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A simulation optimization method for vehicles dispatching among multiple container terminals

Jinghui Tao*, Yuzhuo Qiu

School of Marketing and Logistics Management, Nanjing University of Finance & Economics, Nanjing 210046, PR China
Jiangsu Key Laboratory of Modern Logistics, Nanjing University of Finance & Economics, Nanjing 210046, PR China

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ABSTRACT

Container terminals, serving as the hubs between container ships and other transportations nodes, are of extreme importance in streamlining the ever increasing global trade. Many different factors affect the service efficiency in container terminals, which inspire great interest in both industrial and academic researches. This work focuses on vehicle dispatching problem which decides, for each internal vehicle in the port, where to go to find a new loading or unloading task in container terminals after finishing the previous one. A multi-factor online dispatching method, which takes both empty traveling and location balance into consideration, is proposed to fit the current condition of the physical and information infrastructure in most of the ports in mainland China. Such a method is established by using combined evolution searching function and discrete event simulation. Through comparing our dispatching method with the traditional dedicated vehicle dispatching methods in various simulation cases, together with theoretical analysis, we prove that our method delivers substantial efficiency improvement in terms of reducing ship serving time and vehicle empty traveling, regardless of changing environment we have examined in the study.

1. Introduction

A container terminal not only provides loading and unloading services, but also serves as a temporary storage space for import/export containers, and transit containers which need to change carrying vessels between two marine trips. Fig. 1 is a schematic diagram showing the typical core operations of a container terminal in mainland china.

Based on the type of container handling services, a container terminal can be divided into two main areas, the quayside and the storage yard. The quayside is where vessels are berthed. Query gantry cranes (QCs) load export containers carried to the vessel and unload import or transit containers from the vessel. The storage yard is where containers are stored temporarily. The storage yard is typically made up of blocks of containers. At mainland China, each block consists of about several hundreds of containers, placed in several bays side by side, with each bay including some container stacks that are of several tiers of containers. Most cranes used at container terminal to stack containers in storage yard are Rubber-Tire Gantry Container Cranes (RTGs), whose gantries span across the bays of a block. Internal trailers (ITs) provide transportation of containers between RTGs and QCs during loading and unloading time, while external trailers(XTs) provide transportation of containers between RTGs and Gate of container terminals by bringing import containers from the yard to the customers and bringing export containers from the customers to the yard. At mainland China, although ITs and XTs are of the same trailer type, they could not be used instead of each other.

Each vessel arrives at a determinate time with specific numbers of containers to be unloaded and loaded at the port. The berth allocation, where the vessel is to be berthed, and the stowage plan, and the sequences for unloading containers from the vessel and loading containers to the vessel are determined well before the vessel's arrival. After arrival, certain number of QCs, RTGs and ITs will be assigned to serve the vessel with the loading and unloading work following a scheduling strategy, so that all the equipments will coordinate in an efficient way.

Among various interrelated indicators of the efficiency of a container terminal, the most important and commonly used one at many major container terminals is the vessel berthing time (or makespan). Highly related to this indicator is the average number of containers handled by one QC per hour, namely, QC rate. Since most container terminals charge ship lines partly for each move

* Corresponding author at: 3 Wenyuan Avenue, YaDong New district, School of Marketing and Logistics Management, Nanjing University of Finance & Economics, Nanjing 210046, PR China. Tel.: +86 25 86718471; fax: +86 25 86718480.
E-mail addresses: jinghuitao@sina.com (J. Tao), jadeqyz@126.com (Y. Qiu).

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of a QC. Shorter makespan and high QC rate will improve its profitability.

Literally every decision made at the port will affect these indicators mentioned above, thus affect the efficiency and the profitability of the whole port. These decisions include among others: allocating the vessel to certain berth, making the stowage plan for containers, allocating certain number of QCs, ITs, and RTGs to serve the vessel and dispatching and deploying those equipment in real time. While none of these decisions above can be made independently, dealing with only one problem at a time and assuming others as given may well be a practical way to yield satisfying performance. In this paper, we mainly consider the real-time vehicle (IT) dispatching problem, while treating other decisions as given.

Vehicle (IT) dispatching is an operational-level problem which decides, for each vehicle, where to go to get a new loading/unloading task after finishing the previous one. Ideally, vehicles should appear at places where the most urgent jobs are, so that expensive cranes, especially Query gantry cranes(QCs), don't wait for vehicles, thus the QC rate can be improved.

There are many strategies in vehicle dispatching, either used in practice by real ports or discussed theoretically in academic study. With the infrastructure and the data availability and certainty vary significantly among different container terminals, the feasibility and effect of those strategies will also be different. Traditionally at most container terminals in mainland China, each vehicle only serves one QC exclusively during the whole service of a ship, so each QC forms an 'operati online' with several vehicles serving between it and the yard while different QCs do not share vehicles. The merit of such method is that it can be easily implemented without high-tech infrastructure and easily executed without making too much confusion to vehicle drivers (AGVs are not generally being used at container terminals in mainland China). But the flaw of this method is as evident. Excluding the possibility of sharing vehicles between QCs, some QCs may have to wait for vehicles coming while others having too many queuing below. Moreover, since serving one QC forces vehicles to make empty trip back to the quayside while doing unloading jobs or making empty trip to the yard to pick containers while loading, the vehicle utility will be low-50% approximately. An improvement of efficiency can be achieved by using a new dispatching strategy which somehow combines loading and unloading jobs of different QCs together in one vehicle.

To employ a more sophisticated dispatching strategy, certain infrastructure with supporting software system must be constructed so that real data of the port situation can be collected and instructions can be delivered to the drivers of vehicles. With such system in place, there are several dispatching strategies that can be used, which generally fall into two categories–Online dispatching mode and Offline dispatching mode (Grunow, Günther, & Lehmann, 2006). Online strategies make dispatching decisions only when they have to, that is when an empty vehicle appears, one decision is made to determine where it has to go, while its offline counterparts dispatch vehicles that will become empty in a period of time in the future in a coordinated way. In essence, offline should offer a better solution for vehicle dispatching problem, but online dispatching is usually more appropriate in a highly dynamic planning environment where only limited information about future events is available (Grunow et al., 2006). In most ports we investigated in mainland China, this is the case. So many uncertainties, of which change of the container handling sequence, traffic congestion, crane break-downs and man-made mistakes are just a few, exist in ports that most of the information that we need to implement an offline strategy is either unpredictable or unreliable. So it seems to us that online strategy is a better choice for most China's container terminals to dispatch vehicles, especially taking into consideration that most of the equipment in those ports are not operated automatically, but rather by man.

Over the past few years, there has been a large amount of research focused on improving the operational efficiency of container terminals. For excellent reviews of those works, the reader is referred to the articles by Steenken, Voß, and Stahlbock (2004) and Vis and De Koster (2003). We give the literature review below focused on vehicle dispatching related works.

2. Literature review

Most authors formulate an integer programming model in combination with heuristic-based solution approaches. Bae and Kim (2000) proposed mixed integer programming formulations for the AGV dispatching problem under a discrete event time setting and a heuristic was developed to solve the problem. Chen et al. (1998) proposed a greedy algorithm for a mega container terminal. The heuristic deployed vehicles to the earliest possible container jobs once the vehicle was free. They showed that the strategy could

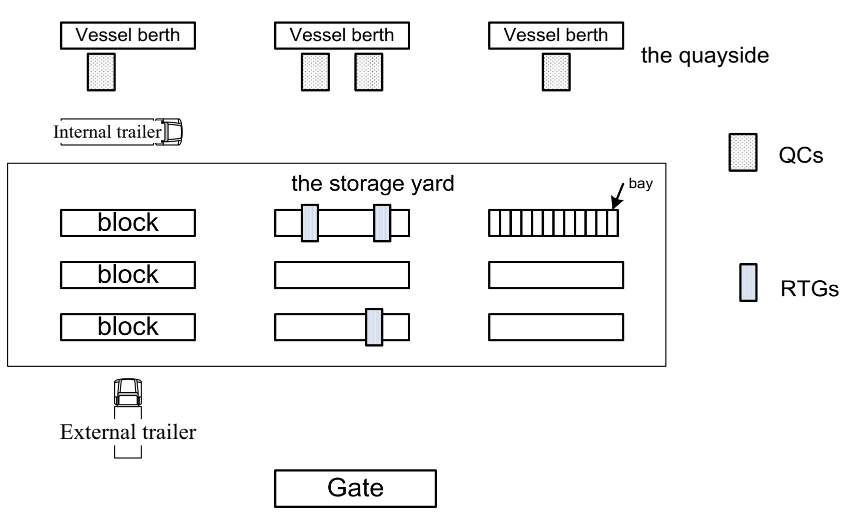

Fig. 1. A Schematic diagram of a container terminal.