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Combined fleet deployment and inventory management in roll-on/roll-off shipping

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ABSTRACT

In maritime transportation of automobiles, roll-on/roll-off (ro–ro) shipping companies operate liner shipping services across major trade routes. Large ro–ro shipping companies are well placed to offer end-to-end integrated logistics services to auto manufacturers engaged in international trade of vehicles. Therefore, we present a new mixed integer programming model for fleet deployment including inventory management at the ports along each trade route. Due to the complexity of the problem, a rolling horizon heuristic (RHH) is proposed. The RHH solves the problem by iteratively solving sub-problems with shorter planning horizon. Computational results based on real instances are presented.

1. Introduction

Roll-on Roll-off (ro–ro) shipping deals with seaborne transportation of all types of rolling material; cars being the most dominant cargo type. In the international trade of automobiles most of the shipping routes originate from the Far East where Japan and South Korea are the major exporters. USA is the largest importer followed by continental Europe. A small but rising share of export volume originates from emerging economies like India and South Africa. According to a Mitsui O.S.K. Lines Ltd. report (MOL, 2013), the average monthly export volume of new vehicles from Japan stood at around 380,000 units from 2010 to 2012. The use of maritime transportation for this type of trade leads to the realization of economies of scale. Further, ro–ro shipping is promoted as a replacement for truck transport as an attempt to reduce environmental emissions, through programs like Marco Polo in Europe and similar initiatives in US and other parts of the world. Thus, this form of shipping is expected to play an even more dominant role in maritime logistics of automobiles in the coming future.

A ro–ro shipping company owns and operates a heterogeneous fleet of ships having different cargo capacities, sailing speed ranges, and bunker consumption profiles. These type of ships operate in liner mode, in which ships sail pre-defined trade routes, as per published itineraries and schedules. Increased logistics outsourcing by auto manufacturers and proliferation of manufacturing and demand locations worldwide has increased complexity of maritime logistics of automobiles. This has led to the emergence of strong logistics service providers (LSPs) offering integrated inter-modal transportation and cargo handling services. Following this trend, the major ro–ro shipping companies are broadening their scope as third party LSPs in finished automobile trade. In this scenario, a ro–ro shipping company in collaboration with other LSPs offers end-to-end integrated maritime logistics solutions to various automobile manufacturers. We refer to a ro–ro shipping company from now on as a *shipping company* or just *company*. Under such a contract, an automobile manufacturer outsources the complete

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maritime logistics of its finished vehicles to a shipping company for overseas distribution. We refer to such an auto manufacturer as a *client* of the shipping company. The shipping company undertakes the full responsibility of inland transportation between the factory and the sea port at both ends, inventory management and cargo handling at these ports, along with overseas maritime transportation. In practice many of these shipping companies operate a separate division for logistics management or may collaborate with a partner LSP to integrate planning of associated services along with maritime transportation. The client is expected to share the production and demand information with the shipping company on a regular basis. In turn the shipping company shares the ship arrival information with these clients to ensure smooth production plans for vehicles meant for export.

The shipping company services a given set of trade routes. A trade route is specified by two or more geographical regions between which goods are traded and consists of a given sequence of loading and discharge ports. The company plans a given number of repeated voyages on each trade route in a given planning horizon. Each such voyage follows the sequence of port calls and must start within a specified time window. The fleet deployment problem deals with finding an optimal assignment of available ships in the fleet to the predefined voyages in a given planning horizon to maximize profits or minimize costs. The shipping company offering integrated maritime logistics services first estimates the shipment sizes of the different cargoes traded in each route in collaboration with clients and partner LSPs. This is followed by fleet deployment in a given planning horizon. Shipment planning may be further refined based on the ship arrival information across each port of a route, based on the fleet deployment planning. This sequential approach to logistics planning is performed under restrictive constraints as fleet deployment planning is carried out under fixed transportation requirements.

Fig. 1 presents two trading routes served by a ro–ro shipping company. In Route-1, represented with solid arcs, cargoes are loaded from European and South African ports and discharged mid route and finally at four successive Australian ports. Two voyage starting dates with ship names are published for this route. Similarly, Route-2, connecting Far-East loading ports with European discharge ports, is represented by dotted arcs. Starting date and ship name for two successive voyages are given. In a fleet deployment planning problem, a ship may first serve a voyage in Route-1. This route will end at a port on the East coast of Australia. The ship may then continue to serve a voyage on Route-2. In this case there would be a ballast voyage from Australia to Far-East between the two voyages.

Container shipping is the major segment of liner shipping. Therefore, most of the literature on fleet deployment focuses on container shipping. Perakis and Jaramillo (1991) present a linear programming (LP) model for a container ship fleet deployment problem. The LP model is concerned with minimizing the annual operating costs for a fleet of liner ships. The model considers allocating owned ships to the trade routes, deciding number and types of ships and duration of chartering-in ships, and number, type and duration of owned ships that are laid-up during the planning horizon. Ships speeds are taken as fixed values and assumed to be the same in the ballast and loaded conditions. It is assumed that a fixed amount of cargo, evenly distributed throughout the year, will be carried between a given pair of ports belonging to a given route. Powell and Perkins (1997) present an integer programming (IP) formulation as an improvement to the existing model.

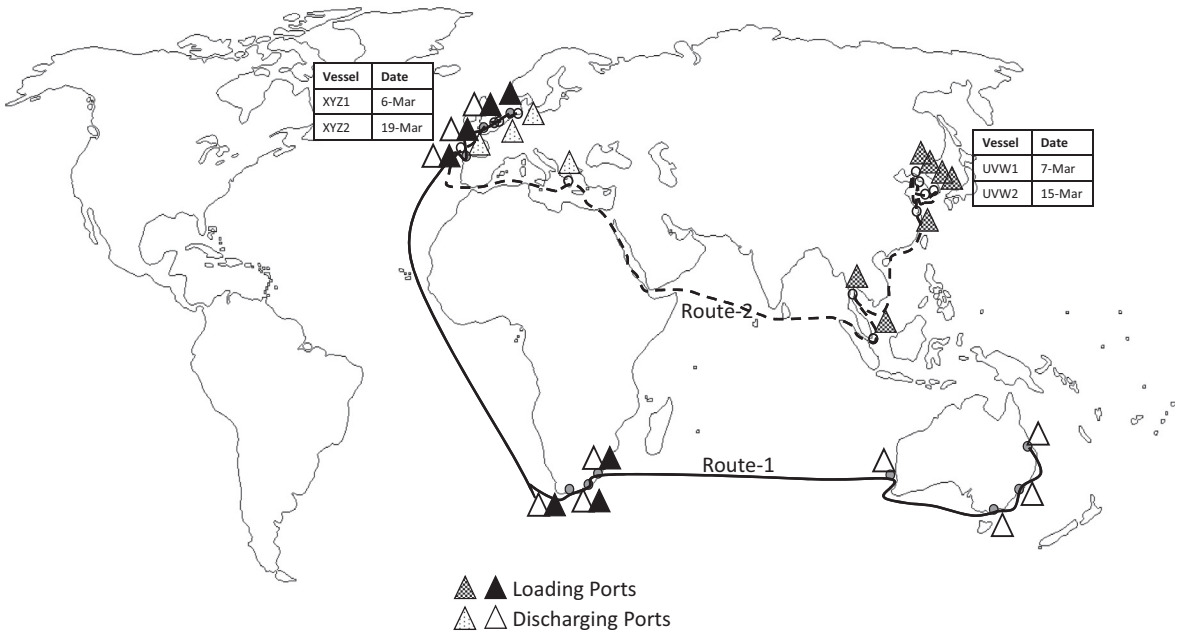

Fig. 1. Two trade routes and respective voyage calls.