

Routing and scheduling for deployment of vessels for one of the world’s leading RoRo carriers

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1 Introduction

Transportation of cars by sea is mainly performed by specialized vessels. These vessels are purpose built for transporting cars and trucks, but some also transport other rolling equipment (high and heavy) and non-containerized cargo (break bulk). In this paper we introduce a routing and scheduling problem for deployment of the fleet of roll-on roll-off (RoRo) vessels. This problem is based on a real-world problem faced by Wallenius Wilhelmsen Logistics (WWL), one of the world’s leading RoRo carriers. WWL operates more than 60 RoRo vessels, and transports more than 2.3 million vehicles, rolling equipment, and static cargo each year to destinations around the world.

Maritime planning problems are also often divided into three modes of operation: liner, tramp, and industrial shipping (Lawrence, 1972). In liner shipping the ships operate according to a published itinerary and schedule similar to a bus, and the operator tries to maximize their profit from cargoes lifted. Tramp shipping resembles taxi services, where the ships follow the available cargoes and the operator tries to maximize the profit from mandatory and optional cargoes. Industrial shipping operators usually own and control both the cargoes and the ships, and the objective of the operator is usually to minimize transportation cost (Christiansen et al., 2007).

Traditionally, planning is divided into three classes based on the length of the planning horizon: strategic, tactical, and operational. Strategic problems are long term planning problems, which in shipping usually means 5 to 20 years. *Fleet size and mix*, *network design*, and *contract evaluation* are all typical strategic planning problems. Problems with a planning horizon length of a few weeks up to 18 months are usually referred to as

tactical planning problems and include problems such as *ship routing and scheduling* and *inventory ship routing* in addition to *fleet deployment* studied in this paper. Short-term, or operational, planning is usually applied when the decisions only have a short-term impact (sometimes as short as only one sailing leg) or the operational environment is highly uncertain. Decisions such as *ship loading* and *speed optimization* are examples of important operational planning problems. For a summary of the major articles within maritime planning see Christiansen et al. (2007).

Container and RoRo vessels usually operate within the category of liner shipping, and operate according to given trade routes or trades. These trades specify two or more regions that goods are moved between. An illustration of trade is given in Figure 1. When creating a fleet deployment plan, the fleet is assumed given from the strategic fleet size and mix, or strategic fleet renewal problem.

Figure 1: A trade from Europe to Oceania.

The literature on maritime routing and scheduling in the maritime industry is quite scarce compared to literature on land based problems, and the number of papers discussing deployment in liner shipping is quite small. Recently, Wang and Meng have published several papers on liner shipping of containers, and some of these discuss deployment of the fleet (see Wang and Meng, 2012a,b). Another recent paper discussing deployment of RoRo vessels is by Fagerholt et al. (2009). Here the authors present a new formulation for fleet deployment within liner shipping, where they consider deploying vessels on trades, not closed loops which is more common in literature. They argue that the simplification of the problem using closed loops imposes an unnecessary restriction from which the solution suffers. We follow the modeling choices made by Fagerholt et al. (2009), but also include some new aspects and introduce additional complexity to the problem, e.g. we do not have a fixed number of voyages that has to be sailed and time windows for these. Instead we propose a more detailed stowage planning and let the expected demand drive the number of voyages on each trade. We also remove time windows and impose spread, minimum frequency, and week day requirements where this is needed.

The aim of this paper is to introduce a real-world RoRo deployment problem where the number of sailings on each trade is decided based on the transportation demand, minimum frequency, and vessels used. We present two formulation for this problem, and use these to solve a set of instances generated from real problem data.

2 Problem description

A RoRo carrier operates a set of trades for customers around the world and is responsible for transporting three main cargo classes, namely cars, high and heavy (HH), and break bulk (BB). There are two main types of trades in addition to ballast legs: charter out

and operational trades. A charter out trade is a contract of usage of a vessel where a vessel with given specifications is rented out for a number of sailings between two regions during the planning horizon. When chartering out vessels the contract specifies a number of sailings, together with a fixed time for each charter. There may also be a requirement of a minimum capacity for the vessel used.

For the operational trades customers have monthly quantities of cargo classes that are to be transported during a planning horizon, specified in number of units for cars, and in m^3 for HH and BB. Some customers may have a frequency requirement, stating the number of visits during a planning horizon or time period. This frequency requirement may be the only requirement for a port or region, or it may be in addition to the demand for product transported. There may also be a minimum capacity requirement for one or several cargo classes on the vessels serving the ports or regions.

In addition to the frequency requirements there may be requirements regarding the spread of the sailings on a trade. This may be stated in two different ways: 1) Weekly departures on the same day every week. 2) Evenly spread, i.e. there are no requirements for the sailing day, but if you have e.g. 4 sailings in a month there should be no less than e.g 6 days between the sailings.

To operate these trades a large heterogeneous fleet of vessels is used, consisting of a mix of large car and truck carriers (LCTC), pure car carriers (PCTC), and RoRo vessels. Not all vessels of a given vessel type are identical, but they share the same characteristics. Only so-called sister vessels, vessels that are built at the same wharf using identical designs, are identical. Capacities of these vessels are given in RT43, an old measurement for the size of a car based on a 1966 Toyota Corona. Since RT43 is an old measurement the number of cars to be transported is adjusted using a conversion factor to align with the capacity of the vessels. This conversion factor describes the average ratio between the new cars from a given port or region and RT43. Demands for HH and BB are usually given in m^3 , but converted to RT43 using the dimensions of RT43 and an adjustment for average space lost due to HH and BB being less uniform than cars.

The capacities of the vessels is given in the following way: there is a capacity for each of the cargo classes, and a total capacity for the vessel. There is also a maximum total capacity for subsets of the product classes, meaning that a vessel with a total capacity of 5000 RT43 may have a HH capacity of 3000, a BB capacity of 1500, and a total capacity of 3000 RT43 equivalents of HH and BB, i.e. there is only a certain fraction of the total capacity of the vessel that may be used for HH and BB. The reason for this is that HH and BB have stronger requirements with regards to deck strength. In addition, some decks are not properly fitted to store cars in an efficient way, so the total capacity in RT43 for cars may be less than the capacity for HH or BB.

There exist region - vessel compatibility restrictions defining which vessel types that

can operate within a given region. These restrictions are based on physical constraints and experience. The physical constraints are usually connected to the vessels length, width, or maximal draft. Experience based constraints are connected to the historical performance of a vessel in a given region with regards to loading time, capacity utilization and so on. It may also be based on customer preferences.

If there is insufficient capacity in the operators fleet to handle the demands it is possible to transport cargo using one of two options: 1) Voyage charter or 2) space charter. When using voyage charter, the operator charters in a vessel for one voyage on a specific trade and has to schedule this vessel, while if using space charter the cargo is loaded on a vessel scheduled by another operator.

3 Model and solution method

In the paper we present two formulations for the problem, one arc flow and one path flow model. The objective is to fulfill the operator's responsibilities to the customers at minimum cost. The path flow formulation is based upon paths for each vessel, and solved using a branch-price-and-cut algorithm. Both formulations are implemented using C++ and solved using a commercial solver. Computational results obtained on a proposed set of benchmark instances will be presented for both formulations.

References

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Figure 1: A trade from Europe to Oceania.

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