Distributed framework for yard planning in container terminals*

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Abstract: This study discusses a yard planning system, which considers various resources such as storage space, yard cranes, and traffic areas in container terminals. The system is based on the function for estimating resource requirements of yard plans. For a given yard plan, the proposed system allows planners to check the feasibility of the plan which requires a certain amount of workload of resources in related blocks during a planning horizon. The yard planning system in this study is aimed at balancing workloads among the blocks and providing the ability to modify current yard plans by detecting blocks and periods with over-loaded workloads. The system implements its planning function in a distributed manner in which planners construct yard plans under their individual control and send and receive only limited necessary information for the negotiation.

Key words: Workload, Yard planning, Container terminal, Distributed planning

1 Introduction

Containers are temporarily stored in the yard of container terminals in the form of blocks before they are loaded onto the target vessel or delivered to consignees. Yard cranes, which are equipped in each yard block, are charged with handling containers for receiving, delivery, loading, and discharging operations. Fig. 1 illustrates a layout of a container terminal.

Generally, according to the flow direction, containers can be classified into three categories: outbound, inbound, and trans-shipment containers. Outbound containers are received from customers by inland transportation methods such as railways and external trucks (receiving operation), and will be loaded onto a vessel (loading operation). Inbound containers are discharged from a vessel (discharging operation), and will be delivered to consignees (delivery operation). Trans-shipment containers are discharged from a vessel and will be loaded onto another vessel after some duration of stay in the storage yard.

Two types of operations will lead to the storage of containers: one is discharging operation from vessels and the other is receiving operation from external vehicles. Discharging operations for a vessel are usually completed within one day, while receiving operations for a vessel last for several days depending on the arrivals of external vehicles. In this study, it is assumed that yard plans are established before discharging operation or receiving operation (Won, 2009).

Yard planning determines the quantity of containers for a vessel to be stored at each block. One of the important considerations in the yard planning is that workloads should be spread over many storage blocks, because the progress of works may be delayed if workloads are concentrated on a few blocks. A good decision also needs to minimize the travel distance of vehicles between storage blocks and berthing positions of vessels so as to minimize the cost and time for traveling. However, the availability of resources restricts the decisions, especially limitations of the
storage capacity of each storage block and the handling capacity of yard cranes equipped in each storage block (Won, 2009).

This study defines a storage activity to be a set of containers of the same type (outbound, inbound, or trans-shipment containers) for a vessel, for which a planner attempts to reserve storage locations (specifically blocks). The yard planning in this study considers storage yards and yard cranes as resources. The required timings of resources are based on the discharging time of containers from vessels and the loading time of containers into vessels. The resources for inbound containers are consumed forward from the start time of the discharging to the completion time of the delivery. The resources for outbound containers are consumed backward from the completion time of the loading to the start time of the receiving. The resources for trans-shipment containers are consumed between the discharging time and the loading time of containers (Won, 2009). The requirements of resources are determined according to the quantity of containers handled and the amount of resources consumed by a container.

The yard planning method has been studied in many previous researches (Kozan, 2000; Preston and Kozan, 2001; Kim and Park, 2003; Zhang et al., 2003; Lee et al., 2006; Han, 2007; Bazzazi et al., 2009; Won, 2009). Won (2009) provided a framework for integrating various planning activities in container terminals. For each planning activity, a decision-making problem is identified, including input parameters, decision variables, objectives, constraints, time buckets, and planning horizon. That framework was developed on the basis of the concept of the capacity planning in production systems. He introduced a concept of a resource profile and a planning procedure by simultaneously considering availabilities of various resources and resource requirements of a yard plan. The yard planning problem was represented as a multi-commodity minimum cost-flow problem. A linear programming model for the yard planning was proposed.

This paper addresses the problem similar to those by Won (2009). However, Won (2009) proposed a centralized planning procedure, this study explores the possibility of a distributed planning framework which seems to be more similar to what practical planners are doing for the yard planning in container terminals. In the distributed framework, the requirements and availabilities of resources can be estimated and the feasibility of a yard plan can be verified. This paper also suggests a decentralized planning procedure which constructs the plans in a distributed manner.

2 Yard planning considering workloads

2.1 Various states of yard plans

The resource requirements come from various sources such as forecasts on future container arrivals (“forecasted requirement”), temporary plans (“temporary”), reservation plan (“reserved”), and containers already arrived (“occupied”). The forecasted requirement does not construct any plan and is for container arrivals in the distant future. For the temporary plans, the space is allocated temporarily but not fixed yet. For a reservation plan, an empty part of the yard is reserved for containers which will arrive at the yard soon. For the occupied space, containers have already arrived at the yard. Fig. 2 shows the relationships among different states of plans.

When there is not enough information about containers for a vessel, the system will forecast the required workload based on the historical data. When planners begin to obtain information on arrivals of containers from consignees or shipping liners, they construct temporary plans for the space allocation. For each temporary plan, the system checks the feasibility of the plan by estimating the required workload over the corresponding blocks during the planning period. If it is feasible, the plan will be