and outputs into a scalar measure of operational efficiency, in comparison to other DMUs. Since DEA offers a relative measurement, it will only distinguish between the set of all DMUs with the least efficient members. A container terminal's capacity to convert a set of inputs into a set of inputs is indicated by an efficiency score. The aforementioned model additionally assigns the efficient DMU a peer group. In other words, the most efficient is given a value of 1, whereas all the other less effective DMUS are given a value between 0 and 1 (Min and Park, 2004).

### 3.2.2 DEA application for benchmarking

According to Koster and Balk (2014), DEA analysis is commonly used to evaluate performance for various operations or activity types. In its use, this technique is used to evaluate the degree of effectiveness by contrasting it with other enterprises or organizations. The efficiency score is calculated using equation 1's output-to-input weights ratio. All resources used for activities or processes are referred to as inputs or production factors, and the output variable is the result of the input. When assessing the productivity or efficiency of terminal operations, several outputs and inputs related to the terminal's production characteristics are taken into consideration. Both elements must be taken into account when calculating an efficiency score.

The DEA model is used to evaluate the performance efficacy of a terminal or DMU by using terminal outcomes as an output and terminal resource utilization as an input (Talley, 2006). A Decision Making Unit (DMU) is the word used to describe the terminal in this investigation. The performance of the terminal cannot be solely dependent on a single productivity factor because the terminal also serves as a berthing facility, a facility for container handling, and a connecting facility for the transportation of goods between land and sea, as was previously mentioned in the section on performance indicators. Data Envelopment Analysis (DEA) is used to analyze the terminal performance of a calculation that includes several input variables and outputs. Performance measurements are measured over several terminals to determine the amount of efficiency. To determine which output offers the best value or results, benchmarking is a measurement technique or activity that contrasts the output of other activities that have the same goal (Rankine, 2013). A value is required to analyze and evaluate terminal performance. Performance efficiency can be determined using a score derived from a comparison of competitors.

This study employs an input-oriented DEA-CCR model to measure the number of terminals or DMUs by minimizing input to satisfy the level of output since the DEA always measures the weighted output to the weighted input. As a result, efficiency scores in the range of 0 and 1 were generated. Efficiency is indicated by a value of 1, whereas inefficiency is shown by a value below 1. The DEA analysis is carried out to assess the effectiveness of multi-terminal operating performance and is calculated by employing different types of software such as Stata, R-studio, Excel, or others (Talley, 2006).

### 3.3 Data

To address the research question with the DEA model, we have to gather the required data to run the model. These data include quay length, number of quay cranes, terminal area, number of yard equipment, and throughput. Data requirements were found in public access databases, i.e. UNACTD, World Bank, Government official websites, and container terminal reports.

### 3.3.1 Terminal selection

The selection criteria used to determine which container terminal will be examined in the DEA model are dependent on several variables. Significant ports in East and Southern Africa are represented by the chosen terminals. Benchmarking with these terminals offers a chance to comprehend and gain knowledge from their accomplishments, setbacks, and experiences. Benchmarking enables the evaluation of various operational approaches, tools, and procedures employed by these terminals. This investigation may reveal best practices that the other Sogester container terminal could adopt or modify to increase production and efficiency. The container terminal chosen and the justification for the DEA model are summarized in the table below.

**Table 7: Container terminal selection rationale**

| Container Terminal | Rationale |
|---|---|
| **Sogester** | The object of this research is to be benchmarked with other terminals |
| **Dar es Salaam** | Comparing the performance of the Sogester container terminal to that of these container terminals gives a comprehensive picture of its operation, enabling targeted improvements, wise decision-making, and increased competitiveness in the African container terminal sector. |
| **Durban pier 2** | |
| **Maputo** | |
| **Mombasa** | |
| **Walvis Bay** | |

Source: Author

### 3.3.2 DEA input and output variables

According to TEMZ and EFECAN (2020) study some variables are the most frequently used as input and output variables when using the DEA method. The main points that significantly affect how input and output components interact within the DEA framework are highlighted in this study. Figure 24 and Figure 25 summarize the most used variables in the DEA model.

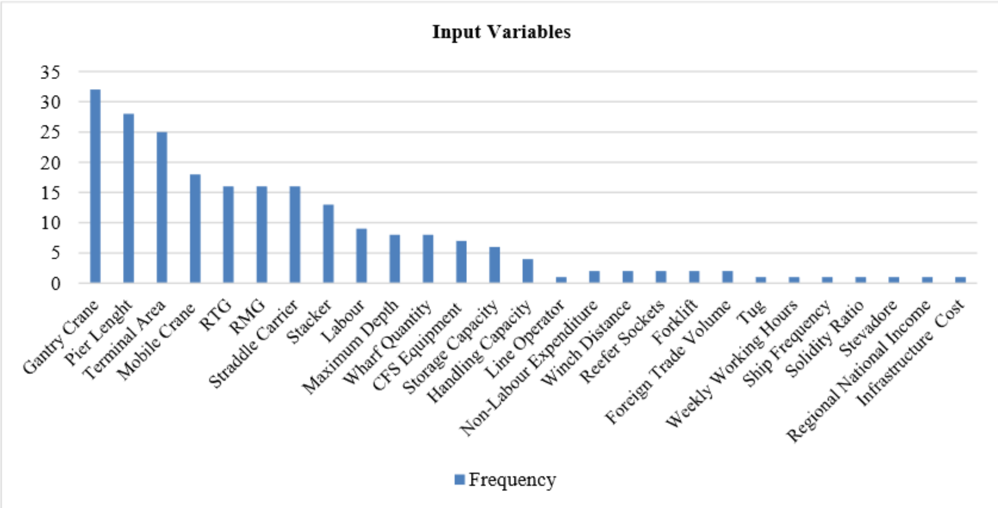


**Figure 24: DEA most used input variables**

Source: EFECAN and TEMİZ, 2020.

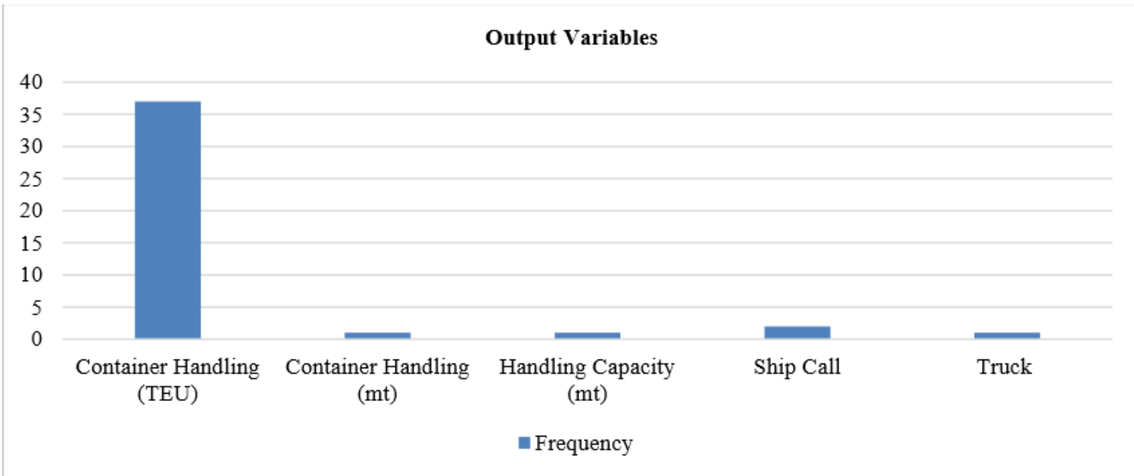


**Figure 25: DEA most used outputs**

Source: EFECAN and TEMİZ, 2020

Only variables with publicly available data were utilized as input and output for this thesis. The number of quay cranes (units), quay length (in meters), terminal area (in meter square), and yard equipment (which only includes reach stackers, forklifts, empty handlers, and RTG) were chosen as the input variables and container traffic (TEUs) is the output variable.

**Table 8: Input and output variables of the DEA model**

| Input variable | Output variable |
|---|---|
| Number of quay cranes (unit | Throughput (TEU) |
| Quay length (meter) | |
| Terminal area (m2) | |
| Yard equipment (unit) | |

Source: Author

### 3.3.3 Key performance indicators selection rationale

The KPI selection rationale is based on how the delivered information can be used to improve the container terminal's operational performance. Additionally, the KPI needs to accurately and consistently reflect a crucial part of the terminal performance. The chosen KPIs offer insightful data on some operational elements of container terminals, turnaround time, berth utilization, and waiting time. Terminals can optimize operations, increase efficiency, and offer better services to consumers and stakeholders by monitoring and improving these KPIs. The criteria and KPIs used are summarized in Table 9.

**Table 9: Key performance Indicator selection Rationale**

| KPI | Rationale |
|---|---|
| **Container traffic** | Reflects the terminal's potential for expansion and competitiveness. |
| **Turnaround Time** | Reduced delays and effective terminal operations are shown by a quicker turnaround time. |
| **Waiting time** | A shorter wait time indicates more effective berth distribution, less traffic, and better terminal operations. |
| **Dwell Time** | A reduced dwell time denotes effective handling and clearing procedures and guarantees that items will be delivered on time. |
| **Crane Productivity** | Increased productivity translates into better terminal performance, reduced waiting times, and optimum equipment use. |
| **Berth Occupancy** | It shows the degree of congestion and the terminal's capacity to receive vessels without experiencing delays. |
| **TEU per crane** | A high rating means that the cranes at the terminal are being used effectively to handle a large number of containers. |
| **TEU per quay length** | A high rating means the terminal is efficiently using the quay area it has to accept a large number of containers. |
| **TEU per area** | A high TEU per hectare figure indicates effective land use in the terminal area. |

Source: Author

## 3.4 Qualitative Analysis

### 3.4.1 The questionnaire

Even though the quantitative analysis offered useful information into the level of the operational performance of the container terminals and preliminary insight into the factors that determine its competitiveness advantage, it has been necessary to expand the research to the qualitative to determine the actual determinants of competitiveness according to the perceptions of end users and key stakeholders of the Sogester container terminal. In this research, we utilize a questionnaire which is a collection of questions that are presented to respondents in a particular order and is the same for all the respondents (De Vaus, 2005). As all of the respondents are based on the Sogester terminal location (Angola), the questionnaire is online-based and self-administered as it is the most practical way to get responses (Saunders et al., 2007). All respondents received an introductory email with a link to the survey, which they were instructed to complete.

### 3.4.2 The questionnaire sections

The online questionnaire was divided into 6 sections for the research. The respondents are requested to fill in their information in the first section. The other sections are multiple-choice questions that assess the factors that influence the Sogester container terminal operating performance. Respondents are asked to rate their degree of satisfaction with the Sogester Container terminal operational performance.

# 4 Chapter - Results and Analysis

In this chapter, we present the main results obtained from our KPI analysis and DEA model. We will first analyze the Key performance indicators among the benchmarked container terminals and summarize the main results. After data is analyzed the DEA model and the main results. In section 4.3.2, we carry out a sensitivity analysis of the DEA model to find out the suitable container throughput for each container terminal. Finally, we present the results of the online questionnaire carried out at the Sogester container terminal.

## 4.1 Data processing and analysis

Table 10 shows the container throughput at the Sogester Container Terminal for four years, from 2019 to 2022. The terminal noticed an increase in container throughput over this time, which amounted to 6,8% in 2022 and resulted in a total throughput of 264380 TEUs. 48,5% of the throughput is made up of exports, 48,5% of imports, and 3,7% of transshipments.

**Table 10: Sogester container terminal throughput 2019 - 2022**

| **Container Throughput (TEU)** | | | | |
|---|---|---|---|---|
| **Ref.** | **2019** | **2020** | **2021** | **2022** |
| **Import** | 82251 | 74269 | 98.626 | 126538 |
| **Export** | 95725 | 80033 | 100387 | 128258 |
| **Transshipment** | 25827 | 44696 | 48520 | 9584 |
| **Total** | 203803 | 198998 | 247533 | 264380 |

Source: Author based on Sogester container terminal database

The Sogester Container Terminal's operational performance analysis for the years 2019 to 2022 reveals interesting trends in key performance parameters. With the number of moves rising from 25 in 2021 to 38 in 2022, there is also a noticeable improvement in berth productivity. However, there was a 12,7% increase in vessel waiting time and turnaround time over the study period. The pattern of the berth occupancy rate has changed throughout time, indicating shifts in the level of berth utilization at any particular period. Notably, the berth occupancy rate rose to 51% in 2022.

**Table 11: Sogester container terminal KPI 2019 - 2022**

| Key performance indicator | | Years | | | |
|---|---|---|---|---|---|
| **Reference** | **Units** | **2019** | **2020** | **2021** | **2022** |
| **Berth Productivity** | Moves/hours | 35 | 30 | 26 | 38 |
| **Berth occupancy** | Percentage | 46% | 48% | 60% | 51% |
| **Vessel Turnaround time** | Days | 1,4 | 1,7 | 2 | 2,2 |
| **Vessel Waiting time** | Days | 1,3 | 1,5 | 1,8 | 2 |

Source: Author-based Sogester container terminal database

### 4.1.1 Container throughput

With the largest container throughput, Durban Pier 2 and Mombasa stand out as significant centers in this region, with an increase of 9,9% and 7% respectively. Dar es Salaam, which ranked third in terms of container throughput in 2022, had a growth rate of 4,8%. In contrast, the Sogester, Maputo, and Walvis Bay container terminals have lower throughputs of containers. Sogester saw a growth of 6,8% in 2022, while Maputo made significant strides with a growth rate of 15%. On the other side, Walvis Bay showed a 9% growth rate.

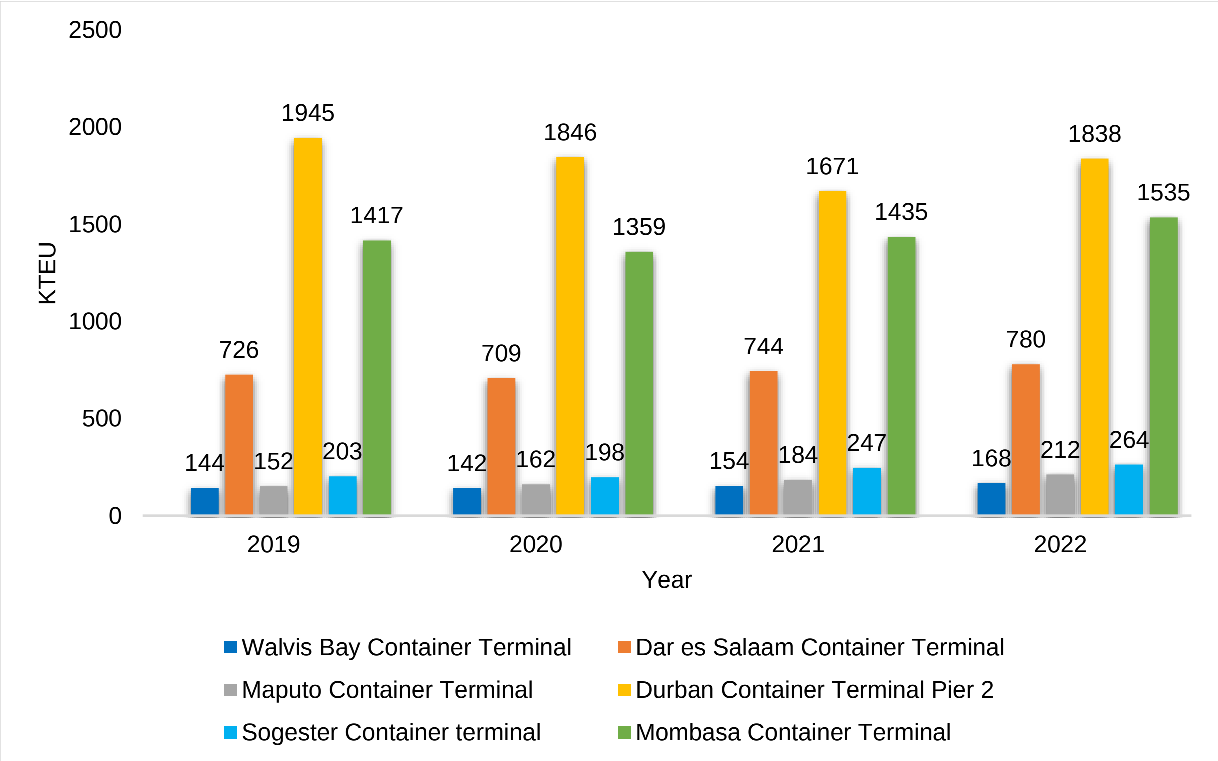


**Figure 26: Container Throughput 2019-2022**

Source: Author based on containers terminals database

### 4.1.2 Number of vessel calls

Durban Pier 2 Container Terminal, in particular, stood out as the terminal that saw the most vessel visits. In 2022, the Durban Pier 2 container terminal was the busiest despite a minor decline of 3,8%, underscoring its role as a key node for container shipping. The Mombasa container terminal, which had a drop in vessel calls of 5,6% in 2022, is in second place. The third-highest number of cargo vessel visits is in Dar es Salaam. The number of vessel calls to Dar es Salaam rose by 6,7% in 2022. The lowest number of vessel visits was seen at Sogester, Walvis Bay, and Maputo container terminals all of which had a decline in vessel calls during the period. In particular, Sogester had a decline of 8,96% in vessel calls, while Walvis Bay and Maputo decreased by 13% and 3,57%, respectively.

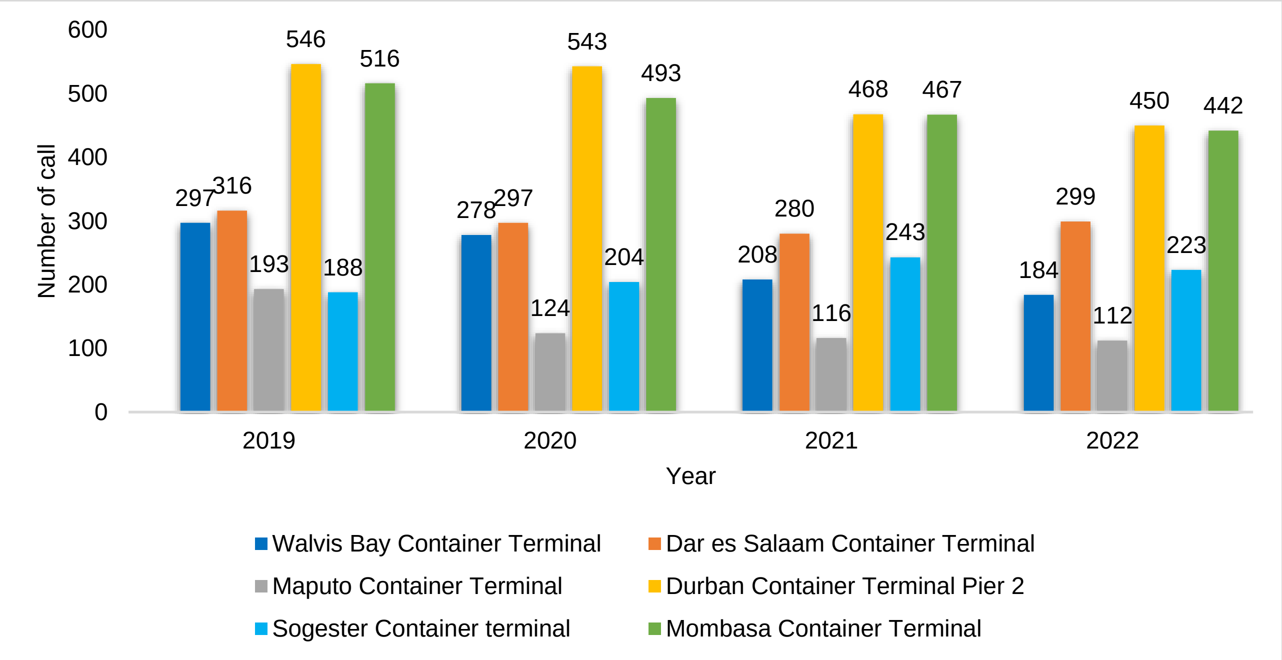


**Figure 27: Number of calls 2019 - 2022**

Source: Author based on containers terminals database

### 4.1.3 Vessel turnaround time

Investigating vessel turnaround times at several container terminals reveals interesting operational efficiency characteristics. Mombasa Container Terminal and Durban Pier 2 have emerged as the terminals with the longest vessel turnaround times, with average turnaround times of 2,9 and 2,7 days, respectively. The Walvis Bay Container Terminal, on the other hand, stands out for excelling in vessel turnaround time, boasting an exceptionally quick average of just 1,6 days. The third best-performing terminal is the Sogester Container Terminal, which has a vessel turnaround time of about 2,2 days.

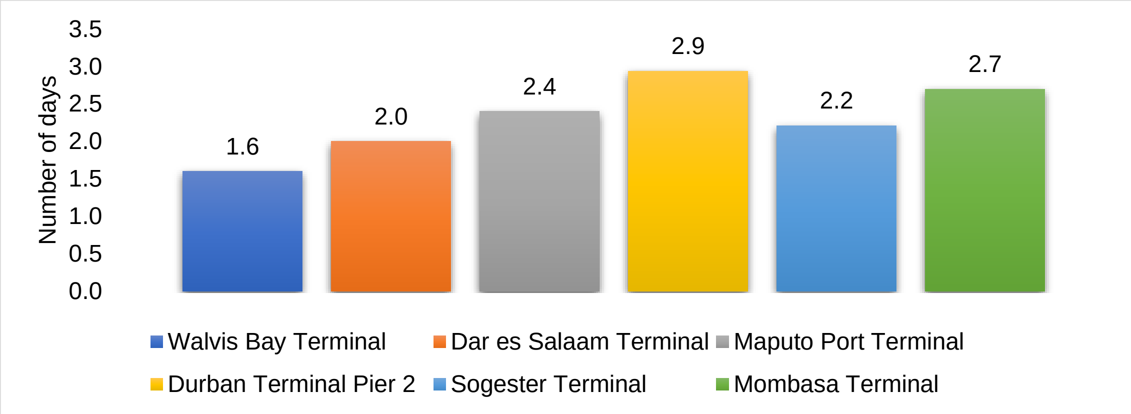


**Figure 28: Turnaround time (days)**

Source: Author based on containers terminals database

### 4.1.4 Vessel waiting time

The analysis shown in Figure 29 explains how different the container terminals perform in terms of vessel waiting time. The Walvis Bay container terminal has a high performance, with an average waiting time of just 1 day. Sogester Container Terminal, in comparison, offers the longest waiting time meaning low performance, with a waiting time of 2 days.

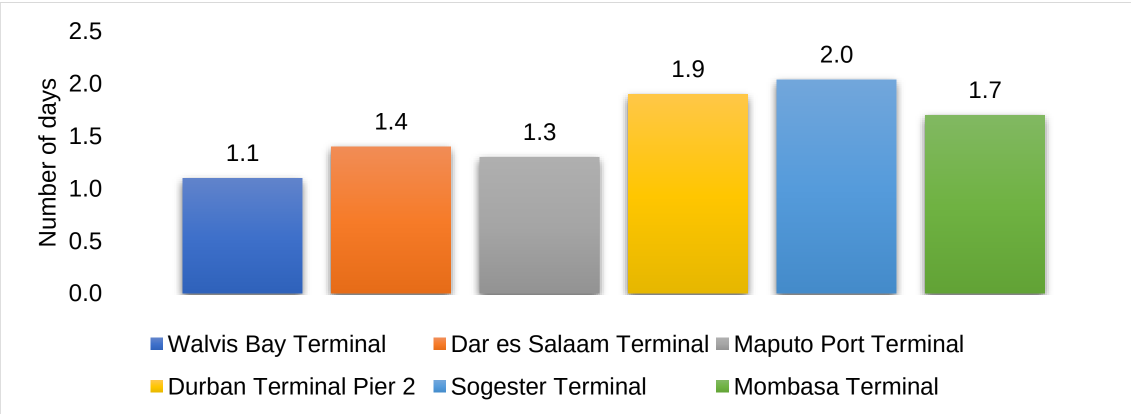


**Figure 29: Waiting time (days)**

Source: Author based on containers terminal database

### 4.1.5 Container dwell time

Average dwell times at the container terminals are examined, and distinct operational efficiency trends emerge. The container terminals at Mombasa and Durban Pier 2 stand out with the lowest container dwell time. The two container terminals Mombasa and Durban Pier 2 with an average time of only 4,6 and 5,5 days, respectively. The Sogester container terminal, on the other hand, has the fourth-worst performance among the analyzed terminals due to its longer average container dwell time of 7,7 days.

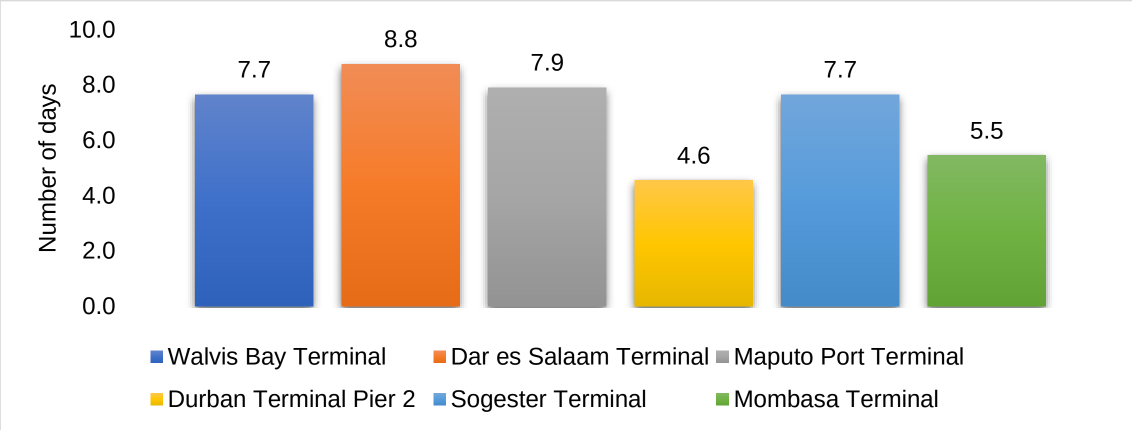


**Figure 30: Average dwell time (days)**

Source: Author based on containers terminals database

### 4.1.6 Berth occupancy rate

There are significant differences in terminal use, as shown in Figure 31 by a review of berth occupancy rates at container terminals. The Maputo container terminal, specifically, has the lowest berth occupancy, with a rate of 45%. The Mombasa container terminal, in contrast, shows the highest berth occupancy, at a significant rate of 90%. A moderate 51% berth occupancy rate is maintained at the Sogester container terminal.

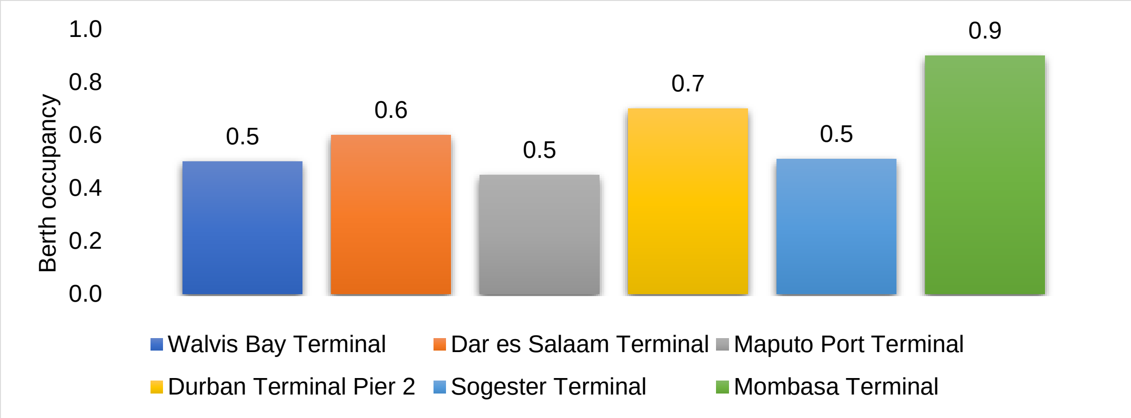


**Figure 31: Berth occupancy rate (%)**

Source: Author based on container terminals database

### 4.1.7 TEU per crane

The ratio of TEUs handled by crane, used to measure container terminal efficiency, provides valuable insights into the level of operational performance. The container terminals in Mombasa and Dar es Salaam stand out in this regard with the highest ratios. Mombasa has a strong ratio of 127917 TEUs per crane, and Durban is just behind it with 83545 TEUs per crane. The Sogester container terminal achieves a ratio of 33000 TEUs per crane, making it the lowest performance in this criterion. The Second-lowest scorer in this category is the Walvis Bay container terminal, which recorded a TEU per crane ratio of 42000.

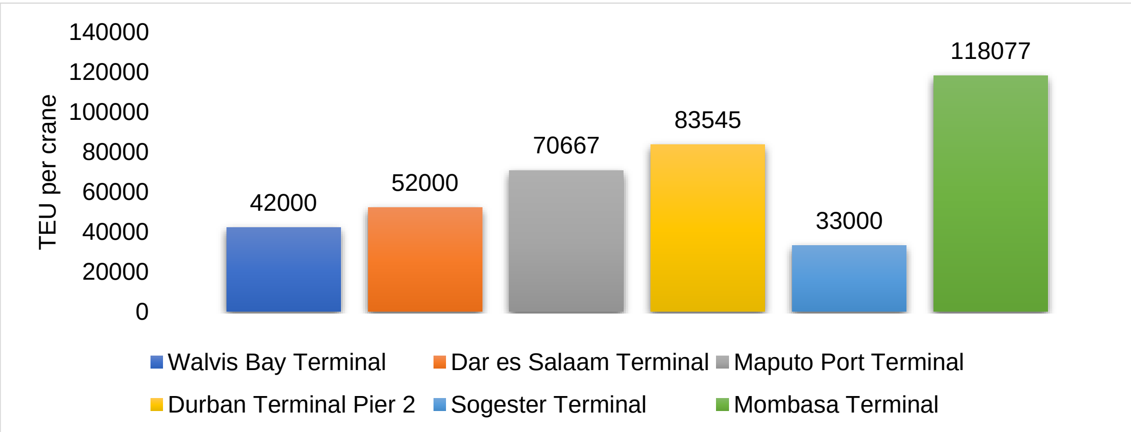


**Figure 32: TEU per crane**

Source: Author based on container terminals database

### 4.1.8 TEU per meter quay length

TEUs per quay length, a measure of container throughput efficiency, provide nuanced insights into the operational effectiveness of different container terminals. The Durban Pier 2 container terminal stands out for having the higher ratio, measuring 1195 TEU per meter of quay length. The Walvis container terminal, on the other hand, shows the lowest TEU per quay length value, at 280. With a rating of 484, the Sogester container terminal ranks second worst in terms of TEUs per quay length.

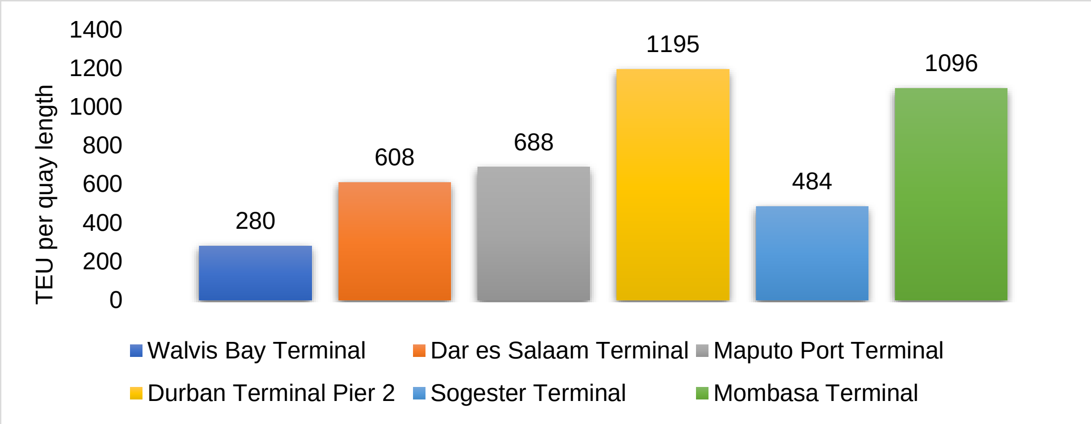


**Figure 33: TEU per meter quay length**

Source: Author based on container terminals database

### 4.1.9 TEU per terminal hectare

The evaluation of the annual throughput per hectare of the terminal gave important insights into the container terminal's operating efficiency. Mombasa and Dar es Salaam have the highest value with 38375 and 29512 TEU per hectare, respectively. The Walvis container terminal, with a value of 9200 TEU per hectare, has the lowest TEU value. With a value of 18592 TEU per hectare, the Sogester container terminal ranks third highest.

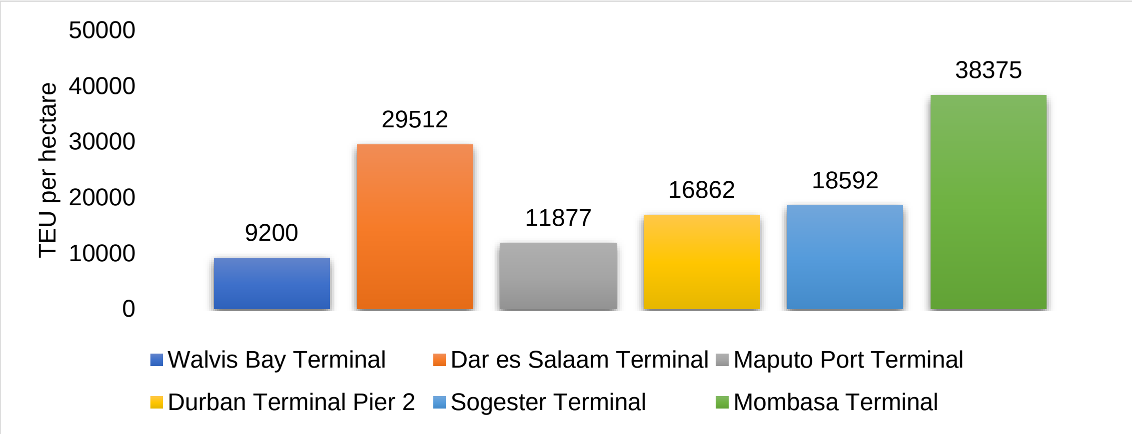


**Figure 34: TEU per hectare**

Source: Author based on container terminals database

### 4.1.10 TEU per yard equipment

The evaluation of terminal throughput per yard of equipment offers insightful information about the operational efficiency at the container terminal. Mombasa has the highest value with 19355 TEU per yard of equipment, followed by Dar es Salaam with 14717 TEU per yard of equipment. The Walvis container terminal, with a value of 6000 TEU per yard equipment, has the lowest TEU per yard equipment. With a value of 8000, the Sogester container terminal ranks second lowest in terms of TEUs per yard equipment.

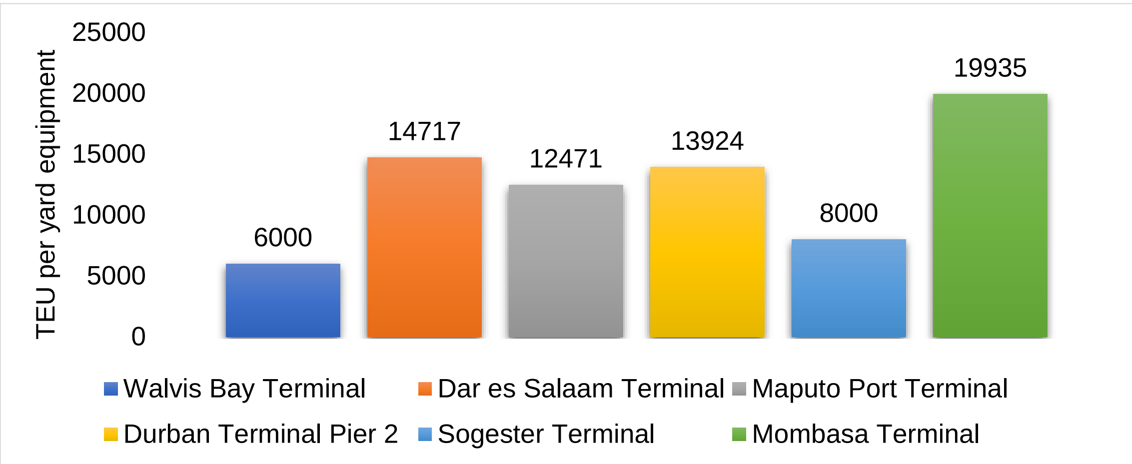


**Figure 35: TEU per yard equipment**

Source: Author based on container terminals database

## 4.2 KPIs Summary

Each container terminal has unique features that affect how well it operates, such as the quantity of equipment, the quay length, the terminal area, and the number of quay cranes. Table 12 shows that Mombasa, Durban, and Dar es Salaam container terminals have the highest values in most of the KPIs, including TEU per quay length, TEU per crane, TEU per area, and TEU per yard equipment, meaning that they have high performance. On the other hand, terminals like Sogester, Maputo, and Walvis Bay have the lowest values in most of the KPIs meaning low performance.

**Table 12: KPI Summary**

| Container terminal name | TEU per quay length | TEU per crane | TEU per area (ha) | TEU per yard equipment | Berth occupancy | Turnaround time (days) | Waiting time (days) |
|---|---|---|---|---|---|---|---|
| Walvis Bay | 280 | 42000 | 9200 | 6000 | 0,50 | 1,60 | 1,10 |
| Dar es Salaam | 608 | 52000 | 29512 | 14717 | 0,60 | 2,00 | 1,40 |
| Maputo | 688 | 70667 | 11877 | 12471 | 0,45 | 2,40 | 1,30 |
| Durban Pier 2 | 1195 | 83545 | 16862 | 13924 | 0,70 | 2,94 | 1,90 |
| Sogester | 484 | 33000 | 18592 | 8000 | 0,51 | 2,21 | 2,04 |
| Mombasa | 1096 | 118077 | 38375 | 19935 | 0,90 | 2,70 | 1,70 |

Source: Author

Table 13 summarizes the KPIs scores for the six benchmarked container terminals. These KPIs have been categorized on a spectrum ranging from 0 to 100%. A terminal achieving an overall score of 100% signifies a high performance, while a score of below 100% denotes that the container terminal performance can be improved.

**Table 13: KPI Scores**

| Container terminal name | TEU per quay length | TEU per crane | TEU per area (ha) | TEU per yard equipment | Berth occupancy | Turnaround time (days) | Waiting time (days) |
|---|---|---|---|---|---|---|---|
| Walvis Bay | 0% | 33% | 0% | 0% | 56% | 100% | 100% |
| Dar es Salaam | 51% | 41% | 77% | 80% | 67% | 75% | 73% |
| Maputo | 58% | 55% | 31% | 63% | 0% | 50% | 82% |
| Durban Pier 2 | 100% | 85% | 70% | 77% | 100% | 0% | 27% |
| Sogester | 41% | 0% | 48% | 40% | 57% | 62% | 0% |
| Mombasa | 92% | 100% | 100% | 100% | 85% | 31% | 45% |

Source: Author

As illustrated above, the analysis reveals that the Durban Pier 2, Mombasa and Dar es Salaam container terminals attain the most distinguished overall score, showing high performance in terms of operational efficiency among the six benchmarked container terminals. Moreover, the Maputo container terminal has intermediate performance in the KPI. In contrast, the Sogester container terminal, the main goal of this research, scored low values in the KPI which reflects substantial room for improvement in the level of operational performance. Moreover, the Walvis Bay container terminal has the worst performance among the benchmarked terminals in terms of Key performance indicators.

## 4.3 DEA inputs and outputs analysis

The study employs six African container terminals as its DMUS and all the specifications of the terminals are gathered and shown in Table 14. The input variables are quay length, number of quay cranes, terminal area, and yard equipment. The output variable is the container throughput at each container terminal.

**Table 14: Input and output values of the DEA model**

| DMU (Terminal) | Input | | | | Output |
|---|---|---|---|---|---|
| | Quay length (unit) | Number of quay cranes (unit) | Terminal area (m2) | Yard Equipment (unit) | Throughput (TEU) |
| Walvis Bay | 600 | 4 | 182600 | 28 | 168000 |
| Dar es Salaam | 1282 | 15 | 264300 | 53 | 780000 |
| Maputo | 308 | 3 | 178500 | 17 | 212000 |
| Durban Pier 2 | 1538 | 22 | 1090000 | 132 | 1838000 |
| Sogester | 545 | 8 | 142000 | 33 | 264000 |
| Mombasa | 1400 | 13 | 400000 | 77 | 1535000 |

Source: Author

The DEA approach utilized in this research uses the R-Studio program, and it calculates efficiency statistics scores for the six container terminal's operational performance. The R-Studio code can be found in Appendix 1.

### 4.3.1 DEA efficiency results

The efficiency of the DMUs is evaluated in this section using the DEA-CCR input-oriented model. The weighted output is compared to the weighted input to determine DEA. This method creates a data frame of score efficiency for each terminal by making an effort to optimize the input variables while accounting for a consistent return to scale. A terminal scoring 1 means maximum efficiency and a value less than 1 indicates less efficiency. According to Table 15, Durban Pier 2 and Mombasa container terminal, scored 1, which denotes maximum efficiency among the benchmarked terminal. On the other hand, the Sogester, Maputo, Walvis Bay, Dar es Salaam, and Sogester container terminals have scores below 1, which denotes less efficiency and opportunities for improvement. The Sogester Container Terminal, the study's target, scores 48% when compared to 100% of some competitors, meaning that the Sogester container terminal does get out the full utilization of the current terminal resources.

**Table 15: Terminals DEA efficiency scores**

| Ref | Terminal name | Efficiency Scores |
|---|---|---|
| 1 | Walvis Bay | 0,33 |
| 2 | Dar es Salaam | 0,77 |
| 3 | Maputo | 0,63 |
| 4 | Durban Pier 2 | 1 |
| 5 | Sogester | 0,48 |
| 6 | Mombasa | 1 |

Source: Author

Analyzing the slack data can provide insights into the reasons behind poor performance in certain container terminals. Slack values deviating from zero indicate potential inefficiencies in terminal operations. Specifically, no zero slack suggests that the input variables are not being utilized optimally, indicating room for improvement. Table 16, shows for all the input variables there are three values: the actual value, which is the input value utilized in the model, the target value, the input value at which the terminal would be effective with the current throughput, and the slack value, represents the discrepancy between the actual value and the goal value. There is 0 slack in all of the input variables for the Mombasa and Durban Pier 2 container terminals because they are soring maximum efficiency among the benchmarked terminals.

The Sogester container terminal, the primary subject of this study, exhibits slack in four variables: the number of quay cranes, the length of the quay, the quantity of yard equipment, and the terminal area. The terminal's slacks result in excess capacity and inefficient resource use, resulting in the terminal's miss utilization of 6 quay cranes, 304 meters of quay length, 20-yard equipment, and an area of 73205 square meters. To become more efficient Sogester container terminal should increase the container throughput or an alternative solution is that the terminal may use this slack area to build a warehouse or sell any extra machinery that is at the terminal.

**Table 16: Inputs and Outputs Slacks**

| DMU | Quay length | | | Number of quay crane | | | Yard Equipment | | | Terminal total area (m2) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Actual value | Target value | Slack value | Actual value | Target value | Slack value | Actual value | Target value | Slack value | Actual value | Target value | Slack value |
| **Walvis Bay** | 600 | 153 | 447 | 4 | 1 | 3 | 28 | 8 | 20 | 182600 | 43779 | 138821 |
| **Dar es Salaam** | 1282 | 711 | 571 | 15 | 7 | 8 | 53 | 39 | 14 | 264300 | 203257 | 61043 |
| **Maputo** | 308 | 193 | 115 | 3 | 2 | 1 | 17 | 11 | 6 | 178500 | 55737 | 122763 |
| **Durban Pier 2** | 1538 | 1538 | 0 | 22 | 22 | 0 | 132 | 132 | 0 | 1100000 | 1100000 | 0 |
| **Sogester** | 545 | 241 | 304 | 8 | 2 | 6 | 33 | 13 | 20 | 142000 | 68795 | 73205 |
| **Mombasa** | 1400 | 1400 | 0 | 13 | 13 | 0 | 77 | 77 | 0 | 400000 | 400000 | 0 |

Source: Author

### 4.3.2 Sensitivity analysis

To determine the circumstances in which the inefficient terminals can become efficient, we perform the sensitivity analysis. We kept the input variables constant to determine the ideal throughput for the container terminal to increase its efficiency. Therefore, we raised the throughput value till the terminal became efficient. The Sogester container terminal has to at least double its current throughput or raise it by a minimum of 110%, to become efficient. This is because the terminal needs to attain a level of throughput of at least half a million TEU to optimize the relation between the inputs and output variables in the DEA model.

**Table 17: DEA Sensitivity Analysis**

| DMU (Terminal) | Quay length | Number of quay crane | Yard equipment | Terminal area (m2) | Old throughput | New throughput | Throughput increase | Efficiency Score |
|---|---|---|---|---|---|---|---|---|
| Walvis Bay | 600 | 4 | 28 | 182600 | 168000 | 487200 | 190% | 1 |
| Dar es Salaam | 1282 | 15 | 53 | 264300 | 780000 | 1053000 | 3% | 1 |
| Maputo | 308 | 3 | 17 | 178500 | 212000 | 339200 | 60% | 1 |
| Durban Pier 2 | 1538 | 22 | 132 | 1100000 | 1838000 | 1838000 | 0 | 1 |
| Sogester | 545 | 8 | 33 | 142000 | 264000 | 554400 | 110% | 1 |
| Mombasa | 1400 | 13 | 77 | 400000 | 1535000 | 1535000 | 0 | 1 |

Source Author

By increasing the terminal throughput the inefficient container terminals can also increase the overall key performance indicator. Table 17 shows that to operate efficiently the Sogester container terminal should at least reach half a million TEU and should at least reach the following values for the KPIs, 1000 TEU per meter quay length, 80000 TEU per crane, 20000 TEU per hectare, 17000 TEU per yard equipment.

## 4.4 Online questionnaire results and descriptive analysis

This section goes through the findings of the online questionnaire carried out at the Sogester Container Terminal. The respondents are Sogester Terminal employees in charge of various divisions, positions, and years of experience. To make it easier for them to complete the survey, the respondents were given a link to access the questionnaire through emails and mobile applications. The questionnaire was carried out between July 31 and August 11, 2023.

### 4.4.1 Response Rate

A diverse group of 20 workers at the Sogester container terminal, representing several divisions, were requested to fill out the online questionnaire. The response rate was 100%, demonstrating the commitment of the terminal employees to understand and evaluate the level of efficiency of the terminal.

### 4.4.2 Initial information.

The purpose of this part is to determine the background of respondents based on the following parameters: total years of experience, division/unit, and position/ category of the company workers.

1- Years of experience of respondents

Table 18 shows the years of experience distribution of the respondents as follows 35% of respondents have between 11-15 years of experience, 30% of respondents have 5-10 years of experience, 25% have 16 years above of experience, and 10% of respondents have below 5 years of experience. From it can be concluded that the majority of the respondents have many years of experience.

**Table 18: Years of experience of respondents**

| Years experience | Frequency | Percentage |
|---|---|---|
| Below 5 years | 2 | 10% |
| 5 – 10 years | 6 | 30% |
| 11 – 15 years | 7 | 35% |
| 16 years above | 5 | 25% |

Source: Author

2- Division/Unit of respondents

Table 19 presents the division/unit distribution of the respondents as follows: 40% operations, 30% engineering, 20% human resources, 5% information technology, 5% commercial, and there is no participation from finance. The operations department has the majority of respondents, followed by the engineering department.

**Table 19: Division/unit of respondents**

| Division/ Unit | Frequency | Percentage |
|---|---|---|
| Human resources | 4 | 20% |
| Finance | 0 | 0 |
| Operations | 8 | 40% |
| Engineering | 6 | 30% |
| Information technology | 1 | 5% |
| Commercial | 1 | 5% |

Source: Author

3- Position/category of respondents

The descriptive statistics shown in Table 20 present that the respondents are distributed as follows: 55% managers, 25% assistant managers, 15% staff, and 5% general managers. Most of the respondents are managers followed by assistant managers.

**Table 20: Position/category of respondents**

| Position / Category | Frequency | Percentage |
|---|---|---|
| General manager | 1 | 5% |
| Manager | 11 | 55% |
| Assistant Manager | 5 | 25% |
| Staff | 3 | 15% |

Source: Author

### 4.4.3 Assessment of container terminal efficiency

This part intends to understand the terminal operations' perception regarding efficiency through a set of questions.

1- Can indicators such as the increasing level of container throughput, resource utilization, and decreasing handling time, be used to assess how efficiently the container terminal is operating?

This question is to understand the respondent's responses to whether the container terminal efficiency can be measured by factors such as increasing in level of container throughput, resource utilization, and decrease in handling time. As shown in Figure 36, the respondent rate is: 45% agree, 40% strongly agree, 10% neutral, 5% disagree, and there is no score for strongly disagree. From this can be concluded that most of the respondents know the indicators that are used to measure terminal operational efficiency.

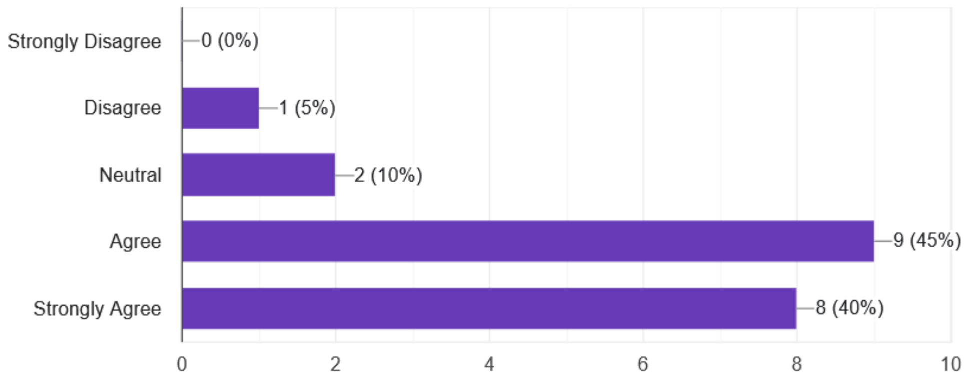


**Figure 36: Terminal efficiency importance**

Source: author

2- How do you assess the resource utilization such as a quay, cranes, yards, and equipment and the current container throughput at the Sogester Container terminal?

This assessment analyses the resource utilization at the Sogester container terminal, as per Figure 37. The response rate is as follows: 40% high, 25% very high, 20% moderate and there is no score for low and very low resource utilization. The assessment shows that according to respondents the level of resource utilization at the Sogester container terminal is high.

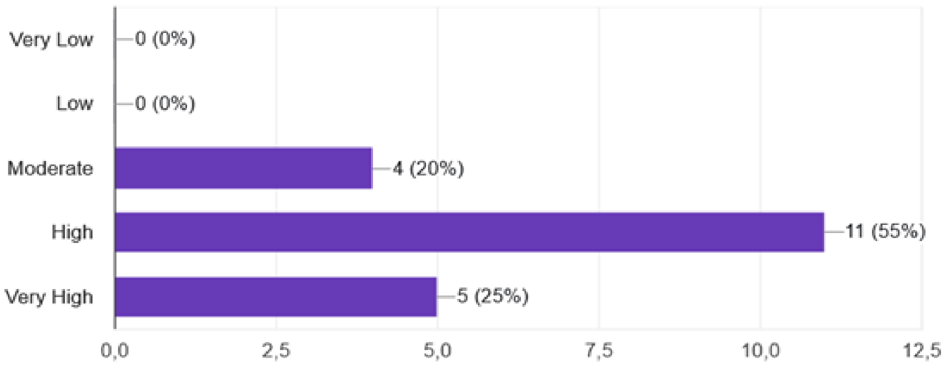


**Figure 37: Resource Utilization**

Source: Author

3- How would you rate the current operating performance at Sogester Container?

This question tries to understand the actual operational performance at the Sogester container terminal. The descriptive statistics show that the response rate is 60% good, 40% very good, and there is no score for poor and very poor, Figure 38. The results show that the operational performance of the Sogester container terminal is good.

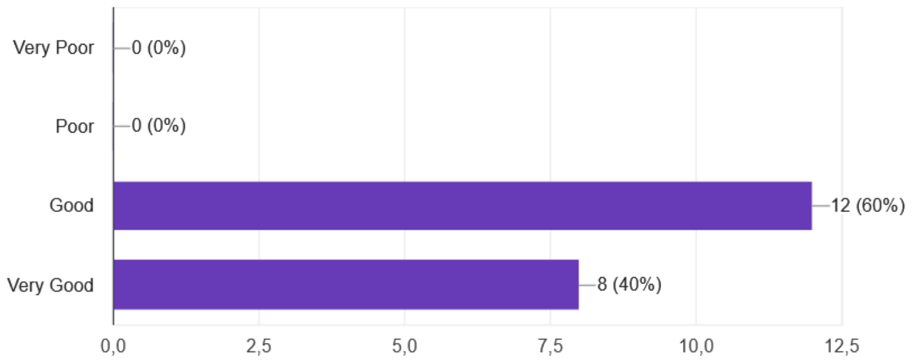


**Figure 38: Operational performance at the container terminal**

Source: Author

4- How important is it to monitor the efficiency of operational performance at Sogester Container Terminal?

This question attempts to find out the importance of monitoring the efficiency of operational performance at the container terminal. The response rate is as follows 75% very important, 15% fairly important, 10% important, there is no score for slightly important and not at all important, Table 39. From this can be concluded that Sogester Workers are aware of the importance of monitoring terminal efficiency to ensure that the company attract more customer and leverage its position in the African container market.

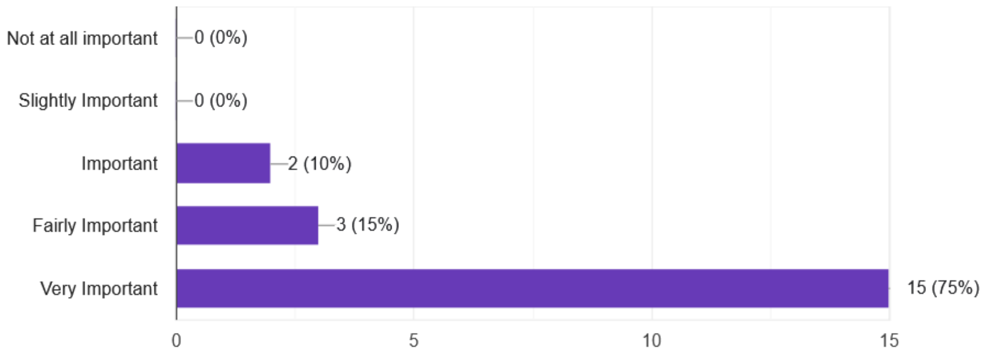


**Figure 39: Terminal efficiency level**

Source: Author

### 4.4.4 Evaluation of quay capacity and availability

This part tries to find out the terminal quay capacity and availability through a set of questions to the terminal workers.

1- How is the current quay capacity for berthing, loading, and unloading activity?

This assessment tries to understand the terminal quay capacity for berthing activities like loading and unloading, the result is presented in Figure 40. The response rate is as follows: 65% good, 25% very good, 5% average, 5% poor, and there is no score for very poor quay capacity. Even though there is a 5% response rate for poor and average as well, more than half of the response rate shows that the Sogester quay capacity is good.

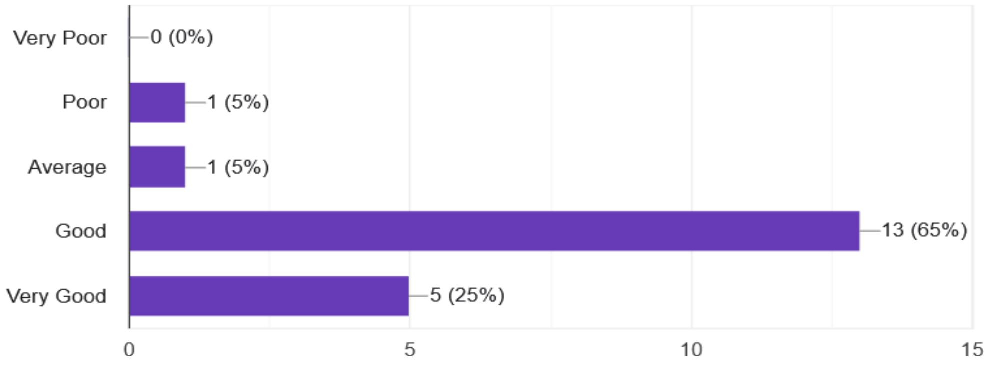


**Figure 40: Quay length capacity**

Source: Author

2- How often do you find no berth available upon vessel arrival?

This question attempts to find out the no berth availability upon vessel arrival at the terminal, Figure 41. The response rate is statically distributed as follows: 50% sometimes, 25% occasionally, 10% frequently, 10% hardly ever, and 5% almost always. As half of the responses regarding the no berth availability is 50%, and can be concluded that the no berth availability upon vessel arrival at the Sogester container terminal occurs sometimes.

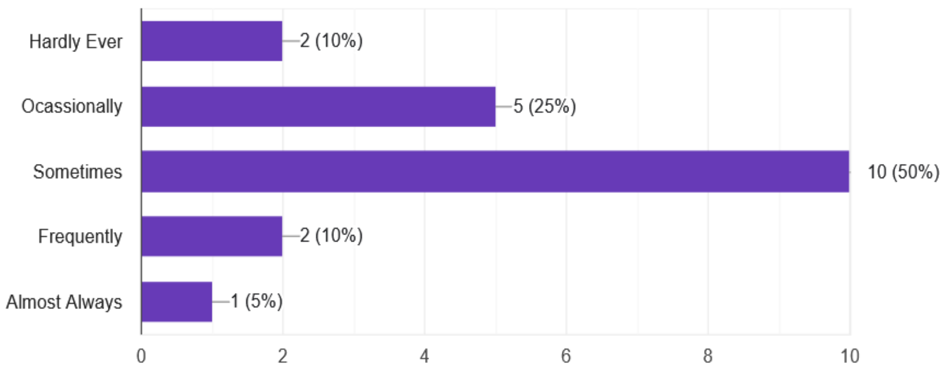


**Figure 41: Sogester berth occupancy level**

Source: Author

### 4.4.5 Evaluation of quay capacity performance

This part attempts to understand the terminal quay capacity performance through a set of questions.

1- How do you assess the performance of the current quay crane at Sogester Container Terminal?

This question attempts to find out the current quay crane performance at the terminal. The response rate is as follows: 35 % very effective, 30% effective, 25% average, 5% ineffective, and 5% very ineffective, Figure 42. The response rate shows that according to the terminal laborers, the quay crane performance at the Sogester container terminal is very effective.

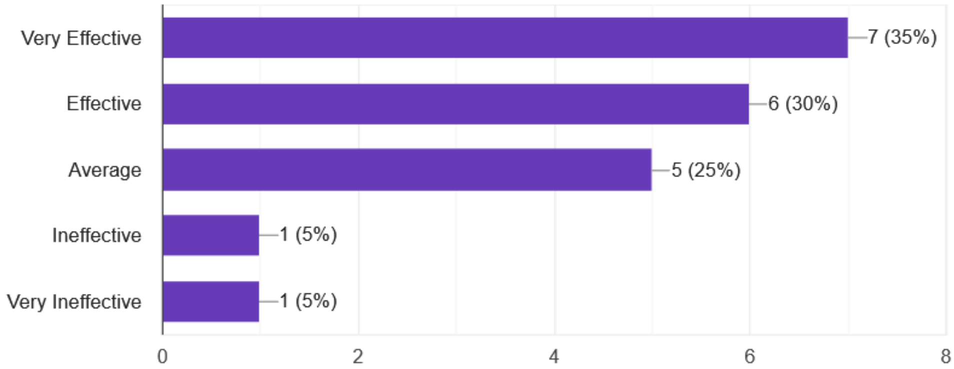


**Figure 42: Quay crane capacity**

Source: Author

### 4.4.6 Evaluation of yard capacity and equipment

This part is based on terminal laborers' daily operations to analyze the terminal yard capacity and equipment by a set of questions.

1- Does the Sogester Container terminal have enough, and reliable yard equipment to improve the productivity and speed of loading and unloading activities?

The following question tries to find out if the current equipment in the terminal is enough and reliable, Figure 43. The response rate is as follows: 70% enough and reliable, 20% not enough but reliable, 5% not reliable but enough, and 5% neither enough nor reliable. The response rate shows that the current equipment at the terminal is reliable, and enough.

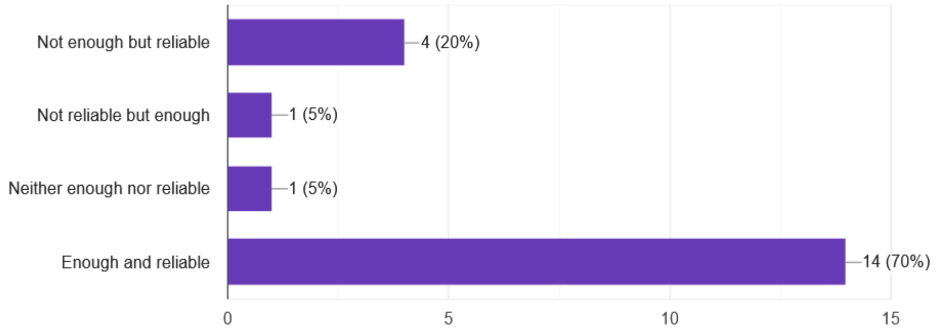


**Figure 43: Yard equipment reliability**

Source: Author

2- How do you measure the efficiency of the yard equipment deployed at the container terminal?

This question attempts to find out the measure of the efficiency of the yard equipment deployment at the Sogester container terminal. The response rate is as follows: 45% efficient, 30% very efficient, 25% average, and there is no score for inefficient and very inefficient. From this, can be concluded the current yard equipment deployment at the Sogester container terminal is efficient.

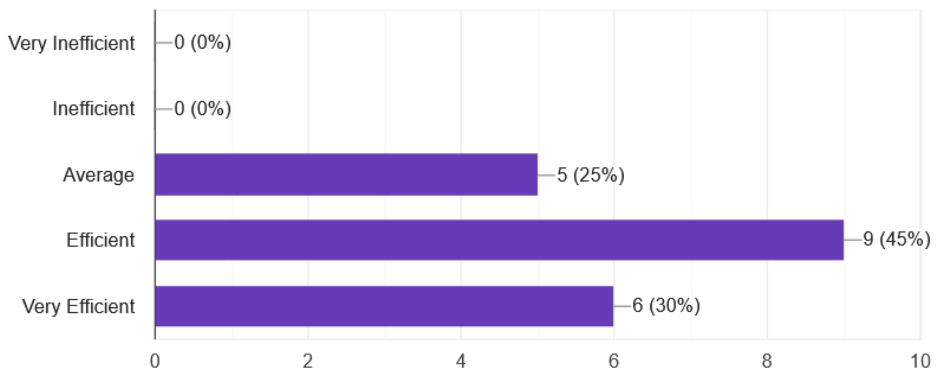


**Figure 44: Efficiency of yard equipment deployment**

Source: Author

### 4.4.7 Dwell time as an indicator of efficiency

This part analyses the dwell time as an indicator of efficiency at the Sogester container terminal by a set of questions.

1- Do you agree or disagree that dwell time is an indicator to measure the efficiency of container terminals?

This question analyses the dwell time as a measure of efficiency at the Sogester container terminal. The response rate is statistically as follows 45% agree, 35% strongly agree, 15% neutral, 5% disagree, and 5% strongly agree. From this can be concluded that the workers of the Sogester container terminal have the knowledge and understanding that dwell time is a measure of terminal efficiency and can affect its productivity.

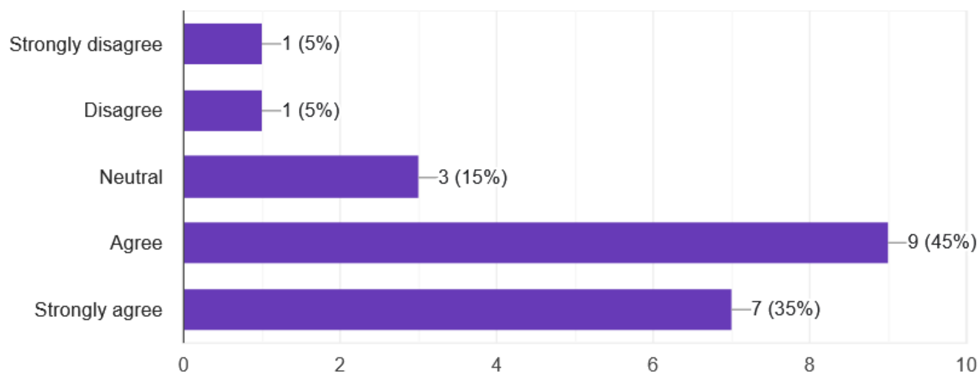


**Figure 45: Dwell time as an efficiency indicator**

Source: Author

2- How do you access the current dwell time at Sogester Container Terminal?

This question tries to find out the current dwell time at the container terminal. The response rate is statistically distributed as follows 50% good, 25% average, 15% very good, 10% very good and there is no score for poor. As half of the response rate is good, can be concluded that the current dwell time Sogester container terminal is good.

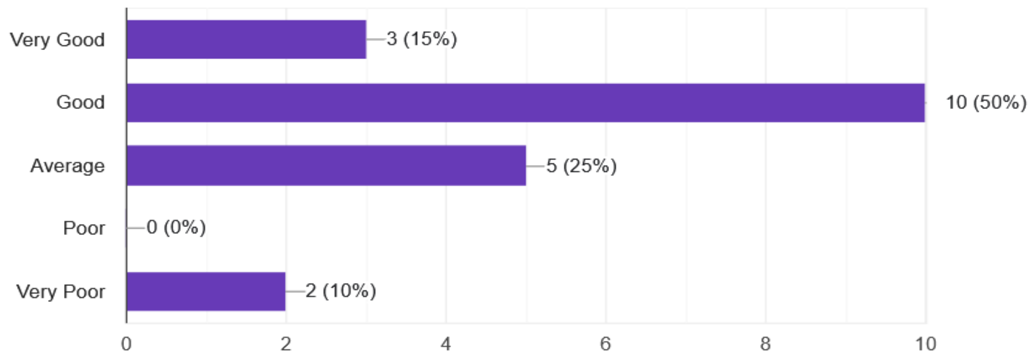


**Figure 46: Dwell time level ate Sogester**

Source: Author

# 5 CHAPTER – CONCLUSIONS AND RECOMMENDATIONS

This final chapter aims to summarise the main findings and results of the research, focusing on the level of operational performance of the Sogester container terminal in comparison to other container terminals in the same region. Additionally, it presented the areas for future research.

## 5.1 Key takeaways

This research aims to evaluate and analyze the operational efficiency of the Sogester container terminal using both quantitative and qualitative approaches. The quantitative method employs Data Envelopment Analysis (DEA) in R Studio and key performance indicator comparison, while the qualitative aspect involves an online questionnaire.

**Key takeaway 1: Key Performance Indicators (KPI)**

The KPI summary table indicates that the Sogester container terminal has consistently received bad ratings across the evaluated criteria, without reaching optimal levels in any of them. This suggests that there is a significant opportunity for the Sogester container terminal to establish itself as a prominent contender in the regional container market. This can be achieved by focusing on enhancing the efficiency of its operational performance. For the Sogester container terminal to excel and stand out among its competitors, a strategic shift towards improving efficiency is essential. By doing so, the terminal can attract a larger share of the container throughput traffic within the region. To guide this improvement effort, the Sogester terminal should focus on specific KPI throughput metrics that need to be elevated to more competitive values: ≥20000 TEU per hectare, ≥80000 TEU per crane, ≥1000 TEU per meter quay length, ≥17000 TEU per yard equipment. Such improvement elevates terminal competitiveness within the sector and regional landscape, and also enhances its overall operational performance, and fosters a positive industry reputation.

**Key takeaway 2: DEA and Online questionnaire**

According to the online questionnaire, respondents perceived the current operational efficiency at the Sogester container terminal as good and efficient. Respondents generally regard the quay length capacity as good and efficiently utilized, although with an average berth occupancy ratio. The performance of quay cranes is predominantly perceived as very good. Concerning yard equipment, most respondents agree that equipment utilization falls within the satisfactory and dependable range.

However, an inconsistency arises between the DEA model and the online questionnaire. The DEA result indicates that the current level of operational performance at the Sogester container terminal was inefficient, suggesting the need to optimize resources to achieve an efficiency score of 1. This gap between the perceptions of local management and the regional comparison (DEA) can be attributed to many reasons. This gap can be explained by the fact that the local management may view past performance as the only measure of success and may disregard more significant changes/trends taking place nearby or the KPI performed by other container terminals in the same regions. Additionally, the local management might focus on the goods parts of the terminal operations that are well known and might see things in a better light than they are and not consider everything together. The objective and quantitative nature of the DEA analysis allows for a more accurate assessment of the terminal's performance in comparison to the overall regional container terminal environment by taking into account some variables and providing an external benchmark. This emphasizes the significance of unbiased, data-driven analyses in developing a thorough grasp of operational efficiency.

The application of DEA shows that the current level of operational performance at the Sogester container terminal is 48% in comparison to 100% of some container terminals in the same region. This score positions the terminal with the second-lowest performance when compared to the six benchmarked container terminals. The sensitivity analysis shows that the terminal should increase the current throughput by 110% to at least achieve a throughput of half a million TEUs to operate efficiently. In essence, the DEA analysis shows an opportunity for the Sogester container terminal to optimize its performance by strategically reconfiguring the allocation and utilization of its quay crane and yard equipment resources. Such measures have the potential to increase the level of operational efficiency of the Sogester container terminal and increase its competitiveness in 1è321the container market of the region.

## 5.2 Suggestions for future research

Due to time constraints and a lack of data, the DEA's study into the Sogester container terminal's operational performance efficiency was limited. As a result, only a small number of input and output variables were examined. The main goal was to compare relative efficiency levels among the various DMUs in the sample to gauge their relative degrees of efficiency. As the DEA results are susceptible to changes in the baseline dataset, it is important to note that they do not produce precise efficiency estimates. Future studies could include examining a wider variety of DMUs and incorporating more input and output factors to improve the precision of efficiency rankings.

The financial performance of the Sogester container terminal is another area of research that merits scholarly consideration. Such an examination has the potential to offer insightful information about how it compares to other terminals in the same geographic area. An enhanced understanding of the terminal's operational effectiveness and financial viability can be gained by looking into the specifics of its financial indicators and contrasting them with those of its regional competitors. This study's expansion has the potential to make a significant contribution to the conversation about port management, operational excellence, and local economic dynamics.

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**APPENDIX 1: Online questionnaire**

Dear Participant,

Thank you for agreeing to participate in this research survey, which is carried out in connection with a Dissertation that will be written by the researcher, in fulfillment of the requirements for the degree of Master of Port Management in Maritime Economics and Logistics at the Erasmus University (RSM) in Rotterdam, Netherlands.

The topic of the Dissertation is "**Benchmarking the operational efficiency of Africa container terminal: A case study of Sogester** ".

The information that you will provide with this survey will be used for research purposes and the results will form part of a dissertation, which will later be published online in the MEL digital repository (MEL) subject to final approval of the University and made available to the public. Your personal information will not be published. You may withdraw from the research at any time, and your data will be immediately deleted.

Anonymized research data will be archived on a secure virtual drive linked to a MEL email address. All the data will be deleted as soon as the degree is awarded.

Your participation in the survey is highly appreciated.

Student's name: Kiende Alfredo Caumba

Specialization: Port Management

Email address: 669303kc@student.eur.nl / kiende.caumba @gmail.com

* * *

**Important:** By proceeding with the questionnaire, I consent to my data, as outlined above, being used for this study. I understand that all personal data relating to participants is held and processed in the strictest confidence, and will be deleted at the end of the researcher's enrolment.

Best regards,

Kiende Caumba

## Introduction

Email *

Name (Optional)

Age *

26 years old and below
27 - 42 years old
43-60 years old
Over 60 years old

Total Years of Experience *

5 - 10 Years
11 - 15 Years
16 years above

Division/ Unit*

Management System
Human Resources
Finance
Operation
Engineering
Information Technology
Commercial

Position/ Category*

General Manager
Manager
Assistant Manager
Operator
Staff

## Assessment of container terminal efficiency

Several indications, such as the increasing level of container throughput and resource utilization (quay, cranes, yards, etc.), decreasing handling time, and minimizing congestion, can be used to assess how efficiently the container terminal is working *

Strongly disagree
Disagree
Neutral

Agree ☐
Strongly agree ☐

How do you assess the resource utilization such as a quay, cranes, yards, and equipment and the current container throughput at the Sogester Container terminal?

Very Low ☐
Low ☐
Moderate ☐
High ☐
Very high ☐

How would you rate the current operating performance at Sogester Container?

Very poor ☐
Poor ☐
Good ☐
Very good ☐

How important is the efficiency of operational performance at Sogester Container Terminal?

Not at all important ☐
Slightly Important ☐
Important ☐
Fairly Important ☐
Very Important ☐

## Evaluation of quay capacity and availability

How is the quay capacity for berthing and loading and unloading activity?

Very poor ☐
Poor ☐
Average ☐
Good ☐
Very good ☐

How often do you find no berth available upon vessel arrival?

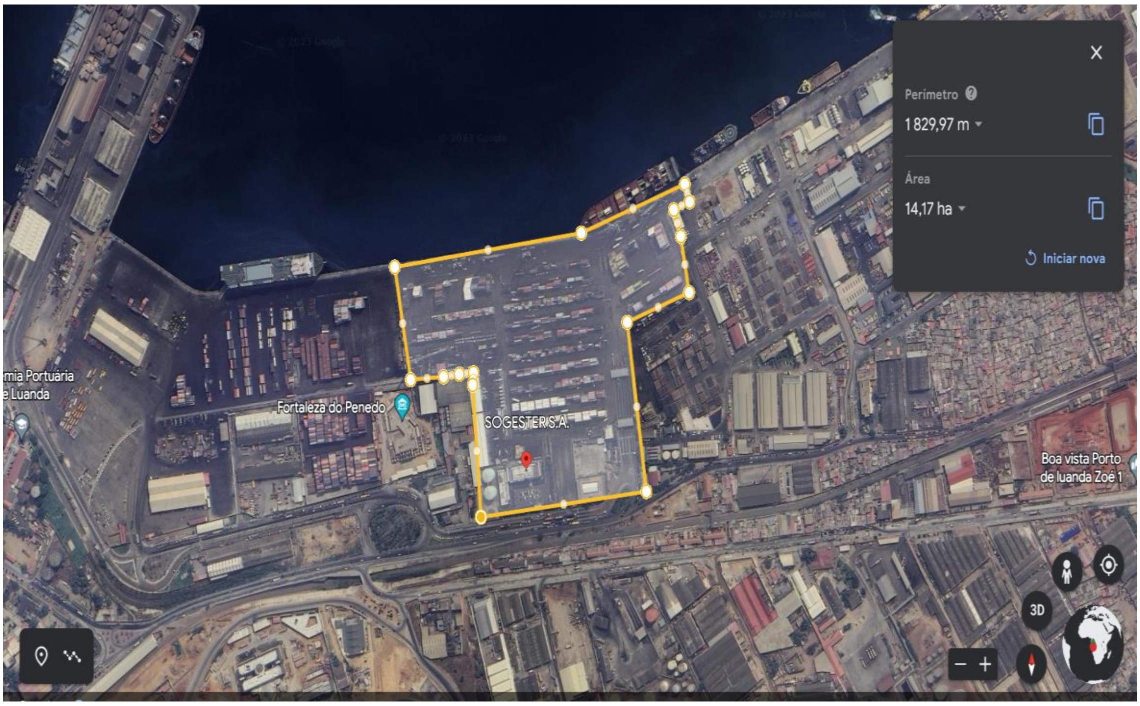
Hardly ever ☐
Occasionally ☐
Sometimes ☐
Frequently ☐
Almost always ☐

## APPENDIX 2: DEA- R studio program

```
install.packages("deaR") # install DEA package

library(Benchmarking) # load DEA package

library(psych) # Load basic statistics package

library(readxl) # Load package to read Excel file

library(dplyr) # Load dplyr package

library(writexl) #

data1<- readxl::read_excel(path="DEA_file.xlsx") # Read the DEA file

View (data1) # See the read file


require(deaR) # call DEA package

ccr_model<- read_data(data1,ni=4,no=1, dmus=1,inputs=2:5, outputs=6) #

View(ccr_model) #

result_ccr = model_basic(ccr_model, orientation="io", rts="crs",dmu_eval = 1:6,
dmu_ref = 1:6)

result_ccr


efficiencies(result_ccr) # efficiencies scores

targets(result_ccr)

plot(result_ccr)

a<-summary(result_ccr) # summary of results

a # To display slacks and other results
```

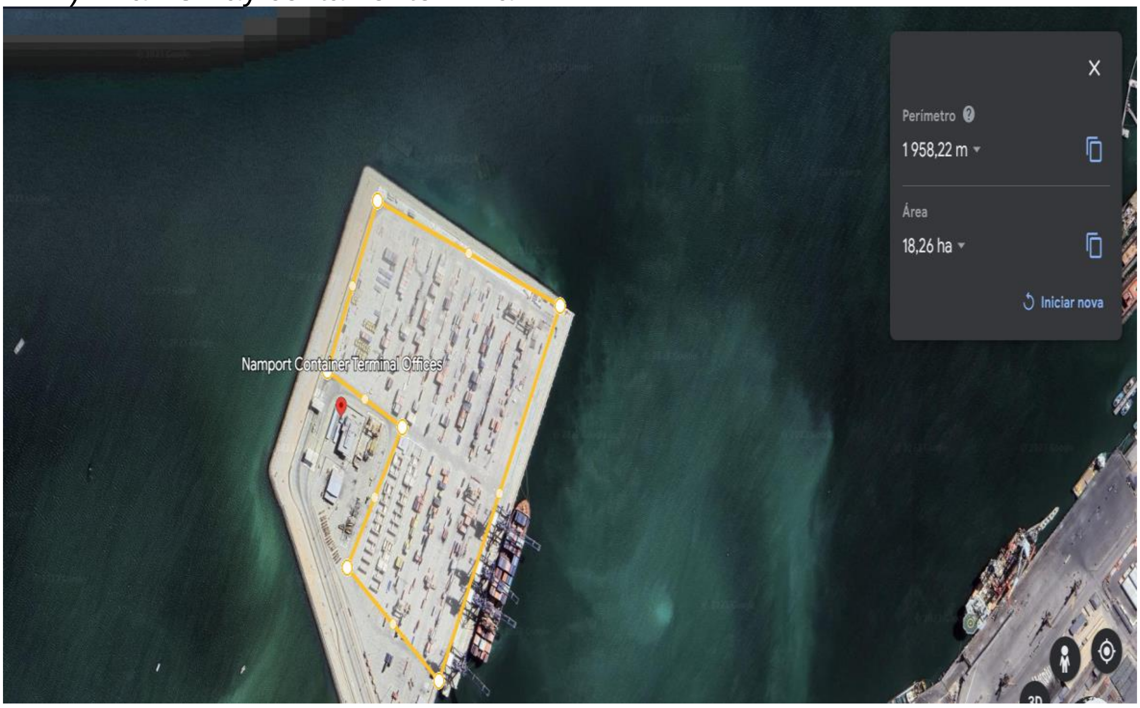
## APPENDIX 3: Container terminals

1) Sogester container terminals




Source: Google Earth, 2023

2) Walvis Bay container terminal




Source: Google Earth, 2023

3) Dar es Salaam container terminal


Source: Google Earth, 2023

4) Maputo container terminal


Source: Google Earth, 2023

5) Durban container terminal


Source: Google Earth, 2023