Port Yard Storage Optimization

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***Abstract*—The port yard storage optimization problem (PYSOP) originates from space allocation needs at the Port of Singapore. Space allocated to cargo is to be minimized in a designated yard within a time interval. The problem is akin to a packing problem in space and time, but where shapes packed and constraints are particular to port operations. Further, space requests can change within the time interval in which it is requested. This basic problem is generic to port operations and may find applications elsewhere. The PYSOP is NP-hard, but we propose a number of metaheuristics. Extensive experiments were conducted and good results obtained.**

***Note to Practitioners*—The Port of Singapore is one of the busisest ports in the world where competing pressures for land use and competition from other regional and international ports force port planners to make best use of available land. Factors that impact storage capacity include stacking heights, net storage area available, storage density (containers per acre), dwell times for empty containers and breakbulk cargo. In studying its operations to find better ways to utilize storage space within the dynamic environment of the port, we narrowed storage problems down and focused on the central allocation process in storage-operations improvement which would allow for better utilization of space. In this process, requests are made from an operations unit which coordinates ship berthing and ship-to-apron loading as well as apron-to-yard transportation. Each request is for a set of spaces within a yard required in a single time interval. If any space is allocated to the request, this space cannot be freed (released) until the request is completed, that is, until the end time point of the time interval. The problem is akin to a packing problem in space and time, but where shapes packed and constraints are particular to port operations. Further, space requests can change within the time interval in which it is requested. This basic problem is generic to port operations and may find applications elsewhere. The PYSOP is NP-hard for which we propose a number of metaheuristics. Extensive experiments were conducted and good results obtained.**

***Index Terms*—Automation, packing, port logistics, scheduling.**

I. Introduction

STORAGE is an important constraining factor in logistics management for many ports. Factors that impact terminal storage capacity include stacking heights, net storage area available, storage density (containers per acre), dwell times for empty containers, and breakbulk cargo. The Port of Singapore, which is one of the world's largest in terms of shipping tonnage handled, faces space constraints in a unique way as it is located on a small island. The competing pressures for land use and competition from other regional and international ports forces port planners to make best use of available land. As such, the optimization of storage of cargo in its available yards is crucial to its operations and commercial viability. In studying its operations to find better ways to utilize storage space within the dynamic environment of the port, we narrowed storage problems down and focused on the central allocation process in storage-operations improvement, which would allow for better utilization of space. In this process, requests are made from an operations unit which coordinates ship berthing and ship-to-apron loading as well as apron-to-yard transportation. Each request is for a set of spaces within a yard required in a single time interval. If any space is allocated to the request, this space cannot be freed (released) until the request is completed, that is, until the end time point of the time interval. A variant of this situation is when space requirements are allowed change during the time interval of any given request. This may arise from changes in the other components of the storage process and is part of the dynamic backdrop of port operations. The final objective is to pack all such requests into a yard space of minimum area within the given constraints.

We propose a model for basic port storage optimization which represents a generic problem we expect will be useful to other port managements. Sabria and Daganzo [1] have given a bibliography on port operations studies with the focus on berthing and cargo-handling systems. On the other hand, traffic and vehicle-flow scheduling on landside up to yard points have been studied well (see, for example, Bish *et al.* [2]). Other than studies such as Gambardella *et al.* [3], which address spatial allocation of containers on a terminal yard using simulation techniques, there has been little direct study on yard space allocation as described in this paper. Further, although related to packing optimization—in particular two-dimensional (2-D) packing—the port yard storage optimization problem (PYSOP) is different from these. It has, for example, a nondecreasing space request constraint and the degree of freedom allowed for objects to be moved into positions differs from packing routines.

We describe the basic model in Section II and provide a transformation of it into a graph problem in Section III. Metaheuristics are used to obtain solutions for the problem: tabu search (TS) in Section V; simulated annealing (SA) in Section VI; and squeaky wheel optimization (SWO) in Section VII. In Section VIII, genetic algorithms (GAs) with various crossover operators are introduced, and in Section IX we provide results of experiments. We conclude this work in Section X.

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