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A simulation study of the performance of twin automated stacking cranes at a seaport container terminal

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ABSTRACT

This paper studies the effect of a handshake area on the performance of twin automated stacking cranes (ASCs) operating on top of a stack with transfer zones at both seaside and landside. The handshake area is a temporary storage location so that one crane can start a request and leave the container there for the other crane to complete the request. By testing settings with and without such a handshake area, the goal is to find robust rules which result in the best performance, measured as (1) the makespan to finish all requests and (2) the total waiting time of the cranes due to interference or nonconsecutive delivery of containers in the handshake area (blocking time). The effect of five decision variables on the performance are tested. The decision variables are (1) the way the requests are handled by the cranes (scheduling), (2) the storage location of the containers in the handshake area, (3) the location of the handshake area in the stack, (4) the size of the handshake area and (5) the number of handshake areas in the stack. For each decision variable, multiple heuristics are developed. The results indicate that settings without a handshake area outperform settings with a handshake area for virtually all instances tested when using the same scheduling heuristic. For both types of settings, the choice for a scheduling heuristic impacts the final performance the most. In this study, we opt for simple heuristics since container terminal operators prefer to avoid any complexity in coordinating and scheduling two ASCs for safety and simplicity reasons.

1. Introduction

Due to globalization the number of containers and size of ships have increased significantly in recent years and the growth is expected in future (Fransoo & Lee, 2013). The global players in a highly competitive market are constantly seeking to improve operations and gain cost efficiency. One of the ways they do, is by selecting container terminals or ports with the best price-performance ratio. Therefore, in order for terminals to remain competitive and have the customers returning, terminals need to increase the turnover of containers and at the same time keep prices low. As a solution, terminals aim to increase storage density meanwhile increasing the level of automation in their daily operations. An example is using automated stacking cranes (ASCs), which are automated rail-mounted gantry cranes. These cranes work in the container storage yard (often referred to as stacks) where containers are temporarily stacked. The stack is one of the areas in a container terminal which is significantly affected by the throughput increase at a container terminal (Vis & Carlo, 2010). New technologies and methods are constantly being developed to efficiently handle stacking operations in order to avoid the stacks becoming the bottleneck of the terminal.

ASCs can be seen as a step in the automation of container terminals to ensure low operating cost, high utilization of yard capacity, and high availability. Among terminals using ASCs, different configurations can be found. The basic configuration is to have one ASC per stack serving requests for both landside and seaside as pick-up and drop-off points, also known as transfer points or input/output (I/O) points. In order to increase the throughput, configurations with two non-passing ASCs per stack are common in practice, in which one ASC serves the landside and the other serves the seaside. In such configurations, the ASCs are non-passing, i.e. there are two identical ASCs which are unable to pass each other (also known as twin cranes, see Fig. 1). In this paper we focus on a stack with twin cranes.

A container stack with twin ASCs typically has I/O points at the seaside and the landside. On the seaside, automatic guided vehicles or terminal trucks pick up and deliver containers while at the landside this function is typically performed by trucks. The difficulty is that when the landside ASC has a request close to the

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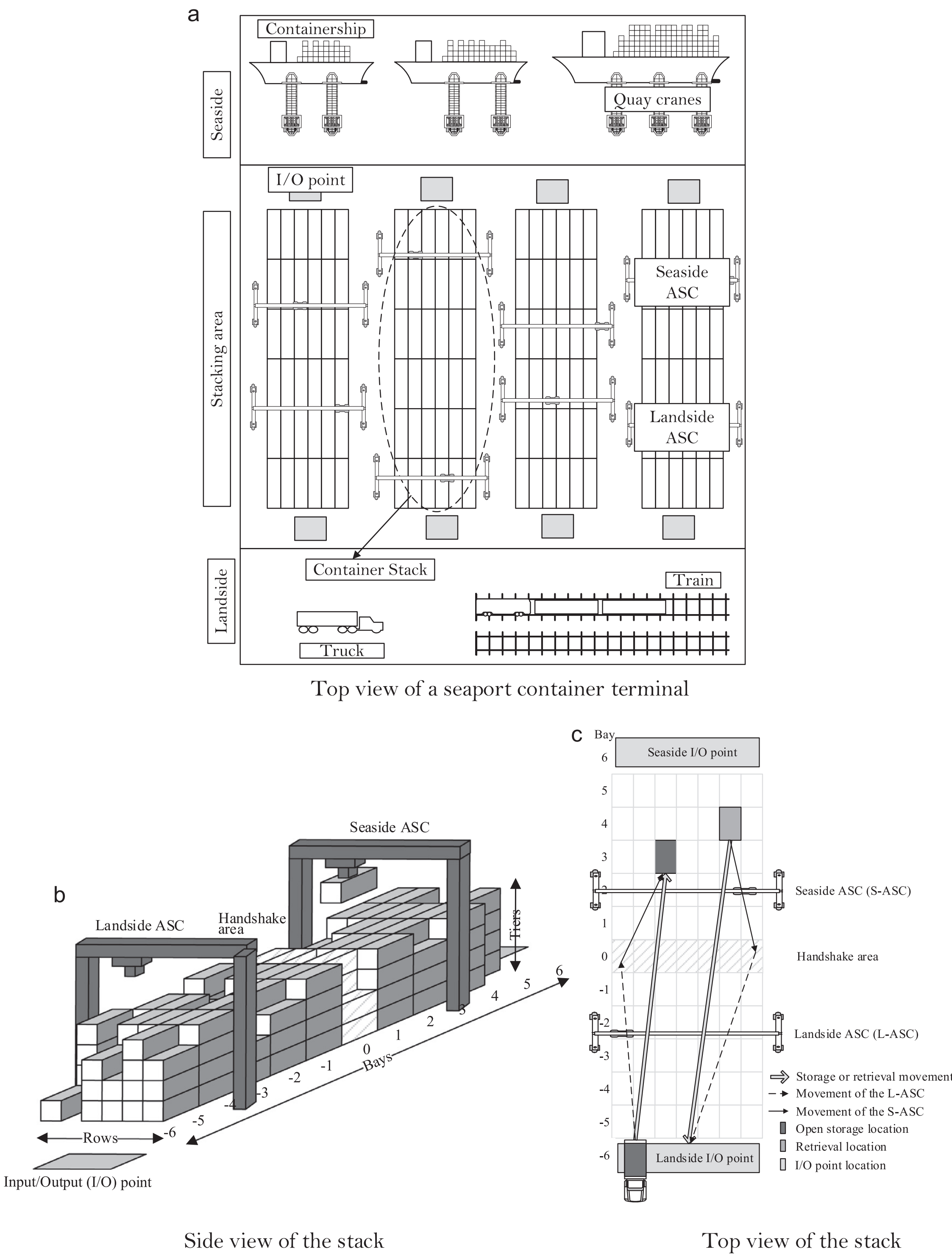

Fig. 1. A seaport container terminal with multiple stacks and twin ASCs.

seaside, the seaside ASC needs to make room or (if possible) even leave the stack in order for the landside ASC to be able to handle its request. This potentially increases the ASC travel time and diminishes the terminal's performance. To address this issue, the ASCs can work together. Such a configuration would need a handshake area in which the ASCs can hand over the containers from one to another. For example, in Fig. 1, the landside ASC first brings the storage container to the handshake area. Then the seaside ASC picks it up and stacks it in its final location. For the retrieval request, the seaside ASC first brings the container to the handshake area. Then the landside ASC retrieves it to the landside I/O point.

This research focuses on optimizing twin ASC operations by implementing a handshake area. Our objective is to minimize the total makespan of a given set of storage and retrieval requests. Makespan is commonly used in practice to measure the performance of twin ASC cranes. Minimizing the makespan is considered to be a good proxy for other objectives for container terminals such as minimizing the total travel time, minimizing the crane wait-