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Container Terminal Modeling, Operational Efficiency and Yard Crane Scheduling

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Abstract
According to Steenken, (2004) a container terminal is a facility where cargo containers are transshipped between different transport vehicles, for onward transportation. The transshipment may be between ships and land vehicles, for example trains or trucks, in which case the terminal is described as a maritime container terminal. Alternatively the transshipment may be between land vehicles, typically between train and truck, in which case the terminal is described as an inland container terminal. Maritime container terminals tend to be part of a larger port, and the biggest maritime container terminals can be found situated around major harbours. Inland container terminals tend to be located in or near major cities, with good rail connections to maritime container terminals. (Ibid)
Keyword: Terminal Modeling, Port Operations, Yard Crane

I. INTRODUCTION

Levinson, (2006) postulated that after more than 50 years of containerization, the true impacts of the container remain to be more comprehensively assessed as they turned out to be more far-reaching than initially expected. Alp and Baraçl (2009) posited that in container terminals bottlenecks occurs because of slow yard crane operations. They argued that a container terminal plays an important role in global manufacturing and international business by serving as a multi-modal interface, usually between the sea and land transports. Its three basic functions are as follows: (1) delivering containers to (carriers for) consignees and receiving containers from shippers, (2) loading containers onto and discharging containers from vessels, (3) storing containers temporarily to account for the differences in arrival times of the sea and land carriers. Ece, (2003) intimated that 95 % of the world's mixed goods are transported by containers because of their trustworthy, low prices and the huge amount of transportability.

Stahlbock, (2008) revealed that both maritime and inland container terminals usually also provide storage facilities for both loaded and empty containers. Loaded containers are stored for relatively short periods, whilst waiting for onward transportation, whilst unloaded containers may be stored for longer periods awaiting their next use. Containers are normally stacked for storage, and the resulting stores are known as container stacks. In recent years methodological advances regarding container terminal operations have considerably improved. (Stahlbock, 2008).

Meanwhile Murphy, (2006) posited that throughout most of maritime history, the competitiveness of a commercial port has been collectively determined by its geographic location, its physical characteristics, and its relationship to landside transportation systems and urban centers. And while these factors remain important, today's ports must also integrate and balance a number of dynamic market-place processes—including globalization, containerization, and modern logistics—as they work to define their particular competitive position. These dynamic processes demand that ports improve their operational and managerial efficiencies and overall productivity, whereas earlier challenges could often be met with physical expansion and engineering.

Murphy, (2006) further revealed that port terminals function as nodal points within a global system of ocean and landside modes of transport. As the demand for international trade and global logistic services continues to increase, substantial investments and improvements in both physical capacity and operational efficiencies are necessary to enhance terminal productivity. To meet growing demand, ports need to enhance capacity. Pure physical expansion is constrained by a limited supply of available land, especially for urban center ports, and escalating environmental concerns. In this context, expanding port capacity by improving the productivity of terminal facilities appears to be the only viable solution. How to improve productivity sufficiently to accommodate a large portion of the anticipated increase in container traffic, however, presents a particular challenge to terminal operators and port authorities.

Kim et al, (2004) stated that as trade among countries grows, the performance of container terminals is becoming more important than ever. In particular, after container vessels of more than 10,000 TEU (Twenty-Equivalent Unit) class start on their voyage, the efficiency of discharging and loading containers becomes a question of vital importance for container terminals. The mission of container terminals is to provide customers with high-quality services, and it can be accomplished through improvement of the productivity that depends on efficient equipment, skilled workers, advanced operating systems, and optimal operation schemes. A simulation study is usually carried out to predict the effects on the performance of a container terminal of the application of new elements and schemes are applied, lest such costly ventures fail.

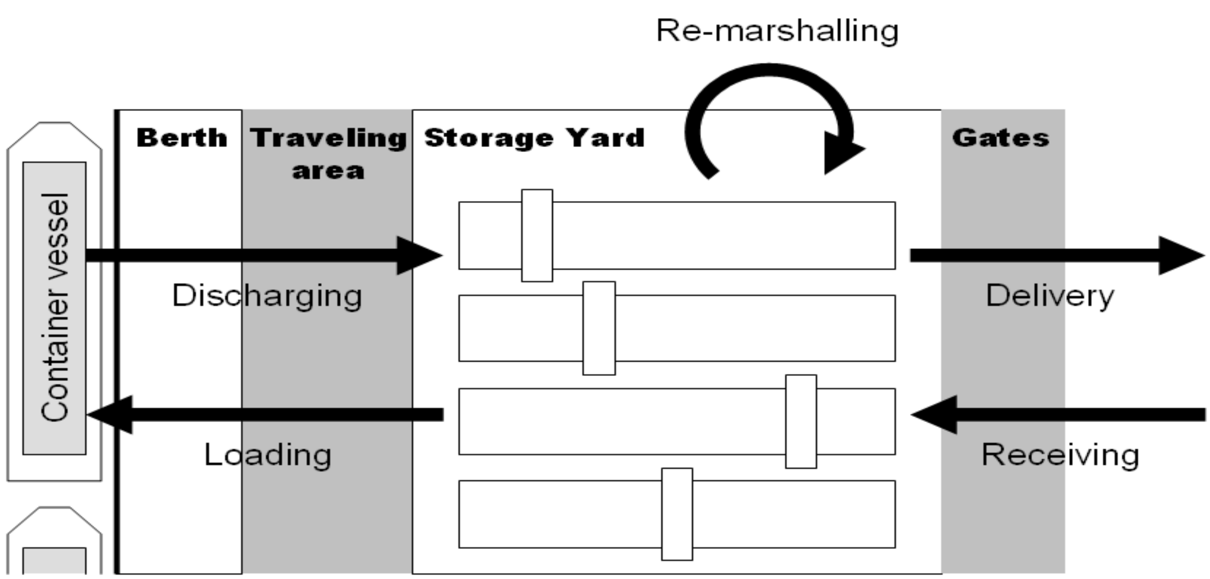
II. LITERATURE REVIEW

A. Container Terminal Modeling

Kim et al, (2004) revealed that container terminals are key hubs of global supply chain networks. The role of a container terminal, as a seamless inter-modal interface between marine and overland transportation, is to stevedore and store containers. Container terminals handle three types of containers: inbound, outbound, and transshipment. Inbound containers are transmitted to container terminals on board container vessels and are delivered to customers by land via external trucks or railway. Outbound containers are received by overland routes and are loaded into container vessels, after which they begin their voyage by sea. Transshipment containers arrive at container terminals via a container vessel and are reloaded to another vessel instead of being delivered by land. Figure 1 is a schematic diagram depicting the types of typical container-handling operation as cited in Kim et al, (2004).

i. Discharging operation: unloading inbound or transshipment containers from a container vessel and placing them in a storage yard
ii. Loading operation: moving outbound or transshipment containers from a storage yard to a berth and loading the containers onto a container vessel
iii. Delivery operation: transporting inbound containers from a storage yard to customers through gates in container terminals
iv. Receiving operation: picking up outbound containers from customers and placing them in a storage yard
v. Re-marshalling operation: arranging containers in a storage yard to minimize rehandling in loading and delivery operations.

Figure 1: Types of typical container-handling operations in container terminals.



Source: Kim et al, 2004

The basic equipments used for handling containers are quay cranes, yard cranes, external trucks, and yard transporters in the traveling area. Examples of yard transporters are yard tractors, shuttle carriers, and AGVs (Automated Guided Vehicles). When a container vessel arrives at a berth, several quay cranes are put in charge of stevedoring containers. While discharging, quay cranes pick up containers from ship bays and load them onto yard transporters. The containers, then, are transferred through the traveling area to blocks in a storage yard and are placed temporarily before they are moved to external trucks for overland transportation or to other container vessels for transshipment. Yard cranes place containers into blocks in a container yard by picking them up from yard transporters. Containers to be exported from land-side arrive at a container terminal by external trucks and are taken to container blocks likewise. The containers are picked up and loaded onto a relevant vessel when the vessel arrives. The notable modeling features of this model are as follows.

First, the particular function of quay and yard cranes is described in detail. The basic function of cranes is to transfer containers and to travel (a crane in a container terminals is not fixed at one location). The function of transferring, again, can be divided into picking-up, vertical/horizontal transference, and release. Specifically, a trolley of a crane moves horizontally and a spreader moves vertically. This simulation model considers all of the above functions. Hence, cranes in the simulation model operate as in real terminals. As a result, the relevant time to perform each function, according to the specific situation, is taken into consideration. Second, the logic for realistic movement of transporters in the traveling area is developed. In the case of most simulation studies related to container terminals, due to its complexity it is not easy to consider transportation details. In this model, however, the tracks for possible routes are predefined and transporters move on the tracks. Though this approach does not solve all of the transportation modeling problems, the key issues in the traveling area, such as congestion, can be partially resolved (Kim et al, 2004). Third, each container either in a vessel or a storage yard is treated as a concrete object in the simulation model. Because abundant containers have to be processed in container terminal simulation, the specific attributes of containers, including their location, are usually left out for the sake of efficiency and avoiding prohibitive complexity. The benefits of modeling each container as an object are not only the possibility of realistic visualization but also the implementation and assessment of planning schemes, such as re-marshalling strategies (Kim et al, 2004).

B. Yard Crane Scheduling In Container Terminals

Bish (2003) studies for determining a storage location for each unloaded container, dispatching vehicles to containers, and scheduling the loading and unloading operations on the cranes, so as minimizing the maximum time it takes to serve a given set of ships. A heuristic algorithm based on formulating the problem as a transshipment problem is developed. The effectiveness of the heuristic is analyzed from both worst-case and computational points of view. *Dohn (2003)* presents the Steel Plate Storage Yard Crane Scheduling Problem. Goodchild and Daganzo (2007) studied the longer term impact of double cycling on port operations including crane, vessel, and berth productivity. According to Alp and Baraçl (2009) double cycling is a technique by which empty crane moves are converted into productive ones. A framework is developed for analysis, and a simple formula is developed to predict the impact on turn-around time. The formula is an accurate predictor of performance. It is shown that double cycling can reduce operating time by 10%, improving vessel, crane and berth productivity and identify additional benefits on the landside, but these are typically much less significant.

Guo *et al* (2008) studied the problem of real time yard crane dispatching in container terminals. A judicious integration of real-time data into the yard crane management system allowed better utilization of terminal resources to improve overall terminal productivity. To minimize average vehicle waiting time, they developed a yard crane dispatching algorithm based on real time data driven simulation. Guo *et al* (2008) generated three scenarios and in these scenarios simulation results showed that dispatching yard crane based on real time data driven simulation is of great value in improving yard crane performance.

Nevertheless, Han *et al* (2008) studied a storage yard management problem in a transshipment hub in order to reduce the number of reshuffles. To reduce the potential traffic congestion of prime movers, they used a high–low workload balancing protocol. They formulated a mixed integer programming model to determine the storage locations of incoming containers, the number of incoming containers and the smallest number of yard cranes to deploy in each shift. They developed an iterative improvement method to solve the problem. Their experiment results showed that the proposed method can generate excellent results within a reasonable time, even for the extreme cases.

Jung and Kim (2006) addressed efficient berth and crane allocation scheduling at a multiuser container terminal. They first introduced a formulation for the simultaneous berth and crane allocation problem. Next, by employing genetic algorithm, they developed a heuristic to find an approximate solution for the problem. The results of numerical experiments showed that the proposed heuristic is applicable to solve this difficult but essential terminal operation problem. Kim vd. (2003) suggested a dynamic programming model for a static sequencing problem in which all the arrivals of trucks are known in advance. In port container terminals, the amount of delay time of outside trucks in the receiving and delivery operations is one of the important measures for the evaluation of the level of customer service.

For dynamic situations where new trucks arrive continuously, they suggested a learning-based method for deriving decision rules. They also suggested several heuristic rules.

Kim and Kim (2007) discussed a method of determining the optimal price schedule for storing inbound containers in a container yard. The price schedule in their study was characterized by the free-time-limit during which a container can be stored without any charge, and by the storage price per unit time for the storage beyond the free-time-limit. The profit or cost models for optimal price schedule were developed from the viewpoint of a public terminal operator as well as a private terminal operator. The probability distribution of delivery times was expressed by a continuous probability function. Various characteristics of the optimal solution were analyzed by numerical experiments. Lee *et al* (2007) investigated how type of transport vehicles and layout of the storage yard affect port operations. They modeled two different types of transport vehicles and two different types of layouts and created a total of four simulation models. To evaluate the performance, the gross crane rate was used as the main performance measure which they defined as the number of containers moved per quay crane per working hour. It was shown that the incorporation of the chassis lane improves the gross crane rate for both prime movers and shuttle carriers. They found that improvement was more substantial when the port utilizes shuttle carriers.

Lee *et al* (2006) studied a yard storage allocation problem in a transshipment hub. The primary challenge was to efficiently shift containers between the vessels and the storage area. In particular, to reduce reshuffling unloaded containers were grouped according to their destination vessel. To reduce traffic congestion, a new workload balancing protocol is proposed. A mixed integer programming model was then formulated to determine the minimum number of yard cranes to deploy and the location where unloaded containers should be stored.

C. Terminal Operational Efficiency

Wu Heng (2003) reported that the most commonly used efficiency measures, proposed by Farrell (1957) upon the work of Debreu (1951) and Koopmans (1951), are technical efficiency, allocative efficiency and economic efficiency. Technical efficiency can be defined as that which reflects the ability of a firm to obtain maximal output from a given set of inputs. Allocative efficiency is concerned with the ability of a firm to make use of the inputs in optimal proportions, given their respective prices and the production technology. Integrating these two measures will provide a measure of total economic efficiency.

According to Wu Heng (2003) methodologically, there are four principal methods for measuring the above different kinds of efficiencies, namely, Least-Squares Econometric Production Models, total factor productivity (TFP) indices, data envelopment analysis (DEA), and Stochastic Frontiers. The four methods can be categorized according to at least two criteria. First, a distinction can be made between whether they recognize inefficiency or not. The first two methods are always chosen for time-series data and offer measures of technical change and/or TFP. Both of these two techniques implicitly assume that all firms are fully efficient. The latter two methods, on the other hand, are usually applied to data on a sample of firms (at one point in time) and provide measures of relative efficiency among those firms. Hence these latter two methods do not assume that all firms are fully efficient. However, multilateral TFP indices can also be used to compare the relative productivity of a group of firms at one point in time. Also DEA and stochastic frontiers can be used to measure both technical change and efficiency change, if panel data available (Battese, Coelli and Prasada, 1998). The second classification is to note that the first and last methods involve the econometric estimation of parametric functions, while the second and third methods do not postulate a particular functional boundary.

Wu Heng (2003) postulated that since efficiency ratings are a powerful management tool for port authorities and port operators, efficiency measurement is also introduced to port performance and competition studies. As to the methods that have been employed to address the subject of port performance, traditionally studies on port efficiency measurement attempt to adopt a multitude of indicators to measure partial productivity or partial out/input ratios such as TEU/crane, ship calls/berth, etc. Although partial productivity measures are helpful for valuing certain aspects of port performance, they do not allow to asset the general efficiency of port production. Thus, DEA and stochastic frontiers, which can be used to measure overall productive efficiency are widely applied in later port performance research. These three major methods and related literature that have paid more attention to port industry will be discussed in the following section.

D. Partial Indicators Method

Wu Heng (2003) reported that the first group of literature estimates the port's efficiency by using a multitude of partial indicators. Many port authorities publish their annual reports by adopting this approach. The more academic research applying this method to focus on inter-port comparison was first suggested by Talley (1994) and Tongzon (1995). They both made use of comparable indicators to measure and compare the efficiency level of selected ports with similar characteristics. Heaver (1995) and the Australian Productivity Commission (1998) carry out further research to study how inter-port competition can be accelerated through comparison of a set of productive indicators among ports.

Although partial productivity measurement is useful for evaluating certain aspects of ports efficiency, their main shortcoming is their partial view which does not yield an analytically consistent approach to the joint contribution of the various inputs to overall efficiency (Estache, Gonzalez and Trujillo, 2002). For example, although a container terminal can be very efficient in terms of the container handling rate (TEU/Hour), this does not consequentially mean that this container terminal utilizes all inputs efficiently in general to produce output. It is possible that other factors are used inefficiently, which will definitely degrade the overall efficiency level of this container terminal; (Wu Heng 2003).

III. CONCLUSION

This study sought to assess the bottlenecks in freight forwarding in Ghana and what could be done to mitigate their impact on the industry. To achieve this main objective, descriptive statistics was used to describe the socioeconomic characteristics of the respondents and the results shows that the demographic age profile of the study participants shows that the industry is dominated by youthful population. The data also shows that both males and females were nearly equally represented in the sample size of this study and the distribution of the level of education and occupation were widely varied. This might have been as a result of the time and venues of data collection.

It was revealed that freight forwarders do not offer varieties of services apart from to a larger extent clearing and to a minimum extent forwarding goods. Only a few of them who are striving to attempt multimodalism have added transportation to their functions. It was also realized that the industry is uncompetitive resulting from the inefficiencies and ineffectiveness in the systems and sometimes from their own end thereby making them unproductive. Indeed it is important to note here that one of the determinants of how competitive an organization is how productive its operations are.

The Impact of Private Container Terminals on the Operations of Tema Port was the topic researched. This was based on two sources of data, primary and secondary. The primary data sources included collection of data from Management and Staff of Tema Port (GPHA, MPS, TCT, and ACS). Data collection was through the use of a structured questionnaire. Secondary data were obtained through libraries, newspapers and the Internet.

It was found out from the research that, 33.8% of the respondents were within the ages of 26 and 35 while 16.2% of them were within the ages of 36 and 45. In addition, majority (50.0%) of the respondents were above the age of 45. The number of male workers at the port was far more than that of the females. This was because, out of the 74 respondents, 60 representing 81.1 percent were males while 14 representing 18.9 percent was females. Majority (50%) of the respondents graduated from the Tertiary institutions while 33.8% were Senior High School (S.H.S) graduates. Only 16.2% of them were Junior High School (J.H.S) graduates. Majority (21.7) of them have within 20-24 years of working experience. 14 of them representing 18.9 percent have within 1-4 years of working experience. 13.5% of the respondents have more than 25 years of working experience. Majority of the respondents are Shipping Agents (43.3%) while 16.2% are Private Container Owners. The others are Drivers, Financial Analysts, Engineers, Asst. Operation Managers, Security Officers and Financial Controllers.

There is a chance for private container terminals to operate because all the respondents agreed that, there are adequate resources available for private container terminals to operate. However, majority of the respondents disagreed with the fact that the effectiveness of the resources is reducing inefficiency at the port. This is because, despite the adequacy of the resources at the port, it has no effect on the efficiency since the resources alone could not reduce the inefficiency at the port unless more private container terminals are allowed to operate. There is a high rate of loading and unloading of container cargoes by private terminals at the port. This therefore means that, the encouragement of private container terminals in operation could reduce inefficiency at the port. It was also agreed that, the present turnaround time by private container terminals is far better than before; which means that, the introduction of private container terminals have helped to improve upon the turnaround time. In addition, the current rate of documentation by private container terminals compared to the previous is better.

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A container terminal was defined by the respondents as a place where containers are discharged off a vessel and stored on behalf of the shipping lines. Or, it is a facility where cargo containers are temporally stored for onward transportation to the end users. In addition, it is a facility where cargo containers are transshipped between different transport vehicles. These definitions therefore conforms to the one defined by Steenken (2004) in the literature review in chapter 2 which states that "a container terminal is a facility where cargo containers are transshipped between different transport vehicles, for onward transportation". Whiles a private container terminal is a container terminal that is owned by private individuals entirely with no recourse to state funds and government not playing any role in its management. Also, it is a container terminal owned by a private entity that is with private capital investment. Besides, it is a container terminal fund by a private or an independent company.

Furthermore, benefits that the community gets from private container terminals are: employment, human resource development, reduces yard congestion, facilitate easy and quick evacuation of container, income to the government through payment of tariffs, foreign exchange and promotes specialization. Moreover, problems that this sector faces are: yard congestion, less data quality, lack of departmental cohesion, lack of government support and wrong documentation of cargo ownership leading to delay in the discharge of cargo to end users. Therefore, they suggested that, there should be optimization of yard, container deliveries should be evacuated in an even manner and at same line and there should be education for both documentation officials and cargo owners in order to reduce wrong documentation.

The findings of this study show that, Private container terminals have positive impact on the Ghanaian Ports. Indeed this is formalized in Vickers and Yarrow's (1989) concluclusion that ownership of a firm will have significant impact on its performance given that ownership rights modify the structure of incentives available to decision-makers in the firm.

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