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A DISCRETE-EVENT SIMULATION MODEL FOR TERMINAL CAPACITY PLANNING IN AN INDONESIAN CONTAINER PORT

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ABSTRACT

This study examines a case study of a container terminal in Surabaya, Indonesia. There are three types of equipment, which are container cranes, RTG cranes, and head trucks. Despite the availability of these resources, their utilization is still low. To address this issue, given the system's inherent complexity and the interdependencies among its components, a discrete-event simulation modeling approach is used. The simulation model explores the potential scenarios for improvements and evaluate the best alternatives to improve the equipment utilization while taking into account the quantity of ships and containers processed. The experiments also consider the combination of equipment assignments during the loading-unloading activities. The results indicate that the increase in equipment utility is not strictly proportional to the increase in the number of containers and ships. In particular, increases in the number of containers and ships do not result in a proportional, linear correlation with equipment utilization rates.

1 INTRODUCTION

Container terminals are one of the services provided by ports to handle loading and unloading processes. The efficiency of port operations depends on the coordination of each process and the various equipment used. Each activity within the loading and unloading process is interrelated, such that inefficiencies in any single activity can propagate delays, leading to the formation of queues and subsequently affecting the timely execution of subsequent activities. Additionally, the complexity of the loading and unloading system is caused by the uncertainty in the number of containers carried by each ship. Therefore, determining the number of container terminal equipment and integrating each piece of equipment is a crucial strategy for improving the efficiency of port logistics processes.

This study takes a case study at a container terminal that handled the loading and unloading of 323,124 boxes in 2022 and 345,083 boxes in 2023. The equipment used at this container terminal includes four container cranes for moving containers from the ship to the head truck or vice versa, 24 head trucks for moving containers from the dock to the container yard or from the container yard to the dock, and eight RTG (Rubber Tyred Gantry) cranes for moving containers within the container yard. The equipment utilization rates in this terminal are still low due to suboptimal equipment usage and the relatively small number of containers processed compared to the amount of equipment available. This low utilization rate can cause a decrease in productivity and increase logistics costs in the terminal.

2 METHOD

Given the variability, uncertainty, and interdependence of the system, these issues can be addressed using simulation methods. A discrete-event simulation approach is adopted as the system described involves the flow of entities from one activity to another at discrete points. Various scenarios are designed to determine the number of container cranes, RTG cranes, and head trucks, as well as the head truck assignment mechanisms to improve efficiency while considering outputs in terms of the number of ships and containers.

In general, the modeling process in this study involves the four steps of simulation model development suggested by Robinson (2014). These steps are conceptual modeling, computer modeling, experimentation, and analysis. The outputs of each stage are, respectively, a conceptual model, a computer model, and a better understanding of the problem in the real world. This simulation model aims to determine the optimal number of container cranes, RTG cranes, and head trucks to achieve a high utilization rate while considering the number of ships and containers.

After developing the conceptual model, the simulation model is developed and executed. The next steps are deciding the number of replications using the equations introduced by Law and Kelton (2002), verification consisting syntax verification and semantic verification to ensure that the simulation can be run and is in accordance with the conceptual model, and validation using the Student's t-test to ensure there are no significant differences between the simulation results and the real-world conditions for the simulation outputs. After running the simulation for the existing condition, improvement scenarios are arranged to increase the utilization rate by modifying the number of container cranes, RTG cranes, head trucks, and the head truck assignment mechanism. There are 8 scenarios are evaluated, each being a combination of 2 or 4 container cranes, 7 or 8 RTG cranes, and 12 or 16 head trucks, with dedicated or undedicated head trucks. Then, from these scenarios, the best scenarios is selected.

3 RESULTS

The simulation of the existing condition indicates that the average utilization rate for container cranes, RTG cranes, and head truck are 49.23%, 54.21%, and 38.13% with the average containers and ships processed are 33,154 boxes and 64 ships. The required number of replications in the simulation is 34, and the simulation length is 30 days. The simulation results suggest that the increase in utility is not directly proportional to the increase in the number of containers and ships. Therefore, the best scenario with the highest utility is selected by considering the number of containers and ships processed. However, the utilization rate must comply with government regulations, which state it must not exceed 80%. Following the execution of various improvement scenarios, the optimal scenario is identified. This scenario entails the deployment of 4 container cranes, 7 RTG cranes, and 16 non-dedicated head trucks. This scenario results in an increase in utilization rates, specifically a 0.35% improvement for container cranes, a 7.32% enhancement for RTG cranes, and an 18.24% rise for head trucks. Additionally, while the number of ships remains constant, the number of containers processed rises by 4.36%. Furthermore, a further analysis is conducted to determine the feasibility of the best scenario by increasing the input number of containers by 10% and 20%. The result of the analysis indicates that the scenario is feasible because the utilization rates of the equipment remain below 80%. In conclusion, the best scenario for improving utilization rates while considering the number of ships and containers processed involves 4 container cranes, 7 RTG cranes, and 16 undedicated head trucks.

4 CONCLUSIONS

Based on the issues at a container port terminal in Indonesia, it was found that the utilization rate of container cranes, RTG cranes, and head trucks were still low. Therefore, a simulation was conducted using the discrete event simulation method to increase the utilization of equipment at the container terminal while still considering the number of ships and containers. The improvement scenario was run with the simulation, and it was determined that the optimal number of equipment is 4 container cranes, 7 RTG cranes, and 16 undedicated head trucks. The best scenario is still feasible with a 20% increase in the number of containers, based on the results of the sensitivity analysis test. This study can be considered to be the basis for further research involving the complexity of resource management problems and loading and unloading capacity at container ports.

5 REFERENCES

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