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EFFICIENCY ASSESSMENT OF OFF-DOCK CONTAINER TERMINALS AT TEMA PORT USING DATA ENVELOPMENT ANALYSIS (DEA)

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***Abstract*: The study looked at four off-dock terminals at Tema port using Data Envelopment Analysis to determine and analyze the efficiency changes using panel data from 2015-2018. The DEA model has commonly been used in the port sector. DEA window analysis is used to determine the efficiency of ports and to observe the possibility of changes in the port efficiency over time. labour, forklifts, reach stackers, trucks, and the terminal storage area were employed as input variables and container throughput as an output variable. Inclusion A.P Moller Terminal showed the highest efficiency result event its labour variable was less efficient compared to other selected terminals understudy. On the other hand, Tema Container terminal found to be the least efficient port obtaining the lowest average efficiency rating over the period under study. Findings from this study showed that some terminals had excess equipment as well as excess labour. And for these terminals to maintain constant and improving efficiency, there would need to cut down some labour and also lease out unused equipment.**

***Keywords:* Data Envelopment Analysis, Efficiency, Off-dock Container Terminals, (DEA), Performance, Windows Analysis**

1. INTRODUCTION

Ports play an important role in a nation's economic growth. In recent years, countries find themselves putting measures in place to ensure the growth of their ports to international standards since this will have a huge impact on the economies of these countries. According to UNCTAD (2017), about 80% of global trade is made by sea and about 70% is a value carried onboard vessels and transported to seaports worldwide making it impossible to underemphasize the importance of maritime transportation of trade and development. Changes in world trade and the shipping environment have created an ever-increasing competition among ports all over the world to serve as the hubs to and from their respective regional areas and to have the due advantages as the bigger and better ports.

The port of Tema is the largest in Ghana. Situated on the eastern coast of the country, it stretches over a 3.9 million square meters of land area. The port receives an average of over 1650 vessel calls per year. These comprise container vessels, general cargo vessels, tankers, Ro-Ro and cruise vessels amongst many others. 85% of Ghana's trade is done through the ports with shipping routes and vessel calls to and from all continents through both direct and transhipment service. Set within the industrial city of Tema and 30km from the capital of Ghana, the port environs serve as a logistic point for activities of inland clearance depot(ICD), warehouses, transport and haulage companies, freight forwarders, factories and related service centres (GPHA, 2016).

One reason for the advancement of the port is the container terminal. These terminals enable the movement of more goods into the country and also a suitable transit point for neighbouring cities. The container as an essential part of the unit-load concept has achieved undoubted importance in international sea freight transportation.

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Off-dock container terminals are container terminals situated outside the port premises. Most ports around the world have encountered various stages of evolution of cargo packaging from the times of general cargo transported in sacks and on pallets to the modern method of containerization through standardization and mass-application of the shipping container in global transportation services. With the development of international trade, container terminals play a more and more important role within the global supply chains in general and the worldwide sea cargo transportation system in particular (Song & Cui, 2011). With growing international sea traffic and changing technology in the maritime transport industry (containerization, integrated logistics services, etc.), seaports are coping with mounting pressures to upgrade and provide cutting-edge technology (Dang, 2012). Due to various advancements, these terminals one way or the other might have gotten their works cut out or improved. This study, therefore, seeks to assess the efficiency of these off-dock container terminals.

2. LITERATURE REVIEW

2.1. Container Terminal

According to Leschine(2006), the increasing competitiveness of the marine transportation industry has brought about demands that container terminal productivity is improved. There have been significant changes over the last 30 years to the interdependence of ports and cities. The relationships between them have been influenced by many factors such as changes in the world transport system, development of container shipping, development of global supply chains and the increasing demand for logistics services (Urbanyi-Popiolek & Klopott, 2016).

A container terminal is a facility where containers are stored for clearance or to be transshipped between different transport vehicles, for onward transportation. Containers brought about these terminals. Some primary reasons for the advancement of the containers were to enable large amounts of goods to be carried, making it easier to transport more, and also to reduce the damage caused as a result of using pallets and wood-like structures for transportation. The evolvement of these containers brought about the creation of the container terminals. These terminals are home to containers awaiting delivery, a temporary place of storage for transshipping goods, exports and empty containers. According to the Port Authority of New York and New Jersey (2014), the first-ever container port was opened on the 15th August 1962. In recent years, methodological advances regarding container ports operations have considerably improved (Stahlbock, 2007). There are two types of container terminals, which are the On-dock container terminal (ONDCT) and the Off-dock container terminal(OFDCT).

According to Manaadiar (2015), On-dock container terminals are container yards situated within the port premises. He explains how containers are off-loaded from ships and moved to the container yard, stored there till the receiver takes delivery, goes ahead to say an off-dock terminal is only different from an on-dock solely because of their geographical locations, size of operations, handling equipment used, but all are of a similar function. Off-dock terminals are situated outside the port premises. For this study, the focus is on Off-dock

2.2. Container Terminal Operations

Container terminal operations are activities for transferring containers between modes of transport and provide a package of activities/services to handle and control container flows from vessel to landside and vice versa. The main activities that make up the traditional container terminals (On-dock Container Terminal) operation can be broken down into the;

- Berth operations
- Yard operations
- Gate operations

According to Manaadiar (2015), a typical flow of container involves the movement of goods from the port through road, straight to the ODCT, where at this point customers makes the necessary checks before the container is released then to the receiver.

2.3. Efficiency Measurement of Container Terminals

According to Ortega (2013), Efficiency is defined as the "degree of optimization of the results obtained about the resources used". Container terminals are facilities for the storage of goods and transferring containers between different

modes of transport and provide a package of activities/services to handle and control container flows from vessel to railroad or road, and vice versa.

Fourgeaud (2000) implied that container terminals performance depends on:

- Ratio loaded vs. unloaded containers: empty boxes are not always included in the port statistics (they may be considered as other tare weights) but have to be handled;
- Unproductive moves, i.e., the handling of all the containers that do not have to be unloaded but have to be moved: mostly empty and light containers and those containing hazardous materials, loaded on top of the deck;
- The level of automation of the gantry-cranes; one of the limiting phases of the handling cycle is the time spent positioning accurately the spreader on a container (loading), or the container on a trailer, a MAFI trailer (specialized equipment used to shift containers within port limits) or a chassis manoeuvring on the apron (unloading).

Most modern gantries are automated and equipped with anti-sway devices, and now, the problem is more the capacity to deliver or remove containers without delaying ship-to-shore operations.

- The average weight of containers and the proportion of containers requiring special attention: flats, liquid bulks, refers etc.; and the mix of containers of various sizes: 20'/40'/45' which will require to manoeuvre or change spreaders;
- Commercial constraints; most of the lines calling at a port may have similar commercial constraints, leading to unevenly distributed calls.

Efficiency has been used by various authors, with numerous methodologies accompanied with them. Ortega and Chavez (2013) in using the DEA, with variable inputs (dock length and number of employees) and outputs (number of TEUs handled annually), identified the DMUs that are considered as a reference for the inefficient DMUs, having similar characteristics. Kennedy, Lin, Yang, & Ruth (2011) using the Stochastic Frontier Production Function with variable inputs as (quay length, terminal area, number of cranes) and variable outputs as (total throughput) analyzed that All beta was statistically significant, showing that the three inputs: total quay length, terminal area and quay cranes, have significant effects on production, consistent with results. Park & De (2004) using the DEA-CC and DEA-BCC, with input variables as (berthing capacity, cargo handling capacity, profitability and revenue) and output variables as (berthing capacity, cargo handling capacity, profitability and revenue) from the study discovers alternative DEA is a suitable way for the evaluation of the overall efficiency of seaports. Cullinane, Song, & Wang (2005) using the DEA CCR and DEA BCC with inputs variables as (terminal length, terminal area, quayside gantry, yard gantry, straddle carrier) and output variables as (container throughput) provided indebt discussion on port privatization, providing a factual explanation between privatization and relative efficiency within the container port environment.

Martinez-Budria, Diaz-Armas, & Ibanez (1999) using the DEA-BCC with input variables as (number of employees, quay length, surface area, labour cost, capital cost, number of passengers) and output variables as (containerized cargo, general bulk cargo, liquid cargo, solid cargo bulk, income), the study resulted in the analysis of the efficiency in the bulk services of Spanish ports payment are and payment for private users. Sala, Molinos-Senante & Medal (2004) using the Non-Radial DEA Model with input variables as (quay length, surface terminal, number of cranes and number of employees) and output variables such as number of full container 20, number of full container 40, number of empty 20, number of empty 40 analyzed that analysis from this proves Spanish ports have a greater average level of efficiency and is expected to rise around 40.20% providing all the ports operate on the efficient frontier.

2.4. Data Envelopment Analysis (DEA)

According to Cherchye & Hennebel (2014), DEA is a non-parametric technique which is broadly employed for analyzing the efficiency of productivity in the public and private sector and also in academia. According to vanDyck (2015), the principal of this statistical method is based on two significant pairs of numerous variables called inputs and outputs. The DEA models can be classified according to;

• The type of efficiency measure that provides: radial and non-radial models.

• The orientation of the model: input-oriented, output-oriented or input-output oriented.

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• The types of returns to scale production technology characterized understood as to how the factors of production can be characterized by the existence of returns to scale: constant or variable to scale (Ortega, 2013). According to Andersen (1993), recent years have brought about a great number of scholarly efforts dedicated to the advancement of efficiency measures, which determines whether the Decision-Making Unit(DMU) is operating near the frontier of its product set. The generalization of single output to a single input is a classical engineering science ratio, definition of multiple output and multiple inputs without requiring preassigned weights (Charnes, 1978a,1979).

According to William W. Cooper (1999), DEA makes use of techniques such as mathematical programming which handles a greater number of variables and relations (constraints), thus flexibility in the requirements often encountered when there's a limitation in choosing only but a few inputs and outputs. In the past decade, DEA has been employed by all and sundry for the evaluation of container port performance (Hung, Lu, & Wang, 2009). The DEA technique is used in the comparison of several units. According to Sherman & Zhu (2006), there are four types of DEA information, which are;

DEA deals with the comparison between services, taking into consideration the resources used and service provided. DEA technique calculates the amount used and type of resources saved for the achievement by the turning of inefficiency units into efficient units. DEA notices specific changes in inefficient services. These changes usually make the efficient unit performance approach the overall unit performance.

Information is received by management about service unit performance used in helping the transfer system and managerial expertise from the less managed, relative efficiency units to the inefficient ones.

The introduction of the first DEA term which made use of single time hypothesized cross-section data in the performance of container port research to evaluate efficiency in container port was done by (Roll, 1993). The application of DEA and FDH (Free disposal hull) was used by (Cullinane K. D., 2005), for the estimation of the performance of 57 international ports. Martinez-Budria (1999), assessed the efficiency of 26 Spanish ports using panel data from 1993-1997.

The usefulness of DEA is how it's able to deal assess the efficiencies of individual firms.

3. METHODOLOGY

DEA which is widely used is made up of two frequently used models; these models are broadly used for the diversity of problem-solving. These models are the DEA-CCR named after Charnes and Cooper and Rhodes, (Charnes A., 1978) also DEA-BCC (Banker, Charnes and Cooper) (Banker, 1984). The former is based on CRS (Constant Return scale) and the other is the VRS (Variable Return Scale). Other models used are the FDH model, SBM model, EBM model, RBM model, NEBM.

The multiple inputs and outputs used in the linear programming measurements of the efficiency of multiple decision making are referred to as Data Envelopment Analysis (Yishi Zhang, Xiong, Wang, & Zhang, 2014). According to Pjevcevic D. B., (2014), research papers can be divided into two groups, one group being studies analyzing cross-sectional data and the other panel data. (Charnes A. C., 1978), illustrates a model which shows the relative efficiency score of the Decision-Making Unit (DMU) in DEA;

$$\max \frac{\sum_{k=1}^{s} u\ kykp}{\sum_{j=1}^{m} vixip} \qquad 1$$

$$\text{subject to } \frac{\sum_{k=1}^{s} UkYkp}{\sum_{j=1}^{m} ViXji} \leq 1 \forall i, \text{and} Uu^{K} \geq \forall k, j \qquad 2$$

Where;

Y_{ki}=amount of output k produced by DMU i

X_{ji}=amount of input j utilized by DMU i

U_k=weight given to output k

V_j=weight given output j

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Converting the formula above to linear Programming from DEA-CCR;

$\max \sum_{k=1}^{s} U_K Y_{kp} = \Theta_p$ 3

subject to $\sum_{j=1}^{m} V_j Y_{jp} = 1$ 4

$\sum_{k=1}^{s} U_k Y_{ki} - \sum_{j=1}^{m} V_j Y_{ji} \leq 0 \; \forall i, U_K, U_j \geq 0 \; \forall k, yj$ 5

Converting the computation above to Linear Programming form of DEA-BCC

$\max$ s.t $\sum_{j=1}^{n} \lambda_j X_{ij} + S^1 = X_{ir} i = 1,2 \ldots, m;$ 6

$\Theta_k Y_{ij} - \sum_{j=1}^{n} \lambda_j Y_{ij} + S^0 = 0, r = Z, \ldots, s;$ 7

$$\sum_{j=1}^{m} \lambda_{ij} = 1$$

$\theta_k \geq 0; \lambda \geq 0, f = 1, .., n$ 8

Where $\Theta_k$is the efficiency of the k^{th} DMU.

To obtain the variations in the performance of these off-dock terminals in this study, windows analysis is being used. According to A.Charnes (1984), the DEA windows analysis introduced is a change in the formal approach that handles cross-section and time-varying data to measure diverse outcomes. This principle helps in the treatment of decision-making units (DMU) as separate units and different periods. According to Yuan (2017), DEA windows analysis gains its grounds on a dynamic perspective, considering the same DMU in different periods as totally different DMUs. Pjevcevic, Radonjic, Hrle, & Colic, (2012), expresses one important advantage of the windows analysis as that, it increases the number of units for evaluation and in effect the discriminatory method power of the method. According to vanDyck (2015), in applying the DEA windows analysis, DEA assesses the performance of all DMU`s in the same window and the efficiency of each DMU would be entered into the right window in the table. For this study, the DEA Solver programme would be used. The steps in using the windows analysis are as follows;

3.1 Sample population and variables

Off-dock terminals are container terminals situated outside the port premises. For this study four terminals where chosen. These terminals are the Tema Bonded Terminal, Tema Container Terminal, Africa Coastal Services and A.P. Moller Terminal.

APMT is owned by the Maersk group was founded in 2001 and is located in Tema and also known as A.P. Moller Terminal is considered one of the largest terminal operators.

Tema Container Terminal (TCT) is an inland container depot which is privately owned and operated. TCT, as a result, is the biggest privately-owned terminal in Tema, this terminal is as a result of a joint venture between Antrak Ghana ltd and SDV Ghana ltd.which is owned by Bolloré Africa Logistics and was incorporated in the year 2000, located in Tema.

African Coastal Services (ACS), a multipurpose container terminal is located along the harbour road and strategically complements the GPHA`s plan of becoming a gateway port to Africa. ACS is owned by Bosco Ngan and was incorporated on the 3rd of March 2004.

Tema Bonded Terminal (TBT), was founded by Enock Adu-Arthur and is located at Tema harbour. All these terminals are close to the Port of Tema (at most two kilometres) from the Port.

Input and output variables used is of great essence when using the DEA model, this is usually for critical and clear analysis. Four off-dock container terminals were chosen for this study, taking into consideration a clear and detailed analysis by using the DEA method these variables are of most importance.

The output variables used in the assessment of the efficiency of these terminals is the Annual Container Throughput. According to the Bureau of Transportation Statistics, (2017), TEU is used as a measure throughout the world to determine container movement and also the capacity of cargo ships. The input variables on which this study is based are on labour,

forklifts, reach stackers, trucks, and the terminal storage area. These variables were chosen based on their importance to terminal operations.

Container throughput is the number of containers handled over a while, further expressed as the standard measure for the productivity of a seaport. Being the primary basis for which terminals are compared, container throughputs are volumes of containers received by a terminal for a particular time. Usually, for variations in efficiency, panel data is taken in other to determine the efficiencies of these terminals.

Labour denotes the person working on these terminals. These people run the day to day works in these terminals that are the people that help in the processing of containers from the time of arrival to its departure. According to the Cambridge Dictionary (2019), Labor is said to be the workers themselves.

Forklifts also called a lift truck are trucks used in conveying or lift materials from one place to the other over a short distance. Forklifts come in different tons but for purposes of this study, 3 tons would be used. This is so because the four off-dock terminals used in this study all have 3 tons, and that is what they have in common and thus the reason for the 3 tons. According to Mheda, (2013), forklifts have become an absolute necessity in the warehousing and terminal industry.

Reach stackers are equipment used in the port alongside the terminal for handling cargo, this equipment can transport cargo quickly over a short distance. Reach stackers aid in piling containers in terminals in sections depending on its accessibility. This equipment is bigger than forklifts. Also, Reach stackers handle laden or stuffed containers whilst unladen containers are handled why empty handlers.

Trucks are vehicles in the terminals designed to transport containers from one place to the other. These trucks could take forty-foot containers as well as a twenty-foot container. Trucks are used by these terminals for transhipment of goods from the terminal to point of destination and also aids in delivery.

Empty Handlers are very large forklifts used in transporting empty containers from one place to the other. Even though its primary purpose is to transport empty containers, the handler can be used in other sections if the need arises.

Terminal Storage Area is a space designated for the storage of cargo, from which these containers are transported to the end-user.

4. DATA AND ANALYSIS

The output used for this research is container throughput. The container throughput trend can be found in figure 4.1. In this figure, there's a clear indication of Tema Container Terminal having the highest container throughput amongst others which has had an increasing trend since 2015. Slight throughput fluctuations are characterized by the other terminals.

Figure 4.1 shows the annual throughput from (2015-2018) for the selected terminals; data presented for Tema Container terminal had an increasing efficiency. For Tema Bonded terminal, 2015-2017 had an increase in throughput but a fall in 2018. A.P Moller terminal had an increase in throughput from 2015-2017, but also a fall in 2018. Finally, ACS experienced a fluctuation in throughput from 2015 to 2016 but experienced an increase in throughput from 2017-2018. Figure 4.1 is a chart indicating container throughput for terminals from 2015-2018 respectively.

Figure 4.1: Container Throughput

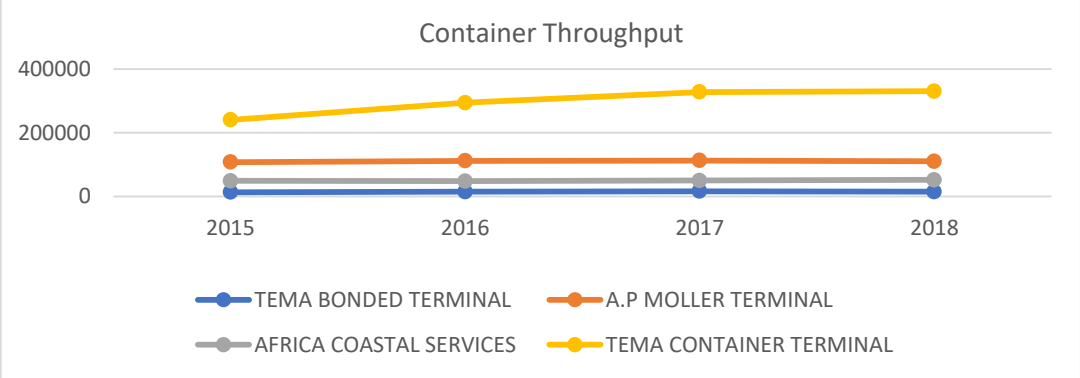

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Table 4.1; Inputs and Output variables for selected off-dock terminals

TERMINALS	VARIABLES	2015	2016	2017	2018
TEMA BONDED TERMINAL	CONTAINER THROUGHPUT	13664.00	15064.00	16685.00	14853.00
	LABOR	61.00	60.00	59.00	59.00
	FORKLIFTS {3}	3.00	3.00	3.00	3.00
	REACHSTACKERS	3.00	3.00	4.00	4.00
	TRUCKS	6.00	6.00	8.00	8.00
	EMPTY HANDLERS	2.00	2.00	2.00	2.00
	TERMINAL STORAGE AREA	30000.00	30000.00	30000.00	30000.00
A.P MOLLER TERMINAL	CONTAINER THROUGHPUT	107762.00	111766.00	113034.00	110646.00
	LABOR	38.00	38.00	37.00	33.00
	FORKLIFTS {3}	3.00	3.00	3.00	3.00
	REACH STACKER	5.00	4.00	4.00	4.00
	TRUCKS	14.00	12.00	10.00	7.00
	EMPTY HANDLERS	0.00	0.00	0.00	0.00
	TERMINAL STORAGE AREA	50000.00	50000.00	50000.00	50000.00
AFRICA COASTAL SERVICES	CONTAINER THROUGHPUT	49104.00	48281.00	49904.00	52000.00
	LABOR	69.00	70.00	80.00	97.00
	FORKLIFTS {3}	2.00	2.00	1.00	2.00
	REACHSTACKERS	2.00	3.00	3.00	4.00
	TRUCKS	40.00	45.00	45.00	54.00
	EMPTY HANDLERS	2.00	2.00	2.00	1.00
	TERMINAL STORAGE AREA	52000.00	52000.00	52000.00	52000.00
TEMA CONTAINER TERMINAL	CONTAINER THROUGHPUT	240581.00	294223.00	328330.00	330840.00
	LABOR	200.00	200.00	200.00	200.00
	FORKLIFTS {3}	4.00	4.00	4.00	4.00
	REACH STACKER	6.00	6.00	6.00	6.00
	TRUCKS	35.00	35.00	35.00	35.00
	EMPTY HANDLERS	5.00	5.00	5.00	5.00
	TERMINAL STORAGE AREA	105000.00	105000.00	105000.00	105000.00

Table 4.1 presents inputs such as reach stackers, trucks, empty handlers, forklifts which were chosen based on the direct contact affecting how well containers are sent out or received and in effect taking into account the turnaround time. Inputs used plays a critical role in analyzing the efficiency of container ports or terminals. The terminal area plays a significant role in this analysis, as it clearly outlines the total storage area of where these containers are stored. Forklifts aid in lifting large cargo loads from one place to the other and considered a vital piece of machinery. Containers are transported by road with trucks. Trucks play a vital role in the supply chain process and also the backbone of trade. The empty handlers' primary purpose is to transport empty containers, which are unladen containers from one place to the other. A reach stacker is the most commonly used equipment in the port. Reach stackers help in transporting laden containers from one location to a designated area. These types of equipment are used in this research because of their frequent usage in the terminal.

The windows analysis with panel data is used to determine efficiency over time, thus preventing seasonal irregularities inefficiency that arises from using cross-sectional data vanDyck (2015). Variables not well defined may lead to misleading or wrong assumptions about terminal efficiency. Container throughput, in turn, was chosen because it remains the primary basis upon which container terminals are compared.

Results found in table 4.2, consists of the summary statistics for off-dock terminals. Table 4.3, consists of the windows analysis results. Table 4.4, also indicates the efficiency ranking for the terminals.

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Table 4.2: Summary Statistics for Sample Off-Dock Container Terminals

	CONTAINER THROUGHPUT (TEUs)	LABOR	FORKLIFTS	REACHSTACKERS	TRUCKS	EMPTY HANDLERS	TERMINAL STORAGE AREA
MEAN	118546.06	93.81	2.93	4.06	24.68	2.18	592.50
STANDARD DEVIATION	114549.60	65.46	0.85	1.18	17.13	1.86	28690.30
MINIMUM	136.64	33.00	1.00	2.00	6.00	0.00	300.00
MAXIMUM	3308.40	200.00	4.00	6.00	54.00	5.00	1050.00

Table 4.2, shows the summary statistics of data used. For both inputs and outputs, the mean mark is taken, Standard deviation, the minimum and also the maximum.

Table 4.3: Windows Analysis Results

	2015	2016	2017	2018
TEMA BONDED TERMINAL	0.99	0.99	0.99	0.99
A.P. MOLLER TERMINAL	0.99	0.99	1.00	1.00
AFRICA COASTAL SERVICES	0.99	0.94	1.00	0.99
TEMA CONTAINER TERMINAL	0.84	0.93	0.99	1.00
Average	0.96	0.97	0.99	1.00

Average	C-Average
0.99	0.99
1.00	1.00
0.98	0.98
0.94	0.94

Table 4.4: Terminal Efficiency Ranking for Off-Dock

TERMINALS	AVERAGE SCORE	RANK
TEMA BONDED TERMINAL	99%	2
A.P. MOLLER TERMINAL	100%	1
AFRICA COASTAL SERVICES	98%	3
TEMA CONTAINER TERMINAL	94%	4

Figure 4.2: Variation by Term

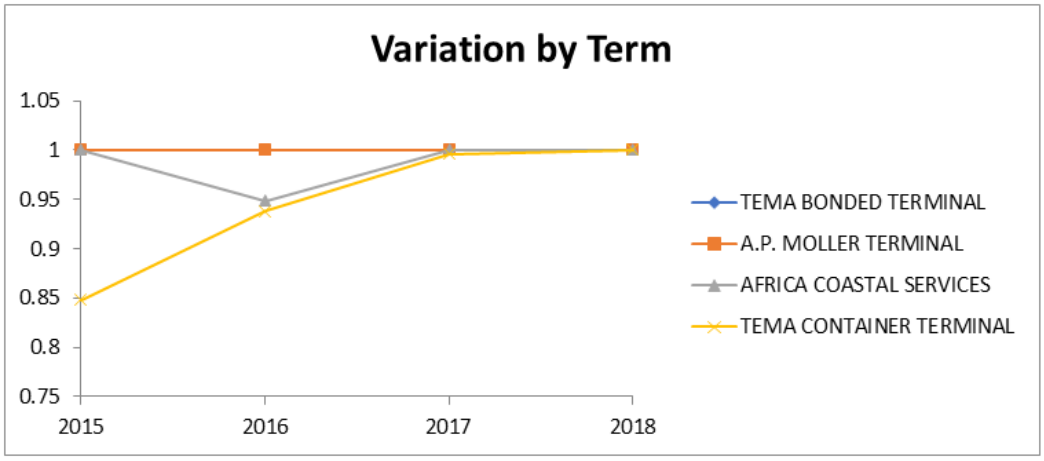

Figure 4.2 presents the terminal efficiency variation by term.

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Table 4.5: Average by Term

TERMINALS	2015	2016	2017	2018
TEMA BONDED TERMINAL	0.99	0.99	0.99	0.99
A.P. MOLLER TERMINAL	0.99	0.99	1.00	1.00
AFRICA COASTAL SERVICES	0.99	0.94	1.00	0.99
TEMA CONTAINER TERMINAL	0.84	0.93	0.99	1.00

Table 4.6: Average Terminal Efficiency through Window

TERMINALS	**2015-2016-2017-2018**
TEMA BONDED TERMINAL	0.9999999054
A.P. MOLLER TERMINAL	0.9999995
AFRICA COASTAL SERVICES	0.9871661
TEMA CONTAINER TERMINAL	0.945448838

Table 4.3, presents results from the windows analysis. From this table, TBTs efficiency was at a constant throughput (0.99) from 2015-2018. APMTs efficiency was constant from 2015-2016 (0.99) but increased from 2017-2018 (1.00). ACS had some fluctuations in efficiency, a decrease from 0.99 in 2015 to 0.94 in 2016,2017 had a comeback (1.00) and in 2018, there was a decrease to 0.99. TCT, unlike other terminals, had a constant increase in throughout the year, with an average rate of increment of 0.04. An average was taken for the respective terminals with their corresponding years as well as their Cumulative-average. The selected window length was 4 to account for a change inefficiency. Averages for all terminals combined were taken with their respective years, and also average was taken for the selected terminals as well as the cumulative average.

Table 4.4 shows the terminal efficiency ranking. From all indications, APMT stands first (1st) by obtaining an efficiency score of 100% with TBT being second (2nd) with an efficiency score of 99%. ACS obtained an efficiency of 98% and thus came third (3rd). Finally, TCT came fourth (4th) with a total efficiency of 94%. Averages by term for the terminals were obtained as well as average terminal efficiency. From results obtain APMT is more efficient followed by TBT, ACS and finally TCT. These results were realized by the combination of the inputs and output.

In *table 4.5*, presents results for the average by term. From this table, TBT on an average was constant throughout the four years. APMT stayed stable from 2015-2016 but rose from 2017-2018. There was an increase in efficiency for the latter years. ACS had fluctuations throughout the years, they recorded an increase in 2017 but in 2018 they decreased. TCT had an increased efficiency from 2015-2018.

Table 4.6, presented the average terminal efficiency through the window. From analysis APMT had a higher average efficiency through the window, TBT followed closely, putting them second to APMT. ACS also followed closely after TBT making them more efficient than TCT. Finally, TCT obtained the least efficiency amongst these terminals.

5. CONCLUSION

From the analysis of the average efficiency, one of the off-dock terminals(APMT) had the highest efficiency equal to 100%, the highest value of average efficiency (1.00). The average efficiencies for the other terminals are lower than the average efficiency for APMT. Apart from APMT which had the least number of labour, all other terminals recorded more than 50 labourers in all the selected years. It was quite important to reduce the number of labourers (input) concerning their throughput. Terminals such as APMT, ACS, TCT had a higher number of trucks; these terminals by way of maintaining constant efficiency and increasing efficiency could rent some idle equipment to other companies in the industry. TBT, which had the lowest of throughput throughout the selected years, could increase that by making sales(marketing), convincing importers and exporters in bringing their containers to their terminals, not forgetting the competition between these terminals. These terminals could improve their operations if they convince the shipping lines enough on how credible they are at delivering their services. Promotions and making sure they use of inputs is equal or proportional to the achieved outputs in these terminals is achieved.

This study which set out to establish the efficiency of off-dock container terminals at the port of Tema was necessitated by the fact that no work has been done on the subject matter in Ghana.

The main aim of this research was to evaluate the efficiency of off-dock terminals at Tema port. A mathematical methodology was used to determine the efficiency as DEA is known for such. This study used four terminals outside the port with the proximity of 2km. This study employing using the DEA methodology employed two significant variables, namely the input and output variable. Several variables such as the labour, forklifts, reach stackers, trucks, empty handlers and terminal storage area were used and container throughput as an output variable. Four terminals were used, using panel data from 2015-2016. Based on the results realized from the DEA windows analysis, APMT obtained an overall efficiency score of 100%, followed closely by TBT with an efficiency score of 99%. ACS obtained an efficiency score of 98% and finally, TCT obtained an efficiency score of 94%. Findings from this study showed that some terminals had excess equipment and if this equipment were leased out it would in a way bring more revenue to these terminals. Some terminals could also increase their throughput by making more sales(marketing), convincing both importers and exporters in bringing their containers, taking into consideration the competitions between these terminals. The performance of TCT adds to the literature that places doubt on the opinion that larger ports or terminals are more efficient.

Terminal Operators for APMT, TCT and ACS should improve the development and maintenance of equipment to lease them to other companies. Which also means apart from the fact that the equipment would be put to use, it would bring move revenue to the terminals.

Terminal Operators for TCT could increase efficiency by promotion and terminal developments, making sales(marketing) and promotion to customers, in turn, increasing their throughput, Convincing the shipping lines enough on how credible they are at delivering their services. These terminals should convince importers and exporters in bringing their containers to their terminals and also, making sure they use of their inputs is proportional to their outputs.

From the study, it was realized some terminals had excess labour, particularly for tasks a few numbers of people can do and achieve the same result. It would be of importance if some of these labour is laid off.

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