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Reduction of Ship Waiting Time at Port Container Terminal Through Enhancement of the Tug/Pilot Machine Operation

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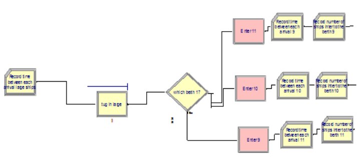
Graphical abstract



Abstract

Port container terminal is one of the important transition points in the shipping industry. Competitiveness is an important factor for port container terminal with the increase in the number of port terminals globally. Vessel processing time port terminals is one of the important factors that influence the port terminal attractiveness. In addition, most port terminals tried to reduce ship waiting time with enhancement of their facilities. This paper focused on the ship waiting time at the berthing area of port container terminal, and tried to solve the queuing problem at ship tugging operation in order to reduce the average waiting time. The data was collected from a major port container terminal in Malaysia as a case study. The port terminal is modeled with Arena 13.5 simulation software and model validation was done based on real data which was taken from the case study. Different scenarios were then tested on the tugging operation at the port simulation model. The results show that after the implementation of these scenarios, the average ship waiting time at the berthing area decreased dramatically from 180 hours to 140 hours for each ship.

Keywords: Port container terminal; ship waiting time; tugging operation; tug/pilot

1.0 INTRODUCTION

At port container terminals, one of the most important factors that have affected customer satisfaction is related to ship waiting time. Ship waiting time is an important contributor to the competitive advantage of a port terminal. Port terminals with low average waiting time can attract more ships than port terminals with high average waiting time. Waiting and queuing times at berthing area of port container terminals are the biggest problem that port managers encounter. Long wait times have a negative impact on port terminal efficiency and ship managers prefer to berth at a port terminal with low waiting time and high efficiency.

At port container terminals, the port management is concerned with service rates because by increasing the service rate port efficiency can be dramatically increased. On the other hand, ship management/control and port customers care about waiting time, which means they tried to select a port terminal with lower service waiting time. At port container terminals port management focused on the port output rate which has an effect on port terminal productivity. On the other hand, port customers and ship management are concerned with terminal waiting time. Ship waiting time at port container terminals includes different types of queue. Ships arriving at port the terminal should wait for a free slot at the berthing area. If the berth is available it should wait for Tug/Pilot machine for tugging into the particular berth. This paper focused on the ship waiting time for tugging operations at berthing areas of port container terminals. This consists of two operations including tugging into the berth when ships enter the berthing area and a tugging out operation when ships want to leave the berthing area of a port container terminal. For improving the tugging operation, this study considered the type of queue that Tug/Pilot machines provide to the ships.

There has been some investigation in the area of improving the port terminal waiting time, but most papers did not consider the tugging operation machine in their study. Edmond worked on the queuing system as one of the first researchers that investigated on this part of port container terminal [1]. Edmond tried to find the optimum number of berthing resources and equipment and considered the cost of these the installation of these resources at berth areas of port container terminals. In addition, Kia focused on the queuing system at port terminals and found the optimum number of berths by considering the ship waiting time at berthing areas and the idle time of berth equipment [2]. Zarnic *et al.* investigated ship waiting time at port container terminals and tried to reduce this time by increasing berth availability and cargo handling capacity [3].

In recent years, many researches focused on the queuing problem issue in the service sector with reference to system output

[4]. Most researchers analyzed this queuing system based on ship arrival and departure time [5]. The main goal of the managers at port container terminals is increasing port efficiency and reducing ship waiting time in a cost effective way. Furthermore they try to reduce excess capacity at the berth area of port container terminals [6]. Many researches worked on ship waiting time based on the number of cranes and number of berths, and proposed some ideas to increase port terminal capacity by increasing the amount of these resources [5]. Legato *et al.* worked on the queuing at port container terminals based on ship arrival and departure time in order to reduce ship turnaround time [5]. They considered ships as one of two types, primary and secondary at Gioia Tauro port container terminal in Italy. In addition to using SLAM language as simulation software, they simulated this port container terminal. Furthermore increasing the number of cranes solved the queuing problem at the port terminal and reduced ship waiting time at berth areas.

Laih *et al.* presented a new method for solving queue problems at berthing areas using a toll scheme aimed at ships adjusting their arrival time and speed in order to arrive at the berthing area on time [7]. By implementing this, ships reduced their waiting cost at the berthing area of port terminals and port average time decreased dramatically. Canonaco *et al.* focused on the optimization of berthing operations at maritime terminals [8]. It should be noted that the minimization of waiting time should be balanced with the maximization of expensive resources. They proposed a queuing system and solved this problem with discrete simulation event. The berth crane services and waiting times have been compared based on some graphs from their work. In this study, authors considered many constraints that cranes encounter during operations. The constraints include fuel supply for vehicles, and maintenance and machine breakdown. Also, there are some meteorological factors which affect cranes such as wind speed. In another paper, ship waiting time was optimized by using Hybrid Genetic Algorithm (GA) and Artificial Neural Network (ANN) through enhancement of ship berthing operation [9].

A complex queuing system model should be designed and implemented. In this research, the queuing system problem is solved with an event graph that is archieved with discrete event simulation.

■6.0 CASE STUDY

In this study, one of the important port terminals in South East Asia was selected as a case study, and data was collected from this port container terminal. This port terminal consists of 3 different berthing areas for 3 kinds of ships that come to the port for servicing. These berthing areas are; three berths for large ships, 3 berths for medium ships and 5 berths for small ships to receive service. In addition this port terminal has 3 Tug/Pilot machines that tug ships in and out of particular berths.

■3.0 SHIP BERTHING OPERATION

The ship operation process begins when ships come to a port container terminal. According to service department, if there is free slot for berthing ships receive permission to enter the berthing area for tugging to a particular berth. For tugging operation, ships need a Tug/Pilot machine to tug in ships to a particular berthing area. The tugging operation at port container terminals consists of two phases; one phase is for entering the ships to the berthing area of the port terminal in order to tug the ships into a particular berth. Another phase occurs when ships want to leave the berth area and in this stage ships tug out from berth with using Tug/Pilot machine. If there is no Tug/Pilot machine for serving, ships at berthing areas should wait at the Tug/Pilot queue. Tug/Pilots serve the ships in queue based on the First Come, First Served rule. Using Arena 13.5, this process was simulated and based on the simulation model the port container system is analyzed.

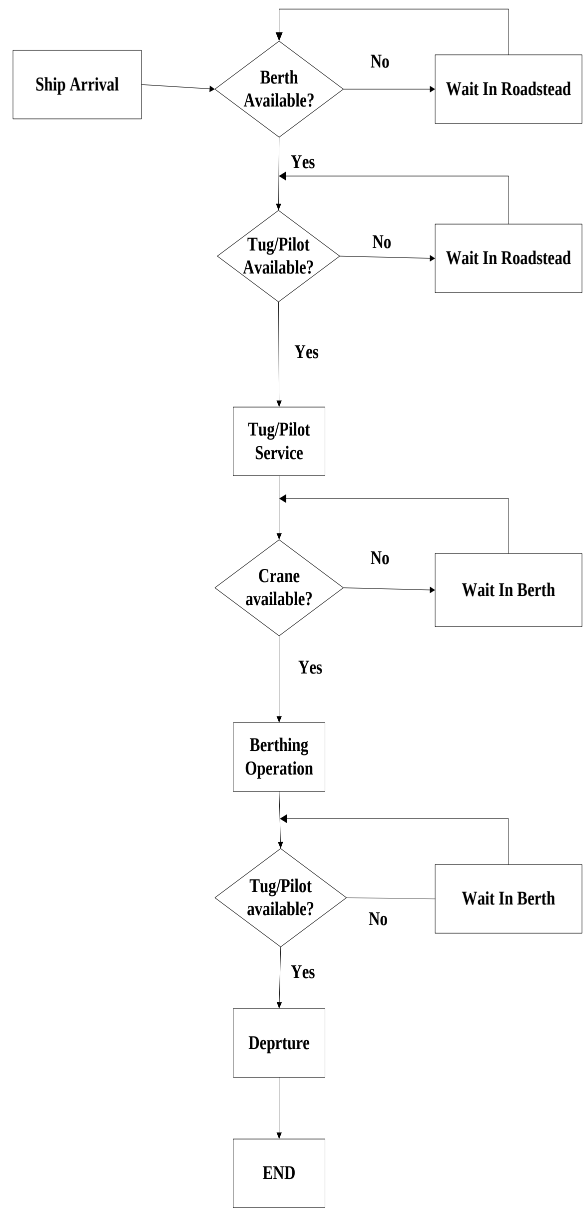


Figure 1 Ship berthing operation at port container terminal

■4.0 SIMULATION MODEL

There are some researchers that applied computer simulation in fields such as supply chain management, construction management, manufacturing system etc [10-11]. The berthing area of a port container terminal is simulated by Arena 13.5 Software, in analyzing the queuing problem. One popular port container terminal located in southern Malaysia region was selected as case study, and the model was built based on the data that was given by this port terminal. For simulation of the berthing area of the port container terminal some assumptions were considered: all hinterland connection and yard operation did not take into the account. Ships which are coming to the berthing area of a port terminal to receive service can be divided into the three categories; large ships, medium ships and small ships. In addition to tugging operations some assumptions were considered. For example, all ships should be tugged to the berth by the same Tug/Pilot machine, and it should be noted that this model considered all Tug/Pilot machines as having the same capability. The simulation model of the berthing area at port container terminals can be simulated as shown in Figure 2.

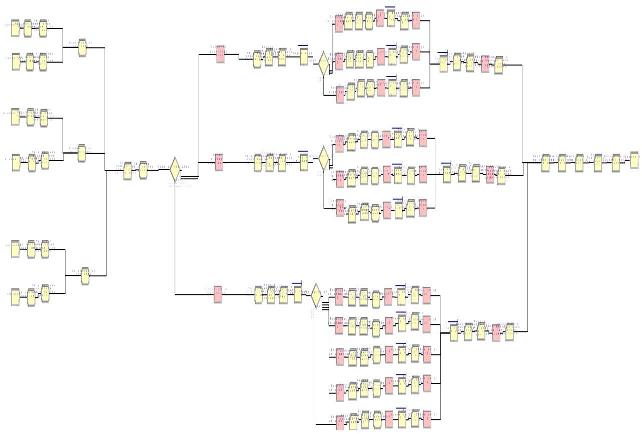


Figure 2 Simulation model of ship berthing operations at port container terminal

As can be seen the port container terminal model consists of 11 berths which are divided into three categories such as berth area for large ships, berthing area for medium ships and berthing area for small ships. Furthermore, all ships should be served with the 3 Tug/Pilot machines as part of the same process, and these Tug/Pilot machines are used for all tugging operations including tug in and tug out operations. Figure 3 shows the tug in operation at a berthing area for large ships.

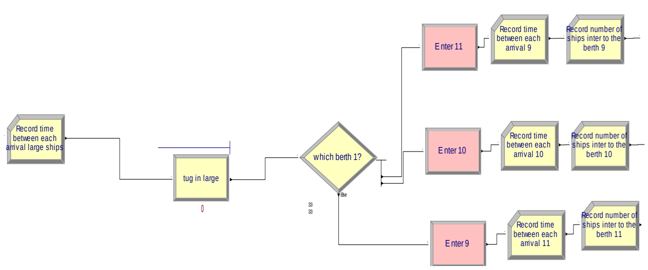


Figure 3 Simulated tugging of large ships to the berth operation

As can be seen in Figure 3, large ships that come to the berthing area should be served by a tug pilot. This process is implemented for all ships of different categories such as large, medium and small ships. In this part of the model, the process module for tug in operation used the same resources as another tugging module.

4.1 Validation Model

Model validation guarantees that the model works the same way as the real system. Furthermore, this model ensures the results achieve an acceptable level of accuracy [12]. To this end, validation of port container terminal model was performed by comparing the result of a simulation model, with real data provided by the case study management. Table 1 illustrates the model validation.

Table 1 Simulation model validation

Case	Annual Productivity	Weekly output
Port container terminal	65% - 70%	About 100 ships
Simulation model	68%	103 ships

As can be seen, Table 1 approved validation of simulation model. The real weekly output of the port terminal is around 100 ships and the simulation model's output is around 103. Furthermore, the real annual productivity rate of case study is between 65% and 70% and productivity of simulation model after running for a one year period is around 68%. This means the simulation model which is built by Arena software is validated with high confidence rate.

■5.0 RESULTS AND DISCUSSION

After running the simulation model it can be seen that the number of Tug/Pilots is not enough for ship berthing operations at this port terminal. In addition, this number of Tug/Pilots creates the issue of bottlenecks for port terminal. The long queue at the roadstead waiting for a free Tug/Pilot machine and long ship waiting times generate expensive costs for ships and customers. High waiting time has an impact on the ships management decision to choose this port terminal for berthing operation. For this reason, all port container terminal managers try to solve the queuing problem at berthing area. This paper tries to solve the queuing problem of tugging operations at port terminals by adding some resources to the process. The Tug/Pilot machine is the main resource of a tugging operation, and to enhance these resources, a number of Tug/Pilots should be added to this process.

5.1 Tested Scnarios

There are many researches that focused on ship waiting time based on the amount of equipment such as berths and cranes. Previously, no research has investigated ship waiting time based on the number of Tug/Pilot machines. According to Figure 1, there are two queues for tugging operations and average ship waiting time at port terminals is 180 hours. In addition, based on the Arena results, there is a noticeable queue for tugging operations at port container terminals. This study tried to reduce the port's average ship waiting time by enhancing the tugging operation at the berthing area. To reduce ship waiting time at tugging operations the number of Tug/Pilot machines should be increased. For this reason different scenarios were tested. Table 2 illustrated the scenarios that were tested in this part.

Table 2 Tested different scenarios at tugging operation of port terminal based on number of Tug/Pilots

Scenario number	1	2	3	4	5	6	7	8
Number of Tug/Pilot	3	5	7	9	10	11	12	13
Ships waiting time	180 hr	175 hr	160 hr	150 hr	140 hr	139.5 hr	139.5 hr	139.5 hr

According to Table 2, by increasing the number of Tug/pilot machines, the ship waiting time reduced dramatically. Increasing the number of Tug/Pilots beyond a specific point does not have an effect on the waiting time at port terminals, because the waiting times come from 4 queues at the berthing area of port container terminal. Many factors are included in the ship waiting time such as number of berths, number of cranes and labor scheduling. In this case after the alternative of 5 and 10 Tug/Pilot machines, any more Tug/pilots added to the process has affect on the average waiting time because the tugging operation capacity in the berthing process is completed in this stage. Figure 4 illustrated the improvement of ship waiting times by increasing the number of Tug/Pilot machines at the berthing area of port container terminals.

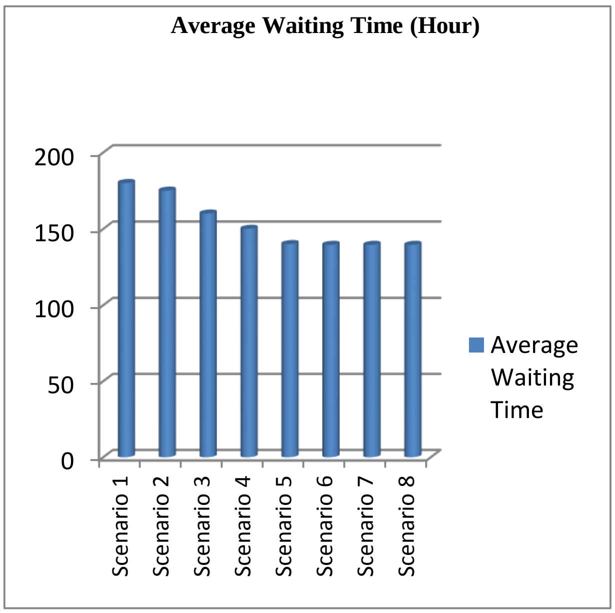


Figure 4 Average ship waiting time at port container terminal based on changing the number of Tug/Pilots

As can be seen in Figure 4, after scenario 5 the ship waiting time remains stead, and an increased number of Tug/Pilots is no longer needed.

■6.0 CONCLUSION

Port container terminals play a leading role in the transportation of goods between continents. The main goal of port management is enhancing the port terminal in order the port terminal service rate and ships waiting time at berthing area of port container terminal. This paper focused on ship waiting time at port terminals and tried to reduce this time. With decreased ship waiting time at specific port terminals, customers and ship managers are motivated to use this port terminal. In this paper, the berthing area of port container terminal was simulated by Arena 13.5. After simulation the port terminal tugging operation was considered as one of the main operation processes at port terminals which will affect the ship waiting time at port terminals. To solve the queuing problem in tug operations, the number of Tug/Pilot machines should be increased. Different scenarios were tested based on the number of Tug/Pilot machines in the simulation model. After running the model based on the different conditions and alternatives the maximum capacity of tugging operations for enhancing the queuing problem and reducing ships waiting time is 10 Tug/Pilot machines. With increasing the number of Tug/Pilots from 3 to 10 the ship waiting time decreased from an average 180 hours to 140 hours. This improvement is attractive for both ships and customers.

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