Transportation Research Part E 69 (2014) 199–217

Contents lists available at ScienceDirect

Transportation Research Part E

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

Container yard template planning under uncertain maritime market

Lu Zhen *

School of Management, Shanghai University, Shanghai, China

ARTICLE INFO

Article history:
Received 13 February 2014
Received in revised form 10 May 2014
Accepted 16 June 2014

Keywords:
Port operation
Yard template
Container terminals
Yard management

ABSTRACT

A yard template determines the assignment of spaces in a yard for arriving vessels. Fluctuation of demand for freight transportation brings new challenges for making a robust yard template when facing uncertain maritime market. A model is proposed for yard template planning considering random numbers of containers that will be loaded onto vessels that visit the port periodically. Traffic congestions and multiple schedule cycle times for vessel arrival patterns are also considered. Moreover, a meta-heuristic method is developed for solving the model in large-scale cases. Numerical experiments are conducted to validate effectiveness and efficiency of the model.

1. Introduction

With advancements of quay side equipments and technologies, the bottleneck of port operations has moved from quay side to yard side (Chang et al., 2010; He et al., 2010). The yard management of a port has significant influences on the competitiveness of the port in a global shipping network. The yard template is a concept applied in container ports, which utilize a consignment strategy (Moorthy and Teo, 2006; Lee et al., 2006; Han et al., 2008; Jiang et al., 2012). This strategy stores export and transshipment containers, which will be loaded onto the same departing vessel, at the same assigned subblocks. The yard template planning is concerned with the assignment of subblocks to vessels. Some dedicated subblocks in the yard are reserved for each vessel. The incoming containers that will be loaded onto the vessel V_i in the future are discharged from incoming vessels and placed in the subblocks reserved for V_i. When V_i arrives at the terminal, all the containers stored in these dedicated subblocks are loaded onto it. This strategy can evidently reduce the number of reshuffles and vessels' turnaround time. The yard template planning aims to minimize the utilization cost of subblocks and the transportation cost for moving containers from their incoming berths to the storage subblocks in the yard and then to their outgoing berths.

In Fig. 1, under the consignment strategy in the terminal, subblocks in the yard are reserved for some vessels. Vessel *B* arrives at the port, and the dashed lines denote the unloading process: containers that will be loaded onto other vessels (i.e., Vessel *D* and Vessel *E*) in future are unloaded to the subblocks which are reserved for these vessels, i.e., *K21*, *23*, *42*, *45* for Vessel *D*, and *K16*, *36*, *38* for Vessel *E*. Meanwhile, the loading process is denoted by the solid lines in Fig. 1. All the containers in subblocks reserved for Vessel *B* (i.e., *K9*, *29*, *48*, *50*) are loaded onto Vessel *B*.

The yard template planning problem is to determine which subblocks should be reserved to which vessels so as to optimize some certain objective functions, which could be the minimization of the number of used subblocks, the route length of all the transshipped container flows in the yard.

* Tel.: +86 21 66134237.
E-mail address: lzhen.sh@gmail.com

http://dx.doi.org/10.1016/j.tre.2014.06.011
1366-5545/

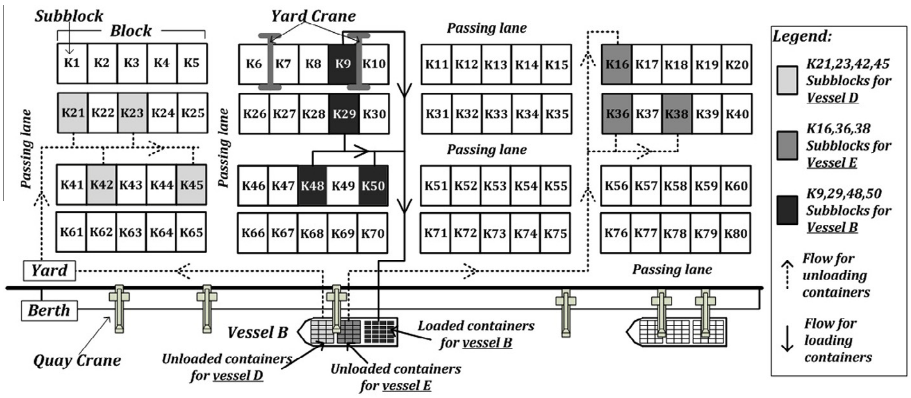

Fig. 1. A typical configuration of transshipment terminal.

Although yard cranes are important resources in yards, the moving time of the yard cranes is not a bottleneck for yard operations when using the yard template (Yan et al., 2011). In the traditional yard management without the yard template, each loading (or unloading) task is usually related with a specific location (block #, row #, column #, tier #) in a yard. When performing a sequence of loading or unloading tasks, yard cranes need to move along the rails back and forth so as to reach the specific locations of the tasks. In addition, reshuffling activities are common in the traditional yard management. The reshuffling can also increase the handling time of yard cranes evidently.

However, by using the yard template, there is no reshuffling; and each loading (or unloading) task is related to a specific location with respect to subblock #. The loading activity is to load all the containers in a subblock onto a vessel, and the unloading activity is to unload a group of containers from a vessel to a subblock. Therefore, when performing loading or unloading tasks, the yard cranes need not to move along the rails back and forth and change their moving directions frequently. The yard cranes usually do not move along the rails for a long distance between two consecutive tasks (He et al., 2013). Based on the above reasons, the handling time of crane movements is not a very important issue for evaluating a yard template, thus the objective for optimizing a yard template mainly considers the route length of transshipped containers, but does not consider the handling time of yard cranes in details.

Most studies on the yard template planning are based on a deterministic environment with respect to numbers of containers that will be loaded onto arriving vessels. However, the global maritime logistic market contains a lot of uncertainties that inherit from the fluctuation of the demand for freight transportation. Shipping liners' vessels visit a port periodically (weekly, 10-days, or biweekly). For a vessel, the numbers of containers loaded onto the vessel are different in each period. The numbers of containers unloaded from the vessels in each period also fluctuate along the time. The randomness contained in the uncertain maritime market has brought new challenges for making a robust yard template so as to improve the efficiency of port operations.

The yard template planning belongs to a tactical level decision in a port. Once determined, the yard template is usually not modified in the planning horizon, and is used as a basis for making some operational level schedules in the port. This paper investigates how to obtain a robust yard template under uncertain numbers of containers that will be loaded onto vessels that visit the port periodically. A comprehensive analysis on all types of costs in a yard template is given in this paper. The traffic congestions in the yard and the multiple schedule cycle times for vessel arrival patterns are also considered in the proposed model. Moreover, a meta-heuristic method is developed for solving the above problem in large-scale realistic environments. Numerical experiments are conducted to validate the effectiveness and efficiency of the proposed model.

The remainder of the paper is organized as follows. Section 2 reviews the related works. Section 3 elaborates the problem backgrounds and analyzes objectives and constraints for the problem. A mathematical model is formulated in Section 4. Then a meta-heuristic solution method is proposed in Section 5 for solving the proposed model. Section 6 shows the results of some numerical experiments. Closing remarks and conclusions are then outlined in the last section.

2. Literature review

For an introduction to the general port operations, we refer readers to the review works given by Vis and de Koster (2003), Steenken et al. (2004), Stahlbock and Voß (2008). The *yard template planning*, i.e., the theme of this study, is a tactical level decision problem, but is closely related to the widely studied *storage allocation problems*, which is operational level decision problems. In addition, the yard template is based on one kind of *yard management policies*. Another highlight of this study is that the *uncertainty* is considered. Thus, this section mainly reviews the related studies through these four topics, i.e., storage allocation, yard management policies, yard template planning, and port operations under uncertainty.