

## ***ABSTRACT***

*Ports play a vital role as a link between sea and land transportation modes, as well as a key node in the global logistics supply chain. PT XYZ, the operator of Panjang Port, faces serious challenges in managing vessel berthing, particularly related to delays that increase operational costs. These problems often arise from suboptimal berth allocation, limited port facilities, and external factors such as bad weather and limited pilot boats. In this context, this study aims to optimize berth allocation by minimizing total vessel operating costs, including waiting costs, handling costs, and penalty costs, using the Cuckoo Search Algorithm (CSA) metaheuristic approach.*

*The initial step in the study was to collect vessel operational data at Panjang Port, including arrival times, berthing times, waiting times, loading and unloading times, and related costs. This data was then used to build an integer programming-based optimization model with constraints and objective functions that reflect the realities of port operations. The model considers several constraints such as berth length, safe time between vessels, berth slot limitations, and preferred berthing positions for each vessel. The objective function was designed to minimize total operational costs by combining the components of waiting costs, handling costs, penalties for non-optimal berthing positions, and penalties for late departures.*

*CSA was implemented as an optimal solution search algorithm due to its ability to handle large and complex search spaces. In CSA, each solution is represented as a "nest" containing combinations of berthing times, positions, and berths for each vessel. The algorithm works by iterating solutions using the Lévy Flight jump principle and selecting based on the lowest fitness value (the smallest total cost). Validation was conducted through simulations on 91 vessels over a 10-day observation period, which then compared actual conditions with the optimization results.*

*The results showed that the application of CSA significantly reduced waiting times with an efficiency of over 90% for vessels previously experiencing delays. Waiting*

*costs, which initially reached IDR 878 million, were reduced to IDR 0, and total penalty costs decreased by up to 74%. Overall, total ship operational costs showed a significant reduction of 40–60%, depending on the characteristics of each vessel. Furthermore, visualization using a Gantt chart demonstrated a more even distribution of berth allocations and minimal schedule overlap.*

*Sensitivity tests to variations in hourly cost parameters confirm the model's high responsiveness to changes in cost values. Increasing waiting costs force the system to prioritize faster allocations, while increasing delay penalties encourage faster vessel departures. This demonstrates that port management can adjust scheduling policies more adaptively and efficiently by using cost parameters as a strategic control instrument.*

*Thus, the implementation of this CSA optimization model is not only effective in solving berth allocation problems but also makes a significant contribution to improving operational efficiency and data-driven decision-making in the port environment. This research is expected to serve as a reference in the development of decision support systems for more adaptive, responsive, and sustainable berth management.*

***Keywords: Port, Berth Allocation, Vessel Delays, Operational Costs, Cuckoo Search Algorithm, Optimization.***