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Estimating the space requirement for outbound container inventories in port container terminals

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ABSTRACT

This paper proposes a method for allocating storage space to groups of outbound containers in port container terminals. For this allocation, a collection of adjacent stacks is reserved for each group of containers with the same attributes. The impacts of various space-reservation strategies on the productivity of the loading operation for outbound containers are discussed. A method is suggested for determining the size of the space requirement for outbound container yards.

1. Introduction

Operations in port container terminals consist of: the discharging operation, during which containers are unloaded from ships; the loading operation, during which containers are loaded onto ships; the delivery operation, during which inbound containers are transferred from the marshalling yard to road trucks; and the receiving operation for outbound containers from road trucks. From the perspective of customer service, the turnaround time of container-ships must be minimized by increasing the speed of ship operation; further, the turnaround time of road trucks must be kept as small as possible.

In container terminals, the loading operation for outbound containers is carefully pre-planned by load planners. For load planning, the concerned container-ship agent usually transfers a stowage plan to the terminal operating company several days before the ship's arrival. In the load profile, each slot is assigned with a container group, which is identified by the port of destination (POD) and the size of the container to be stowed into the slot.

A slot of a ship may be filled with any container as long as the container group specified for that slot is the same as the group of the container. Therefore, the handling effort in the marshalling yard can be reduced by optimally assigning outbound containers to slots and sequencing them for the loading operation. In the decision process, load planners usually attempt to minimize the handling effort for quay cranes and yard equipment at the same time. The output of this decision-making is called the "load sequence list." For an efficient load sequence, outbound containers need be laid out in optimal locations. Fig. 1 (Park, 2003) shows a stowage plan. It shows slots into which containers of two groups (defined by size and destination port) are assigned.

For efficiency in loading, several principles are widely accepted for space planning. The first principle is that yard-bays that are assigned to a container-ship should be located as near as possible to the berthing position of the corresponding ship (the Nearest Location Principle). The second principle is that containers must be located so as to avoid interference between yard cranes during the ship operation (the Least Congestion Principle). Thus, containers that are bound for the same vessel are distributed over several blocks.

The third principle is that containers of the same group must be located close to each other, i.e., in either the same bay or adjacent bays (the Concentrated Location Principle). This is a well-known principle for container handling systems that consist of yard cranes, yard trucks, and storage blocks that are laid out parallel to the quay. This type of handling system is popular in Asian countries. During the loading operations of containers, containers of the same group are likely to be loaded onto slots that are located close together, as illustrated in Fig. 1. Thus, they are usually loaded consecutively during the loading operation. As a result, the travel distance of yard cranes can be reduced by placing containers of the same group in slots that are close to each other. In practice, all the stacks in a yard-bay or in adjacent yard-bays are usually allocated to a container group. Further, since the outbound containers randomly arrive at the yard, such an allocation must be performed in advance, as shown in Fig. 2. In this paper, a set of adjacent stacks, which is allocated to the same container group is called a "cluster." The block in Fig. 2(a) has four clusters. The determination of the reservation (cluster) size of a container group is the main focus of Sections 2–4.

The fourth principle is that containers must be located so as to minimize relocations of containers (the Least Relocation

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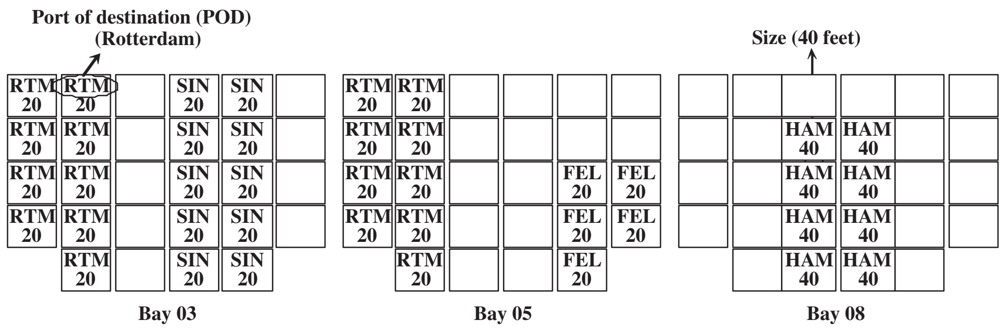

Fig. 1. An example of a stowage plan for a container-ship.

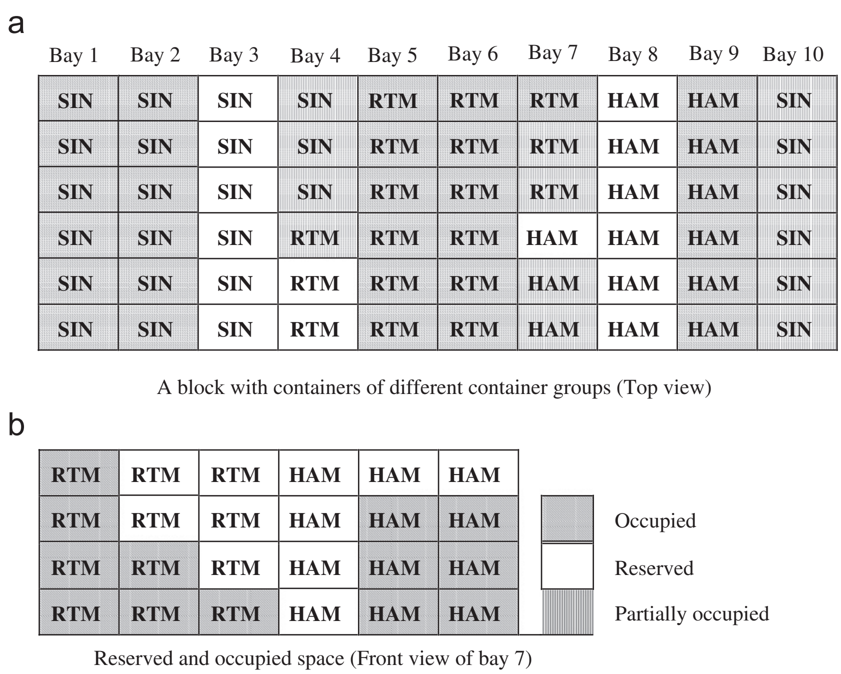

Fig. 2. Occupied, reserved, and partially occupied space.

Principle). Thus, containers of different groups must not be mixed in the same stack. Otherwise, relocations may occur for picking up a container of a group that is located under containers of other groups. We assume that this principle is applied in all the cases in this paper.

For space allocation, yard planners usually consider the four principles introduced above. Among these four principles, the concentrated location principle and the least relocation principle are related to the space requirement, which is the main focus of this study.

Regarding the space allocation for outbound containers, Taleb-Ibrahimi et al. (1993) have suggested a space allocation strategy in which temporary storage areas are provided for containers that arrive before a designated storage space has been allocated for them. The time to allocate designated space to each vessel is determined using a trade-off between the cost of the temporary storage space and the cost of relocating the containers from the temporary storage area to the designated space. Kim and Park (2003) proposed a dynamic method for space allocation for outbound containers in which the space in each block is allocated to each vessel for future container arrivals. Zhang et al. (2003) addressed a similar space allocation problem. They attempted to balance the workload among different blocks to avoid possible bottlenecks in terminal operations. Lim and Xu (2006) addressed the problem of locating the reserved space for each group of containers in a block. They proposed a method for scheduling the allocation of empty spaces to each group so that in the final layout, the reserved spaces for the same group are located adjacent to each other.

Lee et al. (2006) proposed a yard-space allocation method for a transshipment hub port. They suggested an algorithm for assigning parts of blocks (called the sub-blocks) to containers that are to be loaded (discharged) onto (from) a vessel so as to minimize congestion during the discharging and the loading operations. Lee and Hsu (2007) addressed the problem of pre-marshalling outbound containers for speeding up the loading operation. Bazzazi et al. (2008) also addressed the space allocation problem and attempted to minimize the variation in the handling workload across various blocks. For locating containers, Dekker et al. (2006) introduced various algorithms that are useful for automated container yards and compared them in terms of performance. Cordeau et al. (2007) proposed a method for assigning storage spaces to vessels for minimizing container rehandling operations in the yard in a transshipment container terminal.

Kim and Kim (1999) and Narasimhan and Palekar (2002) addressed the problem of determining the visitation sequence for a single yard-crane (YC) with respect to yard-bays and the number of containers to pick up during each visit (to a yard-bay).