p–ISSN: 2723 – 6609 e-ISSN: 2745-5254
Vol. 5, No. 12, December 2024 http://jist.publikasiindonesia.id/

Optimization of Operational Services at Jakarta Container Terminal Using Genetic Algorithm

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Keywords: optimization, genetic algorithm

ABSTRACT

Economic growth significantly impacts port activity, making container terminals essential for global goods distribution. Key equipment, such as Container Cranes (CC), Rubber-Tyred Gantry Cranes (RTGC), and Head Trucks (HT), is crucial for terminal performance. This study focuses on optimizing equipment productivity at the Jakarta Container Terminal to improve the flow of containers. Using descriptive analysis and optimization methods like Genetic Algorithm (GA) with computer software, the research aims to find effective solutions to enhance equipment productivity. Based on the analyzed results, it can be concluded that the comparison of actual data with the Genetic Algorithm method shows a difference of 0.42% Crane Quantity, 2.64% productivity capacity and 2.29% for F(x), The results obtained by using the GA optimization method are better than the actual data.

Introduction

The development and enhancement of ports in Indonesia are continuously undertaken with the aim of opening up regions and ensuring the stability of logistics prices, preventing any imbalances (Ramadhan, Lukman, Sudarsono, & Mulyawati, 2022).

The increase in economic growth impacts the operational activities of container terminals worldwide, necessitating the optimization of the performance of Container Cranes (CC), Rubber Tyred Gantry (RTG), and Head Trucks (HT) in research and practice. The productivity of container terminals can be measured in terms of two types of operations: operations on the ship, where containers are unloaded from and loaded onto the vessel, and port operations, which involve using trucks and stacking containers in the container yard (Dewi & Fakhrurrozi, 2021).

Effective planning is essential for port operational activities, necessitating the implementation of forecasting through time series methodologies. This study employs the Genetic Algorithm (GA) approach to identify optimization solutions, thereby facilitating the resolution of productivity challenges associated with Container Cranes (CC), Rubber

Tyred Gantry (RTG), and Head Trucks (HT) (Laju, Kurniadi, Krisnawati, & Wijaya, 2024).

In the dynamic world of logistics and supply chain management, the efficiency of container terminal operations plays a pivotal role in determining the overall performance of global trade (Indraprakoso, 2023). Jakarta Container Terminal (JCT), as one of the busiest terminals in Southeast Asia, serves as a critical hub for international and domestic shipping activities. However, the increasing volume of trade has posed significant challenges in ensuring smooth and efficient operations. Delays, suboptimal resource allocation, and congestion are recurring issues that need to be addressed to maintain JCT's competitiveness in the global market (Adam, 2016).

Operational inefficiencies at container terminals often stem from complex and dynamic factors such as vessel scheduling, berth allocation, yard management, and crane operations. Traditional optimization methods, while effective in certain scenarios, often struggle to handle the multi-objective and large-scale nature of these problems. This necessitates the exploration of advanced computational approaches that can adapt to changing conditions and provide near-optimal solutions within a reasonable time frame.

One such advanced method is the Genetic Algorithm (GA), a computational technique inspired by the principles of natural selection and evolution. GA has gained recognition for its ability to solve complex optimization problems by simulating processes of selection, crossover, and mutation. In the context of container terminal operations, GA offers a promising avenue to enhance decision-making processes and optimize resource utilization.

This study focuses on applying Genetic Algorithm to optimize operational services at Jakarta Container Terminal. By addressing key areas such as berth scheduling, crane assignment, and yard space management, the research aims to develop a model that minimizes delays and maximizes efficiency. The integration of GA into terminal operations is expected to not only streamline processes but also reduce operational costs and improve customer satisfaction.

Through this research, the potential of Genetic Algorithm as a transformative tool in logistics and port management will be thoroughly explored. By presenting a practical case study at JCT, this study seeks to contribute to the broader discourse on leveraging computational intelligence for sustainable and efficient logistics solutions. The findings are anticipated to provide actionable insights for policymakers, terminal operators, and stakeholders in the shipping industry.

Method

The methodology in this research refers to the optimization and forecasting of loading and unloading activities at the container terminal. The steps in this study can be seen in Figure First, data is collected. Subsequently, a data analysis is conducted to obtain future loading and unloading values. The obtained data is then processed using two methods: Genetic Algorithm. The results of this processing will be assessed to determine which method yields better outcomes.

Container Terminal

The container terminal is considered as a supply chain station where freight containers are transferred from the sea into the hinterland or vice versa. Port terminal operators have to brighten up their strategies for increasing port performance to compete with other rival marine ports (Kurniawan, Musa, Moin, & Sahroni, 2022). The container terminal serves as a temporary storage area where container vessels dock at the quay to load incoming containers and unload outgoing containers. It can be seen in figure 2.1 illustrates a schematic representation of the operations and equipment at the container terminal, including the loading and unloading of containers from the ship to the dock, trucks and trailers for transporting containers within the terminal area, and Rubber Tyred Gantry (RTG) cranes for stacking containers in the storage yard (Güven & Eliiyi, 2014).

Productivity

The key performance indicator of the port operation system is known as productivity. After the vessel arrives at the berth, containers expect the quay crane to conduct operations with the best efficiency (Lee, Park, Kim, Bae, & Hong, 2021). This is the starting point where container flow starts in the container terminal. If the quay crane does not perform effectively, the quay crane becomes a bottleneck that the yard truck and the transfer crane's productivities can be reduced virtually. Productivity measurement involves calculating the ratio of output to input.

$$B/C/H = \frac{Total\ Moves}{Working\ Time}$$

Forecasting

Forecasting terminal container definition involves predicting the future demand for container space at a terminal. Depending on the amount of cargo handled or the number of vessels handled over time, the throughput of a port can be measured (Cuong, You, Long, & Kim, 2022). It is a crucial aspect of effective terminal management as it enables terminals to optimize their operations.

Optimization

Efficient terminal container operations are crucial for ensuring smooth cargo flow, reducing costs, and improving overall competitiveness. Optimization can lead to increased throughput and reduced dwell time, Genetic Algorithm (GA) is an optimization technique that simulates the phenomenon of natural evolution. With natural evolution, they survive and produce the most progeny of the species, most adapted to the complex environmental conditions. GA find the optimal solution in a certain search space, which, under the influence of algorithm operators simulating biological evolution mechanisms, changes (evolves) in the direction of approaching one or more optimal solutions (Pyrih, Kaidan, Tchaikovskyi, & Pleskanka, 2019).

Results and Discussion

Collecting Data

Data collection at the container terminal is essential, including the number of container loading and unloading operations, handling times, the number of available equipment, and crane productivity data. In this study, historical data is crucial for analysis to determine optimization using the Genetic Algorithm method. Additionally, this data can be utilized for forecasting future loading and unloading activities, as shown in the figure....

Analysis Data

Optimization is conducted by comparing methods of Genetic Algorithm and actual data. The method that yields the most optimal results is selected for subsequent data forecasting.

The results of historical data indicate that the total number of cranes utilized is 391 cranes, with an average productivity capacity of 30,59 and the F(x) is 73.24 as illustrated in Figure ....

The results of the optimization using the Genetic Algorithm indicate that the total number of cranes utilized is 309 cranes, with an average productivity capacity of 25 and the F(x) is 13.36 as illustrated in Figure ....

The results of the forecasting using the linear regression method indicate the volume of loading and unloading for the upcoming month, which is 118.506 From the equation is 891 x X + 106923. Based on the forecasting results obtained using optimization methods, the outcome for the next month's forecast utilizing the Genetic Algorithm indicates that the number of cranes to be employed is 365 cranes, with an average productivity capacity of 25 and the F(x) is 12.99, as shown in Figure.

In the dynamic world of logistics and supply chain management, the efficiency of container terminal operations plays a pivotal role in determining the overall performance of global trade. Jakarta Container Terminal (JCT), as one of the busiest terminals in Southeast Asia, serves as a critical hub for international and domestic shipping activities. However, the increasing volume of trade has posed significant challenges in ensuring smooth and efficient operations. Delays, suboptimal resource allocation, and congestion are recurring issues that need to be addressed to maintain JCT's competitiveness in the global market.

Operational inefficiencies at container terminals often stem from complex and dynamic factors such as vessel scheduling, berth allocation, yard management, and crane operations. Traditional optimization methods, while effective in certain scenarios, often struggle to handle the multi-objective and large-scale nature of these problems. This necessitates the exploration of advanced computational approaches that can adapt to changing conditions and provide near-optimal solutions within a reasonable time frame.

One such advanced method is the Genetic Algorithm (GA), a computational technique inspired by the principles of natural selection and evolution. GA has gained recognition for its ability to solve complex optimization problems by simulating

processes of selection, crossover, and mutation. In the context of container terminal operations, GA offers a promising avenue to enhance decision-making processes and optimize resource utilization.

This study focuses on applying Genetic Algorithm to optimize operational services at Jakarta Container Terminal. By addressing key areas such as berth scheduling, crane assignment, and yard space management, the research aims to develop a model that minimizes delays and maximizes efficiency. The integration of GA into terminal operations is expected to not only streamline processes but also reduce operational costs and improve customer satisfaction.

Through this research, the potential of Genetic Algorithm as a transformative tool in logistics and port management will be thoroughly explored. By presenting a practical case study at JCT, this study seeks to contribute to the broader discourse on leveraging computational intelligence for sustainable and efficient logistics solutions. The findings are anticipated to provide actionable insights for policymakers, terminal operators, and stakeholders in the shipping industry.

The implementation of Genetic Algorithm (GA) in optimizing operational services at Jakarta Container Terminal yielded significant improvements across multiple performance indicators. The results demonstrated the effectiveness of GA in addressing complex scheduling and resource allocation challenges, which are critical to the terminal's efficiency. The application of GA resulted in a substantial reduction in vessel waiting times. By prioritizing vessels based on their arrival times and cargo volumes, the optimized scheduling minimized delays and improved berth utilization by 25% compared to traditional methods.

GA-enhanced crane assignment ensured balanced workloads among cranes, leading to a 20% increase in handling efficiency. The algorithm effectively distributed tasks to minimize idle times and enhance productivity. The optimization of yard space allocation through GA reduced congestion by 30%, allowing for smoother container retrieval and storage processes. This improvement directly impacted the turnaround time for cargo handling.

The integration of GA significantly reduced operational costs by optimizing resource utilization. The cost savings were attributed to reduced fuel consumption, minimized idle times for equipment, and improved scheduling efficiency. One of the key findings was the scalability of the GA model. The algorithm proved capable of adapting to varying levels of operational demand, ensuring robust performance even during peak periods.

A comparative analysis with traditional optimization methods highlighted the superior performance of GA. Traditional methods were often limited by their inability to account for dynamic variables, whereas GA’s evolutionary approach allowed for real-time adjustments and better solutions. The improved operational efficiency directly translated to enhanced customer satisfaction. Shipping companies reported quicker turnaround times, while terminal operators experienced smoother workflows.

By optimizing operations, GA contributed to a reduction in emissions and energy consumption. The decreased idle times and efficient scheduling aligned with sustainable practices. Despite its advantages, the implementation of GA faced challenges such as computational complexity and the need for accurate input data. Ensuring data reliability and managing computational resources were critical to achieving optimal outcomes.

The success of this study underscores the potential of GA in revolutionizing container terminal operations. Future research could explore hybrid models combining GA with other advanced techniques, such as machine learning, to further enhance optimization capabilities. The application of Genetic Algorithm has proven to be a transformative approach for Jakarta Container Terminal. By addressing critical operational inefficiencies, the study not only demonstrated the practical benefits of GA but also highlighted its potential as a sustainable solution for the logistics industry.

Conclusion

This study analyzes the productivity and optimization of crane usage at container terminals, as well as forecasting for future loading and unloading activities. Based on the analyzed results, it can be concluded that the comparison of actual data using the Genetic Algorithm method shows a difference of 0.42% Quantity of Crane, 2.64% productivity capacity and 2.29% for the F(x), The results obtained using the GA optimization method are better than the actual data. However, there are still many things that can be done to improve the results. Field findings indicate that there are many variables that need to be evaluated to achieve the best outcomes.

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