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Benefits of a truck appointment system on the service quality of inland transport modes at a multimodal container terminal

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ABSTRACT

Container terminals pay more and more attention to the service quality of inland transport modes such as tucks, trains and barges. Truck appointment systems are a common approach to reduce truck turnaround times. This paper provides a tool to use the truck appointment system to increase not only the service quality of trucks, but also of trains, barges and vessels. We propose a mixed integer linear programming model to determine the number of appointments to offer with regard to the overall workload and the available handling capacity. The model is based on a network flow representation of the terminal and aims to minimize overall delays at the terminal. It simultaneously determines the number of truck appointments to offer and allocates straddle carriers to different transport modes. Numerical experiments, conducted on actual data, quantify the benefits of this combined solution approach. Discrete-event simulation validates the results obtained by the optimization model in a stochastic environment.

1. Introduction

Container terminals play the role of exchange hubs in intermodal transportation. They offer transfer facilities to move containers from vessels to trucks, trains and barges and vice versa. A terminal is composed of quays, the inland area and the yard. Fig. 1 illustrates an exemplary container terminal. Vessels berth at the quay where containers are unloaded and loaded by quay cranes. The inland area is the terminal's interface with the inland transportation system (rail, road and waterway). It provides truck and train receiving gates where rail cars and trucks are unloaded and loaded with the appropriate equipment. Barges may be served at specific barge gates or at the same quay than vessels. The yard serves as a temporary storage location for full and empty containers.

Container terminals are increasingly competing as links within global supply chains and the connection to the hinterland becomes a key area for competition. Especially, fast service of inland transport modes becomes a strong competitive advantage. Container terminals have to deal with a varying workload and irregular truck arrivals over the day. If the peak of truck arrivals coincides with heavy workload periods for vessels, barges and trains this may decrease the performance and service quality of the entire terminal. Several container terminals have introduced truck appointment systems to balance truck arrivals. Many case studies (Maguire, Ivey, Golias, & Lipinsk, 2010; Giuliano & O'Brien, 2007; Morais et al., 2006; Srour, Kennedy, Jensen, & Mitchell, 2003) confirm that appointment systems have the potential to reduce congestion within the terminal.

This paper originates from considerations at a terminal at the Grand Port Maritime de Marseille (France) about introducing a truck appointment system. Several questions were addressed, such as: How to design (reservation and cancellation policy) and implement (technology) the truck appointment system? How to dimension it, e.g., how many appointments should be offered over the day? What are the impacts on the terminal's overall service quality? This paper addresses the last two issues. We propose a new model to dimension the truck appointment system that also estimates the impact on the overall service quality. Although the model presented in this paper represents the situation at this container terminal, it can be adapted to other terminals easily.

Scarce literature exists about modeling and dimensioning truck appointment systems. Huynh and Walton (2008) combine mathematical formulation and simulation to determine the maximum number of trucks to be accepted; their model is based on resource constraints and target truck turnaround times. Murty et al. (2005) mention a simulation model minimizing a combined penalty for yard-crane idle time and for the fraction of time during which the queue of trucks waiting at the yard crane is too long. Chen, Zhou, and List (2011) develop a convex nonlinear programming model minimizing the total truck turnaround time and the difference between preferred arrival times and assigned time slots. In a second step, they determine time-varying tolls that lead to the optimized truck arrival pattern. Guan and Liu (2009) use a multi-server queuing model and a nonlinear optimization model to

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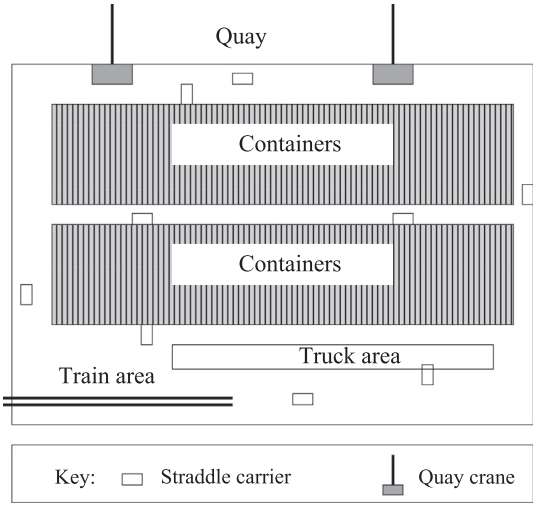

Fig. 1. Schematic view of a container terminal.

determine the optimal number of gate lanes to open while minimizing a combined cost of truck waiting times and gate operating costs.

All these studies have a very local perspective on the problem: they all assume a given handling capacity allocated to trucks and try to minimize queuing consequences. In our opinion, these studies neglect the fact that internal material handling resources serving trucks, also have to serve trains, barges and vessels. We address the problem at a higher level where truck appointments are sized depending on the activity generated by vessels, trains and barges (which can usually be very well anticipated). Typically, the terminal can serve fewer trucks during time slots with high levels of activity for trains, barges and vessels. The terminal should thus offer fewer truck appointments for busy time slots and more appointments for less busy time slots. Consequently, the allocation of handling capacity to different transport modes over the day and the dimensioning of the appointment system should be deeply entwined.

The given container terminal in Marseilles – and presumably most terminals of equivalent size – uses manned straddle carriers for internal transportation and storage operations. Trucks, trains, barges and vessels compete for the available straddle carriers. Allocation decisions are taken on a daily basis based on the forecasted workload over the day. We deal with the problem at a tactical level and combine the allocation of straddle carriers with the dimensioning of the truck appointment system. Our objective is to evaluate if the truck appointment system may be used to reduce overall delays of trucks, trains, barges and vessels at the terminal.

The content of the paper is as follows. Section 2 introduces the combined problem of allocating straddle carriers and determining the number of truck appointments to offer from a practical point of view. It also states the modeling approach and made assumptions. Section 3 presents the corresponding mixed integer linear programming model. Section 4 presents experiments conducted on actual data to evaluate the impact of a truck appointment system on overall delays. Results show that standard IP solvers are able to solve this problem. Section 5 validates the results obtained by the optimization model in a stochastic environment via discrete-event simulation. Section 6 concludes the paper.

2. Problem description and modeling approach

2.1. Problem description

Container terminals use truck appointment systems to limit the number of trucks admitted per time slot in order to even out the demand over the day. Appointment systems may be implemented in different ways. Some terminals make the use of the appointment system mandatory, others serve trucks with and without appointments. Terminals have to decide whether to offer appointments on a container or on a truck basis. In the first case, appointments have to be made to deliver or pick up a specific container; in the second case, appointments are made for trucks without further information on container delivery or pick up. Terminals also differ with regard to the used appointment system provider, the reservation policy (how and when) and the way no-shows are handled. Some terminals prepare container pick-ups based on the made appointments, some make special arrangements at gates for trucks with appointments and others do not differentiate between trucks with and without appointment systems. (Refer to Giuliano & O'Brien (2007) and Morais et al. (2006) for an overview of different appointment systems implemented at container terminals in the US.)

Like Chen et al. (2011), we chose to represent container terminals using obligatory appointment systems. Trucks have to book an appointment for a specific container for a specific time slot to enter the terminal to deliver or pickup this container. Entering the terminal without an appointment is not possible. We suppose that the terminal can estimate the preferred arrival time slots of trucks from historic data. Based on this estimate, it determines the number of appointments to offer per time slot. At an operational level, trucks then book their appointments among available ones. The objective is to offer appointments that match the preferred arrival times. However, serving all trucks at their preferred arrivals may not be the most advantageous situation for the terminal. It may decide to offer fewer appointments than wished for some time slots and more than wished for others. This forces some trucks to enter the terminal during a time slot different from their preferred arrival. To respect preferred truck arrivals, the maximal deviation between preferred and assigned time slots is limited. To compensate trucks for possible deviations and to minimize truck waiting times, each truck is served within a guaranteed service time. Consequently, the terminal has to allocate enough internal handling resources to serve all trucks within their assigned time slots.

Straddle carriers can lift containers on their own and operate independently from the equipment used to (un) load vehicles. We restrict our study to terminals using manned straddle. The terminal operator can assign workers to straddle carriers on a daily basis; some operators (e.g., in Marseilles) can even hire drivers on a daily basis. The number of available straddle carriers depends thus on the number of drivers and varies from day to day. To simplify drivers' jobs, straddle carriers are allocated to one type of task (e.g., serve trucks or serve a vessel) for a given time interval and only altered at discrete points in time. This divides the working day into discrete time periods. This allocation policy is used at Marseilles and other small – and medium-sized container terminals using manned straddle carriers.

At a tactical level, the terminal operator has to decide how many drivers are needed for the next day, how to allocate the available straddle carriers to the different transport modes and how many truck appointments to offer. The difference to a classical allocation problem is that truck arrivals may be deviated if advantageous. The objective is to determine an allocation that minimizes truck deviations and delays of trains, barges and vessels. Inevitably, the number of truck appointments to offer depends on the handling capacity allocated to trucks. But, the proposed allocation takes deviation costs of trucks into account. Once the tactical straddle carrier allocation has been determined, the terminal operator can tackle operational decisions (which straddle carrier to assign to a specific container and which truck to assign to which time slot) for the given allocation with dedicated approaches.