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Simulation Study for Performance Measures of Resources in a Port Container Terminal

*Yong-Seok Choi**

**Shipping, Logistics and Port Research Center, Korea Maritime Institute*

Abstract : *In order to measure the performance of resources in a port container terminal, we conducted a state transition network simulation to model various equipment processes. The processes that container cranes and transfer cranes perform are idle, wait, move, and work. Vehicles perform idle, wait, empty travel, and full travel. Because cranes, vehicles, and vessels are movable entities and all equipment is classified as either a customer or server, we separated the various stages of the process based upon the state transition network. To validate the simulation results, a real system was used to illustrate the use of various measurements using the state transition network.*

Key words : *state transition network, port container terminal, performance measure, simulation*

1. Introduction

There are many performance measures in a port container terminal. Watanabe proposed several performance measures to use when designing container terminals (Watanabe, 1991). Yun & Choi used the utilization of equipment for the analysis of container terminals(Yun & Choi, 1999). Lai & Lam used throughput, utilization, and waiting time as measures for assessing the container yard in Hong Kong(Lai & Lam, 1994). Ramani provided performance indicators such as berth occupancy, vessel waiting time, vessel outputs, and vessel turnaround time(Ramani, 1996). Razman & Khalid used performance indicators such as vessel turnaround time, berth occupancy, vessel outputs, and crane utilization to analyze terminal operation(Razman & Khalid, 2000). Yun et al. provided various output statistics such as waiting times of vessels and yard tractors, the utilization for container cranes, and the berth occupancy rates(Yun et al., 2001). Due to the frequent interaction between equipment, more accurate measures need to be considered.

The methodologies used to develop the measures are based on the analytical queueing model and the simulation model. But complex systems such as port container terminals need more effort and time for modeling and analysis considering the high volume of use. It often turns out that it is not possible to develop analytical models for a queueing system. This can be due to the characteristics of the input or service mechanisms, the complexity of the system design, or the nature of the queue discipline. In port container terminals, the main objective of port management is to optimize the utilization of the port resources, a purpose of operation and planning units is to select the measurements. Optimizing resource utilization encourages trade, improves the competitiveness of the container terminal, and provides efficient and effective services at low cost.

When the resource allocation is planning, the utilization of equipment is less efficient than particular measures as move time, work time, idle time, and wait time. To provide these measures, it needs to use the state transition network about equipment each as a server in queueing model.

In this paper, it is described to the state transition network simulation to model particular measures in a port container terminal.

2. System Operations and Model

The flow of containers is composed of import and export flows. For the import flows, containers are discharged by the cranes from vessels, and transported by the YTs(Yard Tractor) to the import block, then they are stacked in the pre-assigned bay. At the import block, the YTs queue for the TC(Transfer Crane) to stack the containers in the pre-assigned block. For the export containers, the reverse process applied. The operational system for the port is depicted in Fig. 1.

The process begins when a vessel arrives at the berth and joins a "Berth_Buf". The first-come-first-served strategy is usually employed. If a berth is free, then the vessel can enter the berth. A delay occurs for the vessel

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* Corresponding Author : drasto@kmi.re.kr 02)2105-2886

until a berth is available. After the vessel enters the berth, it counts an average delay of about one hour before the discharging operation takes place. Several CC(Container Crane) per vessel are assigned to start the discharging and charging the containers. When these activities are complete, the vessel may have to wait for one hour before it can leave the port. Fig. 1 shows all the equipment and buffers used to transport the import and export containers.

The YTs transport the containers to the pre-assigned bays within yard where the TCs are used to stack them in the pre-assigned bays. When the consignee claims the containers, a truck will then be used to transport them outside the gate. The process for export containers is in the reverse order.

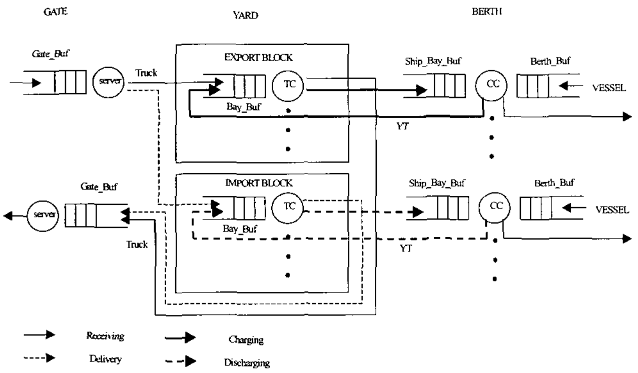

Fig. 1 Terminal Operations with Queueing System

The container terminal operation was formulated as a queueing system where the CC and TC are classified as servers and the vessels, YTs, and trucks are classified as customer. In fact, the system consists of two queueing networks as follows.

1) A close queueing network: The equipment involved in this network is CC, TC, and YT as customers. The YTs are alternatively served by the CC and the TC. That is, the YTs transport containers between these two servers until the loading and unloading process is completed. As the YTs are bound by the container terminal, this is a close queueing network.
2) An open queueing network: The trucks and vessels are involved in this network. Every truck comes through the gate from outside the container terminal and is then served by one of the TCs. Because the trucks are not bound by the container terminal, this is an open queueing network. Similarly the vessel are not bound by the container terminal. They come from outside the port and are then served by several container cranes. So vessels are a component of an open queueing network.

The state transition network presented in this paper has been implemented and solved by Visual C++, a general-purpose programming language, in order to capture all of the details of the resource management policy.

The arrival-service(travel)-departure process followed by any vessel or truck has been represented in terms of a state transition network, to make evident the congestion points along the process evident. Therefore it has been split in Fig. 2 and Fig. 3 which show, respectively, the vessel and the truck state transition network.

The work-move-wait-idle process followed by cranes such as CCs and TCs has been represented as a state transition network, to change the state along the process under work condition. Similarly, The YTs has the travel(empty/full)-wait(TC/CC)-idle process. The state transition network of cranes and YTs is a closed network model to work continuously until all tasks are completed. Let us turn now to the description of the YTs presented in Fig. 4 and the description of the cranes presented in Fig. 5. It shows the state transition networks prescribed route for YTs or trucks approaching the crane from either a gate or a berth.

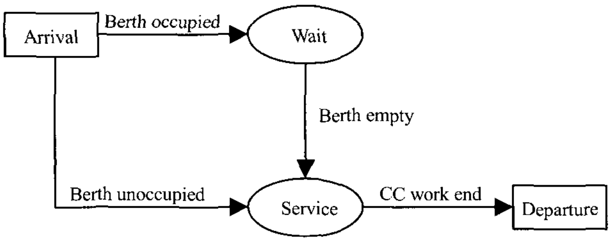

Fig. 2 State Transition Network for Vessels

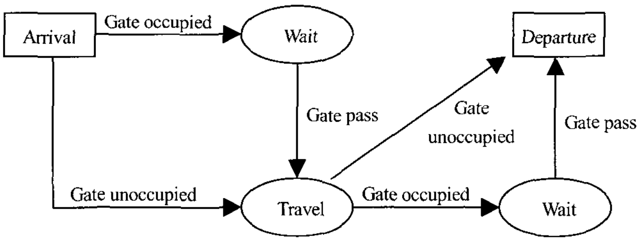

Fig. 3 State Transition Network for Trucks

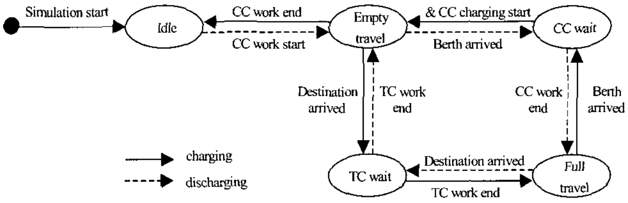

Fig. 4 State Transition Network for YTs

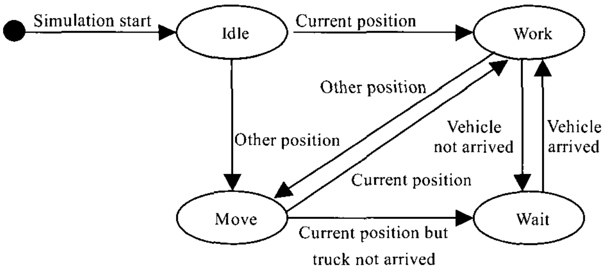

Fig. 5 State Transition Network for Cranes

In the figures above, the box represents the arrival and departure processes in an open network and the circles represent a process under operational conditions in a closed network. These processes are defined as events in the simulation and the operational conditions trigger the execution of the simulation.

3. Simulation System

The simulation system was programmed in the general-purpose language Visual C++ based on object-oriented programming. The object-oriented modeling methodology for object-oriented simulations was used. This approach builds models easily, and is easily modified.

3.1 Performance Measures

The performance measurements that can be collected during the simulation study are shown in Table 1.

Table 1 Performance Measurements

Resources	Prime Measures	Particular Measures
CC	Utilization	Time ratio about work, move, wait, and idle
TC	Utilization	Time ratio about work, move, wait, and idle
YT	Turnaround time	TC waiting time, CC waiting time
Truck	Service time(Travel time)	(min, mean, max) in service time
Vessel	Service time(Berthing time)	(min, mean, max) in service time

From the point of view of a container terminal operator, the average service time of vessel per period is the most important performance measure. This is corresponds to the first four measures above. The selection of a new strategy for allocating equipment at the container terminal will therefore focus on these measures.

3.2 System Parameters

A good understanding of the current container terminal operations was gained through discussions with the container terminal operators. The following three parameters were identified for resource analysis. By combining different values of these parameters, we can assess the performance of different operating strategies and gain insight into the container terminal operations.

Table 2 Values of the Three Parameters under Study

Description	Parameters	Values
Number of container crane per berth	C	1,2,3,4
Number of transfer crane per terminal	T	6,8,10,12
Number of yard tractor per container crane	Y	3,4,5,6

Let S(C, T, Y) be the scenario defined by the values of the parameters C, T, and Y as given in table 2. For example, S(2, 10, 4) denotes the current situation whereby two CCs per berth, ten TCs, and four YTs per container crane are employed during a simulation run.

4. Case Study

We used the UTC (Uam Terminal Co.) located in Pusan, Korea as the model system in this study. The scope of our experimental model is as follows. The gate has two entrances and one exit. The container yard has 12 blocks (7 export blocks and 5 import blocks) and 10 TCs. Each block includes 25 bays and each bay consists of 6 rows by 4 tiers. A quay has two berths and four CCs. The container types include 20 foot and 40 foot containers.

4.1 Experiment Design

This model consider the values of the various parameters of facility operations and the same criteria are used to evaluate the system effectiveness. The parameters are summarized in Table 3 and consist of annual container throughput and the facilities and equipment requirements.

Table 3 Input Data for Container Throughput

Items	Values
Annual export container throughput (TEU)	150,515
Annual import container throughput (TEU)	139,132
Annual transshipment container throughput (TEU)	68,295
Ratios of TEU/VAN	1.33
Annual total number of handled vessels	360

This model use the TC system as yard side equipment and the same operation flows. Therefore as operation policies, the same operation parameters as input in this case are used.

- Opening time of receiving containers before vessel's arrival schedule : four days
- Closing time of receiving containers before vessel's arrival schedule : 10 hours

- Free storage periods for the imported (inbound) containers : four days
- The number of allocated CC per berth : two (default)
- The number of allocated YT per CC : four (default)

The equipment characteristics are summarized in Table 4. We assumed that operation times of CC and TC has a normal distribution(Yun at al., 1998).

Table 4 Equipment Characteristics

Characteristics Equipment	Speed (km/h)	Operation time (min.)	Number of equipment
CC	2.7	N(112.8, 31.2)	4
TC	8.04	N(87, 193)	10
YT	20	-	16
Trailer	20	-	-

4.2 Simulation Experiment

Before the results of simulation runs were collected, the warm-up period was set at ten days. The length of each simulation run was set at 20 days. The prime measures and particular measures of resources obtained from a sample of five independent simulation runs are presented in Table 4.

Table 4 Experiment Results for Current Situation

<table>
<tr><td>Resources</td><td>Prime Measures</td><td colspan="4">Particular Measures</td></tr>
<tr><td></td><td>Utilization (%)</td><td>Work time (%)</td><td>Move time (%)</td><td>Wait time (%)</td><td>Idle time (%)</td></tr>
<tr><td>CC</td><td>52.3</td><td>29.1</td><td>0.6</td><td>20.3</td><td>47.3</td></tr>
<tr><td>TC</td><td>31.6</td><td>15.1</td><td>3.2</td><td>13.3</td><td>68.4</td></tr>
<tr><td></td><td>Utilization (%)</td><td>Turnaround time(Sec.)</td><td colspan="2">TC waiting time(Sec.)</td><td>CC waiting time(Sec)</td></tr>
<tr><td>YT</td><td>44.4</td><td>616.7</td><td colspan="2">34.5</td><td>37.6</td></tr>
<tr><td></td><td>Service time</td><td>Min</td><td colspan="2">Mean</td><td>Max</td></tr>
<tr><td>Vessel</td><td>21.6 hr</td><td>14.0 hr</td><td colspan="2">21.6 hr</td><td>40.8 hr</td></tr>
<tr><td>Truck</td><td>9.3 min</td><td>2.8 min</td><td colspan="2">9.3 min</td><td>169.1 min</td></tr>
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4.3 Scenario Analysis

A scenario analysis is performed to estimate the performance of equipment deployment strategies under different scenarios. In the following figures, the various measures are seen to change as the number of allocated resources are changed.

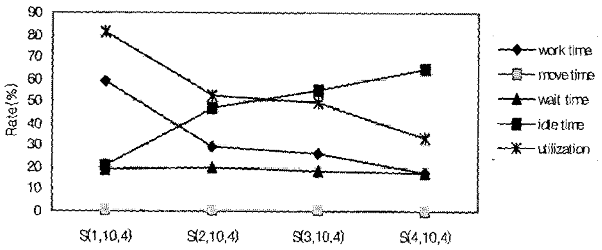

Fig. 6 CC Performance as change of CC number per berth

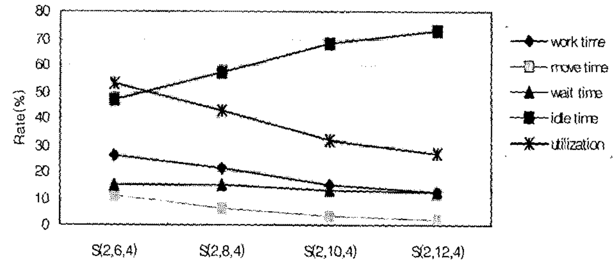

Fig. 7 TC Performance as change of TC number

The utilization of the servers, such as CCs and TCs in Figs. 6 and 7 is seen to decrease as the number of servers in the system are increased. Fig. 6 shows that the move time and wait time of the CCs are similar and work time and idle time are different for each scenario given fixed TC and YT team sizes. This information tells us that two CCs should be enough to handle most of the current load. Fig. 7, however, shows that the utilization levels decreased if the number of TCs is decreased for each scenario given fixed CC and YT team sizes. By contrast, rates of idle time are increased by about 10%.

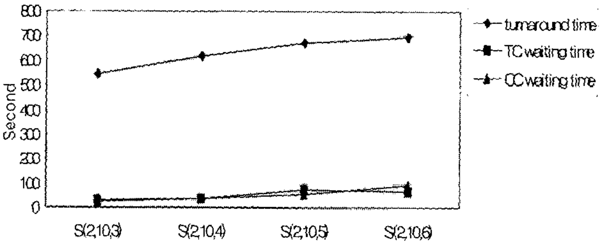

Fig. 8 YT Performance as change of YT number per CC

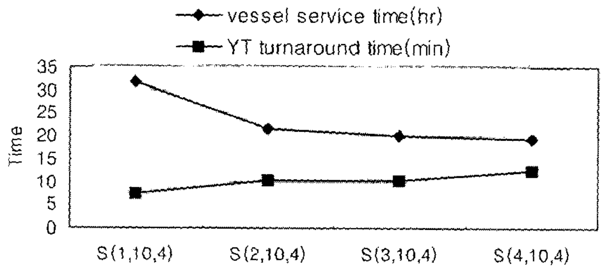

Fig. 9 Performance as change of CC number per berth

Fig. 8 tells us that the turnaround times of YTs between yard and berth increases as the number of assigned YTs per CCs are increased. And the TC waiting time and the CC waiting time increases as the turnaround times of the YTs increases. Therefore, increasing the number of YTs from three to six does not appear to increase the TC and CC waiting times significantly.

Fig. 9 shows that vessel service times decrease as the number of allocated CCs per berth is increased. It tells us that the service level of a container terminal is improved significantly until three CCs per berth are allocated. By contrast, YT turnaround time is increased. In particular, increasing the number of CCs from two to three is gives similar results. Fig. 10 shows that the service of YTs and trucks increasing as TCs decrease. Fig. 11 shows that vessel service time decreases as the number of allocated YTs per CCs is increased. But we found that YT turnaround time increases as the number of YTs per CCs increases.

Through the scenario analysis of the current situation, the simulation results clearly show a difference in the utilization of resources caused by the deployment strategy. Since an efficient system should fully utilize resources, the differences in particular measures among the equipment are used as the performance measures.

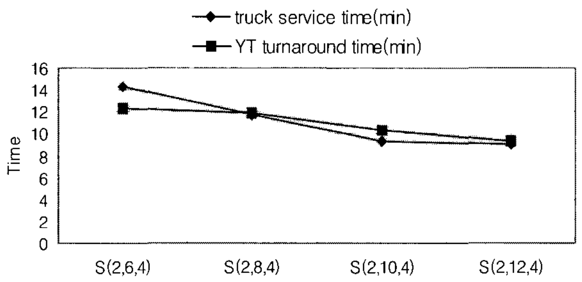

Fig. 10 Performance as change of TC number

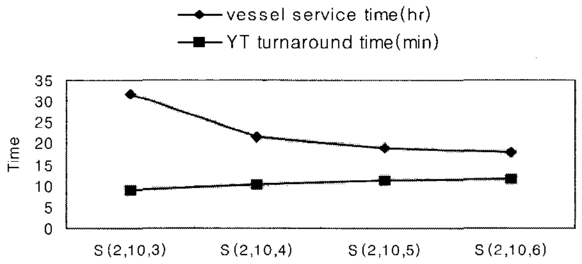

Fig. 11 Performance as change of YT number per CC

5. Conclusion

This is a simulation study that measures the performance of resources in a port container terminal .using the state transition network model for equipment. The objective of this study is to provide the particular measures for assessing the effectiveness of equipment allocation. To validate the developed state transition network model, the simulation is performed using the historical throughput data of an existing container terminal. The simulation experiment is performed on various deployment strategy scenarios which change the allocation of equipment and the results are analyzed using the particular measures. In order to analyze the effectiveness of equipment allocation, the measures we developed will be useful. For further study, we are developing another simulation model in which automated equipments are used.

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