Transportation Research Part C 77 (2017) 389–404

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Review

Container liner fleet deployment: A systematic overview

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ARTICLE INFO

Article history:
Received 1 August 2016
Received in revised form 8 February 2017
Accepted 8 February 2017

Keywords:
Container liner fleet deployment
Transshipment
Green shipping
Mathematical programming models

ABSTRACT

Container liner fleet deployment (CLFD) is the assignment of containerships to port rotations (ship routes) for efficient transport of containers. As liner shipping services have fixed schedules, the ship-related operating cost is determined at the CLFD stage. This paper provides a critical review of existing mathematical models developed for the CLFD problems. It first gives a systematic overview of the fundamental assumptions used by the existing CLFD models. The operating characteristics dealt with in existing studies are then examined, including container transshipment and routing, uncertain demand, empty container repositioning, ship sailing speed optimization and ship repositioning. Finally, this paper points out four important future research opportunities: fleet deployment considering ship surveys and inspections, service dependent demand, pollutant emissions, and CLFD for shipping alliances.

Contents

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http://dx.doi.org/10.1016/j.trc.2017.02.010
0968-090X/

1. Introduction

Container transportation is vital to the world trade and world economy. The total container trade volume amounted in 175 million twenty-foot equivalent units (TEUs) in 2015 (UNCTAD, 2016). Containers are usually transported by liner shipping services with fixed sequences of ports of call at a regular service frequency, which are published by liner shipping companies in advance to attract more cargoes of shippers. Shippers or freight forwarders can pick up and deliver their cargoes at the desired ports. A single shipper usually has far less than a full shipload of cargo. Containerships keep to their published departure dates even when a full payload is not available (Christiansen et al., 2004, 2013). This study focuses on container liner shipping rather than other liner shipping modes such as roll-on-roll-off (RoRo) shipping for cars (Øvstebø et al., 2011). Fig. 1 depicts a liner shipping network consisting of three ship routes with fixed port rotations. When a containership is assigned to a liner ship route, it usually serves the ship route for a period of at least three to six months. Since liner shipping services have fixed port rotations and schedules, ship-related operating cost is determined after the ship-to-route assignment. Moreover, containerships are large as liner shipping companies aim to take advantage of their economies of scale. For example, the average containership size was 3801 TEUs at the end of July 2016 (UNCTAD, 2016). Therefore, it is important for container liner shipping companies to assign ships to port rotations in an efficient manner to transport containers. This tactical decision problem is referred to as container liner fleet deployment (CLFD).

A number of studies have been devoted to the CLFD problem due to its importance. In this paper, we give a comprehensive overview on model building of the problem and point out future research directions. As most of the mathematical formulations are mixed-integer linear programming models, or can be transformed to mixed-integer linear programming models, with a few exceptions using decomposition approaches, they are generally solved by commercial mixed-integer linear programming solvers. Consequently, we do not discuss how to solve the models in this paper.

CLFD is often explicitly or implicitly incorporated in liner shipping service network design, which determines the routes in a network and the deployment of ships to each route. We also mention the studies on liner shipping service network design if their models are highly relevant to CLFD. Some works, such as Andersson et al. (2015), Norstad et al. (2015), Bakkehaug et al. (2016) and Chandra et al. (2016), focus on fleet deployment for ships other than containerships; these works are not reviewed.

The remainder of the paper is organized as follows. Section 2 examines the assumptions in container liner fleet deployment models so that practitioners understand the limitations of the models before putting them to use. Section 3 investigates early CLFD models in which container transshipment or routing are not incorporated. Section 4 focuses on CLFD models for modern global liner shipping companies with container transshipment and routing. Depending on how container routing is formulated, the models are classified as path-based, origin-to-destination-link-based, and origin-link-based. Section 5 reviews models for handling the uncertainty of the container shipment demand, including chance-constrained models and stochastic optimization models. Section 6 is focused on incorporating both laden and empty containers in CLFD. Section 7

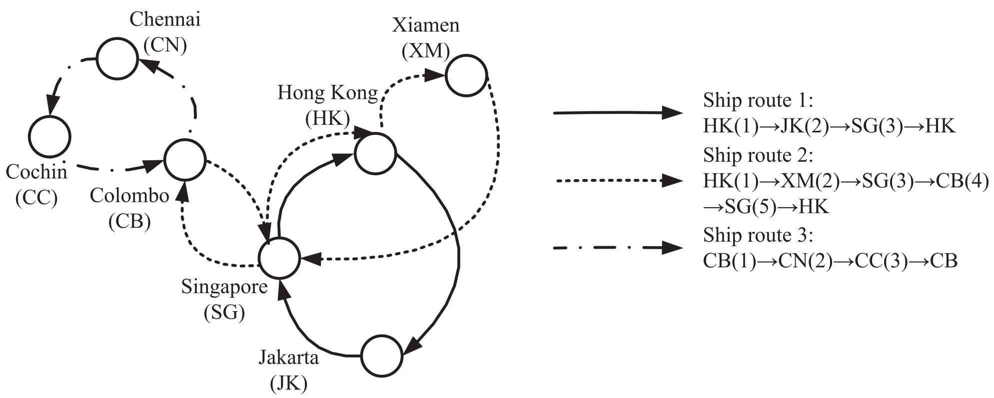

Fig. 1. An illustrative liner shipping network (Wang, 2013).