Operational Effect on the Increase of Quay Cranes to Reduce Dwelling Time at the Container Terminal

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Abstract. Currently, the container terminal is growing rapidly and is the entrance to world trade. Terminal productivity is one of the keys to superior service. One indicator of container terminal productivity is dwelling time. In developing countries, among the causes of high dwelling time is the lack of container handling equipment. This paper aims to study the effect of the number of quay cranes on the number of dwelling time. The investigation was carried out using a container terminal simulation. As a case study, a simulation of a container terminal with a berth length of 300 meters with average daily ship calls is 600 TEUs. The simulation is done by making the parameters of adding quay cranes to each case. The results of the simulation show the addition of a quay crane can reduce the number of dwelling time average by 0.1 days, this decrease depends on the container capacity of the ship. The results of this study provide an overview of the container terminal in port infrastructure planning.

1 Introduction

The flow of world trade using containers continues to increase every year. According to statistical data the total number of container containers in the world reaches four million twenty-foot equivalent unit (TEUs), equivalent to 266 metric tons of cargo [1]. This certainly affects the operational capacity of the container terminal by expanding the port area and increasing the number of container handling equipment [2]. A container terminal is a place for the transfer of goods between land and sea [3]. In this place, there is a complex process in terms of technology and regulation involving many parties including risk policy [4]. Focusing more on technical factors, the container terminal at least has a berth area, stacking yard, and gate in and out of the port [5].

There are several container haulers that work, namely quay cranes, transfer trucks, gantry cranes, side loaders, depending on the type of port layout [6]. All are arranged so that the operation of the container movement runs smoothly, in the current era the container terminal is demanded to have high productivity [7], energy efficient [8] and be environmentally friendly [8, 9]. At present some modern terminals in developed countries have used automated guided vehicle to process the transfer of containers inside the terminal to increase

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productivity [10, 11], in addition, several studies have been carried out to reduce energy consumption in container terminals [13], [14], one of which is in refrigerated containers [15], [16]. The use of technology that leads to automation and minimizes emissions at ports applies in developed countries, this does not apply in developing countries. Terminals in developing countries tend to dwell on the problem of improving port operations, one of which is dwelling time [17].

Dwelling time is the container waiting time starting from getting off the ship to going out of the port gate. Many factors are interconnected in the high dwelling time, in addition to technical factors often the regulatory factors applied to the port [18]. Focusing on the technical factors of port operations, several studies have been carried out to reduce the duration of dwelling time. Several studies conducted in Asia examined the port container waiting time by performing heuristic optimization in the stockyard [19]. Other research optimizes port operations by implementing the scheduling of trucks that will enter the port [20]. There have been many studies that have optimized the scheduling and stacking of containers in the stacking field so that the work of the gantry crane is more optimal [21].

Several studies have carried out the integration of the schedule between quay cranes and internal trucks so that the allocation in the stacking field is more optimal [22], this is mainly done in ports that have limited areas. Research on the integration of berth allocation problem have developed where the arrival time of the ship does not cause severe obstacles at the time of berth [23]. The heuristic solution method based on Lagrange relaxation is proposed to determine the anchored position, anchored time, and assignment of quay cranes [24]. The researcher assumes that the productivity of the crane is proportional to the number of quay cranes that simultaneously serve the ship. Other studies suggest that quay cranes are affected by interference effects that reduce marginal productivity. In addition, the productivity of the crane is also reduced if the ship is anchored regardless of the desired berth position [22], [25].

From the many studies, research on the relationship between the number of quay cranes and the duration of each dwelling time is rarely conducted. From the research gap, the purpose of this study is to determine the effect of increasing the number of quay cranes on the duration of dwelling time at the container terminal. This study contributes to the importance of port infrastructure planning.

2 Research Methodology

2.1. Container Terminal Simulation

Container Terminal Simulation is a simulation model developed based on A discrete-event simulation. Discrete-event simulation models the operation of the system as a sequence of events (discrete) events in time [26]. Every event occurs at a certain time and marks a change in status in the system. Between successive events, no changes in the system are considered to occur; thus the simulation time can jump directly to the next event time, which is called the development of the next event time.

In this study commercial software is used for academic purposes named FlexTerm. FlexTerm is software that specializes in container port simulations [27]. The modules cover all types of port resources such as the most common container port operation, loading operating equipment, horizontal transportation equipment, and storage yard. By using the 3D graphical display function of this simulation software, the user can set the dynamic port container simulation model and simulate a simple port loading procedure. 3D FlexTerm entities include crane docks, yard cranes, empty container forklifts, trucks, container ships, container storage yards, tracks, port gates, and so on.

The purpose of using FlexTerm software is that through simulation the user can optimize operating procedures and achieve implement effects before the operation. The effects that can be achieved by the container port simulation model are: increasing port handling capacity; increase the utilization of port equipment and production efficiency; reduce ship waiting time; develop a strategy of stacking container storage yards; allocating resources effectively and so on.

2.2 Simulation Settings

In the operating environment of a real container dock, all operating links are rather boring. When preparing simulation models, we need to simplify complex problems and make specific problems abstract. In this paper, the model builds on the following assumptions:

- Trucks can only load one container at a time.
- Trucks must operate independently and cannot interfere with each other.
- For all equipment, failures and maintenance are not considered and all equipment must be in a continuous working condition.

Classification of containers is not considered, regarding all containers as being the same.
As a case study, jetty data is 300 meters long, daily ship schedules are used imported container ships and exported vessels as simulation objects. Suppose the imported ship and the exported ship arrived at the same time. Continue to simulate the loading operations of both ships from the arrival of the ship until departure. There are 600 TEUs of imported containers to be unloaded and 600TEU export containers to be loaded. The size of the container used is only the type of 40ft container. The loading equipment parameters involved in the model are shown in Table 1.
The process of the dock crane operation includes loading, unloading, and movement of the dock crane. The process of moving the truck includes loading, unloading, waiting, and transporting the truck. The yard crane operation process includes loading, unloading, and movement. The initial status of the model is that the truck waits for orders in the waiting room and waits at the dock apron for exported containers for shipping to be placed in all areas of the exported carton. During the operation process, all imported containers loaded from ships are transported by trucks to the imported carton area. All containers exported for shipment are transported by trucks from the carton area that are exported to imported ships.

Table 1. Paramater of Container Handling Equipments

Equipment	Parameter	Value
Ship	Lenght Overall	305 meter
	Beam	30 meter
	Draft	15 meter
	Capacity	200-600 TEUs
Quay Crane	Hoise Lift Heigh	30 meter
	Gantry Speeds	2 m/s (max)
	Moving	40 moves/hours
Transfer Truck	Number of unit	3 unit
	Speed	5 m/s
Gantry Crane	Gantry Speed	3 m/s
	Trolley Speed	4 m/s
	Hoist Lift	3 m/s
	Hoist Drop	3 m/s

2.3 Container Simulation Process

During the simulation of the port loading operation, when the mission starts, the truck starts working. When unloading, the truck goes to the dock crane to check that the dock crane is free. It carries one container to the yard crane and checks whether the yard crane in the slot is free and then performs loading and unloading operations. While loading, the truck goes to the yard crane to check whether the yard crane is free. It carries one container in the storage yard to the dock pier and checks whether the dock crane is free to accept the shipping of the dock crane. When the dock crane or yard crane is busy, the truck waits in line, simulating until all imported container are unloaded and all export container are loaded. The specific simulation operation process is illustrated by Figure 1.

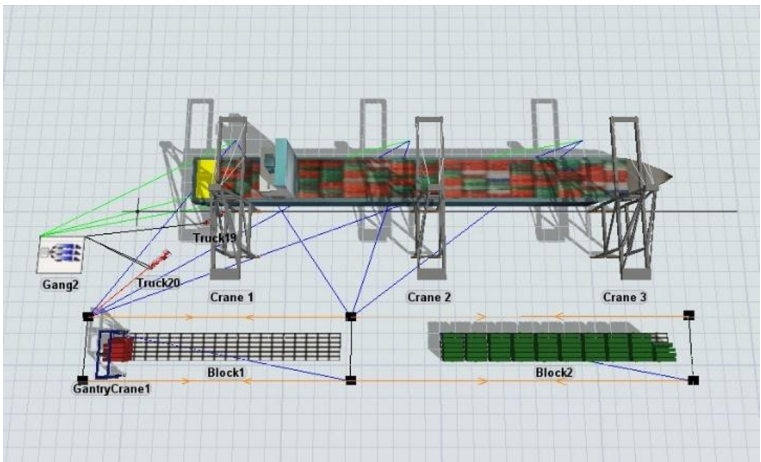

Fig. 1. Container terminal simulation process

3 Result and Discussion

3.1 Increasing the Number of Quay Cranes

From the terminal container simulation, several results were obtained that could contribute to the study of the effect of adding quay cranes to dwelling time. The results obtained in this study are the effect of increasing the number of quay cranes to the dwelling time with a container capacity variation of 200 - 600 TEUs. The first result we get is the length of dwelling time with the number of quay cranes is one, which is shown in Figure 2. These results are important as a basis for evaluating when adding quay cranes.

Figure 2 shows the result of simulation with the number of quay cranes 1, the dwelling time increases with increasing container capacity. In the 200 TEUs container capacity, the dwelling time of 2.8 days is obtained, while in the 600 TEUs container capacity, the dwelling time of 3.4 is obtained. From these results, it can be interpreted that there is an additional dwelling time of 0.6 days along with an increase in container capacity of 400 TEUs. This is the basis for drawing conclusions about whether increasing the number of quay cranes will reduce the dwelling time.

Figure 3 shows the simulation results of the effect of increasing container capacity on dwelling time with the number of quay cranes being two units. From these results, the dwelling time to container capacity is slightly similar when compared to the results of the dwelling time with only one quay crane, however, there is a slight difference in the curve

trend. In the 200 TEUs container capacity, the dwelling time is 2.8 days, while in the 600 TEUs container capacity, the dwelling time is 3.3. From these results, it can be interpreted that there is an additional dwelling time of 0.5 days along with an increase in container capacity of 400 TEUs. There was a slight decrease in dwelling time when 2 quay cranes were added.

Figure 4 shows the simulation results of the effect of increasing container capacity on dwelling time with the number of quay cranes being three units. From these results, it can be seen that there are results that are slightly different from the first results. In the 200 TEUs container capacity, the dwelling time is 3.0 days, while in the 600 TEUs container capacity, the dwelling time is 3.3. From these results, it can be interpreted that there is an additional dwelling time of 0.3 days along with an increase in container capacity of 400 TEUs. When compared with the first results using one quay cranes, overall the dwelling time decreased by 0.3 days.

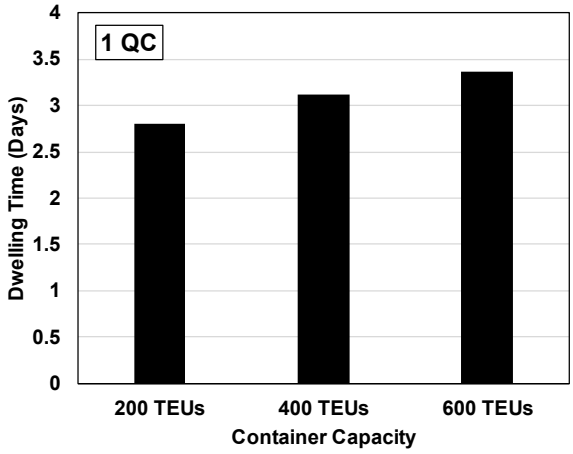

Fig. 2. Number of dwelling time with one quay crane in operation

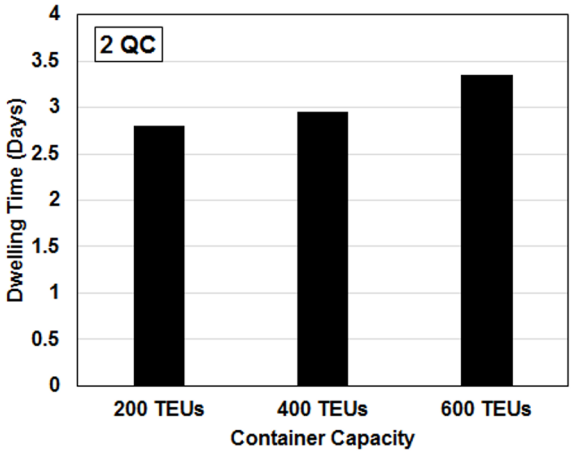

Fig. 3. Number of dwelling time with two quay crane in operation

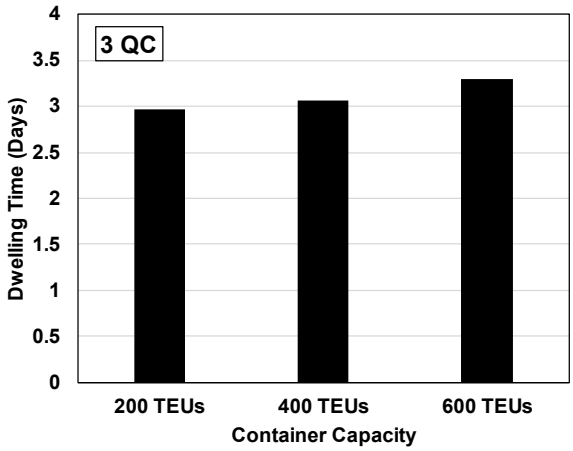

Fig. 4. Number of dwelling time with two quay crane in operation

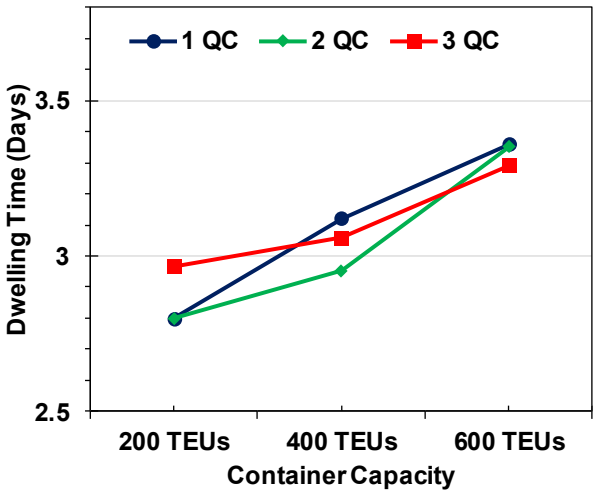

Fig. 5. Effect of the increase of quay cranes on the nuber of dwelling time

Figure 5 shows the relationship between the number of quay cranes and the addition of container capacity to the duration of dwelling time. From this result, we can analyze that at low container capacity, the need for quay cranes does not have to be a lot or enough, but when the container capacity increases, it requires more than one quay cranes. This is an interesting finding if more container capacity data are obtained.

3.2 Berth Occupancy Ratio

In addition to the results of the effect of adding quay cranes to the duration of dwelling time, this study also analyzes the effect of adding quay cranes to the berth occupancy ratio. Berth occupancy is the ratio of the length of the ship to lean on the dock, this can be interpreted the greater the value of the berth occupancy, the longer the ship rests, so that the pier cannot be used for other ship loading and unloading activities. The results of the effect of adding quay cranes to the berth occupancy ratio are shown in Figure 6. In this result the focus is on the

600 TEUs container capacity because of the significant dwelling time results in this capacity. From these results we can see that there is a significant increase in the number of quay cranes in the occupancy ratio. The value of berth occupancy in the number of cranes is only one, namely 66%, while with the addition of the number of quay cranes to three quay cranes, the value of berth occupancy drops to 63%. This is important if a container terminal wants to maximize the port's operational activities.

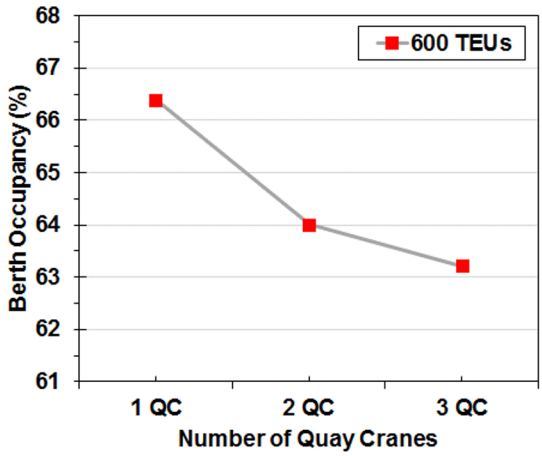

Fig. 6. Effect of number of quay cranes with berth occupancy

4 Conclusions

Studies on increasing the number of quay cranes to reduce dwelling time have been completed using simulation methods. Container terminal simulation based on discrete event simulation has been carried out using FlexTerm commercial software. Simulations have been carried out to find the value of dwelling time with the parameter number of quay cranes and container capacity. The simulation results show that the dwelling time value increases with the addition of container capacity. The simulation results also show that increasing the number of quay cranes can reduce dwelling time, the value depends on the capacity of the container. From the simulation results with a container capacity of 600 TEUs with the addition of a quay crane from one unit to three units, a dwelling time reduction of 0.1 days was obtained, while the berth occupancy ratio for this capacity also dropped by 3%. Thus it can be concluded that the addition of quay cranes can reduce dwelling time, the amount of which depends on the amount of container capacity. These results provide further research directions to conduct research on the effect of the speed of quay cranes on the operational time of container handling in container terminals.

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