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The strategic berth template problem

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ABSTRACT

A marine container terminal operator may have a situation with excessive calling requests to be served especially when some new service contracts are under consideration. For this situation, we propose a strategic berth template problem (BTPS) that selects the ships among the requesting ones to be served and arrange their berth-windows within a limited planning horizon. The BTPS employs the subgradient optimization procedure, which is an improved version of the procedure that the authors developed for the operational berth allocation problem. A wide variety of numerical experiments indicate the improved subgradient procedure works well for the BTPS.

1. Introduction

Sea-borne container shipping plays a major and important role in the world transportation system and the global supply chain. A container terminal, as a nodal point in the transportation network, acts as an interchange of the different modes involved in the overall transportation process. Therefore, efficiency and productivity improvements in the terminal operations are crucial in reducing the overall trip duration and reducing costs and thus have been gaining more attention lately.

The primary aim of a terminal is a quick turnaround or a secured departure deadline of calling ships. Also, the terminal attempts to utilize its costly infrastructure efficiently. Major container ports feature the so-called "multi-user container terminals (MUTs)", which serve a lot of calling ships of different shipping lines with a long quay and vast yard space to provide a huge ship handling capacity. In an era of cost-cutting and competition, shipping lines are less inclined to operate private terminals they used to be (Mongelluzzo, 2013). Due to this growing demand, the need to operate MUTs more efficiently as well as the issues pertaining to the efficient berth scheduling at an MUT have been receiving much attention these days.

Most decision makings can be classified as three broad categories: strategic, tactical and operational. As far as the berth scheduling is concerned, the existing literature may fall into two categories in a relative sense: long-term (tactical) and short-term (operational). Contents of those categories may be summarized as below whilst there exists some diversity in decision making for each category at MUTs.

(1) Tactical berth scheduling (or berth template problem, BTP): finds a set of berth-windows (i.e., berthing locations with the start and end times for service) within the fixed length of planning horizon so as to maximize the service objective.

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(2) Operational berth scheduling (or berth allocation problem, BAP): finds a set of berth-windows within an open-ended planning horizon so as to maximize the service objective.

As will be discussed in the subsequent section, most of the existing papers about berthing decision fall into the operational scheduling, while some are in the tactical scheduling. Also note that it is common in the literature berth scheduling is considered together with other facilities so as to take into account the actual situations of the related resources jointly operated as well as the updated information of the ships to be served.

For a terminal operator, the service contracts with shipping lines are reviewed and renewed as with a regular interval or whenever needed. Alternatively, the terminal operator may receive the berthing request from a new customer. The typical contract negotiation process between a shipping line and a terminal operator can be illustrated by JICT (2014), a webpage of a South Asian terminal operator. Throughout the negotiation process, the operator arranges a template for berthing. As briefly depicted above, the berth template problem (BTP) in the literature determines the template for berthing, i.e., a set of berth-windows of serving ships during a fixed planning horizon, given a long-term calling request profile from shipping lines. In particular, as the most notable distinction between BTP and BAP, the fixed planning horizon is repeated in a cyclic fashion in the BTP and hereafter referred to as the *cylinder*, as used in a pioneering work on the BTP by Moorthy and Teo (2006).

In general, most container shipping services are provided weekly on a fixed day of the week, thus the BTP normally arranges berth-windows to meet all the calling requests within a week. It is noteworthy that, though not very common, it is possible that a terminal has a different calling ship request profile from one week to another. Then, the cylinder for the BTP should be set as the least common multiple. A terminal operator normally applies the same template every week, though some adjustment may be made to accommodate the irregularity associated with the ship arrivals.

For most of the cases for such a new contract or contract renewal, there might be no significant change in the number of overall calling ships when updating the berth template design. This scenario leads to the situation that all calling ship requests can be accommodated in any berth template design. In fact, as will be reviewed in the next section, all of the existing BTP studies assume such a full coverage of calling ships. Their focuses are mainly on reducing the operational cost and/or meeting the requirements/performances of the calling ships.

In contrast, under the inauguration of a new MUT or the completion of major capacity expansion at an existing MUT, the terminal operator may need to design a brand new berth template to incorporate all prospective demands of calling ships. In addition to the decision factors similar to those in the existing BTP literature, the terminal operator may face the issue of excessive demand and require a decision making methodology for determining which part of the demand to be satisfied. This scenario is not addressed in the existing BTP studies. We hereby propose a strategic level of berth scheduling: the strategic berth template problem (BTPS), which chooses ships to be served and those not to be and finds a set of berth-windows for the served ships within a pre-determined fixed length of planning horizon so as to maximize the service objective. For convenience, the BTP at the tactical level addressed in the existing papers is hereafter referred to as BTPT.

This paper introduces an integer programing model for the BTPS and develops a Lagrangian relaxation-based heuristic for it. The contribution of this paper is twofold. One is the introduction of the BTPS concept that deals with the selection of the ships to be served, including the consideration over the mother ship (or shipping line) and the associated feeder under the condition of tight berthing capacity. The other is an approximate solution method for berth scheduling. The BTPS formulation is structured based on the formulation of the dynamic BAP (DBAP) in Imai et al. (2001) to take advantages of the established solution methodology: the subgradient procedure with Lagrangian relaxation. However, we develop new heuristics, on the foundation of the DBAP solving technique, to achieve a better BTPS solution. As will be shown in the numerical experiments, the superiority of these new heuristics for both BTPS and DBAP is demonstrated.

The paper is organized as follows. The next section provides a literature review on the berth scheduling. An integer programming formulation of the BTPS is discussed in Section 3. This is followed by Section 4 which introduces a solution method for the BTPS. In Section 5, a number of computational analyses are carried out, while the final section concludes the paper.

2. Literature review

As the issues related to efficient terminal operations have been constantly gaining importance, there have been a growing number of studies that deal with the BAP models. On the other hand, the BTP is a relatively new research topic with few research works. These two types of problems are reviewed in this section. In particular, to the authors' knowledge, there is no existing BTP research work that focuses on the strategic decision of selecting the shipping lines such as the BTPS in this study.

One of the earliest works of the BAP is Imai et al. (1997) who addressed a BAP in discrete location indices (hereafter referred to as BAPD in this section) for commercial ports. Most service queues are in general processed on an FCFS (First-Come-First-Served) basis. They concluded that in order to achieve high port productivity, an optimal set of ship-to-berth assignments had to be determined, instead of considering the FCFS rule. Their study assumed a static situation where ships to be served for a planning horizon had all arrived at a port before one planed the berth allocation. Thus, their study can be applied only to tremendously busy ports. As far as container shipping is concerned, such busy ports are neither competitive