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Disruption management for truck appointment system at a container terminal: A green initiative

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ABSTRACT

Disruption often occurs in both land-side and sea-side operations at a container terminal, causing substantial interference of scheduled operations and poor green performance. The land-side disruption is rarely researched, and this paper addresses the ordinary level of such disruption where typically some truck arrivals deviate from their schedule in the appointment system. The aim is to find a response strategy that can maintain high resilience ability of the system in neutralizing the impact of disruptions. First, we consider different levels of late or early arrivals, as well as non-appointed arrivals at a container terminal that is running an appointment system. Second, we propose some response strategies to cope with different levels of disruptions, and evaluate their resilience ability with two Key Performance Indicators (KPIs): total waiting time of on-time trucks and total idling emissions of all trucks, in order to balance the service quality to punctual arrivals and green performance of the whole system. Third, we conduct a sensitivity analysis using a discrete event simulation to understand the performance of the proposed strategies. Considering both KPIs, the best strategy in most scenarios is a combined one based on priority and yard-crane moving distance; its performance depends primarily on the concentration level of container locations and secondly on the system utilization. In the other scenarios that have low arrival punctuality, the best strategy could focus purely on yard-crane moving distance, especially when the first KPI is given lower weight than the second one.

Introduction

A container terminal is a complex system transferring containers and interfacing with both land-side and the sea-side services. Ideally, system operations should have a certain level of resilience ability built in to accommodate the frequent deterioration of planned/scheduled services, because such services will frequently experience various disruptive events. For example, truck arrivals may be delayed because of cargoes delay, a traffic jam on the way to the port, or bad weather such as fog. Delays may also occur on the terminal side, such as an unexpected breakdown of the crane, crane driver illness, a strong wind from the sea, and so on. Some of these events can be interrelated and occur simultaneously, causing overlapped service deterioration. These disruptions will impact the system and usually occur on a daily basis, so the terminal system operations should be designed to handle them, in order to maintain the service level and the greenness of operations.

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Much less frequently, disruptions can also be of such a large scale that the whole port system breaks down. These disruptions might include extremely bad weather (dense fog, heavy rain, hurricanes, snowfall, etc.), industrial accidents or other actions of the transport staff, natural disasters (earthquakes, volcanoes, tsunami), traffic incidents/accidents, or terrorist attacks. In such cases, the whole system and related systems on the transport network will be commonly affected, bearing the costs of recovery actions and other associated costs. It can even impact the performance of the overall supply chain, if we consider the affected port as a connecting node in the transport network. However, the management of large-scale system failures is not within the scope of this study. In this paper, we focus on the ordinary disruptions that can be expected to occur frequently in the Truck Appointment System (TAS) at a container terminal, and we aim at developing a good response strategy to maintain an effective level of resilience.

TAS is one of the best and most frequently utilized methods of communication between truck companies and the container terminal. Trucking companies preschedule their truck working times, giving each truck an appointed time (Phan and Kim, 2015), and terminals predetermine the allocation of equipment for the yard (Zhao and Goodchild, 2013). By controlling the distribution of truck arrivals, the waiting time is expected to decrease and thereby emissions from idling truck engines are reduced. The original aim is to control the long queue and large emissions from trucks; however, the practical performances of the Truck Appointment System are not uniform. For example, Morais and Lord (2006) report the successful application of TAS at the Port of Vancouver. Giuliano and O'Brien (2007), on the other hand, find that at the Ports of Los Angeles and Long Beach "there is no evidence to suggest that TAS reduced queuing at terminal gates and hence heavy diesel truck emissions." One of the most important reasons is that disruptive events impede the smooth operation of TAS. So, as one of its first efforts, this study tries to tackle this problem by developing a solution based on service sequence control.

As one of the first studies on this topic, this paper contributes to the literature in the following aspects: (a) it systematically describes and defines the problem; (b) it proposes some key indicators to measure the performance of a disruption management solution; (c) it designs several response strategies based on priority control and equipment efficiency; and (d) it develops a simulation model to test the proposed strategies with numerical experiments.

The structure of this paper is as follows. The literature about truck arrival management and disruption management is analyzed in Section 'Literature review'. In Section 'Disruption response strategies', the disruption problem in TAS is described and the response strategies are set up in detail. Two KPIs are proposed in Section 'Key performance indicators', and a simulation model is designed in Section 'Simulation model'. Section 'Numerical experiments' presents the simulation experiment, and the last part provides discussion and conclusions.

Literature review

Disruption management is the process of coping with unexpected events, with the aim of mitigating the influence of disruption in real time (Yu and Qi, 2004). Kohl et al. (2007) discuss one of the objectives of disruption management in the airline industry is "to get back to the plan as soon as possible." Clausen et al. (2001) define disruption as "a situation during the operation's execution in which the deviation from the plan is sufficiently large that the plan has to be changed substantially." Researchers have applied and improved their methods of disruption management to airline transportation (Clausen et al., 2010; Jarrah et al., 2000), railway transportation, public city transportation (Zeng et al., 2012), delivery logistics (Hu and Sun, 2012), as well as to supply chain management and production management.

In the field of maritime management, Brouer et al. (2013) set up a MIP model of Vessel Schedule Recovery Problem (VSRP). Its aim is to evaluate a given disruption scenario and to select a recovery action balancing the trade-off between increased bunker consumption and the impact on cargo in the remaining network and the customer service level. Dirksen (2011) presents a mathematical model on recovery strategies for disruption management in liner shipping. Kjeldsen (2009) also considers the disruption management in liner shipping. Zeng et al. (2010) develop a disruption management model for berth and quay crane scheduling at container terminal by the methodology of disruption management. Yang et al. (2015) propose an advanced uncertainty model for container port risk analysis, and Lam and Zhang (2015) evaluate the performance of a port-centric transportation network under disruption risks. However, these researchers either focus on sea-side disruptions or treat the disruption problem as a node of the supply chain. To the best knowledge of the authors, there is no existing study on the roadside disruption within container terminal operations. In this study, we try to fill this gap.

The addressed disruption problem has several characteristics as follows. It has the potential to cause a mass disturbance, which may be significantly different from a general disruption problem. Specifically, the disturbance by an individual truck seems minor, but the sum of the disturbance by all trucks cannot be ignored. Moreover, the disturbance might be a mixed one. Sometimes, there might be more than one kind of disturbance, which further complicates the system. To generate a real time response for the trucks' appointment system, the traditional disruption management method has to be renovated properly.

There are a growing number of studies in the area of external truck arrival management at a seaport, mainly due to the fact of serious gate congestion and elevated pressure to yard operations at mega-ports, especially the ones with limited land space and capacity. Such gate congestion results in truck engines idling and generating emissions, including relatively high amounts of particulate matter (PM 2.5) and nitrogen oxides, which are widely considered as the two most harmful air pollutants (Brodrick et al., 2002).

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