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Single string planning problem arising in liner shipping industries: A heuristic approach

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A R T I C L E I N F O

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A B S T R A C T

We propose an efficient heuristic approach for solving instances of the Single String Planning Problem (SSPP) arising in the liner shipping industry. In the SSPP a Liner Service Provider (LSP) only revises one of its many operational strings, and it is assumed that the other strings are unchangeable. A *string* is a service route composed of a sequence of port calls—a call is a visit to a port followed by loading/unloading operations made by a vessel. In a string the vessel's round trip terminates at the same port that it started from, and the port calls follow a published itinerary. The SSPP is regularly encountered by all LSPs, and a major part of their seasonal network planning process is devoted to repeatedly solving SSPP for different regions using experts' knowledge. Despite the practical importance of the problem, very little has been written about it in the literature. A revision is carried out in the form of a controlled re-sequencing, insertion and elimination of ports from along the current string, given a set of ports limited to those that exist on the string and a set of potential ones. The outcome determines the required capacity, service level (frequency), call sequence, etc., corresponding to the LSP's seasonal strategy. Exact decomposition methods are limited and can solve only very small size instances—small in terms of the number of ports, vessel classes, vessel number and commodities. In contrast, the proposed heuristic method is an efficient approach for obtaining high quality and practical solutions to real-size instances in significantly less computational time.

1. Introduction

The liner shipping industry is currently responsible for transporting a major part of the ever growing total global trade volume (excluding crude oil), in the form of containerized cargo. According to statistics, by the end of 2008, the world container port throughput grew by an estimated 4% to reach 506 million TEUs (Twenty-foot Equivalent Units). At the beginning of 2009 the world merchant fleet reached 1.19 billion deadweight tons, a 6.7% increase from January 2008. In 2008, the world total of containerized trade was estimated at 137 million TEUs (1.3 billion tons), an increase of 5.4% on the previous year. This volume is transported on three major east–west liner trade routes: *trans-Pacific*, *Asia–Europe* and the *trans-Atlantic* [35]. As shown in Fig. 1, in the absence of worldwide economic downturns, the containerization rate is rapidly growing. Therefore, given the heavy investments and fierce competition involved in this industry, better management strategies for planning routes and capacity are now vital for the efficiency and competitiveness of all global Liner Service Providers (LSP's) (see Fig. 1).

There are several reasons why maritime transportation is generally preferred to other modes of transport. The two major ones are: (i) the economy of scale exploited by the concentration of cargo on high-capacity vessels, which makes it much cheaper to transport cargo with these vessels than with any other mode of transport and (ii) for a given quantity of cargo, maritime transport has considerably less environmental impact than alternatives such as air and road transport.[1]

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[1] According to the Ministère des Transports du Québec (MTQ), in 2007, for 1 liter of fuel, 1 t of cargo is carried more than 241 km by ship compared to 95 km by train and 28 km by truck.

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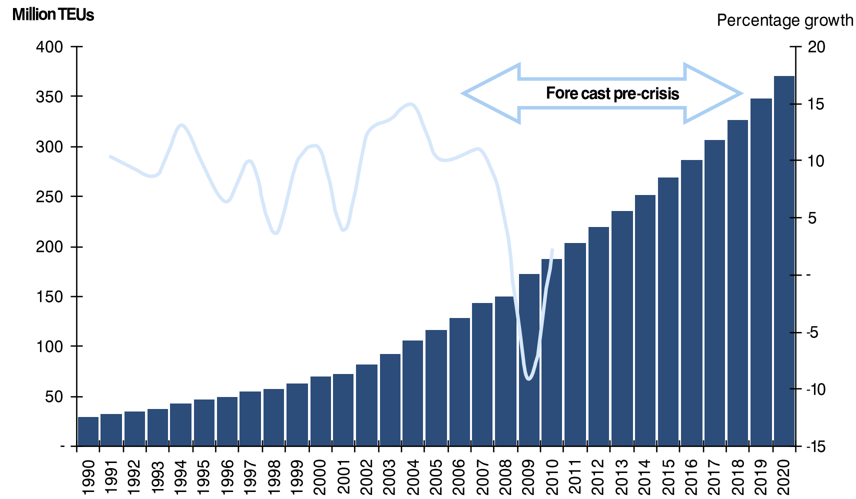

Source: Drewry Shipping Consultants. *Container Market Review and Forecast 2006/2007* and *2008/2009,* and Clarkson Research Services Limited, *Container Intelligence Monthly,* September 2009.

Fig. 1. Global container trade, 1990–2020 (TEUs and percentage change).

Fig. 2. An operational string of an anonymous LSP.

A LSP operates on a set of circular strings (routes). A *string* is a sequence of visits, known as *calls*. A call is a visit to a port followed by loading/unloading operations. Calls to a set of ports, forming that string, are performed according to a published (*a priori* given) itinerary, and the last port that is called on the inbound voyage coincides with the first port on the outbound voyage. Typically, on every string, a port is called at no more than twice along the string —on outbound or inbound directions. The size of a string, as a rule, is an approximate multiple of a week (i.e. seven days), so that the same port is called at on the same day of each week. In this way the published itinerary can remain valid throughout the voyage season. Some of the strings are inter-linked, whereas others are not. A major LSP usually operates on more than 100 strings, which cover around 300 ports where each port is either called at directly on one or more ocean-going strings, or is called at by a feeder string. On every string, the frequency and/or schedule is described in the published itinerary, whereas some other pieces of information such as vessel type or other pieces of technical information are not necessarily reported in the published itinerary. Such information consists mainly of tactical level decisions with respect to the length of planning horizon, which the customer is unlikely to be concerned with or interested in. An example of such a string, with six ports along it and operated by one of the major LSPs is depicted in Fig. 2. The rotation starts by calling at three European ports, then calling at three ports along the US East Coast.

Many LSPs are aware of the inefficiencies involved in their operations, or of the implications of making changes in their operational strategies such as changes to the network design, frequency settings, number of vessels on a service route, deployment strategies, etc. Nonetheless, they insist on smooth and gradual revisions rather than sudden and radical changes, which risk causing customer dissatisfaction and threatening the LSP's market share. Considering this, it seems the best way to improve efficiency is through evaluating the system performance by generating scenarios based on making small and yet controllable changes in the network. In practice, this is carried out by revising the service network in a *string-by-string* manner.

Although we shall only concentrate on economic aspects in this work, there are *currently* three main implications for such revisions: (1) Periodic seasonal change in response to fluctuations in demands and the trade volume throughout a planning horizon. For example, the demand in the West for goods produced in the East dramatically increases just before Christmas and sharply drops down after that. The sequence of port calls and the vessel size deployed during peak season may not be optimal for low-demand seasons. There are in general three to four seasons across the year with the different patterns of demand. (2) Commitments to green logistics policies. Take the example of A.P. Moller Maersk A.S., the world's largest container ship fleet operator, which has pledged to reduce its CO_2 emissions by 20% by 2017 [23]. (3) Some unpredicted safety and security issues such as piracy and natural disasters can make such revisions inevitable. A recent example is the re-routing of vessels by the *Cape of Good Hope*, a South African port, to avoid piracy-ridden areas. This has been adopted by MAERSK Line on route AE7 (see Fig. 3) of an east-bound leg towards Asia, as well as a joint service of CMA-CGM and China Shipping Container Line. On AE7l, the inbound voyage had been designed to pass through Malaga, the Suez Canal and the Gulf of Aden. However, due to the threat of piracy activities in the Gulf area, the string has been revised to skip some of the ports, which used to be called at North Africa. Instead it calls at the Cape of Good Hope, South Africa, on the way to Asia (see dashed line in Fig. 3).

1.1. *Literature review*

Most of the relevant existent literature on shipping has been reviewed by Gelareh and Pisinger [9], including work on problems in network design and fleet deployment, routing and scheduling.

However, to the best of our knowledge, no piece of work has yet addressed the problem addressed in this paper. The problems of scheduling and routing appear more frequently in other types of maritime transport such as *tramp* and *industrial* shipping, than in liner shipping. Tramp shipping in particular has schedules and routes that change very frequently. The operation of tramp ships is