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Enhancing Port Efficiency and Sustainability through Just-in-Time Arrivals and Tugboat Resource Management

Maritime transport and port operations are vital to global trade but face growing pressure to improve efficiency and lower greenhouse gas (GHG) emissions. Just-in-Time (JIT) arrival offers a promising management solution, involving speed adjustments so that vessels reach the pilot boarding point only when port services are confirmed. This approach aims to cut fuel and emissions by reducing idle time at anchor. However, JIT success depends on efficient tugboat operations, which are essential for berthing and departure. Their effective scheduling is crucial to avoid congestion, especially in high-traffic ports.

In this work a discrete event simulation-based decision-support tool was developed to assess JIT arrival strategies in container terminals, focusing on tugboat resource allocation and scheduling. By modelling port processes and analysing scenarios involving vessel speed optimisation and tugboat availability, the tool evaluates impacts on a set of key performance indicators: waiting times, emissions, and resource utilisation.

A case study at a Portuguese seaport shows the effectiveness of the model, revealing notable reductions in emissions and operational inefficiencies. These findings highlight the potential of JIT operations and effective tugboat scheduling to enhance sustainability and efficiency in the maritime sector. Future work will extend the current approach by the adoption of a mixed-integer linear programming model for tugboat scheduling with time constraints.

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