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# A Simulation Modeling Approach for Analysing the Transportation of Containers in a Container Terminal System

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**Abstract**

Container terminal includes logistics activities that are needed to processing of containers considering cost, time and environmental issues. This makes terminal management problems important. These problems aim to decide the efficient planning of the terminals considering the cost and time minimization. Terminal operations include the movement of the full and empty containers between gateways of the terminals and berths by transport modes. Cranes and trucks are used in the study for the transportation. In this study, management of container processes problem has been proposed. The problem aims to perform the movement of the containers at the terminal efficiently. A simulation modelling approach has been proposed and solved by Arena software.

***Keywords:*** "Terminal Vehicle Movements, Transport of Containers, Simulation"

## 1. Introduction

Terminal processes need critical management and control. Transport vehicles and users of these vehicles at terminals play an important role in this critic management. Therefore, the need to improve the transportation vehicles and personal capability has risen. Accompanied by a steady growth of the terminal traffic, efficient and sustainable container terminal system is very important. To achieve this goal, different solutions can be offered. Terminal operations can be expressed as the transportation of containers by multiple transport vehicles without any change. The process of unloading the container from the ship and moving of this container to the yard area or the depots by truck is followed. For transporting containers safely and quickly to the other phase of the logistics system, only loading and unloading operations are not sufficient, but also the provision of value-added ervices such as storage, storage, packaging and internal transport modes are important [1,3]. Simulation-based studies have been widely carried out in port management. By simulation approach, alternatives are evaluated by examining the performance variables such as port traffic, vessel delay rate, number of ships in the system for different values of source quantities in the port. A decision support system is developed to simulate activities at the terminal. In this system, by simulation model, ship cycle times, usage rates of crane carriers and terminal congestion are examined. In addition, efforts have been made to improve terminal performance and prevent the use of inefficient resources [4]. A simulation is used to develop operations at a lower cost to identify and examine the port site. The model support is also provided for the planning of operations in the terminal, equipment replacement, and so on. In the created model, it was possible to analyse the operation times such as traffic conditions of vessels, fixed and operation costs, size of the area. The study is mostly suggestions on investment topics [5]. A simulation model is developed for performance indicators such as ship waiting times, ship movements and dock occupation to improve terminal logistics. In the study, dock occupation and ship waiting time are examined .The input to the simulation is the probability distributions of the number of berths, the number of berths, the number of berths, the number of berths, the number of berths, the number of berths, the probability distributions of ship waiting times. The results of the model are examined in the context of the time the ship waiting to leave the dock [6]. A simulation model is used with indicators such as berth crane location, resource assignment and port movements to improve logistical processes in ports. In the model, all processes are simulated with the Arena program in order to get the desired performance from the port. The study is a study of Kelang container terminal operations. In the developed model, dock occupation, ship output, usage rates of cranes and carriers, ship cycle times are derived. In the model, the expected statistics for ports and operations are obtained successfully [7]. A simulation model is developed to predict operations in terminal management. It also allows terminal tools to improve their performance and make cost estimates. The study is conducted at the Kwai Chung terminal. In the model, the inter-arrival times of the vessels are

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determined as negative exponential distribution and it is a study to analyze when the dock is needed [8]. The equipments are compared that provides transport in the terminal. In the study, the performance of automated transport tools and automated routing tools are measured using the simulation model. The comparative performance of unmanned terminal vehicles with the Arena software used in the study is shown [9]. A simulation method is used as a decision support system in port management and two different operation systems are being investigated by simulation. According to the model it has been proven that the vessels reduce the waiting time on the dock for loading on the railway. It has been determined that the inter-arrival wage is exponential, and the number of vessels arriving to the port with the hourly poisson distribution. With the simulated model created, statistics related to service output of the port are obtained and it is determined that the port dock assignments, efficient use of the port area, intra-port transportation efficiency and future port strategies could be done [10]. A container port settlement is designed. In order to create a settlement, the type of settlement, the port plan and the number of passes are determined. For the design, a formulation has been developed for the number of crane displacements and the movement distances of the trucks [11]. Simulations are used to evaluate field operations in the terminal. Material handling time, the routing of cranes and tractors, ship and cargo arrival time are modeled by simulation [12]. A simulation method is provided to manage loading or unloading containers in container terminals and optimization algorithm and the simulation method are integrated for this problem [13]. A simulation model is developed to determine the optimum number of container handling equipment of a Turkish port. Environmental damage of handling equipment is discussed in the study [14]. A container terminal's long-run average quay crane rate considering the capacity of the terminal's container storage yard, the number of yard cranes and trucks, their operating characteristics, the terminal operating system's ability, scale of the facility by discrete event simulation model are determined [15]. A simulation model is developed to determine the stockyard size for dry bulk terminals. the Stochastic variations in the ship interarrival times, ship sizes and bulk material storage times are used by the simulation model for a specific import terminal [16]. Container terminals are simulated to evaluate the floaterm concept [17]. The capacity of the roro terminals is examined by using a simulation approach. Number of trucks arriving to terminals, distance between terminals and Ro-Ro ship capacity are investigated for the effects to the terminal. Number of trucks is given as the most important parameter for this problem [18]. A discrete event simulation model is proposed for bulk carrier unloading and material transport, storage and discharge and berth occupancy, costs have also been identified [19].

This paper presents a simulation model for the terminal container transportation that does not only consider container movement allocation of the containers to the vehicles. The main contributions of this study are two-folds: (i) proposed a new simulation programming model considers from the unloading of containers from the ships and to container storage area and vice versa, (ii) this study demonstrates applicability of the proposed model for a regional container terminal system using a computer program.

The remainder of the paper is organized as follows. We present the problem definition in Section 2. We present the simulation model in Section 3. We conduct a case study to illustrate the benefit of the models in Section 4. Discussion is presented in Section 5. We conclude the paper with a summary of the study and future directions in Section 6.

## 2. Material and Method

Terminal in this study is defined as the area that the movement of the full and empty containers between berths and gate of the terminal is processed. Fig.1 shows a terminal system considered in this study. The problem includes full-empty containers, personals, terminal and transportation vehicles. The containers are classified as export and import containers according to the type of the container, full and empty according to the condition of the container. There are four types of container: inbound full (IF), inbound empty (IE), outbound full (OF), outbound empty (OE). Containers are called as inbound containers which are in the terminal expected to transport to the customers in the hinterland region. Containers are called as outbound containers which are carried to terminals to load them to the ships [20]. Containers are transferred by trucks or train line among the customers, depots and terminals. İnbound containers are distributed to the customers from the terminal in full condition, then the empty containers formed after unloading the inbound container are distributed to the depots or a customer serviced for the export container demand. Outbound containers are distributed to the terminals from the customers in full condition. The depots are used for the empty containers and trucks. Trucks and empty containers are in the depots. Trucks start and end their routes at the depots.

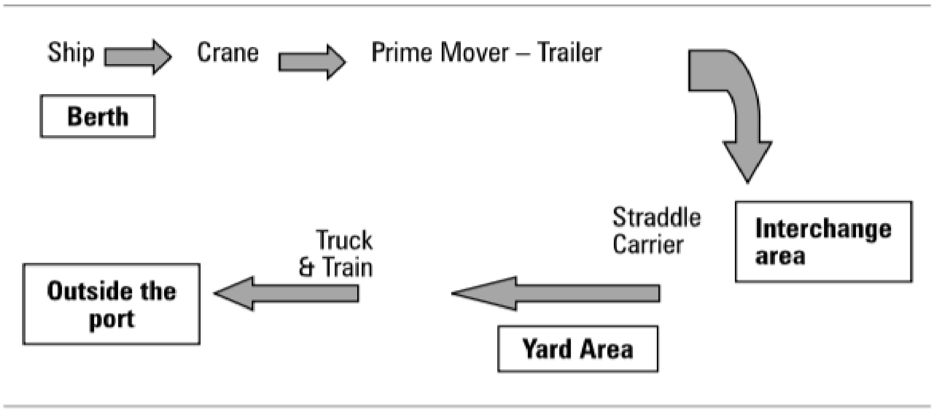



**Fig 1. Terminal flow [7]**

## 3. Implementation

In this study, a simulation model is developed for a container terminal system considering loading and unloading processes. Our model is solved by ARENA simulation software. According to the results of the model, yard cranes, berth cranes, transport vehicles and operators are examined.

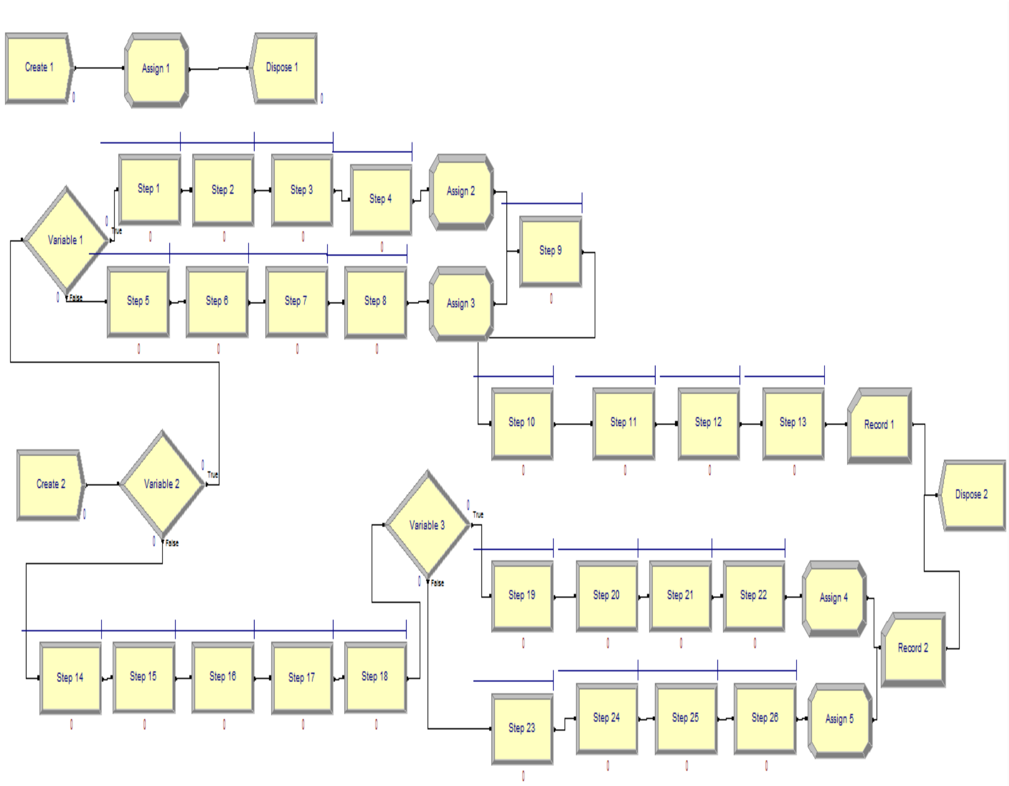



**Fig 2. Simulation model developed by the authors**

A simulation model figure developed by the authors is given Figure 2. The modules of the model are explained as bellows:

- Create 2: Times between arrivals of the ships
- Variable 2: This decision variable is about the loading or unloading decision of the ship
- The modules as below are about the loading the containers to the ship.
- Variable 1: This decision variable is about the deciding the empty yard crane
- Step 1: Process of the movement of the yard crane1 to the container

- Step 2: Process of the handling of the container by the yard crane1
- Step 3: Process of the movement of the yard crane1 to the transport vehicle with the container
- Step 4: Process of the loading of the container from the yard crane1 to the vehicle
- Step 5: Process of the movement of the yard crane2 to the container
- Step 6: Process of the handling of the container by the yard crane2
- Step 7: Process of the movement of the yard crane2 to the transport vehicle with the container
- Step 8: Process of the loading of the container from the yard crane2 to the vehicle
- Step 9: Transporting the container by the transport vehicle to the berth area
- Step 10: Process of the movement of the berth crane to the transport vehicle
- Step 11: Process of the handling of the container by the berth crane
- Step 12: Process of the movement of the berth crane to the ship with the container
- Step 13: Process of the loading of the container from the berth crane to the ship
- Record 1: The number of the container loaded

The modules as below are about the unloading the containers from the ship.

- Step 14: Process of the movement of the berth crane to the ship with the container
- Step 15: Process of the handling of the container by the berth crane
- Step 16: Process of the movement of the berth crane to the transport vehicle
- Step 17: Process of the loading the container by the berth crane to the vehicle
- Step 18: Transporting the container by the transport vehicle to the yard area
- Variable 3: This decision variable is about the deciding the empty yard crane
- Step 19: Process of the movement of the yard crane1 to the container
- Step 20: Process of the handling of the container by the yard crane1
- Step 21: Process of the movement of the yard crane1 to the yard area with the container
- Step 22: Process of the unloading of the container from the yard crane1 to the yard area
- Step 23: Process of the movement of the yard crane2 to the container
- Step 24: Process of the handling of the container by the yard crane2
- Step 25: Process of the movement of the yard crane2 to the yard area with the container
- Step 26: Process of the unloading of the container from the yard crane2 to the yard area
- Record 1: The number of the container unloaded

Assign modules provides to use the empty cranes. If yard crane1 is busy, yard crane2 is guided for the operations; if yard crane2 is busy, yard crane1 is guided for the operations.

## 4. Results

The results that ship waiting times, queue time of the processes, number of the containers at queue, resource utilization, number of busy resources, usage rate of the resources and the number of the loading-unloading containers are given.

| Wait Time | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| Entity 1 | 0.00 | 0,00 | 0.00 | 0.00 | 0.00 | 0. |
| ship | 5.6655 | 1,90 | 2.9478 | 11.6511 | 0.00 | 26.79 |

**Fig 3. Ship wait time**

Average, minimum and maximum waiting times as hours of the ships are given in Figure 3.

## Queue

### Time

| Waiting Time | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| Step 1.Queue | 0.08903670 | 0,02 | 0.05947582 | 0.1377 | 0.00 | 1.13 |
| Step 10.Queue | 0.7328 | 0,17 | 0.4579 | 1.1481 | 0.00 | 8.10 |
| Step 11.Queue | 0.7120 | 0,17 | 0.4353 | 1.0797 | 0.00 | 8.05 |
| Step 12.Queue | 0.7080 | 0,18 | 0.4361 | 1.0598 | 0.00 | 6.33 |
| Step 13.Queue | 0.7352 | 0,19 | 0.4391 | 1.1022 | 0.00 | 7.98 |
| Step 14.Queue | 0.7562 | 0,18 | 0.4568 | 1.1576 | 0.00 | 6.39 |
| Step 15.Queue | 0.7589 | 0,18 | 0.4770 | 1.2245 | 0.00 | 6.14 |
| Step 16.Queue | 0.7630 | 0,18 | 0.4661 | 1.1505 | 0.00 | 6.50 |
| Step 17.Queue | 0.8166 | 0,23 | 0.4654 | 1.3746 | 0.00 | 6.32 |
| Step 18.Queue | 2.3393 | 1,28 | 0.8425 | 6.8338 | 0.00 | 16.24 |
| Step 19.Queue | 0.07210140 | 0,01 | 0.05125798 | 0.1159 | 0.00 | 1.08 |
| Step 2.Queue | 0.0909 | 0,02 | 0.05744764 | 0.1319 | 0.00 | 1.03 |
| Step 20.Queue | 0.06846295 | 0,01 | 0.04801861 | 0.1042 | 0.00 | 1.08 |
| Step 21.Queue | 0.05984683 | 0,01 | 0.04581827 | 0.08357101 | 0.00 | 0.98 |
| Step 22.Queue | 0.04911496 | 0,01 | 0.03585378 | 0.07206289 | 0.00 | 0.80 |
| Step 23.Queue | 0.06755147 | 0,01 | 0.04819279 | 0.1106 | 0.00 | 0.90 |
| Step 24.Queue | 0.06575164 | 0,01 | 0.04235114 | 0.1069 | 0.00 | 1.22 |
| Step 25.Queue | 0.06740246 | 0,01 | 0.04220681 | 0.1019 | 0.00 | 1.15 |
| Step 26.Queue | 0.07688612 | 0,02 | 0.05088838 | 0.1333 | 0.00 | 1.08 |
| Step 3.Queue | 0.07895031 | 0,01 | 0.05495129 | 0.1112 | 0.00 | 1.03 |
| Step 4.Queue | 0.08707731 | 0,02 | 0.05487076 | 0.1270 | 0.00 | 0.92 |
| Step 5.Queue | 0.08554467 | 0,01 | 0.07111971 | 0.1252 | 0.00 | 0.90 |
| Step 6.Queue | 0.1068 | 0,01 | 0.0903 | 0.1455 | 0.00 | 1.12 |
| Step 7.Queue | 0.1080 | 0,02 | 0.08023948 | 0.1530 | 0.00 | 1.01 |
| Step 8.Queue | 0.1214 | 0,02 | 0.07899224 | 0.1807 | 0.00 | 1.05 |
| Step 9.Queue | 2.4772 | 1,31 | 0.8978 | 7.0748 | 0.00 | 16.80 |

**Fig 4. Queue waiting time**

Waiting times as hours at queues of the processes are given in Figure 4. Step 9 and step 18 is shown as more than 2 hours. Step 9 is transporting the container by the transport vehicle to the berth area. Step 18 is transporting the container by the transport vehicle to the yard area.

## Queue

### Other

| Number Waiting | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| Step 1.Queue | 0.03229829 | 0,01 | 0.01950807 | 0.05175938 | 0.00 | 3.00 |
| Step 10.Queue | 0.5429 | 0,15 | 0.3059 | 0.9379 | 0.00 | 8.00 |
| Step 11.Queue | 0.5268 | 0,14 | 0.2899 | 0.8792 | 0.00 | 9.00 |
| Step 12.Queue | 0.5239 | 0,15 | 0.2904 | 0.8624 | 0.00 | 11.00 |
| Step 13.Queue | 0.5381 | 0,16 | 0.2926 | 0.8950 | 0.00 | 13.00 |
| Step 14.Queue | 0.5770 | 0,15 | 0.3381 | 0.8691 | 0.00 | 8.00 |
| Step 15.Queue | 0.5774 | 0,15 | 0.3429 | 0.9118 | 0.00 | 12.00 |
| Step 16.Queue | 0.5808 | 0,15 | 0.3422 | 0.8757 | 0.00 | 12.00 |
| Step 17.Queue | 0.6185 | 0,18 | 0.3346 | 1.0131 | 0.00 | 14.00 |
| Step 18.Queue | 1.7922 | 1,04 | 0.6218 | 5.4973 | 0.00 | 15.00 |
| Step 19.Queue | 0.02631761 | 0,01 | 0.01822478 | 0.04032057 | 0.00 | 2.00 |
| Step 2.Queue | 0.03290656 | 0,01 | 0.01884283 | 0.04960003 | 0.00 | 3.00 |
| Step 20.Queue | 0.02496039 | 0,00 | 0.01767085 | 0.03626107 | 0.00 | 2.00 |
| Step 21.Queue | 0.02175748 | 0,00 | 0.01594156 | 0.02908271 | 0.00 | 2.00 |
| Step 22.Queue | 0.01784853 | 0,00 | 0.01219029 | 0.02507789 | 0.00 | 2.00 |
| Step 23.Queue | 0.02544827 | 0,01 | 0.01783133 | 0.04689858 | 0.00 | 2.00 |
| Step 24.Queue | 0.02475205 | 0,01 | 0.01558522 | 0.04533517 | 0.00 | 2.00 |
| Step 25.Queue | 0.02531277 | 0,01 | 0.01561652 | 0.04319996 | 0.00 | 2.00 |
| Step 26.Queue | 0.02896691 | 0,01 | 0.01833418 | 0.05652576 | 0.00 | 2.00 |
| Step 3.Queue | 0.02860300 | 0,01 | 0.01802402 | 0.04580791 | 0.00 | 3.00 |
| Step 4.Queue | 0.03145117 | 0,01 | 0.01843657 | 0.04775984 | 0.00 | 3.00 |
| Step 5.Queue | 0.03298394 | 0,01 | 0.02474966 | 0.04732771 | 0.00 | 4.00 |
| Step 6.Queue | 0.04113910 | 0,01 | 0.03108281 | 0.05471356 | 0.00 | 4.00 |
| Step 7.Queue | 0.04162724 | 0,01 | 0.02856525 | 0.05754023 | 0.00 | 4.00 |
| Step 8.Queue | 0.04688631 | 0,01 | 0.02812124 | 0.06794909 | 0.00 | 4.00 |
| Step 9.Queue | 1.9147 | 1,13 | 0.6033 | 6.0043 | 0.00 | 17.00 |

**Fig 5. Queue number waiting**

Number of waiting processes as hours at queues is given in Figure 5. Step 9 and step 18 is shown as more than 1. Step 9 is transporting the container by the transport vehicle to the berth area. Step 18 is transporting the container by the transport vehicle to the yard area.

## Resource

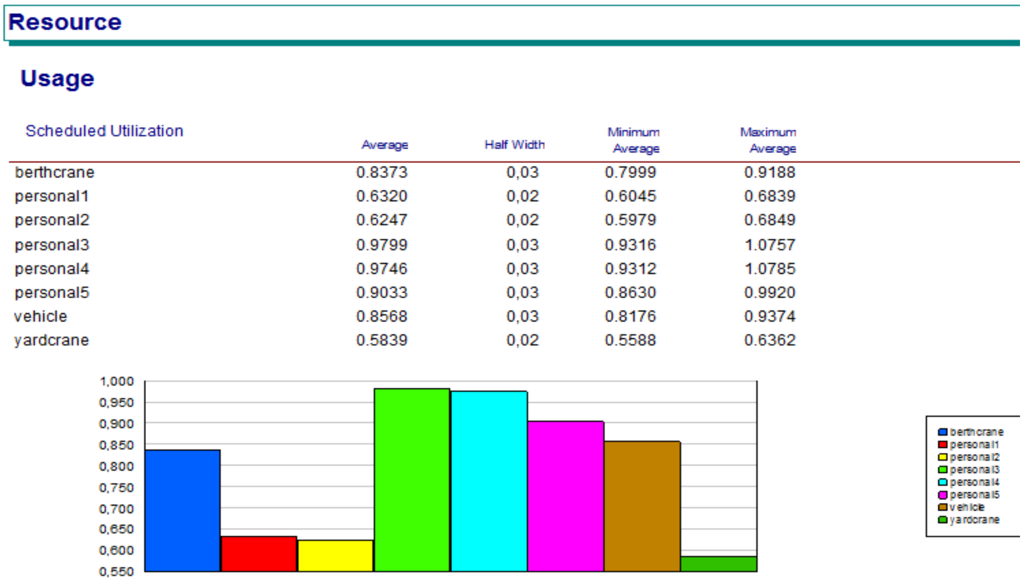
### Usage

| Instantaneous Utilization | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| berthcrane | 0.8373 | 0,03 | 0.7999 | 0.9188 | 0.00 | 1.00 |
| personal1 | 0.5875 | 0,02 | 0.5615 | 0.6359 | 0.00 | 1.00 |
| personal2 | 0.5803 | 0,02 | 0.5560 | 0.6365 | 0.00 | 1.00 |
| personal3 | 0.8578 | 0,03 | 0.8154 | 0.9390 | 0.00 | 1.00 |
| personal4 | 0.8558 | 0,03 | 0.8198 | 0.9358 | 0.00 | 1.00 |
| personal5 | 0.8373 | 0,03 | 0.7999 | 0.9188 | 0.00 | 1.00 |
| vehicle | 0.8568 | 0,03 | 0.8176 | 0.9374 | 0.00 | 1.00 |
| yardcrane | 0.5839 | 0,02 | 0.5588 | 0.6362 | 0.00 | 1.00 |

| Number Busy | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| berthcrane | 0.8373 | 0,03 | 0.7999 | 0.9188 | 0.00 | 1.00 |
| personal1 | 0.5875 | 0,02 | 0.5615 | 0.6359 | 0.00 | 1.00 |
| personal2 | 0.5803 | 0,02 | 0.5560 | 0.6365 | 0.00 | 1.00 |
| personal3 | 0.8578 | 0,03 | 0.8154 | 0.9390 | 0.00 | 1.00 |
| personal4 | 0.8558 | 0,03 | 0.8198 | 0.9358 | 0.00 | 1.00 |
| personal5 | 0.8373 | 0,03 | 0.7999 | 0.9188 | 0.00 | 1.00 |
| vehicle | 1.7136 | 0,05 | 1.6352 | 1.8748 | 0.00 | 2.00 |
| yardcrane | 1.1678 | 0,04 | 1.1175 | 1.2724 | 0.00 | 2.00 |

**Fig 6. Instantaneous utilization and resource busy**

Personal 1 and 2 works for the yard crane; personal 3-4 works for the vehicle; personal 5 works for the berth crane. Figure 6 shows that personal 3-4-5 are the busiest resources in the system.



Resource

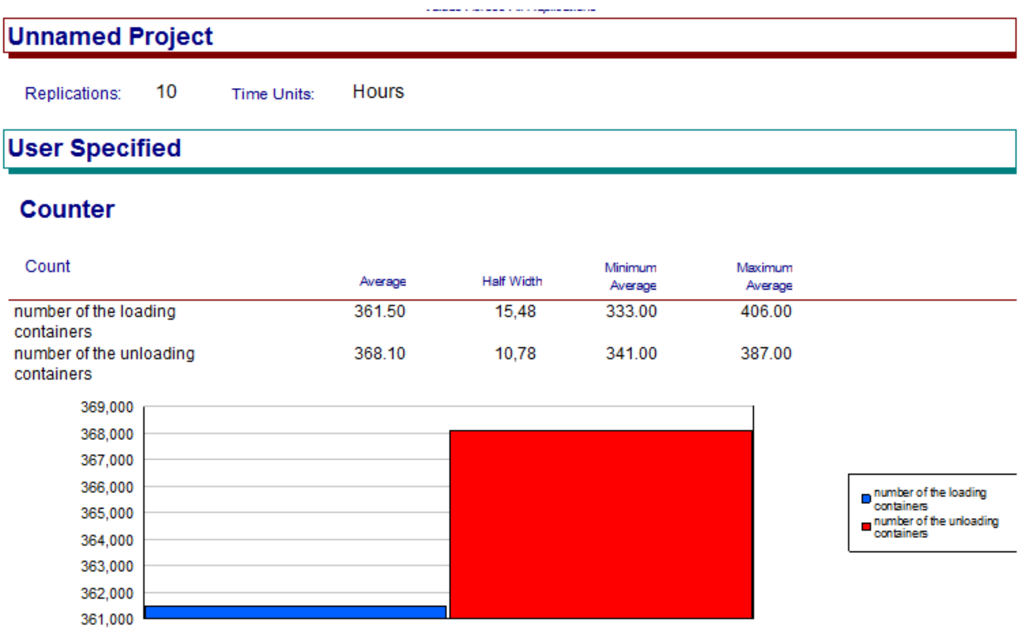
Usage

| Scheduled Utilization | Average | Half Width | Minimum Average | Maximum Average |
|---|---|---|---|---|
| berthcrane | 0.8373 | 0,03 | 0.7999 | 0.9188 |
| personal1 | 0.6320 | 0,02 | 0.6045 | 0.6839 |
| personal2 | 0.6247 | 0,02 | 0.5979 | 0.6849 |
| personal3 | 0.9799 | 0,03 | 0.9316 | 1.0757 |
| personal4 | 0.9746 | 0,03 | 0.9312 | 1.0785 |
| personal5 | 0.9033 | 0,03 | 0.8630 | 0.9920 |
| vehicle | 0.8568 | 0,03 | 0.8176 | 0.9374 |
| yardcrane | 0.5839 | 0,02 | 0.5588 | 0.6362 |



**Fig 7. Scheduled utilization of resources**

Personal 1 and 2 works for the yard crane; personal 3-4 works for the vehicle; personal 5 works for the berth crane. Figure 7 shows that personal 3-4-5 are the busiest resources in the system. Personals are assumed to work for 8 hours. Personal 1-2 have a break times in order; for example, personal 1 works for 4 hours and has a break for half hours, personal 2 has a break after the personal 1's break. The same process continues for personal 3-4.



Unnamed Project

Replications: 10 Time Units: Hours

User Specified

Counter

| Count | Average | Half Width | Minimum Average | Maximum Average |
|---|---|---|---|---|
| number of the loading containers | 361.50 | 15,48 | 333.00 | 406.00 |
| number of the unloading containers | 368.10 | 10,78 | 341.00 | 387.00 |



**Fig 8. Number of loading containers and unloading containers**

Replication number is determined as 10. Number of loading containers and unloading containers are given in Figure 8.

## 5. Sensitivity Analysis

Sensitivity analysis is applied to see the effects of the inputs to the output With changes the coefficients or weights. In this section, a sensitivity analysis 1 is applied for changing the berth crane numbers and personal numbers. Sensitivity analysis 2 is applied for the number of the transport vehicle.

| Scheduled Utilization | Average | Half Width | Minimum Average | Maximum Average |
|---|---|---|---|---|
| berthcrane | 0.4220 | 0,01 | 0.3913 | 0.4482 |
| personal1 | 0.6400 | 0,02 | 0.6010 | 0.6899 |
| personal2 | 0.6335 | 0,02 | 0.5879 | 0.6753 |
| personal3 | 0.9900 | 0,03 | 0.9137 | 1.0578 |
| personal4 | 0.9881 | 0,03 | 0.9228 | 1.0498 |
| personal5 | 0.4515 | 0,01 | 0.4132 | 0.4814 |
| personal6 | 0.4536 | 0,01 | 0.4254 | 0.4813 |
| vehicle | 0.8667 | 0,03 | 0.8083 | 0.9219 |
| yardcrane | 0.5911 | 0,02 | 0.5520 | 0.6332 |

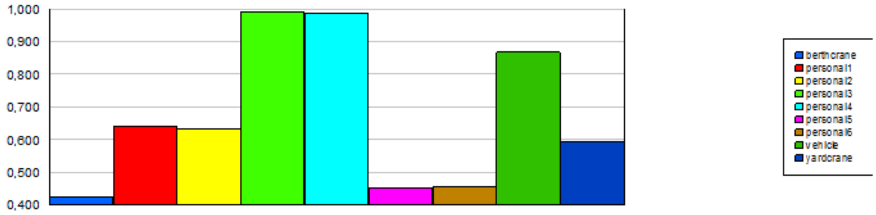



**Fig 9. Result of sensitivity analysis 1**

| Scheduled Utilization | Average | Half Width | Minimum Average | Maximum Average |
|---|---|---|---|---|
| berthcrane | 0.8506 | 0,02 | 0.8041 | 0.8856 |
| personal1 | 0.6458 | 0,01 | 0.6088 | 0.6734 |
| personal2 | 0.6430 | 0,02 | 0.6098 | 0.6854 |
| personal3 | 0.6539 | 0,02 | 0.6236 | 0.6970 |
| personal4 | 0.6572 | 0,02 | 0.6258 | 0.6808 |
| personal5 | 0.9173 | 0,02 | 0.8676 | 0.9580 |
| personal6 | 0.6568 | 0,02 | 0.6142 | 0.6831 |
| vehicle | 0.5881 | 0,01 | 0.5598 | 0.6171 |
| yardcrane | 0.5981 | 0,01 | 0.5664 | 0.6287 |

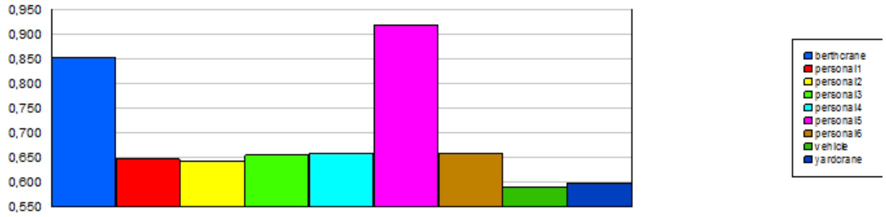



**Fig 10. Result of sensitivity analysis 2**

For the results of sensitivity analysis 1, adding more personal to the system provides to decrease of the workloads; adding more berth crane to the system also decrease the usage of the crane. For sensitivity analysis 2, adding more transport vehicles to the system decrease the usage of the vehicle shown in Figure 9-10.

## 6. Conclusion

Container terminal is a good area for applying operational methods and simulation approaches. Processes at the terminals need to control efficiently to management the terminal system. Pre haulage of the terminal starts with the unloading the containers from the ships and vice versa for the loading operations. Then, main haulage continues as transporting the containers to the yard area or berth area. In this study, we deal with the pre haulage and main haulage of the terminal management. A new simulation model is provided for a terminal dataset developed by the authors and usage, waiting times, and number of the terminal resources is determined. A sensitivity analysis is used for the effects of the resources to the outputs in case of the changes.

For future works, hybrid models integrate both of the simulation model and heuristic methods are applied for real case studies. In addition, a larger problem covers the hinterland of the terminal can be examined.

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