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A two-phase heuristic for an in-port ship routing problem with tank allocation

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ABSTRACT

This paper addresses an in-port ship routing problem with tank allocation that arises in the chemical shipping industry. The aim is to optimize a tanker's port call operation that integrates sequencing decisions for visiting terminals and allocating cargo loads to available tanks while taking into account cargo time windows, terminal draft limits and various tank allocation restrictions. We model the problem as a Traveling Salesman Problem with Pickups and Deliveries, Time Windows, Draft Limits and Tank Allocation (TSPPD–TWDLTA), and propose a two-phase heuristic to solve it. Computational studies show that the heuristic is able to provide good solutions to real-sized in-port routing problems with tank allocation in chemical shipping in a reasonable amount of time.

1. Introduction

This paper introduces a real-life in-port ship routing problem with tank allocation faced by Odfjell, a Norwegian public listed chemical shipping and tank terminal company based in Bergen, Norway. The problem considers a tanker arriving at a particular port with numerous terminals and the aim is finding an optimized plan with shortest time spent in port that comprises sequencing decisions for visiting terminals, and the corresponding tank allocation plan. Fig. 1 shows a small example port call at the Port of Houston. In this example, the ship enters the port via an anchorage point in the Galveston Bay, and services three terminals along the channel before sailing off for a new voyage. In Arnesen et al. (2017), we have studied a simplified version of this problem without tank allocation, by modeling the in-port ship routing problem as a Traveling Salesman Problem with Pickups and Deliveries, Time Windows and Draft Limits (TSPPD–TWDL), and proposed a solution method based on forward dynamic programming (DP). In this paper, we explicitly take into account tank allocation as an essential component of the port call plan, i.e. the decisions with regards to which tank(s) should be used for each cargo, which is an important aspect of reality in the daily operations in chemical shipping.

The chemical shipping market is defined as the market for transportation of bulk liquid chemicals by sea. Compared to most other bulk shipping markets, the shipments in the chemical shipping industry are usually of smaller sizes and thus allow the carrier to combine and transport different cargoes on one single tanker. Chemical tankers are therefore designed with a large number of compartments or tanks, each being able to carry several product types, which makes chemical tankers very flexible. In the mean time, more sophisticated allocation plans are required to deal with the large number of tanks and a wide range of chemical products.

The number of tanks on a typical tanker in chemical shipping can range from 15 to over 50, and the tanks often differ in shapes and volumes. Fig. 2 shows the tank configuration of two tankers operated by Odfjell that have 52 and 40 tanks, respectively. The tanks may be coated with different materials, e.g. stainless steel, zinc, epoxy or polymer, and cargoes can only be allocated to tanks with compatible coatings. Other constraints, such as tank capacities and stability of the ship, also need to be considered when allocating cargo loads to the tanks on board the ship.

In maritime transportation, there exists a rather limited literature on the *tank allocation problem* (TAP), and usually for a fixed set of cargoes on a given route. Vouros et al. (1996) propose a framework for developing Expert Loading Systems for allocating chemical products to the compartments of a ship and for planning cargo handling operations, but for a fixed set of cargoes only. Hvattum et al. (2009) present several models for the TAP that arises in maritime liquid bulk shipping, considering the loads being moved on and off the ship along a given trading route. Vilhelmsen et al. (2016) further propose a hybrid method that

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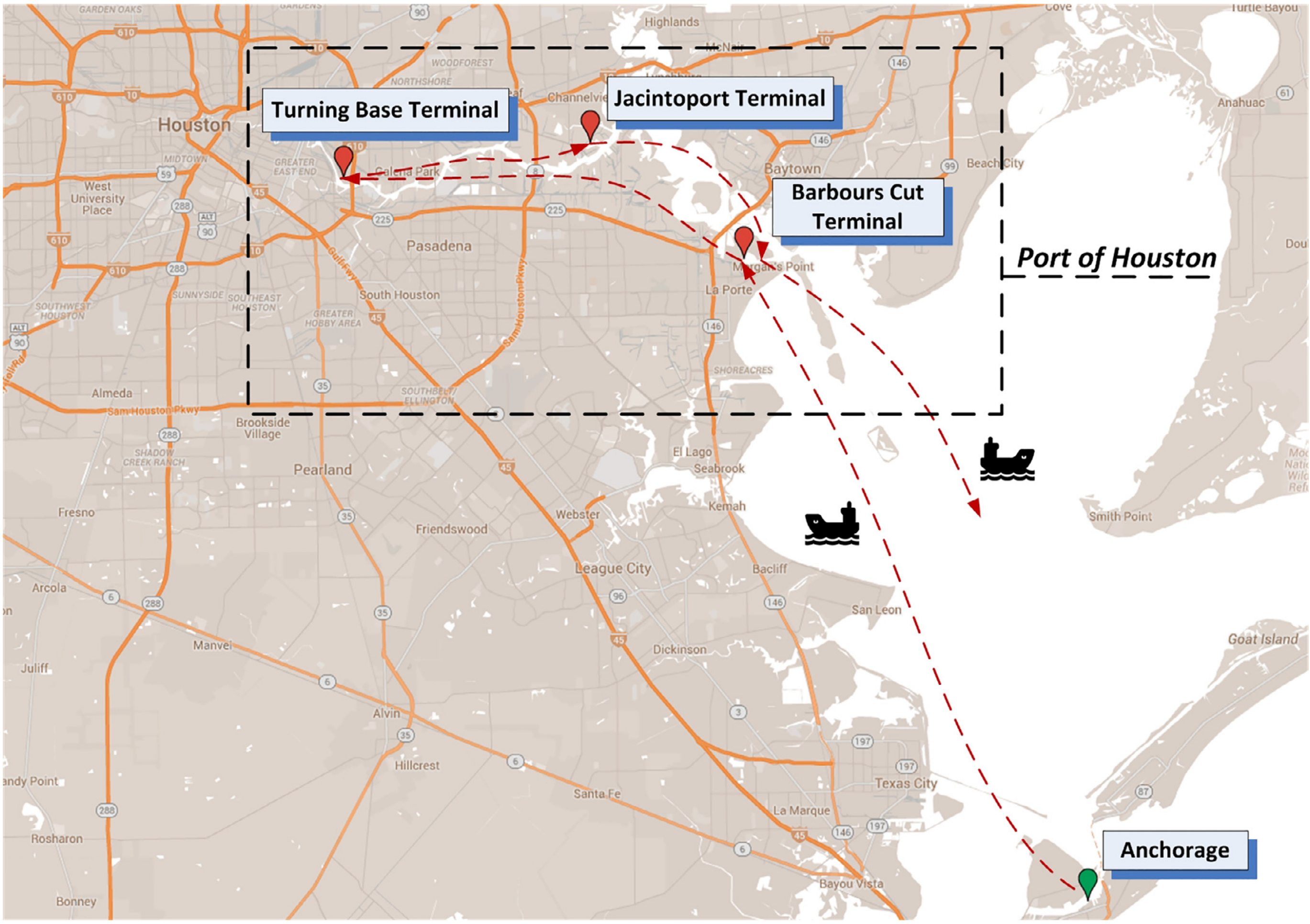

Fig. 1. Illustration of an example port call. The ship approaches the Port of Houston from an anchorage point in the Galveston Bay and services three terminals within the port.

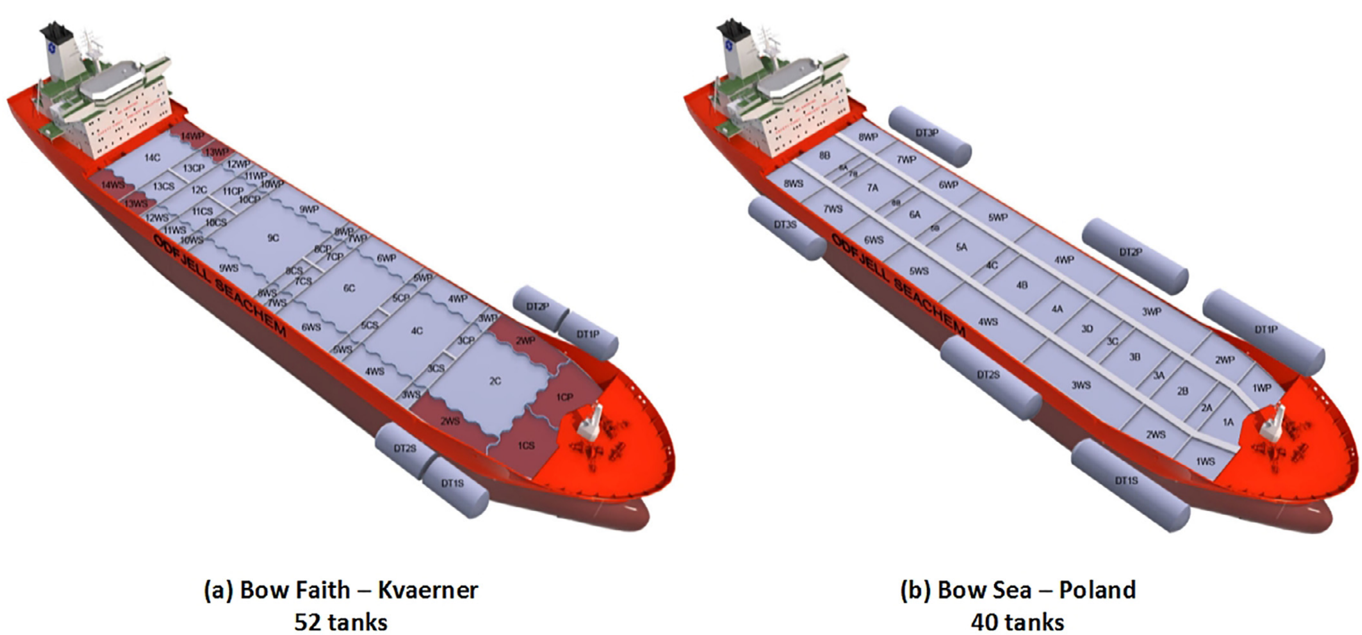

Fig. 2. Illustration of the tank configuration of (a) tanker Bow Faith of class Kvaerner with 52 tanks, and (b) tanker Bow Sea of class Poland with 40 tanks (Odfjell, 2016).