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Measuring and Benchmarking Efficiency and Productivity Levels of Liquid Bulk Terminal Operations Using a DEA AND OEE Approach

Considering Nigeria's Atlas Cove Jetty and Depot Facility

by

Ugonna A. Madueke

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Abstract

In an era characterized by globalized production and consumption of goods and commodities, the growing need for efficient and productive terminal operations continues to prove apparent. These facilities however in order to maintain and increase their market share have to constantly improve their operational practice, an exercise usually brought about by measuring and benchmarking its current operations against industry best or projected forecasts.

Since the beginning of the decade all forms of cargo (general, dry bulk and liquid bulk) have registered an increase in shipping tonnage with Crude oil, petroleum and liquefied gas contributing to about half of the total commodities handled by seaborne traffic. Terminals, the link between sea going vessels and inland transportation, have and continue to play a vital role in the success of maritime transport. The competitive environment that exist amongst these facilities, port/terminal, makes performance measurement not only a powerful management tool for port/terminal operations, but also constitutes informative input for regional and national planning and operation

This paper focuses on the atlas cove jetty of the product and pipeline marketing company of Nigeria as its target terminal and compares its performance level on a both a macro scale and micro scale using the DEA and OEE benchmarking approach respectively. This thesis conducts an empirical study that indicates where potential technical efficiency gains for the PPMC terminal could be exploited. Thus providing them with insights that may guide them to initiate and execute development policy strategies that would yield a more efficient terminal.
An extensive literature review on the subject matter indicated the possible use of the DEA technique to benchmark the performance levels of liquid bulk terminals as it noted to be widely used in similar exercises for container terminals and ports. Our DEA model compared the relative efficiency of 4 terminals shortlisted from a panel of 84 terminals on the basis of the class of product handled.

In table 10 of chapter 6, we see the outcome of using a linear program to create a hypothetical composite terminal based on selected output and input variables of the four terminals in the module. We ran a linear program to minimize of the objective function with the goal of identifying if our target terminal was performing at levels relatively inefficient. The outcomes were inconclusive. As an extension to this approach, we decided to attempt a more concentrated technique and used the OEE approach to compare performance level of equipments and sub-processes within our target terminal and our benchmark terminal. We evaluate the Average Vessel Turnaround Time, the Berth Occupancy, and the Average Pump Rate and are able to observe conclusive outcomes shown in tables 13 and 14, chapter 6, that infer our target terminal indeed has potential technical efficiency gains to be exploited

While the inconclusiveness of the DEA approach may have been as a result of limited sample data, this research concludes that the difference in asset specificity of liquid bulk terminals and container terminals support the limited review's found on this topic. This infers that the approach is more suitable for the latter. Further study using the DEA is recommended, however the author opines that the OEE approach to benchmarking is a better suiting technique for liquid bulk terminals

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List of Abbreviations

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

OEE……………..…….……… Operational Equipment Efficiency

NNPC…………….…….. Nigerian National petroleum Company

PPMC……………..….. Products and Pipeline Marketing Company

OISD…………………..………..Oil Industry Safety Directorate

BIS…………………………………… Bureau of Indian Standards

KPI…………………………………… Key Performance Indicators

DMU…………………………………..…… Decision Making Unit

BOP…………………….………. Berth Occupancy percentage

VTAT…………………………………… Vessel Turn-Around Time

APR………………………………..……… Average Pumping Rate

TBT………………………………..……………… Total Berth Time

Chapter 1 Introduction

1.1 Liquid bulk transport and terminals

1.1.1. Liquid bulk transport worldwide

In an era characterized by globalized production and consumption of goods and commodities, the growing need for efficient and productive terminal operations continues to prove apparent. Maritime transportation is a major channel of international trade. According to UNCTAD (2009), an increase of over 120% by weight, has been witnessed in the international sea borne trade, from 1980 to 2008. Some of the major contributing factors to the continuing growth in maritime transportation are population growth, increasing standard of living, rapid industrialization, the exhaustion of local resources, road congestion, and elimination of trade barriers (Umang et al. 2011). Many studies have also shown that the rapid growth in freight transport from one part of the world to the other can also be directly attributed to the numerous technical and economic advantages it possesses over traditional methods of transportation (Wang et al. 2002).

Since the beginning of the decade all forms of cargo (general, dry bulk and liquid bulk) have registered an increase in shipping tonnage, with the figures for dry bulk, liquid bulk and containerized cargo being particularly impressive at 52%, 48% and 154% respectively (Umang et al. 2011). Crude oil, petroleum and liquefied gas are among the major commodities handled by seaborne traffic, amounting to about half of total traffic volume and cementing liquid bulk as one of the world's most important commodities (Umang et al. 2011).

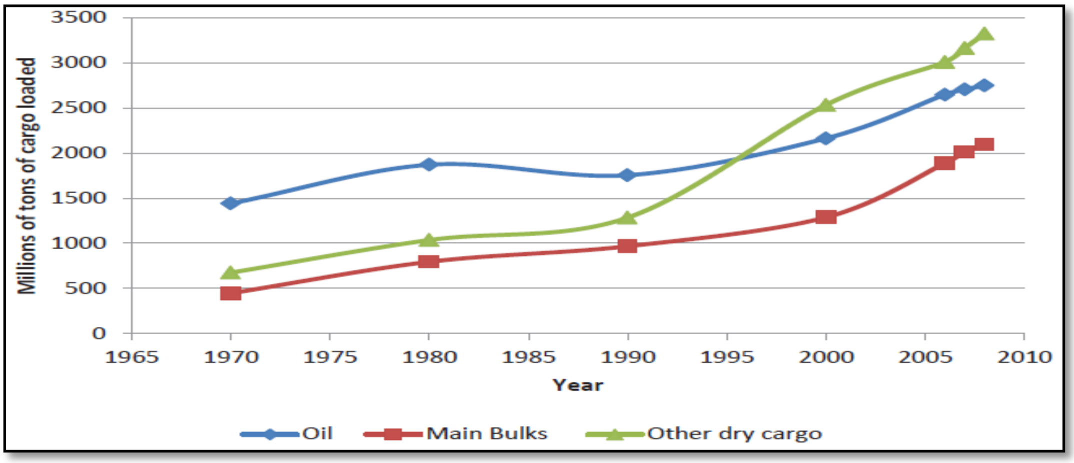


Figure 1: Development of international sea borne trade (Source: Umang et al. 2011)

1.1.1 liquid bulk terminals and performance measuring

Terminals, the link between sea going vessels and inland transportation, have and continue to play a vital role in the success of maritime transport. Studies have shown that traffic volumes of petroleum products are not only determined by the fluctuations in world oil supply and demand but are heavily impacted by the efficiency of terminals in ports to berth oil tankers, handle liquid oil/gas via pipelines, or to provide substantial storage capacity (Merk & Dang, 2012). The continuous battle amongst ports and terminals to increase their market share and costumer patronage has led to an increasing competitiveness in the maritime transportation industry, which in turn has brought about steep demands that require the productivity of ports and container terminals be improved (Kaiser et al. 2006). Similar competition is witnessed within the liquid bulk terminals and thus the demand for improved productivity is no different. Terminals today are faced with the challenge to constantly upgrade their infrastructure to handle larger volumes of product and also to increase their overall efficiency so as to possess comparative advantage over their competitors and to increase their market share (Merk & Dang, 2012). In order to provide adequate service for the increasing traffic volumes, ports, and more importantly terminals, must either expand their facilities or improve the efficiency level of their operations (Kaiser et al. 2006).

The internal and external pressures put on terminals are usually handled through measuring the level of performance within their operations. This is an exercise that involves monitoring and benchmarking a company's production. A discussion on performance management will however not be complete without mentioning the concept of productivity and efficiency. Productivity and efficiency are the two important concepts that are frequently utilized when measuring performance (Wang et al. 2002). To determine that terminal productivity is up to par, terminals would often conduct an exercise where they measure the efficiency of certain activities within their operational processes, and determine if levels of operation are optimal or not.

Under the current competitive environment in the port and maritime industry, port and terminal performance measurement is no longer only a powerful management tool for their operations, but also constitutes informative input for regional and national planning and operation (Kaiser et al. 2006). Terminal efficiency is often associated with productivity and performance as a measure of their operating technology or total throughput volumes (Verheul, 2013) and for the purpose of this study, we will investigate how efficiently terminals use inputs to produce current output levels and whether the technologies adopted by terminals are the most efficient.

With respect to liquid bulk terminals, they typically have 4 operations under which the efficient use of inputs to produce outputs, in other words, the level of terminal productivity, may be evaluated. These operations later described in this paper include:

- Berth and vessel activities;
- Ship loading or discharge;
- Storage;
- Intermodal transfer and inland distribution.

It should however be mentioned from the onset that in order for a terminal to achieve optimal operation levels, it is important that the infrastructure built be able to adequately support the storage capacity of the facility. As a result, the intent to measure the performance level and efficiency of a terminal is actually a measure of existing inefficiencies assessed against the most efficient terminals, and the relative differences in adopted technologies, production scales and input utilizations.

The indication of productive terminal efficiency can thus be defined along: i) an efficient production frontier, which maximizes terminal output for different input levels; ii) a benchmark of best practices, based on terminals located on the efficient production frontier; iii) observable gaps between what terminals currently produce and what they would optimally produce if they were operating efficiently (Merk & Dang, 2012). In this thesis, we attempt to benchmark terminal performance a target facility, against industry best practices based on other terminals located on the efficient production frontier.

1.1.2 The Nigerian National Petroleum Corporation

The reorganization of the Nigerian National Petroleum Corporation (NNPC) in March 1988, for the purpose of proper capitalization and commercialization led to the creation of the pipelines and product marketing company (PPMC) amongst other subsidiaries (PPMC, 2013). The PPMC according to its website, was created with the primary purpose of directly handling the responsibility for the comparative ease with which petroleum products are sourced and distributed to all parts of the country, at uniform prices, and is often referred to as the most significant event of the 1988 reorganization. The PPMC ensures, among other things, the availability of petroleum products to sustain local industries and consumption: run automobiles and for domestic cooking. Petroleum products imported, to supplement local production from the home refineries are received by the PPMC through various import jetties and then they are distributed through a robust network of pipelines to depots strategically located all over the region and finally transported by trucks to designated retail outlets.

The PPMC has been identified to be the nucleus of the distribution of refined products to the respective stakeholders, consumers/off takers. They are charged with the responsibility of providing a consistent supply of product in the nation to continuously meet the country's local demand and prevent the occurrence of scarcity. In economic terms they are to ensure an efficient allocation of resources to allow that operations dependent on the availability of petroleum products, be carried out in the shortest possible time while still providing the highest possible yield. In a bid to identify if these terminal facilities owned and operated by the PPMC are operating at optimal efficiency levels, their individual performance levels will have to be measured. Hence this thesis will indicate where potential technical efficiency gains for the PPMC terminal could be exploited, providing them with insights that may guide them to initiate and execute development policy strategies that yields more efficient terminals.

1.2 Scope of research and Research Question

Refined petroleum products are only as valuable as the demand from potential off takers and consumers alike. To get these products from where they are sourced to where they are demanded a chain of operations are followed. Product commodity is first transported, usually by vessel tankers, from their source and received at jetties where the product is transferred from the vessel into land storage through a series of pipeline networks. Finally, the product after being temporarily stored, is transported to the hinterlands by means of road, train or pipelines to the final consumers / off takers.

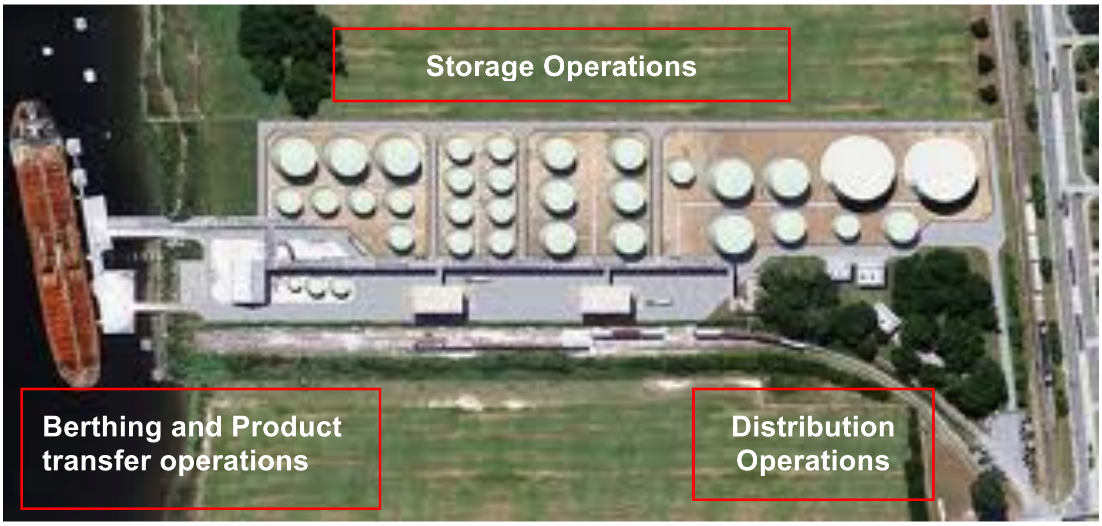


Figure 2: Pictorial process of operations in a terminal

A review of research and theory relating to measuring the 'Total' efficiency of a liquid bulk terminal is beyond the scope of this study, which is purposed to only evaluate the performance levels and technical efficiency of the operations that occur at the sea/land interface of the terminal (berthing and product transfer operations) and the terminal operations that occur in the facility itself (storage operations).

Earlier on in the chapter we made mention of the concept of efficiency and productivity and their importance in performance measurement. Of the many reasons to be concerned with efficiency and productivity, directly influenced by the levels are the financial margins exploited by such facilities. The cost implications of operating a terminal facility are already high, thinning whatever margins available for profit generation. In line with the concept that higher efficiency translates to less time, which ultimately reduces operational costs, it is evident that an efficiently run terminal has a positive influence on the financial performance of the facility. Thus for a terminal to execute its tasks as best as possible, it is essential that the operations in the terminals and depot facility be:

- **Highly Productive:** A measure of the amount time a terminal spend on "productive" tasks (Jetty operations and Landside Operations)
- **Highly Efficient:** A measure of how much a terminal produces for a given amount of "productive" time.

<u>Research Question:</u> "**How can the technical performance level of a liquid bulk terminal be measured in comparison to similar terminals in its industry?"**

In order to effectively answer this research question, we have built in some sub questions to provide a seamless structure which when also answered will provide the reader with an encompassed knowledge of the subject matter and the process of benchmarking performance levels. These questions include;

- How can the performance of Liquid Bulk Terminals be benchmarked
- What is Benchmarking?
- How appropriate are the DEA and OEE approach to liquid bulk terminal benchmarking?
- How best can you evaluate the performance of liquid bulk terminals?

Firstly, this thesis will assess the current operations within the Atlas cove jetty and depot facility of the PPMC. It will analyse current performance levels and bench mark them with performance thresholds of frontier companies in the sector that operate with the Best Industry Practices.

Furthermore, the thesis will try to proffer suggestions as to how the gap in performance levels can be reduced, thus increasing the efficiency and productivity of the operations at the Atlas cove jetty and depot facility. The analysis will be a technical/operational performance audit focusing on the transportation, transfer, and storage of refined petroleum product.

Finally, review has shown that research concerning the productivity and performance of liquid bulk terminals has been falling behind compared to that of ports and their clusters and container terminals. With the growing importance of oil trade and storage, this paper attempts to bridge that gap in academic research and provide substantial material on how liquid terminals can evaluate their own performance levels

1.3 Research methodology and Outline of thesis

This paper we will be benchmarking terminal best practices based on terminals located on the efficient production frontier. To execute this exercise, our methodology includes answering the sub research questions earlier stated, in an attempt to arrive a conclusive resolve to the main research question.

Sub question 1 and 2 are answered by an extensive review of relevant academic and professional literature. In this review we will pay attention to the approach to benchmarking widely used in the port and container terminal industry. The major goal of the review is of three fold. Firstly, to define key terms in the industry that will assist in understanding the basic functions and operations within our objective unit of analysis "the terminal". It is by properly understanding its function that we can know how best to evaluate is level of performance. Second, we identify and explore studies supporting this research. By so doing, we are able to identify the key variables that indicate performance efficiency levels. It is from this knowledge that we will thirdly modify techniques used in reviewed literature to better suite our research model.

We will take a small sample of liquid bulk terminals with homogeneous processes. Selected common variables (input variables) across the sample will be used to formulate a linear model which when fed into a “Black box” yields a common output variable.

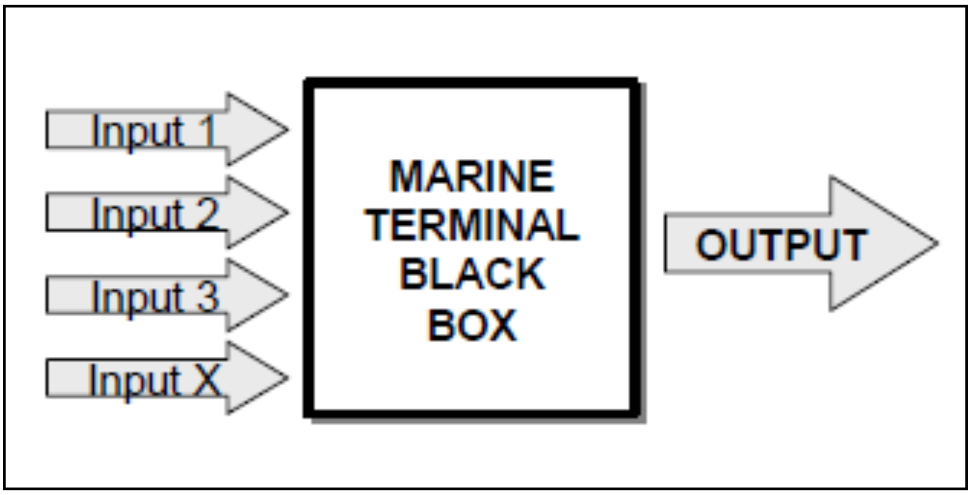
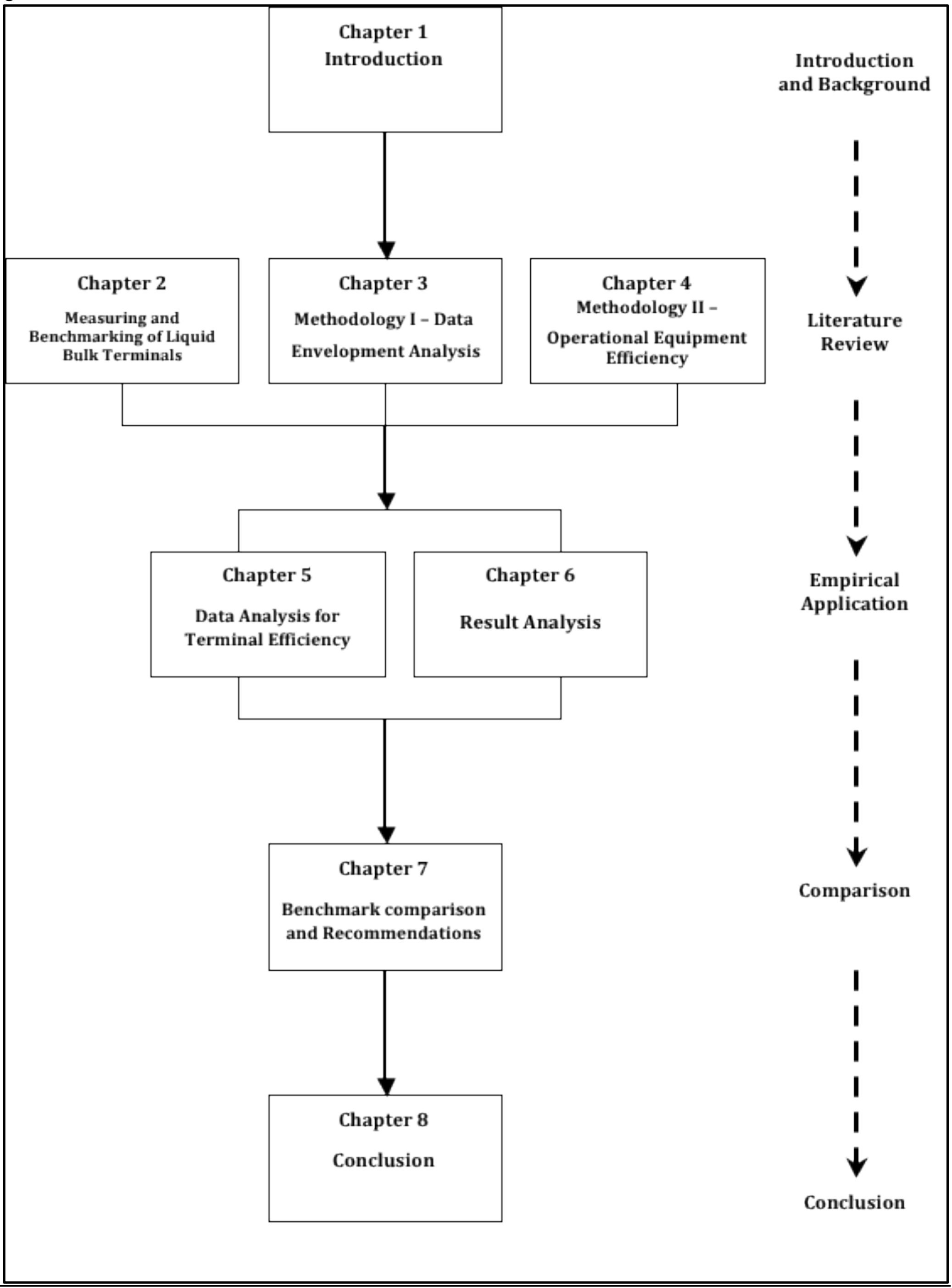


Figure 3: Marine Terminal Black Box (Source: Centre for the Commercial deployment of Transportation Technologies (CCDoTT), 2000)

Figure 3 shows the interaction between input and output variables as organized by the “black box” to produce a relative hierarchy of the terminals based on their efficiency levels. In chapter 2 we discover through extensive reviews that many researchers have in the past relied on the ability to determine comparative efficiency amongst similar companies in the same industry through the use of a unique technique termed the ‘Data envelopment Analysis’ (DEA). Chapter 3 goes further to discuss the methodology behind the DEA approach, which gives us a macro look at the industry from “most efficient performance” to “least efficient performance” in comparison to one another. In chapter 4 we draw from the results of the earlier conducted quantitative exercise and select two terminals that will be evaluated on a more specific -equipment production- basis. This selection will include one of Vopak’s terminals operating at optimal levels and the Atlas cove terminal (our target terminal), which we believe will be found lagging behind its peers. This approach will compare levels of efficiency of specific identified processes within both terminals, providing a basis for micro comparison between the two terminals. We will then be able to see in more detail, what operations within the terminal may be causing low productivity and poor levels of efficiency. In chapter 5 we will analyse the data selection needed to execute this exercise. The outcomes of the two approaches used in this paper; the DEA approach and the OEE Approach will be discussed and theoretically applied in chapters 6 and 7 and in chapter 8 we will draw reasonable conclusions to the efforts of this paper.

Fig 4: Schematic Outline of thesis flow



Chapter 2 Measuring and benchmarking performance of liquid bulk terminals

This chapter seeks to answer sub-question 1 by describing how liquid bulk terminals can be measured and benchmarked. It focuses on the important findings from academic literature regarding terminals, their function and how their performance levels are measured and bench marked for the purpose of improving efficiency and productivity. The outcomes of this literature review will be used to define the idea, approach and methodology used by the author of this paper in conducting an investigative research as to how liquid bulk terminal performance can be measured.

This chapter is organized as follows. In section 1 we define and introduce the terminal and its functions. We then narrow our focus in section 2 to describe the two subsystems (Handling and storage system) within the terminal whose performance level we are concerned with. We proceed to explain the earlier introduced concept of Productivity and Efficiency and describe how indicators are selected for the purpose of measuring performance. To answer sub-question 2, in section 5 of this chapter, we introduce Benchmarking as a competitive tool used to compare companies, firms and organizations with peers in their respective industries. We do this by describing its various types and outlining a step-wise approach to executing the process. Finally, we round up the chapter with Benchmarking within the oil and gas industry.

2.1 Defining liquid bulk terminals

In general terms, a terminal may be defined as any facility where passengers and freight are assembled or dispersed (Rodrigue et al. 2013). Passengers assemble at a bus terminal or an airport to catch their desired mode of transport to reach their final destination, so also are goods and commodities consolidated at freight terminals to be transported by vessel to their final destination. Focusing on ports, Van Duijn (2009), defines the primary function of the terminal as a place that connects different modalities together, to provide a buffer for (temporary) storage and to change product flow size and behaviour.

If we compare the functions of the liquid bulk terminal to that of other terminals, we note that there is no difference, other than, liquid bulk terminals as the name implies, specialize in a particular cargo type, with a majority of their cargo being petroleum products (CCDOTT, 2000). At a liquid terminal, freight originates, terminates or is handled in the transportation process. Terminals are thus referred to as being central and intermediate locations in the movement of passengers and freight that require specific facilities and equipment to accommodate the traffic they handle (Rodrigue et al. 2013).

The following diagram, figure 5, illustrates the general operation of a liquid bulk terminal (CCDOTT, 2000). The vessel laden with product makes its approach to be moored at the selected port terminal. Once vessel is berthed, pipes connecting the outlet manifold from the vessel and inlet manifolds of the tank (discharge operation) are put in place and the process of unloading begins. Product is transferred from the vessel to the storage tank facilities where it is held temporarily before products are then again pumped for hinterland transportation either by rail truck or pipelines.

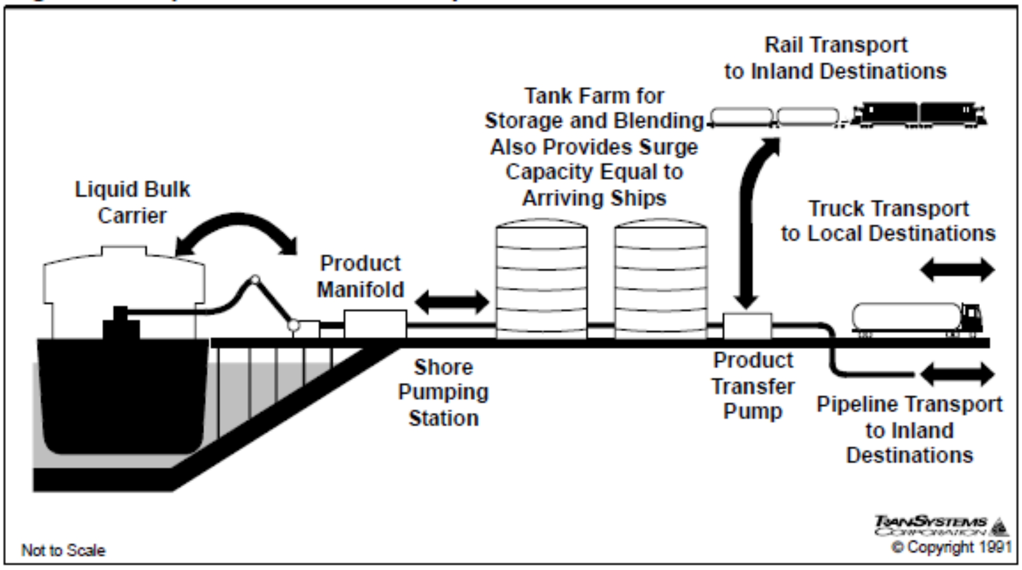


Figure 5: Operations at a Liquid Bulk terminal (Source: enter for the commercial Deployment of Transport Technologies)

The main function of a terminal is to handle and tranship freight since modes and cargo are physically separated (Rodrigue et al. 2013). Some of the key challenges terminals face in order to secure traffic flows and prevent diversion of patronage to nearby terminals include handling product more rapidly, providing more adequate and performing equipment, reducing berth times and delays, enabling large storage capacity and ensuring multi-modal connections to hinterland (Merk & Dang, 2012). Terminals are constantly plagued with the burden of increasing their capacity and upgrading their operating equipment's to keep up with increased vessel sizes. As a result, the performance of terminals plays a very critical role in determining their market share.

Earlier in the first chapter, we mentioned the four principal components in terminal operations that can be evaluated to ascertain its productivity level (CCDOTT, 2000). We will now briefly describe the activities that take place in each of these processes.

1. Vessel and Berth Activities: These activities comprise the berth availability and berth limitations on vessel capacity. These limitations are particularly important where vessel draft is concerned.
2. Ship loading or Discharge: hoses load Liquid bulk cargo and pumps located on the pier; discharge is accomplished through the use of ships pumps.
3. Storage: Liquid bulk cargo is stored at a tank farm on or near the terminal. The storage component of liquid bulk may also include value-added activities such a blending or processing.
4. Inland Transfer: Liquid bulk cargo is distributed by rail, truck or pipeline. The capacities of these modes determine the total storage required.

Terminals have a nominal capacity, which is related to the amount of land they occupy and their level of technological, labour and managerial intensity (Rodrigue et al. 2013). Infrastructure considerations are consequently important as they must accommodate current traffic and anticipate future trends and also technological and logistical changes. In simple words, the terminal structure must be inline with its storage capacity.

2.2 Product Classifications and Specification

Petroleum products have been classified by the likes of OISD (Oil Industry Safety Directorate), and BIS (Bureau of Indian Standards) according to their flashpoint property. This property is simply the lowest temperature at which the product can vaporize to form an ignitable mixture in air. Terminals we will choose for this study will only handle the following proposed classifications

Table 1: Product classification table

Class	Product characteristics	Product name
Class A Petroleum Product-	Liquids which have a flash point less than 23 degree C	Naphtha and Gasoline
Class B Petroleum Product-	Liquids which have a flash point 23 degree C and above but below 65 degree C	Diesel oil and Kerosene
Class C Petroleum Product-	Liquids which have a flash point 65 degree C and above but below 93 degree C	Not Proposed
Excluded Petroleum Products	Liquids which have a flash point 93 degree C and above	Not Proposed

(Source: Frederic R. Harris. Inc. (1998))

The products, as listed above will be the sole cargoes handled by the selected terminals for this study. They are generally classified as white petroleum products and their properties are summarised hereunder:

Table 2: Product specification table

Product	Density (te/m3)	Viscosity (centistokes)	Pumping temperature
Diesel Oil	0.85	7.5	Ambient
Kerosene	0.82	8.0	Ambient
Naphtha	0.74	Less than 1	Ambient
Gasoline	0.73	Less than 1	Ambient

(Source: Frederic R. Harris. Inc. (1998))

2.3 Terminal Sub-processes:

The operations in a terminal that we will be concerned with for the scope of this paper can be categorized into two groups, defined by Pappu, 2013; "handling process' and 'storage process'

Handling Process (Pump Systems)

Handling process (Pump System): The handling process includes all operations that occur between the interface of the marine transport and inland transport and temporary storage of cargo. According to the earlier identified components that can be evaluated in the terminal, the handling process involves all the equipment used for the loading and unloading of the vessels. Efficiency in the handling process depends not only on the pumping power at the jetty activity, but also on the extent to which the link-ups (Surface and underground pipe network) between this system and all subsequent ones are well integrated. To properly analyze this system, one will look at factors such as:

- Number, length and types of berths,
- Number of Gantries (Loading arms),
- Berth storage transfer capabilities and capacities,
- Storage-inland transport transfer capabilities and
- Gate processing rates
- Size and length of pipelines between waterside and tanks

Inefficiencies in any one of these stages would result in a "bottle-neck," affecting the performance of the total system. As such, maximum improvement in the handling system can only be achieved if all the above-mentioned activities are optimally integrated.

Storage Process

Storage Process: Storage processes provide a major service of temporarily 'holding' products in tanks until such a time where product is delivered to its final consumer in this chain; serving as a kind of "buffer" between marine transport and inland transport. There are two major challenges faced in this sub-process:

- Limited space available leading to a high level of planning and scheduling to ensure that the use tank facilities are maximized
- Accurate inventory management from the time product is pumped from the quayside to the storage tanks and further on to the end consumers.

Improved logistics and inventory controls and innovative storage pricing policies have all gone a long way in improving the efficient utilization of the tank facilities in the terminal.
The afore-mentioned challenges not only have drastic effects on the efficiency of the terminal but also determine the financial position of the facility. A utilization of 75-80% is considered to be the optimal since above this level, congestion starts to arise, undermining the reliability of the terminal facility (Rodrigue et al. 2013).

2.4 Productivity and Efficiency concept

To better understand productivity, we start off from defining production as a process by which inputs are combined, transformed and turned into outputs (Case and Fair, 1999). We most often find that these inputs are normally natural resources such as land, human resources, and equipment's. Outputs on the other hand are categorized into more tangible products like goods and also intangible products like services (Wang et al. 2002).

Productivity and efficiency, earlier mentioned as the two most important concepts relevant in measuring performance have over the years been mistakenly treated as having the same meaning in most of the literature available on this topic (Wang et al. 2002).

Productivity on the one hand is easily described as the ratio of output(s) to input(s). When however there are multiple variables to be compared, this definition may not be suitable. In such a scenario, we refer to productivity as the 'Total Factor Productivity', which is a productivity measure involving all factors of production (Coelli et al. 1998). Efficiency on the other hand is defined as the relative productivity over a given time period either within a firm or amongst firms (Wang et al. 2006). The former involves measuring the use of the firm's own production potential by computing the productivity level over time relative to a firm-specific Production Frontier, which refers to the set of maximum outputs given the different level of inputs. In contrast, the latter measures the performance of a particular firm relative to its best counterpart(s) available in the industry (Lansink et al. 2001).

2.4.1 Performance Management and Indicators to measure performance of liquid terminals

Performance management plays an essential role in the evaluation of production because it not only defines the current state of the system but also makes future predictions (Dyson, 2001). In order to measure performance, one has to carefully select certain key activities performed within the firm and these are usually termed as "performance indicators". These performance indicators quantify and simplify information for decision-makers and other stakeholders to assess how activities and operations affect the direction and magnitude of change in terms of social economic, governance and environmental conditions (Vitsounis, 2013). Thanassoulis (2001) identifies the following information that can be obtained as outcomes from performance measurement exercises:

- The identification of good operating practices for dissemination;
- The most productive operating scale;
- The scope for efficiency savings in resources use and/or for output augmentation;
- The most suitable role model for an inefficient unit to emulate to improve its performance;
- The marginal rates of substitution between the factors of production; and
- The productivity changes over time by each operating unit and by the most efficient of the operating units at each point in time.

Below are certain performance indicators suggested by UNCTAD (1976), as shown in Table 3. This shows productivity and effectiveness measures that can be used as a reference point for measurement of the performance level of liquid bulk terminals.

Table 3: Performance Indicators Suggested by UNCTAD

Financial Indicator	Operational Indicator
Tonnage worked	Arrival Time
Berth Occupancy Revenue per ton	Waiting Time
Cargo Handling revenue per ton	Service Time
Labor Expenditure	Turn Around Time
Capital Equipment expenditure per ton	Tonnage per ship
Contribution per ton	Fraction of time berthed per ship per shift
Total contribution	Tons per ship-hour in port
	Tons per ship-hour at berth
	Tons per gang hours (Net Pump Ratio)
	Fraction of time gangs idle (Pump Idle time)

(Source: UNCTAD 1976, pp7-8)

We can thus infer that measuring performance helps move the system in the desired direction through effect exerted by the behavioural responses towards these performances that exist within the system (Wang et al. 2002).

2.4.2 Process and Identified KPI's to be used for this study.

KPI's are key activities performed within the firms operation which when measured show the level of productivity and efficiency of the firm. To execute our performance measurement process for this study, we have highlighted certain processes within the terminal and outlined their activities. We have also described what these indicators measure and stated the basis under which outcomes will be analyzed.

Table 4: Identified KPI's according Vopak

PROCESS	ACTIVITY	MEASUREMENT OF KPI	ANALYSIS
BERTHING VESSEL	• Vessel queue • Vessel Approach • Vessel Mooring • Pre-operation documentation • Operations (loading/unloading) • Post-operation documentation • Last rope removed • Vessel sail	Average Berth Time Vessel Turn Around Time	Efficient or not Efficient
(UN) LOADING	• Pre-pump inspection • Connect manifolds • Pumping • Disconnect manifold • Post-pump inspections	Net Pump Ratio Vessel Idle ratio	Efficient or not Efficient
STORAGE (Loading to reporting stock)	• Pre-pump documentation • Post-pump documentation	On Time in Full	Efficient or not Efficient
FINANCIAL GROWTH	N/A	Profit-Margins/ Annual ROE	Optimization

Source: Vopak Operating Manual

2.5 Introduction to Benchmarking

Benchmarking is commonly defined as the process of comparing the business processes and performance metrics of a company to that of the industry best standards and/or best practices from other like companies. It is a process used by many organizations in order to understand what practices are necessary to reach word class standards (Voss et al. 1997).

To effectively carry out this operation, the author is challenged with the task to identify and understudy a firm that practices best operating practices in the same industry or any other industry where similar processes exist. He essentially uses them as a yardstick to assess the operations of the firm of his interest. It is the intent that after such a process, the target firm will be able to develop plans on how to make improvements or adapt specific operational practices, with the aim of increasing some aspect of performance and ultimately creating a more capable firm.

2.6 The Benchmarking Concept

The concept of "best practice benchmarking" or "process benchmarking" helps firms and industries alike to develop a vision for change and improvement. It is a tool often used in highly competitive industries where the only controllable way to improve margins is by cutting cost (Manderstam group, 2013). By targeting key operations within the firms' processes, it is able to evaluate various aspects of their operational processes in relation to best-known practice of similar companies. These sample companies are usually carefully selected for the purposes of comparison (WCIR, 2009). This allows the firm to develop plans on how to make improvements or adapt specific operational practices, with the aim of increasing some aspect of performance and ultimately creating a more capable firm. Benchmarking may be a one-off event, but is often treated as a continuous process in which organizations continually seek to improve their practices and help them achieve business excellence (WCIR 2009).

2.6.1 Types of Benchmarking

Pioneered by Xerox, benchmarking has been widely adopted by companies as an improvement initiative (Port and Smith, 1992). There are several methods of benchmarking that firms often engage in depending on their desired outcome. Different authors that have described many of these types, often name them differently despite their similarity. For the purpose of this paper, we refer to Dr.R.Camp's four-steps typology because of its simplicity and evolutional approach (Camp, 1989).

1. *Internal Benchmarking -* This type of benchmarking is defined by its limitations to scope of application, which is within the boundaries of a single company. It is usually used to compare performance between different units and departments within the same organization.
2. *Competitive Benchmarking* – In this type of benchmarking, the focus shifts from within the company to external environments. This process usually involves one observing, comparing, and analyzing the behaviour, products and services of their direct competitors and tries to adapt so that they stay competitive. It is always performed in the same industry where company operates and because of the competitive nature, data is highly protected by firms which tends to hamper such exercise
3. *Functional Benchmarking* - Functional benchmarking can be described as an evolution of the competitive benchmarking process, as this exercise in on the basis of operational performance. Companies start to seek best practices in comparable industries (i.e. oil and gas companies seeking comparison with mining and chemical companies). Information sharing is more favourable and the exercise is not hampered, due to the lack of direct competitors.
4. *Generic Benchmarking -* Finally, the generic type of benchmarking is the most pure form of benchmarking that exists today. In a sense it is a combination of all the other types of benchmarking as it not only encompasses a larger and deeper scope but it makes its comparison against the best processes around regardless of the industry. It is often referred to as an exercise in creativity.

2.7 Benchmarking in the Oil and Gas industry

The Oil and gas industry is no stranger to benchmarking, as this has been the reason for its continuous improvement of the past decades (Manderstam group, 2013). It is however important to state that up until recent times, the benchmarking process for storage terminals however had lacked a systematic approach (WCIR, 2009). Disparate data sources resulting from silo IT implementations, more efforts spent on collecting and compiling data rather than on validating and analyzing them, no standardization of existing processes across corporation, data quality issues, lot of time consuming manual efforts, no standard process for opportunity capture and follow through, amongst a few others, are common challenges faced with the benchmarking exercises today (WCIR 2009).

In this study, we adopt a functional benchmarking method as defined by Camp, (2009). The success of such an elaborate exercise ultimately lies in the quality and the homogeneity of the collected data and terminal information (Garvin, 1991). Functional benchmarking; A process used to measure your performance against the best in the industry and then using the outcome to meet and /or surpass the best in class (Pryor and Kratz, 1993 p.7), is simply a tool used to identify and understand practices needed to reach new goals (Voss et al. 1997). With the development of IT and more concentrated functional benchmarking approaches like the DEA and the OEE, such benchmarking efforts can be more cohesive, more aligned towards vision and mission of oil storage and distribution companies (WCIR, 2009). For example, Shell has substantially reduced its maintenance manning levels, NAM has trimmed down its energy costs, Total has recovered a relative competitive weakness in the safety area, Statoil has improved its budgeting forecasts, and BP achieved multi-million savings (Manderstam group, 2013).

2.7.1 Benchmarking of Fuel Terminals – Business Drivers

Benchmarking can be an effective tool for the planning and implementing change processes that lead to organizational improvement when the knowledge gained is converted into a detailed action plan to improve competitive advantage (Pryor and Kratz, 1993). The ability to benchmark the productivity of their projects provides terminals a number of advantages. (Briand et al 2008) Certain drivers, as outlined by WCIR, 2009, that lead to such an exercise being conducted includes, but are not limited to the following:

• <u>Current Scenario Snapshot</u> – The benchmarking process will help the companies to determine their current standing i.e. what is their performance at this point of time vis-à-vis desired level

• <u>Improve Terminal Performance</u> – Once gaps in performance have been identified, targeted KPI's are closely monitored over a period of time against industry peers and subsequent steps can be taken to enable them improve terminal performance

• <u>Savings in terms of Money & Efforts</u> -Once a centralized benchmarking effort executed well, it would result in significant of savings in manpower efforts to generate inter terminal comparison reports and also leads to a reduction in operating cost.

• Efforts aligned to Company Strategic Goals – Benchmarking will concentrate performance improvement efforts towards key company visions/strategic goals.

• Framework for Comparing Apples-to-Apples – Benchmarking efforts provide a platform to compare performance of different assets in different location on similar platform, i.e. it allows users to bring all terminals to common comparison platform by correcting the different data sets.

2.7.2 How to benchmark fuel terminals across the enterprise

The inclusion of benchmarking in the Baldrige quality Award (the only formal recognition of the performance excellence of both public and private U.S. organizations given by the President of the United States) reflects its popularity (Voss et al. 2001). Benchmarking exercises follow a similar stepwise process in general, however for simplicity, we refer to the process outlined by WCIR, (2009) in this paper:

- Identify processes that have to be monitored over a period of time with the purpose of identifying over capacities or underutilizations,
- Determine KPI's that captures the essential functions of the identified process, keeping in mind the generally, Pareto rule where 20% of the KPIs could be responsible for 80% performance output of the processes,
- Measure KPI's by monitoring them at frequent intervals to identify opportunities to enhance operational efficiency.
- Analyze measured indicators proffer suggestions where gaps are identified.

These processes will result in sustained improvement of business performance over a period of time. Monitoring and improvement of the KPIs is a continuous process that has to be carried on till there is a need to drastically change the existing benchmarking processes in order to match current changed business scenarios that make existing processes irrelevant (WCIR 2009).

Chapter 3 Methodology I: Data Envelopment Analysis (DEA)

For the purpose of this study, we will investigate the operational efficiency and productivity of the Atlas Cove terminal, a liquid bulk terminal in Nigeria (target terminal) in comparison to that of an identified company selected in the Netherlands, (Benchmark terminal) believed to be a world leader in the industry. We have chosen Vopak as our benchmark company, and comparing the results and processes of its operations with that of our 'target terminal' (Atlas cove jetty), we learn how well the target is performing and, more importantly, where it is necessary to and how to invest in building core competencies that will help to sustain its competitive advantage.

This chapter seeks to analyse the applicability of Data Envelopment Analysis to the liquid bulk terminal industry and to identify performance implications that can be derived from its application. To achieve this, the fundamentals of the DEA approach will be presented in section 3.1, highlighting its applications in port research. In an illustrative example provided we briefly show how the DEA technique might be applied in practice. In section 3.2, we provide a methodology for arriving at a definition of the input and output variables needed to drive the DEA. In Section 3.3, we discuss two theoretical and practical considerations to take into account when applying this analysis and in section 3.4, we will review previous applications of the technique to the port industry and container terminals. From this section it will appear that limited study has been performed with the application of the DEA technique to liquid bulk terminals, however, by adopting and modelling the application and use of the technique in container terminals, we attempt to make the approach suitable for liquid bulk.

3.1 DEA approach: Fundamental and application in port research

'An introduction to Management science', Anderson, 2011 defines DEA as an application of linear programming used to measure the relative efficiency of operating units with the same goals and objectives. DEA concerns itself with assessing the relative efficiency of a sample selection of organisations, which form the fundamental unit of analysis within the approach.

The aggregation of these organizations that perform the same processes and make up the sample for analysis are typically defined as the Unit of Assessment (Thanassoulis, 2001) or the Decision Making Unit (DMU) (Charnes, Cooper, & Rhodes, 1978). In either case, the terminology refers to the organizational entity responsible for controlling the process of production and for making decisions at various levels (for example, daily operational, short-term tactical and long-term strategic decisions) that may influence the productive process and, invariably, the level of efficiency it is associated with (Cullinane et al. 2007).

This technical efficiency, which was mentioned in the earlier chapters of this study as an important concept to understand in order to perform bench marking operations is a fundamental concept in the field of economics and has been defined in different textbooks as the economic use of limited resources (inputs) for optimal production output levels, given the limited and finite nature of resources available to every productive process (Cullinane et al. 2007). The importance of studying efficiency is thus self-evident

DEA can be used to measure the technical efficiency of an organization by comparing it with other similar units that transform the same group of “measurable inputs” into the same types of “measurable outputs”. This homogeneity of both the inputs and outputs constitutes a fundamental underlying assumption upon which the veracity of DEA efficiency measures is based, and without which the relevance of measuring efficiency across any set of DMUs could undoubtedly be called into question (Cullinane et al. 2007).

The basic principle of utilizing DEA to measure the efficiency level within a given sample can be explained through the use of the example data presented in Table 5 and the conceptual illustration provided in Figure 6 below

Table 5: Single input and output model

Terminal	T1	T2	T3	T4	T5	T6	T7	T8
Stevedores	10	20	30	40	50	50	60	80
Throughput	10	40	30	60	80	40	60	100
Productivity (throughput/stevedores)	1	2	1	1.5	1.6	0.8	1	1.25
Efficiency (%)	50	100	50	75	80	40	50	62.5

(Source: Cullinane et al. 2007)

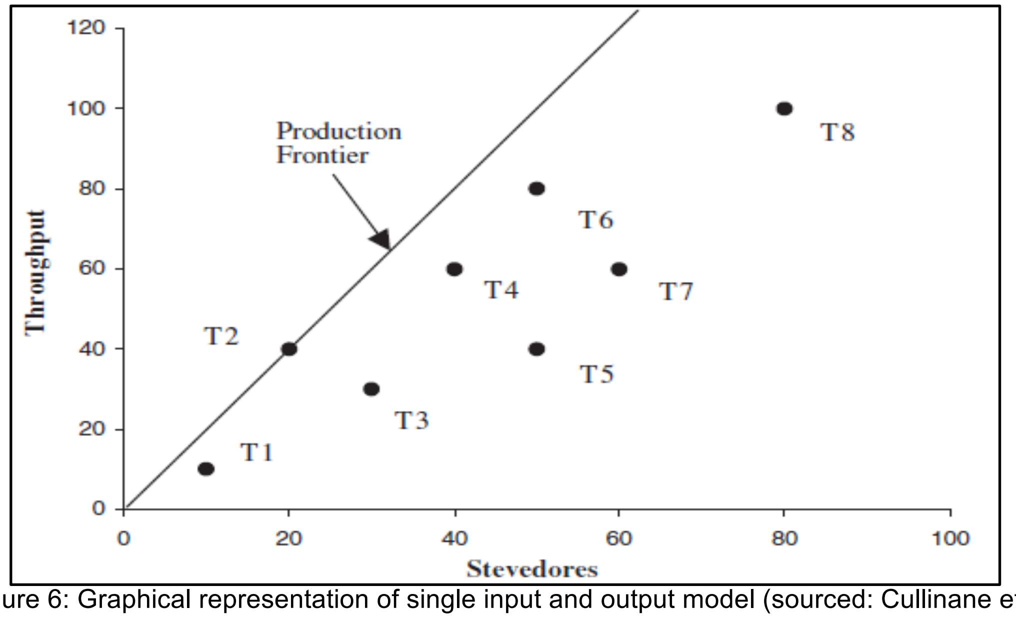


Figure 6: Graphical representation of single input and output model (sourced: Cullinane et al. 2007)

In the above, extracted from Cullanane et al. 2007, table 5 and figure 6 present a simplified vision of the production process of 8 container terminals, with a single input, ‘Stevedores’ and output, ‘throughput’ (i.e. containers per unit time) considered.

The productivity of any operation is simply defined as the absolute measure of the ratio of outputs to inputs and, therefore, in Table 5 the productivity of each terminal is represented by the calculated ratio of ‘throughput to stevedore’. It should be noted that this measure is equivalent to the slope of the line connecting each point to the origin in Fig. 6 and similarly reflects the number of containers moved per stevedore per unit time It is clear from Fig.6 that T2 has the highest absolute level of productivity compared with the other points and is, therefore, the most efficient unit in the sample. Therefore, the line from the origin through T2 is deemed to define the production frontier, based on the limited sample. All the other points are deemed inefficient when compared with T2, and are termed as being physically ‘enveloped’ by the production frontier curve (Cullinane et al. 2007). In the context of DEA, the relative efficiencies of all units of analysis other than T2 (as shown in the bottom line of Table 5) are measured by comparing their productivity with that of T2. The term ‘Data Envelopment Analysis’ stems directly from this graphical representation of a frontier ‘enveloping’ data points and of data points being ‘enveloped’ by a frontier.

The ability of this approach to also handle multiple inputs and output models makes it a preferred approach to benchmarking. Other very strong attributes this approach possesses are its ability to compare Assessment units directly against peers. It’s non-parametric characteristic does not impose any functional form to the production function (relating to inputs and outputs) and its variables can have different units. These same characteristics that make DEA a powerful tool can also create problems. DEA is also described as an extreme point technique. This deterministic property does not allow random noises (even symmetrical noise with zero mean) or measurement errors to be isolated from the measure of pure inefficiency. DEA is good at estimating "relative" efficiency of a DMU but it converges very slowly to "absolute" efficiency. In other words, it can tell you how well you are doing compared to your peers but not compared to a "theoretical maximum,” (Trick, 2002). Its non-parametric characteristic also statistical hypothesis tests more difficult. However, use of the Bonilla (2000) and Barros (2007) bootstrapping technique when needed helps limit some of these effects.

3.2 Definition of the input and output variables

Precisely defining and identifying appropriate output and input variables for terminal production function is crucial for a successful exercise and meaningful results. This is simply because the validity of the model is heavily dependent on the quality and integrity of the data used. As a result, erroneous or ill-defined specification of variables for collection, collation and subsequent analysis will inevitably lead to the results that are easily misinterpreted and possibly misleading. The input/output variables must reflect the main objectives of a terminal, which in this study is about maximizing ship-to-shore product throughput and productivity while efficiently using infrastructure and equipment.

For this study we will consider labour and capital as inputs. To compensate for the difficulty and complexity that arises with aggregating labour amongst different terminals (full- and part-time contracts and contracts partly managed by private, public and port authorities), proxies are often used along the argument that labour is usually closely and negatively correlated to handling equipment, we thus use loading/unloading equipment from ship-to-shore/ ship-to-tank per terminal as a proxy for labour inputs (Merk & Dang, 2012). Capital inputs, on the other hand, are more readily available as they refer to land and infrastructure (terminal surface, quay length or storage capacity).

The aim of this study – the assessment of liquid bulk terminals- Earlier studies focusing on container terminals have benefited from relatively comprehensive existing datasets on container terminal output, with output measured in twenty-foot equivalent units (TEUs) (Merk & Dang, 2012). Norman and Stoker (1991) points out that the golden rule in selecting output variables is to be as inclusive and comprehensive as possible in covering the whole gamut of work (production) that the firms undertake. Such a comprehensive and comparative dataset similarly exist for bulk terminals in form of Product Volumes.

Data collection risk double counting due to variations in terminal calculation of throughput. For example, in a container terminal, in instances of transport from an inland to a deep-sea terminal (counted as an incoming and outgoing container in the river terminal and then incoming and outgoing for the deep sea terminal) one container could end up being counted four times.

3.3 Theoretical and Practical considerations is selecting sample size

Sarkis, (2002) introduces us to some important considerations to make when evaluating the size of the data set used in applying the DEA. The choice and the number of inputs and outputs, and the DMUs determine how good of a discrimination exists between efficient and inefficient units. He highlights two conflicting considerations according to Golany and Roll 1989; "One consideration is to include as many DMUs as possible because with a larger population there is a greater probability of capturing high performance units that would determine the efficient frontier and improve discriminatory power." The other conflicting consideration with a large data set is that "the homogeneity of the data set may decrease, meaning that some exogenous impacts of no interest to the analyst or beyond control of the manager may affect the results."

As these data sets get larger, computational requirements tend to also increase, however there are some rules of thumb on the number of inputs and outputs to select and their relation to the number of DMUs to make sure that the basic productivity models are more discriminatory (Sarkis, 2002). Boussofiane et al, (1991), proposes that to get good discriminatory power out of the DEA-CCR and DEA-BCC models, the minimum sample of DMUs should be the multiple of the number of inputs and the number of outputs. Golany and Roll (1989) establish a rule of thumb that the number of units should be at least twice the number of inputs and outputs considered while Bowlin (1998), mentions the need to have three times the number of DMUs as there are input and output variables and Dyson et al (2001), recommend a total of two times the product of the number of input and output variables. If we exemplify the rules prescribed from each of these authors, with a 3 input, 4 output model, according to Golany and Roll, the minimum recommend assessment units is 14 DMUs, while Bowlin recommends 21 units, and Dyson et al. recommend 24. In any circumstance, these numbers should probably be used as minimums for the basic productivity models.

3.4 Previous applications of the technique to the port industry and container terminals

In recent years, DEA has been increasingly used to analyze port and container terminal production. According to Pallis et al. (2011), it remains the most widely applied method to measure terminal efficiency. DEA is more advantageous than other traditional approaches in providing an overall summary evaluation of performance because it can cater for multiple inputs to and outputs from the production process, which is a characteristic of ports and terminals. These advantages are explained later on in the chapter. There are two methods of the DEA approach, the DEA_CCR which is based on the assumption of constant returns-to-scale of production outcomes and on the other hand, the DEA-BCC which is based on the assumption of variable returns-to scale of production outcomes. Both names are however simply in recognition of the academic contributors to the approach. For our study, we will be assuming constant returns-to-scale of operational outcomes, however we will simply refer to the approach as DEA. Table 6 below gives an overview of a few of the previous application of the DEA.

- Roll and Hayuth's (1993) application of the DEA technique to the ports context probably represents the first work to use the DEA approach for benchmarking ports. It however, has been described to be purely theoretical exposition, rather than a practical study and application.

- Martinez-Budria, Diaz-Armas, Navarro-Ibanez, and Ravelo-Mesa (1999) applied DEA by classifying 26 ports into three groups, namely high-, medium- and low complexity ports. Using the DEA-BCC to examine the efficiency of these ports, the authors came to a conclusion that the ports of high complexity are associated with high efficiency, compared with the medium and low efficiency found in other groups of ports.

- Tongzon (2001) uses both DEA-CCR and DEA-Additive models to analyze the efficiency of four Australian and 12 other international container ports for 1996. The exercise is described, by (Cullinane et al. 2007), to have been plagued by a lack of data availability and the small sample size (only 16 observations), as a result, more efficient ports than inefficient ports are naturally identified. Realizing this serious drawback, the author concludes that further work should be done in collecting more observations to enlarge the sample analyzed.

- Valentine and Gray (2001) apply the DEA-CCR model to 31 container ports out of the world's top 100 container ports for 1998 to determine if there exists any relationship between port efficiency with a particular type of ownership and organizational structure. The authors conclude that clusters and synergies analysis is a viable tool for identifying organizational structures and that the ports sector exhibits three structural forms that seem to have a relationship to estimated levels of efficiency.

- For the period 1990–1999, Itoh (2002) conducted a DEA window analysis using panel data relating to the eight international container ports in Japan. The objective of this research was to compare infrastructure and labour productivity over a period of time.

- Barros and Athanassiou (2004) apply DEA to the estimation of the relative efficiency of a sample of Portuguese and Greek seaports to facilitate benchmarking so that areas for improvement to management practices and strategies could be identified. The authors conclude that there are economic benefits from the implementation of this form of benchmarking and go on to evaluate their extent.

- Park and De (2004) develop and apply what they refer to as a 'Four-Stage DEA Method'. The approach compensated for limitations in assessing the efficiency of ports solely on the basis of capital and labour inputs by involving the disaggregation of the overall efficiency model into its constituent components. With this approach, better insight can be gained into the real sources of efficiency. The model comprises individual DEA components that determine the respective efficiency related to productivity, profitability, marketability and overall.

- Cullinane, Wang, Song, and Ji (2005) apply both DEA and Stochastic Frontier Analysis (SFA) to the set of container port data for the world's largest container ports and compare the results obtained.

Table 6: Efficiency measures in port sector: non-parametric approach

Author	Unit of Analysis	Purpose	Variables	
			Outputs	Inputs
Roll and Hayuth (1993)	Units not specified	Not Specified	Cargo Service level User satisfaction Number ship calls	Labour Capital (monetary) Cargo uniformity
Martinez-Budria, Diaz-Armas, Navarro-Ibanez, and Ravelo-Mesa (1999)	26 container ports	Provision of Infrastructure	Cargo Income	Labour Capital (monetary) Intermediate inputs
Tongzon (2001)	4 Australian ports and 12 International container ports	Port Efficiency	Service levels Number Containers	Labour Capital (physical) Waiting time
Valentine and Gray (2001)	31 out of the worlds top 100 container ports (1998)	Correlation between operation efficiency vs. ownership structure	Number Containers Cargo	Capital (physical) Labour
Itoh (2002) For the period 1990–1999,	8 International container ports (Japan)	Productivity wrt. Infrastructure and labour	N/A	N/A
_ Barros and Athanassiou (2004)	Portuguese and Greek container ports	Port Efficiency	Cargo types Number ship calls Number Containers	Input- Labour Input-capital (monetary)
Park and De (2004)	Units not specified	Port Efficiency	Cargo Types Income User Satisfaction Number Ship calls	Labour
Cullinane et al (2005)	Units not specified	Handling efficiency	Number of Containers	Capital (physical)

(Source: compiled by author)

The few selected applications of the DEA give us a preview of the evolution of the application of the DEA to attain more accurate outcomes, and the diversity of the approach in its use in various scenarios with varying variables and objects of comparison. For this reason we are confident that such an approach will be suitable in measuring the performance of liquid bulk terminals.

Chapter 4 Methodology II – Operational Equipment Efficiency (OEE)

This section seeks to analyze the applicability of Operational Equipment Efficiency to the Bulk Terminal Industry and to identify performance implications that can be derived from its application. To achieve this, the fundamentals of the OEE concept will be presented in section 1. Understanding that limited study has been performed with the application of the OEE technique to bulk terminals, in section 2, we describe according to Verheul (2013), the necessary subsystems within the terminal that will allow for the OEE to be effectively executed. An illustrative example is also provided to show how the OEE technique might be applied in practice in and next; we detail the sample data for the purpose of this paper and the process by which they were collected. We then round up the chapter by providing a methodology for arriving at a definition of the input and output variables needed and highlighting the steps this paper will take in order to draw conclusions.

4.1 Fundamental concept of OEE

The OEE unlike the DEA is a more micro approach to benchmarking usually used to make comparisons on a more specific and detailed level. In this case performance measurements are activity specific and when multiple activities have been evaluated, results are then aggregated to provide the overall technical efficiency of the terminal. Operational equipment Efficiency is defined in the industry as the fully productive time of a manufacturing line divided by its planned operation time. The fully productive time is thus described as the time a manufacturing line is producing goods of required quality at maximum speed. In essence to calculate the OEE of equipment, it is the subtraction of all losses related to either unavailability or underperformance from the planned operating time.

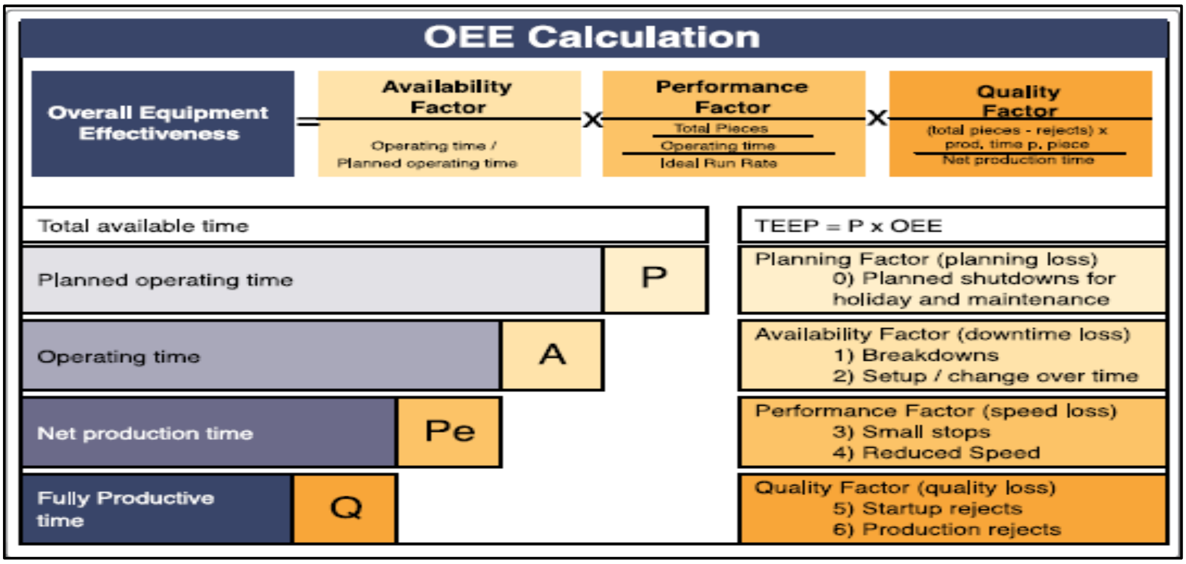


Figure 7: General Theory of the OEE Concept (Source: Verheul, 2013)

The OEE is has been prolifically used when measuring the productivity of production lines and supply chains. It involves singling out each activity in the chain and evaluating if it is efficient or not. It is thus often defined as a tool that ensures maximum productivity of equipment leading to maximized financial return during operating hours.

The OEE is applied per equipment type and this singular property facilitates simplification of complex systems into easy-to-follow subsystems. It is very practical approach and difficult to tamper with, which makes it an excellent KPI to base performance incentives on. Categorization of the non-productive time per type of loss provides a good yardstick with which to measure where you are and how you can improve your operations (Verhaul, 2013). For this reason, OEE is often used in Operational Excellence and Lean Manufacturing programs.

4.2 Liquid bulk terminal subsystems

We have earlier discussed of its ability to break complex operations into more easy to follow sub systems. To effectively use the OEE in the liquid bulk terminal industry, three levels of subsystems namely, 1) the Transport and Service system, 2) Subsystem per equipment group and 3) Subsystem per functional process, are defined within the terminal (as illustrated in Figure below):

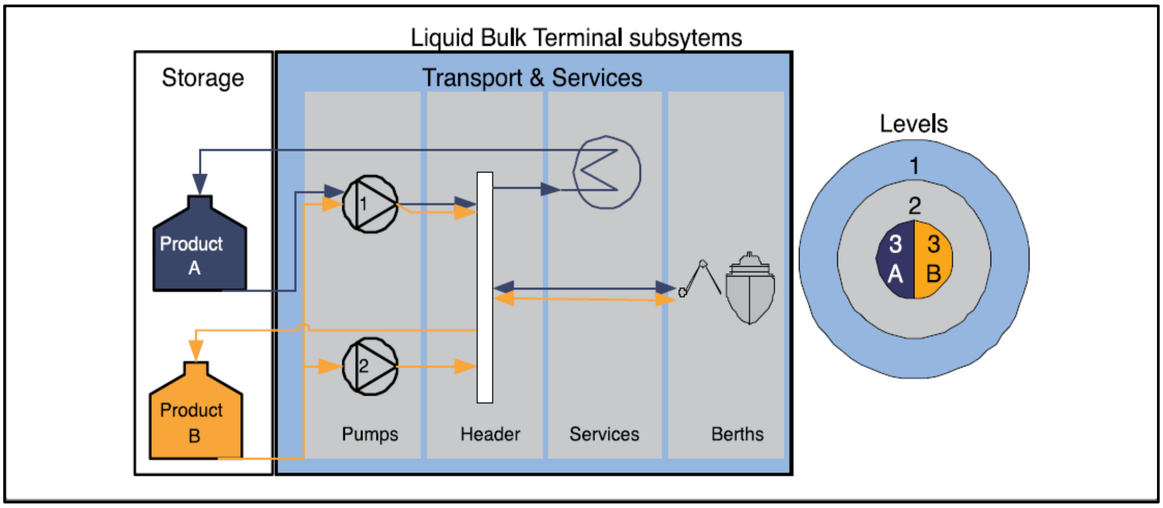


Figure 8: Example of liquid bulk terminal system and subsystems (Source: Verheul, 2013)

1. The transport and service system: like the name infers this subsystem includes all the main equipment in the terminal (Level 1). Determining the OEE of the terminal at this level simply involves measuring the productive time of all the equipment. It is worthy of mention that irrespective the terminal's characteristics, even if differences may be experienced per equipment type, on aggregation level 1 the terminal should always aim for an optimal OEE and for this reason a terminal with dedicated systems per product, and a fully flexible terminal can be compared to one another.

2. Subsystem per equipment group: in this sub system, we identify independent equipment's in the terminal that form the chain of operations and facilitates optimization of equipment productivity (Level 2). A low performance factor of one of these equipments affects the performance factor of the whole line. For example, if the pumps in the terminal are analyzed to have low performance, it indicates the inefficiency in the overall terminal process can be "pin pointed" to the pumps; either that the investments in pumps are not effective or the pumping rates are not optimal. Analyzing and reducing typical productivity losses can improve the return on investment of this type of equipment.

3. Subsystem per functional process: It can be useful to define a subsystem per functional process type. Equipments in this level are primarily the storage facilities (level 3). In order to answer detailed questions like: "What is the set-up loss caused by switching between loading and unloading?" and "How often is the pump blocked for product A due to pumping of product B?" evaluating the utilization of tank/storage space is essential. Figure 2 shows two examples of subsystems per product.

As OEE is always calculated by measuring productive time, the OEE for each of the subsystems can be calculated from the OEEs of lower level subsystems (e.g. the productive time of all pumps is the sum of the productive time of each pump) in the same vein, the OEE of each subsystem when aggregated also give the overall performance level of the facility.

4.3 DEA and OEE applied to Liquid Bulk Terminals

For the purpose of this study, we will first of all perform the DEA. An excel model as described in chapter 3 will be built to analyze terminal technical efficiency across a sample of liquid bulk terminals at aggregated and disaggregated activity levels, using gathered data for the most recent available year (2012). The database of this model covers approximately 4 terminals, listed in table 7 of chapter 5, and all of the input and output variables are drawn from the company log books for the terminals in the sample pool. Once all information is gathered it is run through a linear program "black box" used to measure the relative efficiency of terminals

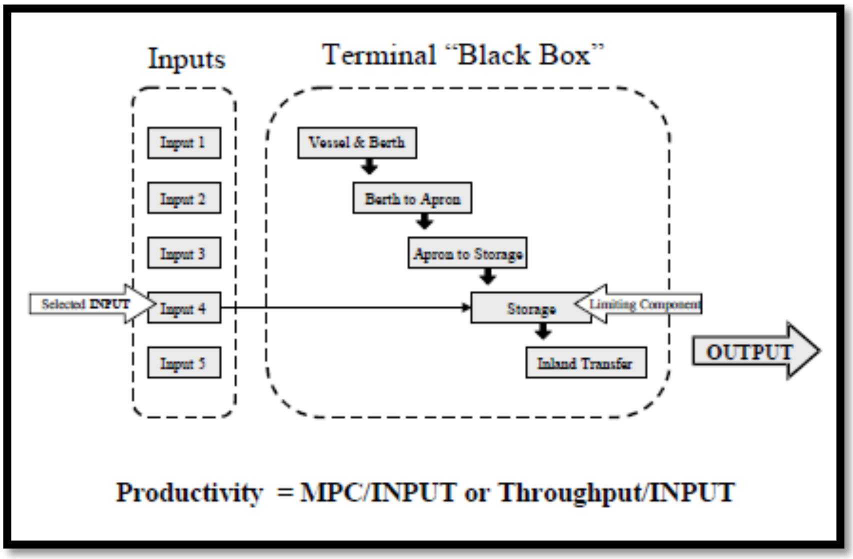


Figure 9: Marine Terminal Productivity Analysis methodology (Source- CCDoTT, 2000)

Given limitations in the application of the DEA methodology, discussed earlier in section 1 of chapter 3, a number of approximations and extrapolations were performed in order to ensure estimate reliability of selected data. From the result and outcomes of the DEA approach exercise, we will select two terminals and compare their performance levels on a more detailed scale using the OEE concept.

For the application of the OEE approach, having identified the subsystems, defined in section 2 of chapter 4, the operation efficiency of the terminal can now be calculated. We will take selected processes and activities and measure their indicators to determine their performance level (Refer to table 4 on page 13). To do this, all productivity-related time and capacity data will be gathered. For each of the two terminals, by computing operational ratios, performance level of each system will be measured and aggregated to get the overall technical performance level of the terminal, which will be discussed in chapters 5 and 6. Both terminals, in chapter 7 will then be compared on these outcomes and ideal industry levels as extrapolated from conversation and academic discussions with industry professionals. The input and output variables used to derive efficiency indicators will be described in the following chapter.

Chapter 5 Data analysis for terminal Efficiency

5.1 Data Selection

In this chapter we evaluate data from a panel of 4 liquid bulk terminals in the year 2012. Of the four terminals, one is in Africa, one in the United Arab Emirates, and two terminals in Europe. The terminal operators of the facility in Africa are the Pipeline and Product Marketing Company (PPMC) of Nigeria while Vopak are the operators of the other three selected facilities. The 4 selected terminals were shortlisted from a pool of over 84 terminals (panel of data in appendix I.) on the sole basis of providing dedicated cargo handling service for only petroleum products. In the previous chapter we discussed theoretical and practical considerations to make with respect to the process of selecting a suitable sample size. In our study we have not met the required minimum however, it was important to make such a selection as "liquid bulk" terminals handle a variety of liquids and chemicals that all have different handling processes. This will render the DEA approach unsuitable for a comparison analysis as its success is based on the homogeneity of the operational processes in the facilities being evaluated as stated earlier on in this paper.

The 4 terminals studied in this chapter are located in 3 different continents and represent 4 different countries.

Figure 10: Location of the 4 selected Liquid Bulk Terminals in three different continents.

Not only do the size and types of operations amongst these terminals differ but they are all faced with different peculiar challenges be it natural geographic constraints to human/environment interaction as we will see later on in the report.

Table 7: Location, name and Size of selected facilities

COUNTRY	TERMINAL NAME	CAPACITY (M3)	DISCHARGE VOLUME (MT)
NETHERLANDS (Amsterdam)	WestPoort	1,216,180	4,205,190
NETHERLANDS (Rotterdam)	Laurenshaven	924,862	2,456,094
NIGERIA	Atlas cove	129,681	1,866,602
UNITED ARAB EMIRATES	Horizon Fujairah	2,130,541	15,096,763

The key function and facilities in a liquid bulk terminal are often the same regardless of their size and purpose. In chapter 2, we discussed key components or processes that occur within the terminal and from these four processes we have identified, collected and used their corresponding physical assets as inputs in the model. The assets are: Number of Berths, Transfer pipeline capacity, Terminal draught and Storage Capacity which represent the different components that form the operations in the terminal. The volume discharged at a terminal; measured in Metric tons, the universal measurement for liquid bulk cargoes, and forms the output variable used in this model.

The number of berths and storage capacity represent the infrastructure and handling capacity while the pipeline capacity fits into the equipment category, and the discharge quantifies, the volumetric outcome of their process, thereby providing an overview of how the terminal combines its assets to yield it operating outcomes. Comprehensive information on these assets is generally available from annual terminal reports and vessel time-log sheets produced and kept by the terminal operators.

The data used in this chapter was collected from the operators of the selected facilities. The limited access granted to external bodies attempting to access such data however presents one of the major challenges in embarking on such a study. A summary of our variable specification is provided below:

Output	Y_1	Discharge Volume	Metric Tons (MT)
	Y_2	Number of vessels Calling	Number
Inputs	X_1	Number of Berths	Number
	X_2	Aggregate Capacity of Transfer Pipelines	M^3
	X_3	Aggregate Draught at Terminal	M
	X_4	Storage Capacity	M^3
Exogenous Factor	Z	Operation Type	Binary (0=only distribution, 1= multiple operations)

Table 8: Input and output variable Specification for terminal data

5.2 Data Description of Variables used in empirical studies

Discharge Volumes: This is simply the total volume of product that is transferred over the shore-land interface within a certain time interval.

Number of calls at terminal: This is described as the total number of vessels that berth at the terminal for the purpose of discharging cargo from vessel to tank storage.

Number of berths at the terminal: The berths can be seen as the entry channel into the terminal from the sea. The number of berths in a terminal depend on certain factors, some of which are; the kind of product being trafficked, the size and type of vessels likely to be calling at the terminal, the speed with which the vessels are unloaded/loaded and the ability of the tanker to turn around and sail off in as little time as possible. In essence one can conclude that the more the number of berths present at the terminal, the more vessels they can more and operate simultaneously which directly correlates to a higher volume of traffic passing through the facility over the same interval.

Pipeline Transfer Capacity (Size and length of pipelines): The products from the vessel are transferred by a means of pump and pipeline network from the vessel to the tanks where they are temporarily stored. The integrity of the pipelines (size and length) determines the pressure level at which products can be pumped from the vessel to the tanks. In this instance we can infer that wider the pipeline diameters the higher the ability to pump at higher pressures which means more volumes can be transferred from the vessel to tank in shorter time periods. This allows for more vessels to be able to call at the terminal and invariably larger volumes passing through the facility.

Draught at terminal: draught is defined as the height from sea level to the waterbed. This is one of the most important characteristics of the access channel to the terminal as it is the major constraint to the size of vessels able to manoeuvre. The higher the terminal draught, the larger the size of vessels that can call at its berth, thus allowing for large volumes of product to be discharged at a time, thus increasing the total throughput passing through the facility over any selected interval.

Storage capacity of the terminal: we earlier on in this paper described one of the functions of the terminal to be temporary storage. This capacity determines the total possible amount of products that can be stored in the facility at any given time. The larger the storage capacity, the more volumes con pass through the facility over any given interval.

Table 9: Collected data on the selected terminals

	Terminals	Laurenshaven	Westport	Fujairah	Atlas Cove
Input Variables	Number of Berths	3.00	7.00	7.00	2.00
	Capacity of pipes	4,318.00	1,717.85	4,510.00	1,219.20
	Draught (M)	14.00	13.70	12.00	13.30
	Storage capacity (cbm)	924,862.00	1,216,180.00	2,130,541.00	129,681.00
	Operation type	0.00	0.00	0.00	1.00
Output Variables	Annual Volume in 2012(MT)	2,456,094.00	4,205,190.00	15,096,763.00	1,866,602.00
	Number of vessels calling	597.00	385.00	1,371.00	78.00

Table 10: Descriptive Statistics for terminal data

Variables	Y_1	Y_2	X_1	X_2	X_3	X_4
	Discharge Volume	Number of Vessel calling	Number of Berth	Transfer pipeline capacity	Aggregate Draught	Storage Capacity
Mean	5,983,502.25	522.75	4.75	2,941.26	13.25	1,100,316.00
Std. Dev	6,151,385.16	579.35	2.63	1,714.50	0.88	826,176.82
Skewness	1.86	1.72	-0.124	-0.06	-1.40	0.21
Minimum	1,866,602.00	1,371.00	2.00	1,219.20	12.00	129,681.00
Maximum	15,096,763.00	78.00	7.00	4,510.00	14.00	2,130,541.00

From the descriptive table above, we see that we are comparing a rather small sample of terminals with large differences in the size of operations. Such large disparities could later be found to be a reason for foreseen inconclusive results from the DEA approach. We also notice that of the six variables selected, only the discharge volume, Number of vessels calling and Storage capacity of the facility positively skew level operational outcomes.

5.3 Data Testing

The ability to use multiple variables when making comparisons of operations is on the premise that such variables are somewhat interdependent on one another. To determine this, we conduct a correlation test between each of the variables. Table 11 below illustrates this correlation. Of the dependent and independent variables we observe that all except the Draught share reasonable correlations with one another. We can deduce that of the four input variables, X_4 (storage capacity) has the highest correlation with Y_1 (annual volume discharged in 2012) whereas the draught, X_3 shows a negative correlation with the same output variable, Y_1.

This outcome suggests a very low importance of the terminal draught to the efficient throughput volumes of liquid cargoes. Among the other inputs we see convincing evidence that shows they are correlated to one another. We also see a strong correlation between the exogenous variable (operation type) and all the other variables except from the draught restrictions.

	Number of Berths	Capacity of pipes (M^3)	Draught (M)	Storage capacity (cbm)	Annual Volume in 2012(MT)	Number of vessels calling	Operation type
Number of Berths	1						
Capacity of pipes	0.229416768	1					
Draught (M)	-0.46740822	-0.34525417	1				
Storage capacity (cbm)	0.852198322	0.683463238	-0.64815590	1			
Annual Volume in 2012(MT)	0.694226467	0.585892867	-0.91668194	0.896860579	1		
Number of vessels calling	0.61845714	0.83433604	-0.74657601	0.93368832	0.931712354	1	
Operation type	0.697096676	0.6696059	-0.03782347	0.783234269	0.433869736	0.64021268	1

Table 11: Correlation between Variables

Chapter 6 Result Analysis

In this chapter, we analyze the results from the DEA and OEE study carried out. Both approaches are used to primarily draw inference about the ideal performance levels at liquid bulk terminals. As explained in the earlier chapters, due to the characteristics of the DEA approach, results are more general (on a macro level) and are used to expatiate on sub research questions 1 and 2. The OEE approach is more deliberate as it focuses on sub processes within the terminal and evaluating its efficiency against ideal industry standards. This includes calculating the vessel turn-around times and the jetty and average pumping rates at the jetty, which help explain further the percentage occupancy at the jetties and utilization ratios of the facility. This portion of the results helps to shed some more insight on sub research questions 3 and 4.

6.2 DEA Results

Four terminals that are designed to receive and handle refined petroleum products were selected for this exercise with the Atlas cove jetty as our target facility whose performance levels we are interested in. We used a linear program to create a hypothetical composite terminal based on the output and input variables for the four terminals in the problem. To run this linear program, we minimize the objective function with the goal of identifying if our target terminal was operating relatively inefficiently to the others. We arrived at an efficiency index outcome of 1. See table that shows outcome of linear program.

Table12: Outcome of linear program 4-input 2-output Model

	Terminals	Laurenshaven	Westport	Fujairah	Atlas Cove	Composite Terminal	Atlas Cove times Efficiency
Input Variables	Number of Berths	3.00	7.00	7.00	2.00	2.00	2.00
	Capacity of pipes	4,318.00	1,717.85	4,510.00	1,219.20	1,219.20	1,219.20
	Draught (M)	14.00	13.70	12.00	13.30	13.30	13.30
	Storage capacity (cbm)	924,862.00	1,216,180.00	2,130,541.00	129,681.00	129,681.12	129,681.12
	Operation type	0.00	0.00	0.00	1.00	1.00	1.00
Output Variables	Annual Volume in 2012(MT)	2,456,094.00	4,205,190.00	15,096,763.00	1,866,602.00	1,866,602.39	1,866,602.39
	Number of vessels calling	597.00	385.00	1,371.00	78.00	78.00	78.00
						Weight Sum	Efficiency
	Weights	0.00	0.00	0.00	1.00	1.00	1.00
							1.00

The Outcome of the linear program (optimal solution) is shown in the table 12 above. We first of all notice that the objective function shows the efficiency score for the Atlas cove terminal is 1.00. This score tells us that the composite terminal can obtain at least the level of each output that the atlas cove obtains by having available the same input resources available to the atlas cove. From the solution, we see that the weighted solution for the Laurenshaven, Westport and Fujairah are 0.00 thus the composite terminal is solely formed from the weight of the Atlas cove terminal. We can't infer that that the composite is any more or less efficient than the Atlas cove terminal and thus there is no conclusive evidence that the Atlas cove terminal operations are inefficient.

In earlier parts of this study, we mention that there are common activities with all terminals irrespective of size, throughput and purpose function. Liquid bulk terminals are purpose built facilities and for this study we have only classified terminals based on the product, which they handle. Another way to make such classification is based on its position in the supply chain. The role a terminal is built to play in a supply chain determines certain logistic functions that will have a more prominent role in determining their performance levels. The list below shows the four main terminal types ranging from the strategic terminals to hub terminals.

- Strategic terminals, used for strategic storage by governments.
- Industrial terminals used for storage of raw materials and finalized goods at the production site.
- Import or export terminals, primarily focused on make or break bulk services.
- Hub terminals, high volume market places with many logistics services.

The inconclusive outcome from this study could be attributed to the purposed build nature of such facilities. Because terminal type is expected to affect the productivity losses at the terminal, this results in a unique optimum performance level for each terminal type.

6.3 OEE Analysis results

To perform the OEE approach we focus on certain processes within the facility to determine if they are performing at optimal levels. We evaluate the Average Vessel turnaround time, the Berth Occupancy, and The average Pump rate.

Table 13: Horizon Fujairah, February 2012 Operation Summary

Year 2012	Number of Calls	Average Berth Time per berth (Hours)	VTAT-Vessel Turnaround Time (Hours)	Berth Occupancy (%)	
Berth 1	17	484.71	28.51	72.3	
Berth 2	14	455.82	32.56	67.83	
Berth3	13	323.97	24.92	48.21	
Berth 4	23	359.18	15.62	53.45	
Berth 5	11	455.55	41.41	67.79	
Berth 6	11	356.29	32.39	53.02	
Berth 7/ SPM	12	474.10	39.51	70.55	
		SUMMARY			
Monthly total Number of calls	**Monthly Average berth time (Hour)**	**Monthly Average VTAT (Hour)**	**Monthly Average Berth Occupancy (%)**	**Monthly discharged volume (MT)**	**Monthly average pump rate (mt/hr)**
101	**415.66**	**30.70**	**61.85**	**927,157**	**2230.561**

(Calculated by author)

Table 14: Atlas cove, February 2012 Operation Summary

Year 2012	Number of Calls	Average Berth Time per berth (Hours)	VTAT-Vessel Turnaround Time (Hours)	Berth Occupancy (%)	
Berth 1	4	529.54	132.38	78.80	
Berth 2/ SPM	6	616.90	102.82	91,80	
		SUMMARY			
Monthly total Number of calls	**Monthly Average berth time (Hour)**	**Monthly Average VTAT (Hour)**	**Monthly Average Berth Occupancy (%)**	**Monthly discharged volume (MT)**	**Monthly average pump rate (mt/hr)**
10	**573.22**	**117.60**	**85.30**	**186,687**	**325.68**

(Calculated by author)

We collected 2012 vessel time logs at 2 terminals; a) the Atlas cove terminal in Nigeria, and b) Vopak Horizon Fujairah terminal in UAE, and from this data logs, we were able to compute the average time the vessel spends at the berth, we were able to determine the Berth Occupancy at the facility and with information on monthly discharged quantities, we were also able to determine the average pump rate at the facility. For both terminals we selected data for 3 months where market fluctuations were at their peak.

6.3.1 Process evaluation

The number of vessels that call at the terminal is greatly affected by the total time a vessel spends at the berth to perform its operations. This time at the berth is determined by how quickly the vessel can discharge their cargo, which is dependent on the discharge pump rate. An evaluation (Ratio) of the time spent at the berth for operation and the available time for such operations over a selected interval then determines the percentage occupancy of the berth over that period of time.

Total time at berth (TBT) is a measure of time a berth is occupied by a vessel engaged in an operation.

$$\textbf{Sum } (T_{B1}+T_{B2}+T_{B3}\ldots\ldots\ldots\ldots T_{Bn})$$

Where:
T_B= time vessel 1 stayed at berth
'n' = total number of vessels calling in time interval

Vessel Turn Around Time (VTAT) is a measure of the time needed pre vessel for (un) loading operations.

$$VTAT = \frac{\text{Sum } (T_6-T_1)}{VT}$$

Where:
T_1= time of 'first rope' at mooring
T_6= time of 'last rope' at departure
VT= number of vessels in the frequency

Average Pumping Rate (APR) provides insight on the pumping speed during a discharge operation.

$$APR = \frac{\text{Sum } Q}{\text{Sum } (T_4-T_3)}$$

Where:
Q= quantity pumped in (M^3)
T_3= start pumping time
T_4= stop pumping time

Berth Occupancy percentage (BOP) is a measure of the fractional availability at the berth over a selected interval.

$$BOP = \frac{\text{Total time used}}{\text{Total time available}} \times 100$$

Find operation summary for the selected months below:

Table 15: Aggregated Operation Summary, Fujairah

Average Number of calls	Average berth time (Hours)	Average VTAT (Hours)	Average Berth Occupancy (%)	Average discharged volume (MT)	Average pump rate (mt/hr)
111.33	**456.46**	**31.07**	**64.55**	**1,137,548**	**2433.298**

(February, March and August, 2012)

Table 16: Aggregated Operation Summary, Atlas Cove

Average Number of calls	Average berth time (Hours)	Average VTAT (Hours)	Average Berth Occupancy (%)	Average discharged volume (MT)	Average pump rate (mt/hr)
9	**527.11**	**127.41**	**73.6**	**163606**	**311.28**

(February, March and August 2012)

We see in table15 above the operation summary of Fujairah and in the table16 that of Atlas cove for the months of February, March and April. We can infer from our outcomes that on an equipment /process level analysis, the performance level at Fujairah is a lot higher than that at the Atlas cove terminal.

Chapter 7 Benchmark Comparison and Recommendations

To comprehensively compare our target terminal with our bench mark terminal we will use this section to highlight the differences in performance levels with the berth occupancy as a function of the total time the vessel spends at the berth and the vessel turn around time vis-a-vis the pumping rates and average discharge volumes for the data period collected. We will also proffer some explanation to why the conditions being faced occur and how they be remedied.

7.1 Berth Occupancy Percentages

This term has been earlier on described at the percentage chance of availability to berth a vessel that randomly calls at your facility. The number of berths you have at your facility and the average time a vessel spends at the berth for each call are two conditions that determine this ratio. While increasing the number of berths available can easily increase this percent chance, it is not commonly the optimal way to remedy this situation. How ever increasing the operational efficiency of the handling process at the terminal ultimately reduces the average time a vessel has to stay berthed. This allows the berth more free time and reduces its occupancy percentage.

The average berth occupancy at the Atlas cove jetty is calculated at 73.6% while that of the Horizon Fujairah terminal is calculated at 64.55%. From the above description we can conclude that the Horizon Fujairah terminal has a higher performance level than the Atlas cove jetty. When we investigate the two conditions highlighted above for the two terminals, we get the following results:

Table 17: comparison statistics for berth occupancy percentage

Terminals	Fujairah	Atlas Cove
Number of Berths	7.00	2.00
Average Total Berth Time per Month	6.48 Hours	86.28 Hours

The Fujairah terminal has 5 more berths than the atlas cove, which allows for them to have higher availability even if both terminals have averagely the same number of vessel calls in a month. In this scenario, the Fujairah terminal operates an average total berth time of 6.5 hours per vessel in a month, while the atlas cove uses times 14 hours, averaging its monthly operations at 86 hours total berth time per vessel per month.

In both conditions, the performance level of the atlas cove jetty is consistently less efficient. In order to reduce their berth occupancy percentage, they should consider

- Increasing the number of berths at the facility
- Reduce their cargo handling process time by using less time for cargo inspection and documentation, and reducing their discharge operating times.

7.2 Vessel turn around time

This as the name implies is to total time it takes for the vessel to berth complete its operations and sail away. This time is determined by to sets of processes.

- Documentation period: for every vessel that enters a terminal to discharge cargo, certain documentation processes and inspections are carried out to ensure that the operations are occurring within full legal terms. This process is usually standardized and the time required for this is commonly consistent from vessel to vessel and is usually a constant in turnaround time calculations.

- Operation period: The operation period simply defines the time needed to fully discharge the product onboard the vessel. This process is dependent on the pumping rate of the vessel, which in its self is a factor of the integrity and size of the transfer equipments (loading arms and pipelines) and the availability of ullage at the facility. Ullage is simply the volume available at the terminal to receive product for temporary storage at any given time.

Table 18: Comparison statistics for Vessel turn-around time

Terminals	Fujairah	Atlas Cove
Average Vessel Turn Around time (for months collected)	31.07 hrs	127.41hrs
Capacity of pipes	4,510.00	1,219.20
Storage capacity (cbm)	2,130,541.00	129,681.00
Average Pump Rates (for month collected)	2433.30 mt/hr	311.28 mt/hr

The vessel turn around time at the Fujairah terminal is 4 times faster than that at the atlas cove jetty, with Fujairah averaging 31.07 hours/VTAT and the Atlas cove averaging 127.41 hours/VTAT. Again, we can conclude that the Horizon Fujairah terminal has a higher performance level than the Atlas cove jetty. When we investigate the conditions highlighted above for the two terminals, we get the following results, (view in fig above).

The storage capacity and pipeline capacity of Fujairah terminal are 2,130,541 m3 and 4,510 m3 respectively whole that of the atlas cove jetty are 129,681 and 1,219 m3. These constraints are seen to directly affect the average pumping rate at the two facilities. As expected, the Fujairah terminal pumps and a rate 8 times higher than the atlas cove jetty.

An increase of storage capacity allows for more ullage, which was mentioned earlier as a constraint for vessel operation time and pump rates; but more importantly the ability of the transfer pipeline to withstand high pressure without erupting (integrity of the equipment) plays a very crucial role in the pumping rates and invariably the vessel operation time. By upgrading the pipelines capacity and integrity at the Atlas cove jetty, vessel pumping rates can be greatly improved allowing for vessels to sped shorter times when they call at the terminal berth.

7.3 Hinterland Distribution

All this while we must remember that chapter one; Scope of study, we identified that for the purpose of this study we will only look at the operations that occur at the interface between sea transport and terminal operations and the Liquid bulk terminal operations itself.

Figure 11: Pictorial process of operations in a terminal

We have only chosen to consider the performance level on the sea/land interface operations and operations on the actual storage facility with the assumption that the third phase of operations in the terminal was efficient.

We cannot however understand the full reasons for the levels of performance at the jetty side and on the facility without evaluating the level of congestion at the hinterland distribution-phase of the terminal operation. For a terminal to operate at optimal levels at the berth and on the storage facility, they have to be able to efficiently push out the volumes coming to avoid congestion. Congestion at the hinterland gates reduces the amount of space available in the storage capacity to receive cargo; this is termed as 'limiting ullage' in the industry. Vessels that have arrived the terminal to discharge their product are thus faced with the challenge of having to queue for longer periods before enough space is created for them to discharge their product into. The pumping level of these vessels is also constrained, as the vessel has to reduce its pump speed in order not to over boarding the storage facility with large volumes at high pressures. These low pump rates result in the vessel having to spend longer times at the berth, (increasing the vessel turn around time) and thus increasing the berth occupancy of the facility.

The impact of effective hinterland distribution and its effect on the level of performance of the terminal can be said to be one of the pertinent challenges if not the singular major setback being faced by the atlas cove in attaining better performance levels. Over the past decade, Nigeria has been plagued with increasing occurrences of oil leakage from pipelines, usually caused as a result of poor management & maintenance and deliberate attacks ('interdictions') on oil pipelines from indigenes. These attacks are often accompanied by oil theft carried out by well-equipped professionals and/or at a smaller scale by opportunistic local residents. The causes of these attacks, and the extent of subsequent damage to local communities and the environment, are obscured by a complex web of stakeholders, claims and actions.

The occurrence and reoccurrence of such acts cause continuous shutdown of operations in the terminal. Desired ullage cannot be realised, as product cannot be pumped out of the storage to make space thus bringing the terminal operations to a complete halt.

To mitigate against these incidents, a full proof security monitoring and response scheme to combat the occurrences of pipeline vandalism and the full corporation of international players in the campaign against corruption will be needed.

Chapter 8 Conclusion

This study was guided by the main research question of how the performance level at liquid bulk terminals are measured and benchmarked against one and other. The concept of measuring performance level is based on the derived ever-growing demand for terminals to be more efficient and productive given the progressive growth in the maritime industry with respect to transportation and trade. As such terminals in its own right do not demand higher efficiency and productivity, however given the competitive nature of the industry, any increase in value add opportunities given to costumer directly increases the patronage and market share of the terminal.

In order to provide a detailed analysis the main research question was divided into four sub-research question. First it was relevant to accurately define what a terminal is. Since approximately 90% of the worlds trade is by maritime transport the importance of terminals as the interface between sea and land transportation remains invaluable. Thus it is necessary to properly understand the primary and even tertiary functions of the terminal. Consequently, time was spent to define and categorize the different types of terminals that are available and then properly expatiate on the functions of our desired terminal given the scope of our study; “liquid bulk terminals”.

Secondly, we discuss the activities that occur within a terminal facility irrespective of their size, throughput and purpose function in order to properly understand what activities were common ‘key’ amongst terminals. We noted that the only basis for comparison between any two units would be on the homogeneity of activities that occur in the respective units.

After performing an extensive literature review on the topic of benchmarking terminals and ports in the industry, it be came apparent that the most widely used technique was a tool termed DEA “Data Envelopment Analysis”. It is from this observation that we thirdly identify performance indicators on which the productivity and efficiency levels of operations within the terminal process were going to be determined and finally, by using the DEA approach we were able to conduct a macro level analysis on the relative technical efficiency amongst 4 terminals.

In extension to the DEA we implored on the benefits of conducting a more micro level analysis between 2 terminals, and conducted the OEE “operational Equipment Efficiency” analysis from where we were able to observe the direct operational implications of how the level of productivity and efficiency affect the terminals production outcomes

The DEA approach has earlier been defined to be an application of linear programming used to measure the relative efficiency of operating units (terminals) with the same goals and objectives. This approach was particularly geared towards determining amongst the selected sample of DMUs, which facilities were performing inefficiently in comparison to the others. Within the scope of the applied methodology, it was necessary to select terminals that not only performed the same functions, but also in this case handled the same class of cargoes. Since our study alludes performance level being a function of outcome (volume quantity) within a set interval, it is pertinent to mention that different cargoes have different handling processes with different handling times, as such it will be somewhat misleading to compare two terminals that handle different products on the basis of their volume outputs over a selected time period. For this reason an initial panel of 84 DMUs was drastically reduced to only 4 terminals being able to be subjected to this benchmarking exercise and were compared based on interactions between selected input and output variables. This included their physical assets, handling and transfer equipments and received product volumes.

The DEA model after being executed proved to be relatively ineffective in measuring efficiency levels of liquid bulk terminals. While its inconclusive outcome could be attributed to the limited number of DMUs analysed, there is cause to believe that the reason why limited literature if at all any has been performed on using this technique to benchmark liquid bulk terminals is as a result of high asset specificity.

From our literature review, we came across extensive works performed on using the DEA to measure container terminals and ports performance levels and nothing on liquid bulk terminals. Even though a lot of similarity supported the idea that this technique could be modified and adopted to suite the desired sector, there was a major oversight on the issue of asset specificity. Container terminals and ports alike are assets that are built with intentions of handling volatile market fluctuations, bulk terminals on the other hand are specific projects, built to handle the direct supply and demand need of identified invested partners usually between refineries and International Oil Companies operating in upstream (exploration and production) and downstream (refined product distribution) activities.

Extension of the benchmarking attempt to the OEE approach however yielded some workable outcomes. The OEE as mentioned earlier is defined as a more micro level approach to benchmarking usually focused on the efficiency level of equipments, sub-systems and sub-processes within the major activities of the terminal. To execute this we picked our target terminal 'atlas cove jetty' and our benchmarking terminal, 'Horizon Fujairah' and analysed key equipment performance and sub-process efficiency levels. From running these micro level analysis we were able to see variations in performance in sub activities like the berth utilization rate, the vessel turn around times, the terminal transfer pipeline capacity and integrity and the average pumping rates at the facility. We were thus able t not only infer where our target terminal was inefficient but also proffer reasons as to why this was the scenario and offer possible solutions to remedy the situation.

The OEE approach has thus proven to be a relatively more effective in comparing performance levels of liquid bulk terminals. However after speaking with industry experts and combining their opinion of ideal terminal performance levels with our outcome we were able to conclude that our target terminal is indeed performing under ideal capacity and has a lot of room for improvement.

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Appendices

I. Liquid Bulk terminals, location, product type and services

Table 19: Panel of 84 Terminals from which Sample Terminals were selected

	Terminal Name	Country	Product types	Services
	Europe, Middle East & Africa			
1	Vopak Terminal ACS- Antwerpen	Belgium	Multiple Products	Multiple
2	Vopak Terminal Eurotank NV	Belgium	Multiple Products	Multiple
3	Vopak Chemical Terminals Belgium NV	Belgium	Multiple Products	Multiple
4	AS Vopak E.O.S. -Tallinn	Estonia	Multiple Products	Multiple
5	Vopak Terminal Hamina	Finland	Multiple Products	Multiple
6	Vopak Terminal Mussalo- Kotka	Finland	Multiple Products	Multiple
7	Vopak Dupeg Terminal Hamburg	Germany	Multiple Products	Multiple
8	Vopak Terminal Amsterdam Petroleumhaven	Netherlands	Multiple Products	Multiple
9	Vopak Terminal Amsterdam Westpoort	Netherlands	Refined Petroleum Product	Dedicated Service
10	Vopak Terminal Eemshaven – Groningen	Netherlands	Multiple Products	Multiple
11	Vopak Terminal Botlek-Noord	Netherlands	Multiple Products	Multiple
12	Vopak Terminal Botlek (Zuid)	Netherlands	Multiple Products	Multiple
13	Vopak Terminal Chemiehaven	Netherlands	Multiple Products	Multiple
14	Vopak Terminal Europoort	Netherlands	Multiple Products	Multiple
15	Gate Terminal - Rotterdam	Netherlands	Multiple Products	Multiple
16	Vopak Terminal Laurenshaven	Netherlands	Refined Petroleum Product	Dedicated Service
17	Maasvlakte Olie Terminal – Rotterdam	Netherlands	Multiple Products	Multiple
18	Vopak Terminal TTR – Rotterdam	Netherlands	Multiple Products	Multiple
19	Vopak Terminal Vlaardingen	Netherlands	Multiple Products	Multiple
20	Vopak Terminal Vlissingen	Netherlands	Multiple Products	Multiple
21	Vopak Agencies	Netherlands	Multiple Products	Multiple

22	Rotterdam – Vondelingenplaat	Netherlands	Multiple Products	Multiple
23	Vopak Terminal Algeciras	Spain	Multiple Products	Multiple
24	Vopak Terminal Terquimsa Barcelona	Spain	Multiple Products	Multiple
25	Vopak Terminal Terquimsa Tarragona	Spain	Multiple Products	Multiple
26	Vopak Terminal Gavle	Sweden	Multiple Products	Multiple
27	Vopak Terminal Gothenburg	Sweden	Multiple Products	Multiple
28	Vopak Terminal Malmo	Sweden	Multiple Products	Multiple
29	Vopak Terminal Sodertalje	Sweden	Multiple Products	Multiple
30	Vopak Terminal London Limited B.V.	U.K	Multiple Products	Multiple
31	Vopak Terminal Teesside Ltd.	U.K	Multiple Products	Multiple
32	Vopak Terminal Windmill Ltd.	U.K	Multiple Products	Multiple
	Middle East & Africa			
33			Multiple Products	Multiple
34	Sab Tank- Al Jubail	Saudi Arabia	Multiple Products	Multiple
35	Sab Tank – Yanbu	Saudi Arabia	Multiple Products	Multiple
36	Vopak Horizon Fujairah Ltd	Saudi Arabia	Refined Petroleum Product	Dedicated Service
37	Vopak Terminal Durban	South Africa	Multiple Products	Multiple
38	Atlas cove jetty	Nigeria	Refined Petroleum Product	Multiple
39	Bonny Export Terminal	Nigeria	Multiple Products	Multiple
40	Escravos terminal – Warri	Nigeria	Multiple Products	Multiple
	Asia/Australia			
41	Vopak Sealink Terminal (Dongguan) Co. Ltd.	China	Multiple Products	Multiple
42	Vopak Terminal Ningbo Co. Ltd.	China	Multiple Products	Multiple
43	Vopak Terminal Shandong Lanshan	China	Multiple Products	Multiple
44	Vopak Shanghai Caojing	China	Multiple Products	Multiple
45	Vopak Ethylene Terminal Tianjin Co. Ltd.	China	Multiple Products	Multiple
46	Vopak Nanjiang Petrochemicals Terminal Tianjin Company Ltd.	China	Multiple Products	Multiple
47	Vopak Terminal Tianjin Lingang	China	Multiple	Multiple

			Products	
48	Xiamen Paktank	China	Multiple Products	Multiple
49	Vopak Terminal SDIC Yangpu Co. Ltd.	China	Multiple Products	Multiple
50	Vopak Terminal Zhangjiagang	China	Multiple Products	Multiple
51	Vopak Terminals Kandla (CRL Terminals)	India	Multiple Products	Multiple
52	Vopak Terminal Jakarta	Indonesia	Multiple Products	Multiple
53	PT Vopak Terminal Merak	Indonesia	Multiple Products	Multiple
54	Nippon Vopak – Kawasaki Terminal	Japan	Multiple Products	Multiple
55	Nippon Vopak – Kobe Terminal	Japan	Multiple Products	Multiple
56	Nippon Vopak – Moji Terminal	Japan	Multiple Products	Multiple
57	Nippon Vopak – Nagoya Terminal	Japan	Multiple Products	Multiple
58	Nippon Vopak – Yokohama Terminal	Japan	Multiple Products	Multiple
59	Vopak Terminals Korea - Ulsan	Korea	Multiple Products	Multiple
60	Kertih Terminals	Malaysia	Multiple Products	Multiple
61	Vopak Terminals Pasir Gudang	Malaysia	Multiple Products	Multiple
62	Vopak Terminal Pengerang Terminal	Malaysia	Multiple Products	Multiple
63	Engro Vopak Terminal Ltd. (50%)	Pakistan	Multiple Products	Multiple
64	Vopak Singapore – Banyan Terminal	Singapore	Multiple Products	Multiple
65	Vopak Singapore - Penjuru Terminal	Singapore	Multiple Products	Multiple
66	Vopak Terminals Singapore – Sakra Terminal	Singapore	Multiple Products	Multiple
67	Vopak Singapore – Sebarok Terminal	Singapore	Multiple Products	Multiple
68	Thai Tank Terminal	Thailand	Multiple Products	Multiple
69	Vopak Vietnam Co. Ltd.	Vietnam	Multiple Products	Multiple
70	Vopak Terminal Darwin	Australia	Multiple Products	Multiple
71	Vopak Terminals Sydney – Site A	Australia	Multiple Products	Multiple
72	Vopak Terminals Sydney – Side B	Australia	Multiple Products	Multiple
	North America			
73	Vopak Terminals – Hamilton, Ontario.	Canada	Multiple Products	Multiple
74	Vopak Terminals – Montreal, Quebec	Canada	Multiple	Multiple

			Products	
75	Vopak Terminal Deer Park Inc.	USA	Multiple Products	Multiple
76	Vopak Terminal Galena Park Inc.	USA	Multiple Products	Multiple
77	Vopak Terminal Long Beach Inc.	USA	Multiple Products	Multiple
78	Vopak Terminal Los Angeles Inc.	USA	Multiple Products	Multiple
79	Vopak Terminal Savannah Inc.	USA	Multiple Products	Multiple
80	Vopak Terminal North Wilmington Inc.	USA	Multiple Products	Multiple
81	Vopak Terminal South Wilmington Inc.	USA	Multiple Products	Multiple
	Latin America			
82	Vopak Brasil – Iiha Barnabe Terminal	Brazil	Multiple Products	Multiple
83	Uniao/Vopak Armazens Gerais	Brazil	Multiple Products	Multiple
84	Vopak Chile- San Antonio Terminal	Chile	Multiple Products	Multiple

II. Operational Summary for Horizon Fujairah Terminal

Table 20: Horizon Fujairah, March 2012 Operation Summary

Year 2012	Number of Calls	Average Berth Time per berth (Hours)	VTAT-Vessel Turnaround Time (Hours)	Berth Occupancy	
Berth 1	20	565.74	28.29	76.04	
Berth 2	19	585.97	30.84	78.76	
Berth3	9	213.01	23.67	28.63	
Berth 4	24	431.00	17.96	57.93	
Berth 5	16	551.97	34.50	74.19	
Berth 6	14	560.01	40.00	75.27	
Berth 7/ SPM	11	535.98	48.73	72.04	
		SUMMARY			
Monthly total Number of calls	**Monthly Average berth time**	**Monthly Average VTAT**	**Monthly Average Berth Occupancy**	**Monthly discharged volume**	**Monthly average pump rate**
113	**491.95**	**32.00**	**66.12**	**1,198,736**	**2436.683**

(Calculated by author)

Table 21: Horizon Fujairah, August 2012 Operation Summary

Year 2012	Number of Calls	Average Berth Time per berth (Hours)	VTAT-Vessel Turnaround Time (Hours)	Berth Occupancy	
Berth 1	15	621.02	28.51	72.3	
Berth 2	17	498.03	32.56	67.83	
Berth3	17	301.99	24.92	48.21	
Berth 4	26	417.98	15.62	53.45	
Berth 5	18	478.99	41.41	67.79	
Berth 6	12	530.32	32.39	53.02	
Berth 7/ SPM	15	573.03	39.51	70.55	
		SUMMARY			
Monthly total Number of calls	**Monthly Average berth time**	**Monthly Average VTAT**	**Monthly Average Berth Occupancy**	**Monthly discharged volume**	**Monthly average pump rate**
120	**488.77**	**30.51**	**65.69**	**1,286,752.39**	**2632.65.**

(Calculated by author)

III. Operational Summary for Atlas Cove Jetty

Table 22: Atlas cove, March 2012 Operation Summary

Year 2012	Number of Calls	Average Berth Time per berth (Hours)	VTAT- Vessel Turnaround Time (Hours)	Berth Occupancy	
Berth 1	5	487.32	97.46	65.50	
Berth 2/ SPM	6	467.23	77.87	62.80	
		SUMMARY			
Monthly total Number of calls	**Monthly Average berth time**	**Monthly Average VTAT**	**Monthly Average Berth Occupancy**	**Monthly discharged volume**	**Monthly average pump rate**
11	**477.28**	**87.67**	**64.15**	**166,708**	**349.29**

(Calculated by author)

Table 23: Atlas cove, August 2012 Operation Summary

Year 2012	Number of Calls	Average Berth Time per berth (Hours)	VTAT- Vessel Turnaround Time (Hours)	Berth Occupancy	
Berth 1	3	624.22	208.07	83.90	
Berth 2/ SPM	3	437.47	145.82	58.80	
		SUMMARY			
Monthly total Number of calls	**Monthly Average berth time**	**Monthly Average VTAT**	**Monthly Average Berth Occupancy**	**Monthly discharged volume**	**Monthly average pump rate**
6	**530.84**	**176.95**	**71.35**	**137,423**	**258.88**

(Calculated by author)