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An Approach for Scheduling Problem in Port Container Terminals: Moving and Stacking

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Abstract

In this study, we consider the transportation problem in port container terminals. It aims to determine positions in yards to place the containers at the adequate times. The containers on ship must be unloaded one by one from top to bottom, and placed in the main yard in order to reduce additional cost required for unnecessary unloading when getting out by customer with given timetable. The cost for transportation at container terminals could be reduced by a new approach in scheduling: move the containers from ship and stack them onto main yard that minimizes cost of yard crane operation when unloading for customer.

Keywords: *container terminal; scheduling; stacking.*

1. Introduction

In logistic industry, container is an important instrument for goods transportation, especially in the cases of heavy goods and long-distance transportation. Therefore, activities in container terminals and managing their cost are exciting topics for managers as well as researchers. There are many research aspects related to reducing cost in container terminals which can be categorized into quay crane scheduling, yard crane scheduling, truck scheduling, yard allocation, *etc*. Many different solutions were proposed such as dynamic rolling-horizon decision in *Zhang et al.* (2001) [1], or a heuristic algorithm for yard truck scheduling and storage allocation problems in *Lee et al.* (2009) [2]. In [5], *Steenken et al.* summarized and gave a classification and literature review for container terminal operation, and then *Stahlbock et al.* [4] also gave a literature update.

In [3], *Ng. and Mak* proposed a solution for yard crane scheduling problem in port container terminals. They consider a problem of scheduling a yard crane to perform a given set of loading/unloading jobs with different ready times. The objective is to minimize the sum of job waiting times. A branch and bound algorithm was proposed to solve that scheduling problem optimally. They also proposed efficient and effective algorithms to find lower bounds and upper bounds.

In that study, the authors also focused on minimizing the waiting time of yard cranes with given positions of containers, from ship to yard, and from yard to customers' trucks. A question comes up is "How to generate the list of those positions efficiently." This turns out to be a tough problem in container terminal scheduling.

In this paper, we study the problem of scheduling quay cranes, yard cranes sand trucks to move containers from ships and stack them onto the main yard considering the ordering of delivery to customers.

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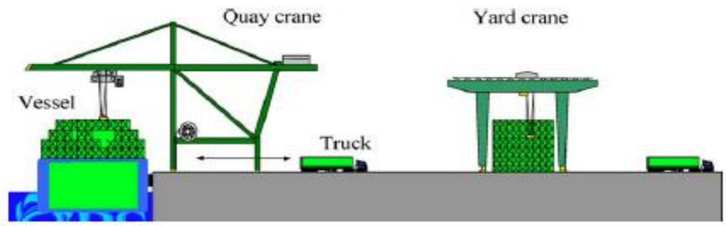

Figure 1. Loading/Unloading procedures in port container terminal

The problem in this study is stated as below:

- Position of containers on a ship should be informed before the ship arrives in the port. Then a timetable of delivering containers to customers is collected before scheduling.
- Containers on ship and yards must be unloaded from top to bottom. To unload an overridden container *a*, the container *b* locates on it should be temporarily unloaded first, then get out the expected container *a* and move *b* back. When this happens, we call it an *exchanging*.
- Containers should be moved from ship to the main yard and unloaded to customer in the main yard as well. If the container cannot be stacked to the main yard in some cases, it may be placed in the temporary yard and then moved to main yard whenever possible.
- We take the cost for moving a container from one place to another into account. In this study, we suppose that all these moving costs are equal to each other.
- The objective solution is to generate a schedule of container moving and stacking such that all containers when transporting from the main yard to customers always appear on top of stack. The objective function is to minimize total cost for unloading containers from ship to the main yard. Note that there is no *container exchanging* in the main yard and maybe there exists some containers that need to move to the temporary yard before putting on the main yard.

2. Modeling

To simplify the problem, we have some further assumptions.

- The cost for temporarily moving containers on ship, but not in the delivery list, is ignored.
- The size of the temporary yard is unlimited.
- Each container is moved only once, if it is moved to the temporary yard, then we will have another algorithm to move it to the main yard
- Each container has a unique identifier number (ID), this number is also the ordering of delivery to customers. The container has smaller ID should be delivered to customer before the greater ones.

In solving this problem, to avoid *exchanging* when getting out containers for customers, the containers should be stacked on columns in main yard such that the ID numbers are increased from top to bottom. It means that the container received before others should be stacked on top of those ones. Let denote by

- $I = \{1,2,\dots,n\}$: the set of containers' indices, where the index of a container represents exactly the order of their transportation by a customer out of the port,
- $J = \{0,1,2,\dots,m\}$: the set of columns' indices, where Y_0 is the temporary yard, Y_1 to Y_m are the columns in the main yard,
- $T = \{1,\dots,t^*\}$: the set of time points at which containers are moved from ship to yards, with $t^* = n$,
- D_i: a set of containers which are located **on** top of the container i, D_i may be empty,
- *h*: maximum height of columns in main yards, and this is NOT applied for the temporary yard.

2.1. Decision Variable

For each $i \in I, j \in J, t \in T$, let's define

$$x_{ijt} = \begin{cases} 1, & \text{if container } i \text{ is placed at the } j^{\text{th}} \text{ column at time } t, \\ 0, & \text{otherwise.} \end{cases} \tag{1}$$

2.2. Constraints

By the problem specifications as above, for every container, the constraints needed to be considered are verbally stated and reformulated using above notations and settings as follows:

a) Location Dependency: A container is moved from ship to yards only if there is no container locates on it, i.e.,

$$\sum_{j \in J} \sum_{t \in T} t \,.\, x_{ijt} > \sum_{j \in J} \sum_{t \in T} t \,.\, x_{kjt}, \forall i \in I, \forall k \in D_i. \tag{2}$$

b) Ordering Dependency: A container has lower ID number must be stacked on the ones with greater ID in the main yard. Here, we need an intermediate variable to represent the presence of two containers in the same column in the main yard, says y_{ikj}. Then, $\forall i \in I, \forall k \in I, \forall j \in J, j > 0,$

$$y_{ikj} = \begin{cases} 0, & \text{if container } i \text{ and container } k \text{ are stacked on the same } j^{\text{th}} \text{ column in the main yard,} \\ 1, & \text{otherwise.} \end{cases}$$

Therefore, the constraint is now reformulated as below

$$n.\, y_{ikj} + \sum_{t \in T} t \,.\, x_{ijt} - \sum_{t \in T} t \,.\, x_{kjt} > 0, \forall i \in I, \forall k \in I, k > i, \forall j \in J, j > 0. \tag{3}$$

Then we have to transform the intermediate variable into our model as new constrains

$$y_{ikj} \geq 1 - \tfrac{1}{2}\left(\textstyle\sum_{t \in T} x_{ijt} + \sum_{t \in T} x_{kjt}\right), \tag{4}$$

$$y_{ikj} \leq 2 - \left(\sum_{t \in T} x_{ijt} + \sum_{t \in T} x_{kjt}\right), \tag{5}$$

$\forall i \in I, \forall k \in I, \forall j \in J, j > 0$

c) The crane can move at most one container at a time, i.e.,

$$\textstyle\sum_{i \in I} \sum_{j \in J} x_{ijt} = 1, \forall t \in T. \tag{6}$$

d) Number of container on a main yard column is less than or equal column's height, i.e.,

$$\textstyle\sum_{i \in I} \sum_{t \in T} x_{ijt} \leq h, \forall j \in J, j > 0. \tag{7}$$

e) All containers in the given list must be moved from ship to main yard, i.e.,

$$\textstyle\sum_{i \in I} \sum_{j \in J} \sum_{t \in T} x_{ijt} = n. \tag{8}$$

f) Each container is moved to yards only once, i.e.,

$$\textstyle\sum_{j \in J} \sum_{t \in T} x_{ijt} = 1, \forall i \in I. \tag{9}$$

g) Containers in temporary yard have no constraint: we already described it in above constrains by NOT considering column number Y_0.

h) Moving container from ships to a temporary yard takes double cost compared to moving it to the main yard. For this constraint, we describe it in the objective function.

2.3. Objective function

Our simultaneous objectives are: (1) determine a feasible solution, such that (2) the total cost of container transportation is minimum. The objective function is reformulated as below

$$\text{minimize} \sum_{i \in I} \sum_{\substack{j \in J \\ j > 0}} \sum_{t \in T} x_{ijt} + 2 \sum_{i \in I} \sum_{t \in T} x_{i0t}. \tag{10}$$

3. Heuristic Algorithm

The solution for this scheduling problem can be found by stacking “Set of containers” (SOC) to fulfill the columns in the main yard one by one such that no constraint violated. A SOC must have following properties:

- Number of containers in a SOC is equal to the height of columns in main yard. In the case that the number of remaining containers on ship and in temporary yard is less than the main yard’s height, the SOC includes all of those containers.
- At least one container locates on top of the ship, others can be overridden directly by containers which are already selected in SOC.
- Selected overridden container must have ID number less than the ID numbers of the ones staked on it
- Containers in SOC may be selected from temporary yard, then no constraint required for this container.

A heuristic is proposed to find a solution using SOCs. While any container is locating on ship or temporary yard, find a SOC and stack them onto the main yard following ordering rule stated as above. In case of no SOC available, we select a lowest ID container on top of the ship and move it to temporary yard. Let’s define

- B: Temporary Yard
- m: Total number of columns in the main yard
- $SOC = \{a_1, a_2, ..., a_n\}$: set of container defined as above
- Y_j: the j^{th} column in the main yard

Pseudo code:

```
j = 1;
While any container left on ship or in B;
       Find SOC;
       If SOC is not empty
              Sort SOC by container ID numbers in ascending;
              For each container i ∈ SOC from top to bottom
                     Move(container i,Yj); j = j + 1;
              End For;
       Else
              On top of ship, select container k has lowest ID number;
              Move(container k,B);
       End If;
End While;
```

An example for this algorithm:

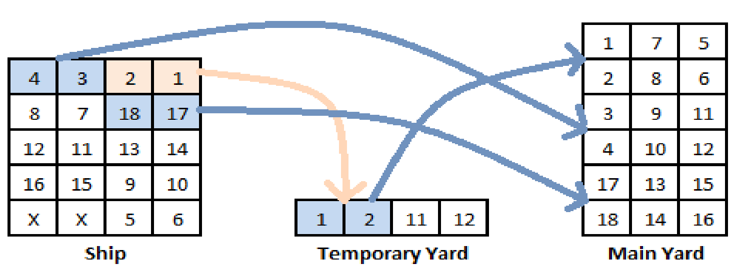

Figure 2. Example for Container Transportation

4. Conclusion

In this paper, the transportation problem in port container terminals for moving containers from a ship to main yards has been studied. A mixed integer programming algorithm has been proposed to solve the problem, and the properties of the problem have been studied in detail. Based on these properties, a heuristic algorithm has been developed. The performance of the algorithm has been evaluated by using a set of test problems. The computational results have shown that the algorithm works well for most of the test problems.

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