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The liner shipping berth scheduling problem with transit times

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ABSTRACT

In this paper speed optimization of an existing liner shipping network is solved by adjusting the port berth times. The objective is to minimize fuel consumption while retaining the customer transit times including the transhipment times. To avoid too many changes to the time table, changes of port berth times are only accepted if they lead to savings above a threshold value. Since the fuel consumption of a vessel is a non-linear convex function of the speed, it is approximated by a piecewise linear function. The developed model is solved using exact methods in less than two minutes for large instances. Computational experiments on real-size liner shipping networks are presented showing that fuels savings in the magnitude 2–10% can be obtained. The work has been carried out in collaboration with Maersk Line and the tests instances are confirmed to be representative of real-life networks.

1. Introduction

Container shipping companies are currently facing combined challenges of overcapacity and volatile fuel prices. In addition, rising concerns about greenhouse gas emissions has made it crucial for shipping companies to reduce their fuel consumption. In the beginning of 2008, the future of maritime transportation looked remarkably bright. Major actors of the sector responded to an ever-increasing demand by extending the fleet capacity. At the end of 2008 orders for new ships were equivalent to almost 80% of the current fleet capacity (UNCTAD, 2013). However, when the economic crisis hit the liner shipping sector in 2009, a severe downturn in trade left the sector with overcapacity. As a direct consequence, freight rates dropped 28% on average (Maersk, 2009). As a response, shipping companies deployed less capacity on their networks and by the end of 2009, 12% of the global container fleet was laid up, compared to 3% one year earlier (Maersk, 2009).

Another response to the over capacity was slow steaming (Cariou, 2011). The slow steaming strategy has been employed by most container lines since 2009. While reducing bunker consumption, slow steaming will frequently also extend the round-trip time of a service. Since liner-shipping companies generally provide weekly shipping services, the number of vessels deployed on a service would then increase with the duration of the round-trip. Because of this, more vessels are needed to operate the same tour and slow steaming can absorb some of the excess carrying capacity. This makes slow steaming the most relevant option to choose in order to reduce operational cost while utilizing the available vessel capacity. However, while slow steaming reduces the bunker consumption it may also extend the delivery times, resulting in unattractive service times for the customers.

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According to Stopford (2009), the bunker cost is 35–50% of a vessels cost and according to Maersk (2013) around 21% of the company expenses. Hence, bunker consumption is a critical item for achieving cost reduction. The 2013 maritime report of the United Nations (UNCTAD, 2013) goes further by linking consumption cost and environmental concerns. As a result a better handling of fuel consumption may reduce both environmental impact and cost.

1.1. The liner shipping berth scheduling with transit times problem

The slow steaming strategy exploits the relation between speed and bunker consumption. However, lowering the speed will obviously also result in longer transit times. Freight rates and transit times are crucial criteria for customers when they choose a carrier. Brouer et al. (2014) list nine parameters for the services that liner shipping companies can offer, mentioning that only freight rates and transit times are regarded as key factors. Consequently, the negative impact of slow steaming on the transit time could cause loss of customers. Therefore, lowering speed is a tradeoff between bunker consumption and customer satisfaction.

The networks of most liner-shipping companies are organized around services that repeatedly serve a set of ports in a predefined sequence. A set of homogeneous vessels are deployed on the service to provide a periodic service, usually a weekly service. A service is defined by a port sequence, a timetable, a number of vessels deployed and a frequency. On the example shown in Fig. 1, port sequences of three constructed services are depicted. For clarity, the number of vessels and frequencies are omitted.

The implementation of slow steaming can be done at two different stages of the network design process. It can either be done when the rotation is designed and then it will influence the port sequence and the number of vessels deployed. Alternatively it can be done when the rotation is already defined, so only the schedule is re-optimized to smooth out the speed along the rotation.

Both approaches have their advantages and drawbacks. The first method implies solving a large integrated problem. This may prove too complex to be solved by current techniques and implementing the solution may prove impossible for strategic reasons. The second method consists of optimizing subproblems individually as this is easier for a company to implement in their current network. This is, however, at the cost of possibly missing savings from a more holistic approach.

In the variant studied here, only the arrival times in the serviced ports are rescheduled. We will denote it the *The Liner Shipping Berth Scheduling with Transit Times Problem* (BTRSP).

Earlier we defined a service as a port sequence, a timetable, a number of vessels deployed and a frequency. In the problem studied here the port sequence, number of vessels deployed and the frequency will remain the same and only the timetable is changed. The arrival times define the schedule for each service of the network and they are limited by the sailing speed.

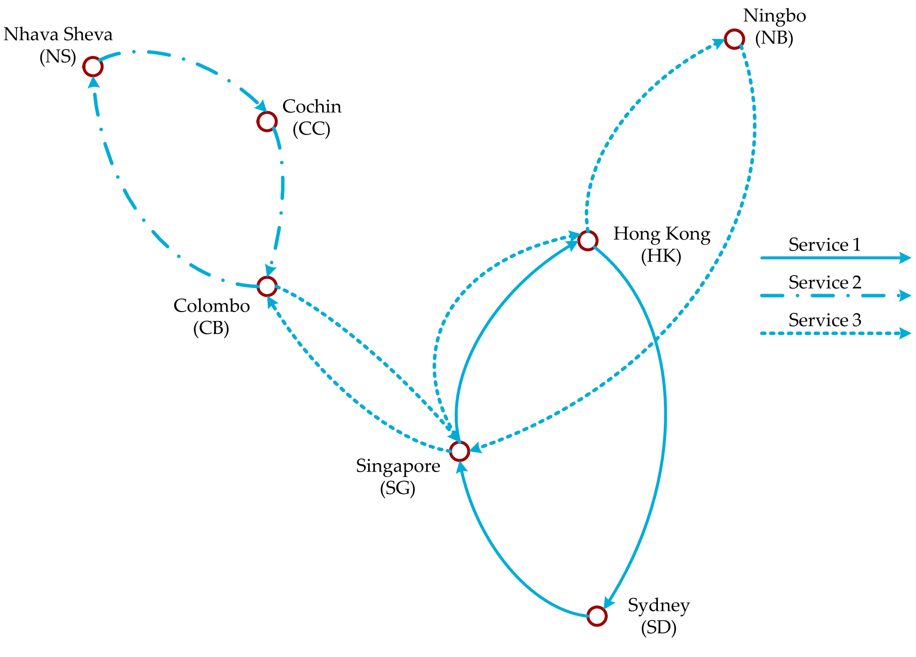

Fig. 1. An example of a network containing three services with possible transhipment locations at Hong Kong, Singapore and Colombo. The network is similar to the one presented in Wang and Meng (2012a).