EasyChair Preprint

№ 2681

A System Performance Analysis of Ship to Shore Operation Considering Crane Availabilities using Simulation Approach

Bayu Dwi Aqsha, Nurhadi Siswanto and Suparno

EasyChair preprints are intended for rapid dissemination of research results and are integrated with the rest of EasyChair.

February 17, 2020

A System Performance Analysis of Ship to Shore Operation Considering Crane Availabilities using Simulation Approach

BD Aqsha[1,2], N Siswanto[1,3], and Suparno[1,4]

[1]Department of Industrial Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
[2]Bayudwiaqsha@gmail.com, [3]siswanto@ie.its.ac.id, [4]suparno@ie.its.ac.id

Abstract. Indonesia which consists of many islands has difficulty in establishing national distribution logistics. Because of the sea traffic expansion in Eastern part of Indonesia, the existing port is limited and cannot handle such a problem. To accommodate this problem, new port is built in Surabaya, East Java, Indonesia. However, the new port usually faces to handle an unlimited demand with limited resources. This paper evaluates the port productivity of container loading and unloading activities. Equipments used in container loading and unloading at this port include cranes and other equipments. Because of many complexities in the observed system, discrete event simulation is used to evaluate the terminal operation performance. The simulation results show that STS crane quantities and formations for loading and unloading activities are affecting the new port productivity.
Keywords: Container Terminal; Discrete Event Simulation; Port Logistics; Ship to Shore Crane;

1. Introduction

Indonesia as one of the largest archipelago states in the world needs many harbors ports, and sea terminals to develop national commodities distributions. Production competition from national to international markets, internal distribution efficiency, and integrated national economy are affected by seaport system performance. The distribution system using sea transportation must be controlled effectively and efficiently. However, many Indonesian ports are lack of efficient and not managed well. According to Indonesian Statistics Bureau, unloading and loading activities are increasing from year to year in domestic and international ports in Indonesia [1]. These activities are the main business process in a seaport. If these activities are held, many queue events will rise in incoming and outgoing vessels. To handle such a problem, shore to crane operation builds and one of the main tools in the operation is the crane availabilities. However, crane reliability sometimes makes the unloading and loading process hold up. Some of the researches consider the routing decision for those vessels in minimizing the cost and the route [2]. These situations can decrease system performance in port terminals [3]. The case study of this research is in the new seaport terminal in Surabaya, East Java, Indonesia. This port is a new port built with the eco-green port concept. The port is using environmentally-friendly equipment to run their operations. However, this port also has an increase in container flow that has to be loaded and unloaded. Unfortunately, to cope with this problem, many pieces of equipment should be adjusted. Adjusting equipments in seaport terminals is a complex decision because many seaport operations can be affected, from economical until the technical perspective.

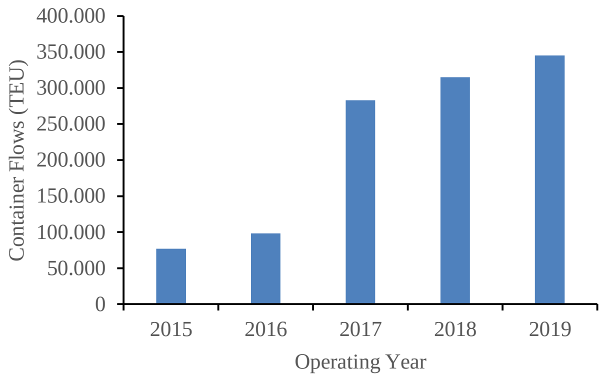

Figure 1. Graphic of Container Flows in the Case Study Port Terminal

Port terminal logistic research is done by many academics and researchers. This problem is so complex that using a mathematical model needs to be done with careful planning. That is why these kinds of problems usually solved using a simulation approach to cope with the uncertainty. The focus of the research goal should be pointed to evaluate the unloading and loading activities by using discrete event simulation (DES) to model the problems [4]. This is difference with other research which is focus on analysing crane availabilities [5]. The other research use mathematical model due to without stochastic settings to understand the behaviour the crane strength in a ship to shore operation [3]. Then, another analytical research study a new port development with limited capacity to handle the increaseing demand [6]. In the port development, some of the port should manage their environment to lower their pollution [7]. From this perspective, there is a limited study about crane availabilities in a ship to shore operations at a new port that performs an eco-green labelled port. This kind of novelty is used in this research.

The steps to conduct this research is (1) to make a model system and simulation of loading and unloading considering crane availabilities, then (2) to determine how many equipment should be prepared to find the best performances in the activities. Thus, this research objective is to develop a simulation model of unloading and loading activities considering ship to shore crane and testing the additional equipments needed to improve the system performance. The novelty of this research is the implementation of crane decision to ship to shore operation in an uncertain environment at new port labelled as an eco-green port. For the managerial implication, the simulation can give an insight analysis of the significant effects of adding more equipments in a ship to shore crane to port terminal performance. This research does not analysis financial and economic aspects and let these as our further research. The research assumptions are (1) the service operational activity is working normally, (2) the berthing time is the same, (3) there are no break down and maintenance activity in the crane, (4) the unloading rate is constant, and finally (5) the ship delivery time is in stochastic settings.

2. Literature Review

2.1. Ship to Shore (STS) Operations in Port Terminal Logistics

The port terminal is located in Surabaya, East Java, Indonesia as in Figure 2. It is the first new port that performs the eco-friendly concept. Besides that, this port is using much modern equipment and is developed to help the distribution on the east part of Indonesia. The container yard is one of the most important places that can provide economic assistance in the region [8]. Port with container yard is a holistic complex system that many resources, entities, and transport equipments are involved to do unloading and loading activities. This operation is included in the distribution and transportation system because it has a function to deliver a product from one node to other nodes [9].

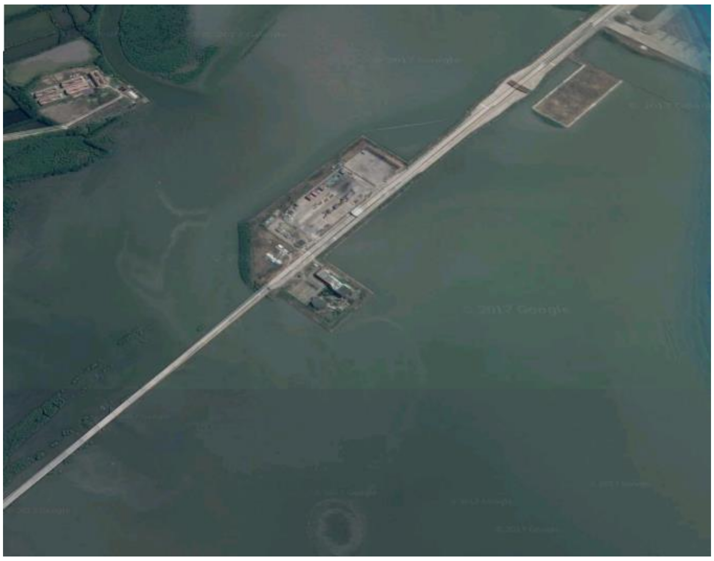

Figure 2. The Sightings of the Case Study Port Terminal

2.2. Discrete Event Simulation (DES)

Discrete event simulation (DES) is a system modelling and simulation of an event in a matter of time where state variables are changing instantaneously and separated at some point of time and forming a discrete even. This kind of simulation is different from a continuous simulation which is used to observe system behaviour through time, such as system dynamics.

Table 1. Previous Research and Research Gap.

No	Author	Port Terminal Logistic			Model Settings		Analysis
		Crane Availabilities	***New Port Development***	***Eco green Port***	***Stochastic Process***	***Simulation Approach***	
1	*Tang et al (2019)*	✓					*Mathematical model of crane strength*
2	*Kotachi et al (2013)*				✓	✓	*Simulation on multimodal transportation*
3	*Kotachi et al (2016)*		✓		✓	✓	*Simulation on new port*
4	*Aljena et al (2016)*			✓	✓	✓	*Forecasting port capacity*
5	*Ursavas (2015)*	✓			✓	✓	*Dynamic Discrete Event Simulation*
6	*Rusgiyanti et al (2017)*			✓	✓	✓	*Simulation of yard extension*
7	*Siswanto et al (2018)*				✓	✓	*Disruptive supply and congestion problems*
8	*This Paper*	✓	✓	✓	✓	✓	*Simulation on crane availabilities*

However, DES is triggered by some events. In everyday life, the discrete event is pictured by system capabilities that cannot process more entities causing some queuing events. This type of simulation is usually used in port logistics problems. The disruption in unloading and loading activity may cause queue in incoming vessels and container yard operations will be obstructed. This simulation is used to know the system's performance by adding and/or modifying more parameters, entities, and variables. Table 1 shows the research gap between previous researches and this research.

3. Methodology

3.1. Model Development

This first step of this research is conducting survey in the port to collect secondary data. The survey is done to gather information about the main activity, facility and equipment, container service procedure, operational performance, and the problems in container operations. After the information is obtained, the model is developed using Simulation Software in the form of a block flow diagram. Then the entities, activities, and the resource of the model is filled up in the software. The following is a general description of container loading and unloading activities. The system variables are shown in Table 2 as below:

Table 2stem**.** Sy Variables

Decision Variables	**Response Variables**	**State Variables**
STS Crane Quantities	*Service Level*	*Crane Busy & Idle Status*
STS Crane Formation	*Utility Level*	*Port Busy and Idle Status*

3.2. Model Verification and Validation

After the model is built, the verification phase begins for testing the model justification and reliability according to researcher observation and from other related resources. Then the model needs to be validated by using hypotheses testing of two samples variances in T-test with significance level 95%. If the model is not verified or validated, then the model will be reformulated. The hypothesis is shown below:

H_0: The model simulation data variance is equal to the real data variance
H_1: The model simulation data variance is not equal to the real data variance.

3.3. Scenario Testing

After the model is verified and validated, the model is simulated using five alternative scenarios. The alternatives are compared to the existing scenario for their system performances as seen in Table 3. The used response variables for comparison are the service and utility level of the port.

Table 3. System Scenarios of STS Crane Quantities and Formations.

No	Scenario	Formation	Information
1	*Existing*	*2-1-1-1*	• *Two STS Crane for one vessel* • *Other vessels served by one STS Crane*
2	*1st*	*1-1-1-1-1*	• *Each vessel served to be one STS Crane*
3	*2nd*	*2-2-1*	• *One vessel is served by one STS Crane* • *Other vessels served by two STS Crane*
4	*3rd*	*3-1-1*	• *Three STS Crane for one vessel* • *Other vessels served by one STS Crane*
5	*4th*	*3-2*	• *Three STS Crane for one vessel* • *Other vessel served by two STS Crane*
6	*5th*	*4-1*	• *Four STS Crane for one vessel* • *Other vessel served by one STS Crane*

4. Results and Discussions

Container service in the domestic region has a 450-meter port length for berthing operations. Container vessels can dock at the same time in the dock if the total length of the docked vessel does not exceed the total length of the pier. Also, the loading and unloading activities can be performed if there is still STS equipment available. The stochastic parameters of the model ship are the arrival time, the vessel length overall (LOA), the vessel gross register tonnage, the number of unloaded containers, and the number of loaded containers. Modelling is developed by changing the number of STS equipment in serving container loading and unloading vessels as in Table 3. Ships that dock at the pier will be regulated by the amount of equipment to be used in container loading and unloading activities. With a total domestic dock length of 450 m, the number of STS equipment at the domestic pier is 5 units and total trucks available are 50 units. The model flow is stated in the Figure 3 below.

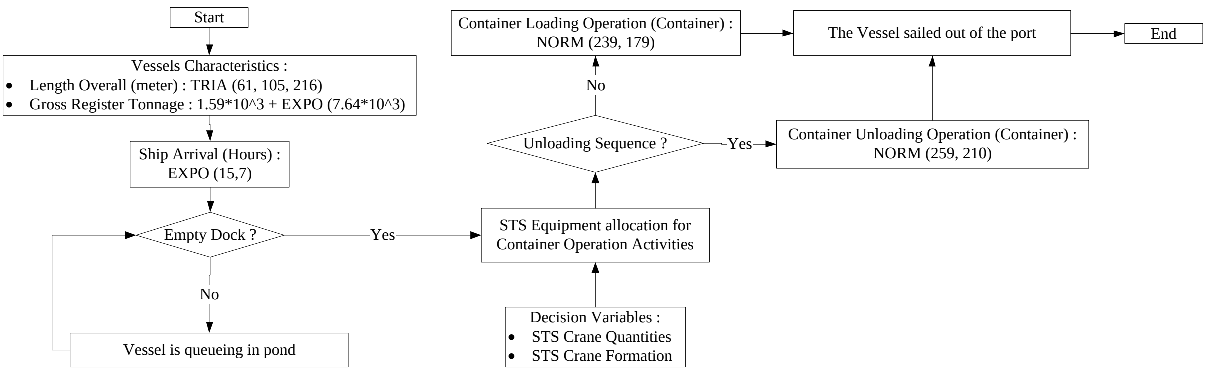

Figure 3. The System Model Flow

The model limitations is only reviewed the problem in container loading and unloading activities in vessels using ship to shore cranes. The model assumptions is that no machine failures in the cranes, so the STS cranes capacities are the same to load/unload 25-30 containers per hours. After the model is developed using the software, the model is verified and validated. The research process is continued to the validation test to make sure that the model simulation fits with the real system. For the simulation result based on an existing condition is shown in the Table 4 below:

Table 4. Simulation Result for Validation.

Month Simulation	Incoming Vessels	Unloading and Loading Activities (Hours)	
		Effective Time	Total Time
July	*51*	*832.22*	*1057.36*
August	*59*	*997.99*	*1264.07*
September	*45*	*694.65*	*879.61*
October	*43*	*645.56*	*817.92*
November	*48*	*760.71*	*961.93*
December	*50*	*745.72*	*979.06*

The simulation result is compared to the real existing data as in Table 4. The validation is using a T-test statistic with a significance level of 95%. The parameters used for validation are the number of incoming vessels, the effective time, and the port total time. The calculated t-value is compared to the upper and lower limit of the two tail of T-table. If the simulation is inside the limit, then the null hypothesis is accepted, and the model simulation is considered as a representation of the real system. The validation test result is shown in the Table 5 below.

Table 5. Validation Test Result.

Validated Parameters	Calculated T-Value	T Critical two-tail	Condition
Incoming Vessels	*1.004720719*	*2.570581836*	*Accept H0*
Effective Time	*-0.078268079*	*2.570581836*	*Accept H0*
Total Time	*0.244462296*	*2.570581836*	*Accept H0*

*Significance Level 95%

After the model is validated, this research has a model of simulation that imitates the real system. Models of several scenarios are ready to be developed to obtain simulation results which have the most positive impacts on operational activities. These activities include the number of docked ships, the length of loading and unloading activities at the docks and the utilization of equipments. Three indicators, known as response variables, are chosen: the number of serviced vessels, the average effective time, and the utilization percentage.

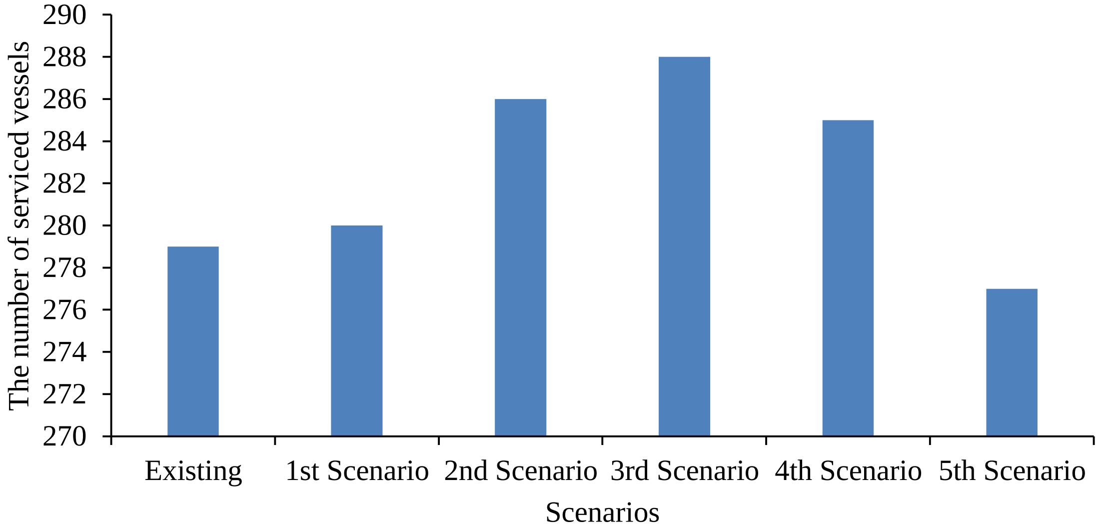

Figure 4. The Number of Serviced Vessels Chart

The simulation is conducted with the lenght of six months simulation time with the result that the highest vessel can be serviced is on the 3rd scenario for 288 vessels. However, the lowest serviced vessels can be utilized is 277 vessels with the 5th scenario. The high serviced vessel quantity cannot be strong evidence for evaluating port productivity. It still needs more response variables to conclude which scenario produce the most productivity.

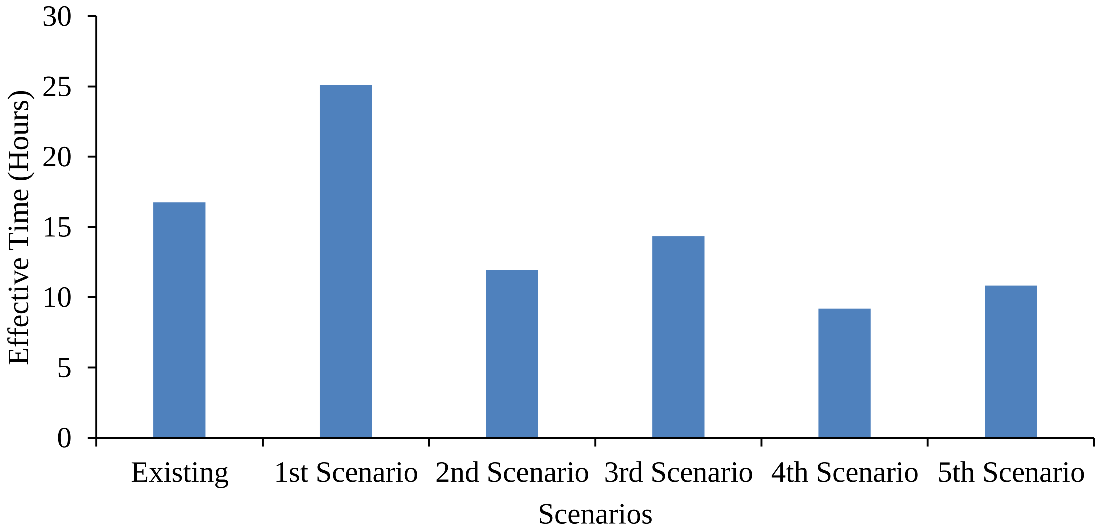

Figure 5. Chart of Effective Time

The effective time of the unloading and loading activities is significant to the port system performance. Effective time is a time for unloading and loading activities without any disruptions. The effective time is calculated from the first time the container is unloaded to the last time the container is loaded to the ship. The highest effective time is reached from the 4th scenario with 9.19 hours. The lowest effective time is the result from the first alternative scenario with 25.09 hours.

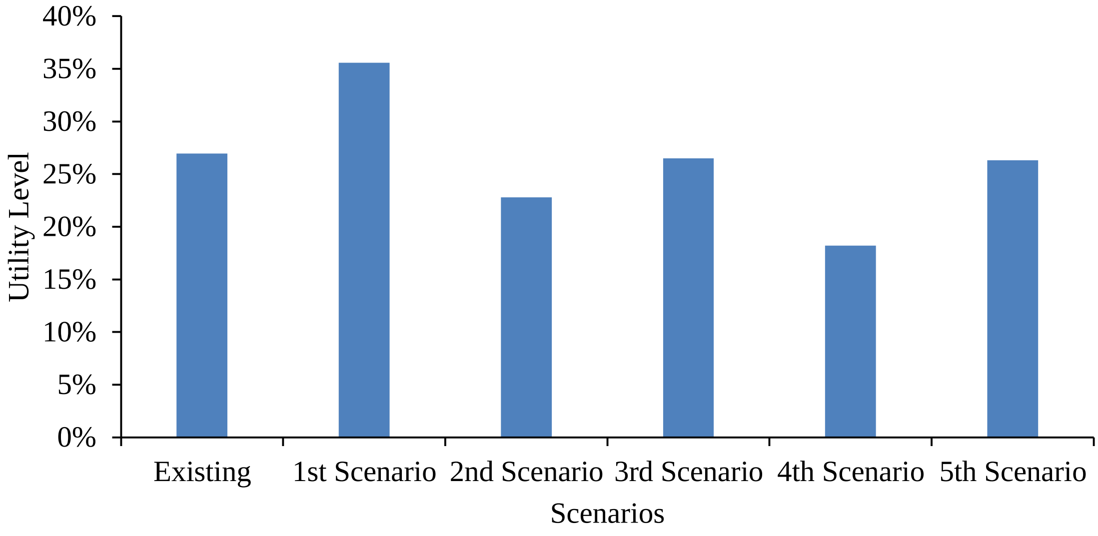

Figure 6. Chart of Utility Level

The utilization level in the port terminal system is an equipment indicator of handling unloading and loading containers in the docks. The higher the value of the utilization indicates that the equipment is all used. From the simulation results, it can be seen that the highest utilization is reached from the first scenario. Higher utilization can make the operation time longer. However, the 4th scenario has the lowest utilization value. Thus, this scenario has the fastest time of operation.

5. Conclusion

Port development in Indonesia is one of the fundamental factors to improve national logistics performance. To support this event, many ports are being developed, one of them is the case study port. This kind of port is performing an eco-green labelled to minimize carbon emission. However, this new port's development is having a difficult problem, with limited resources and tools. So, the port must handle the demand increase of container processing from incoming vessels. A discrete event model and simulation are used in this research to solve the problem. The existing model shows that the port will be experienced limitations of the resources in the next few years with the options that the available cranes and the crane formation must be decided. Several simulation scenarios are conducted that show crane assignment decision is having a significant relationship to port system performance in a ship to shore operations. The best system performance has ever been recorded from the simulation is using the 4th scenario with 3 STS crane for one vessel and 2 STS crane for other vessels. With this configuration, the effective time is 9.19 hours and the utilization equipment is 18.21%.

The research is having some limitations to the problems. The paper focus only on the number of cranes availabilities for the loading and unloading operations. The research could be more interesting if there are reliability analyses for the use of cranes and the trucks. Besides determining the number of trucks, scheduling and routing decision can be added to make the system more complex.

6. References

[1] Badan Pusat Statistik., 2017. *Statistik Transportasi Laut*. Jakarta: Badan Pusat Statistik.

[2] Siswanto, N., Wiratno, S.E., Rusdiansyah, A., and Sarker. R., 2019. "Maritime inventory routing problem with multiple time windows," *J. Ind. Manag. Optim.*, vol. 15(3), pp. 1185–1211.

[3] Tang, G., Shi, C., Wang, Y., and Hu, X., 2019. "Strength Analysis of the Main Structural Component in Ship-to-Shore Cranes under Dynamic Load," *IEEE Access*, vol. 7, pp. 23959–23966.

[4] Siswanto, N., Kurniawati, U., Latiffianti, E., Rusdiansyah, A., and Sarker. R., 2018 "A Simulation study of sea transport based fertilizer product considering disruptive supply and congestion problems," *Asian Journal of Shipping and Logistics*, vol. 34(4.), pp. 269–278.

[5] Ursavas, E,. 2015. "Priority control of berth allocation problem in container terminals," *Ann. Oper. Res.*, pp. 1–20.

[6] Kotachi, M., and Msakni, M., 2016. "A Discrete Event Simulation for The Logistics of Hamad's Container Terminal of Qatar," in *Proceedings of the 2016 Winter Simulation Conference*, pp. 2262–2271.

[7] Souf-Aljen, A. S., Maimun, A., Rahimuddin, and Zairie, N., 2016. "Port capacity forecasting and the impact of the dredging works on port sea operations using discrete event simulation," *J. Teknol.*, vol. 78, no. 9–4, pp. 31–40, 2016.

[8] Yuan, Z., 2016 "A Brief Literature Review on Ship Management in Maritime Transportation," Brussels.

[9] Chopra, S., and P. Meindl., 2007. "Supply chain management. Strategy, planning & operation," *Das Summa Summ. des Manag.*, pp. 265–275.