A Representative Formulation of the Container Vessel Stowage Problem and a new Non-Hierarchical LNS Solution Approach

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Abstract. Global containerized trade resulted in 149 million twenty-foot equivalent units in 2020 and this number grows about 4% on a yearly basis [1]. Considering the volume of shipped goods, research resulting in improvements of the stowage plans can yield remarkable economic and CO2 emissions savings. With almost 10 years of experience working closely with several shipping companies we realized that the container vessel stowage problem is poorly understood in the literature and lacking a standardized definition that researchers can refer to. This work contributes a realistic description of the problem, matched with an extensive benchmark suite based on real-life data.

The container vessel stowage problem is complex and has several constraints and objectives interacting with each other. While creating a standard description, it is crucial to carefully choose which objectives and constraints to consider to fully capture the nature of the problem without overly complicating or simplifying the problem. Besides basic stack capacity limits and stowage rules, the constraints we chose include hydrostatic limits, minimum crane intensity, lashing forces using simplified moment-based calculations and block stowage. The objective function is a mix of the number of containers stowed on the vessel and the amount of free space left. More details on the selection of key aspects will be presented.

The benchmark suite comprises different types of vessels and port call lists to challenge different aspects of the container vessel stowage problem: finding space for large amounts of refrigerated containers, heavy containers, or dangerous cargo, etc. The benchmark suite contains 4 vessel profiles of different sizes, each vessel has 5 different rotations assigned and each rotation includes at least 25 load lists based on real-life data, resulting in around 500 different problem instances.
A large neighborhood search (LNS) was implemented working with the Sealytix company to provide initial feasible solutions for the described benchmark suite. The academic research on stowage planning often favors hierarchical decomposed algorithms where the container ship stowage problem is divided into 2 or more subproblems that are solved separately [2]. Our experience building a 4-phase algorithm for use in the industry is that such multi-phase algorithms with different representations and methods used in each phase often break down in practice. They are expensive to maintain, and it is challenging to ensure that the problems solved by each phase are aligned. Our non-hierarchical LNS approach scales well with medium-size vessels, but future research is needed for bigger vessels with longer port call lists.

Keywords: Stowage Planning, Optimization, Benchmark, LNS

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