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Truck appointment systems considering impact to drayage truck tours

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ABSTRACT

This paper proposes a novel approach for designing a Truck Appointment System (TAS) intended to serve both the maritime container terminal operator and drayage operators. The aim of the proposed TAS is to minimize the impact to both terminal and drayage operations. In regard to terminal operations, the TAS seeks to distribute the truck arrivals evenly throughout the day to avoid gate and yard congestion. In regard to drayage operations, the TAS explicitly considers the drayage truck tours and seeks to provide appointment times such that trucks do not have to deviate greatly from their original schedule. The proposed TAS is formulated as a mixed integer nonlinear program (MINLP) and the model is solved using the Lingo commercial software. Experimental results indicate that the proposed TAS reduces the drayage operation cost by 11.5% compared to a TAS where its aim is only to minimize gate queuing time by making truck arrivals uniform throughout the day.

1. Introduction

The problematic issues surrounding gate congestion at maritime container terminals have been well documented. Namboothiri and Erera (2008) reported that gate congestion leads to a decrease in drayage productivity. That is, drivers typically experience longer waiting time when they arrive during peak hours, which would require longer truck turn time (the sum of terminal gate queue time and in-terminal time), and thereby reduce their available time to perform other moves. Truck turn time refers to the time it takes a truck to complete the delivery or pick-up transaction; it is the difference between the gate out time and the gate in time. A byproduct of gate congestion is a concentration of idling trucks. It has been documented that when trucks are idling they emit a greater amount of emissions compared to when they are moving. Emissions from diesel trucks are known to contain a number of carcinogens and are associated with elevated levels of asthma attacks, emergency room visits, hospitalizations, heart attacks, strokes and untimely deaths (Hill, 2005; Saxe and Larsen, 2004; Giuliano and O'Brien, 2007; Schulte et al., 2015, 2017). Heilig et al. (2017a) provided a broad overview of academic works related to environmental sustainability in ports, hinterland operations, and combination of both operations.

To reduce gate congestion, more and more maritime container terminals (e.g., the Port of Baltimore, Port of Vancouver, and Port of Hamburg) are adopting the use of a truck appointment system (TAS) as called in the U.S. and vehicle booking system (VBS) in other parts of the world (Heilig and Voß, 2017). A TAS provides several key benefits to the terminal operators (the company or port authority that is managing the terminal operations). One, it allows the terminal operators to match demands (container transactions) to supplies (labor and equipment availability). Second, it allows the terminal operators to evenly distribute truck arrivals throughout the day, and hence, reduce truck queuing at the gate. Lastly, the advanced entry of container and truck information via the TAS

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expedites the processing of the trucks upon their arrivals at the terminal.

The typical function of most existing TASs is that they allow the terminal operators to set a quota for the maximum number of trucks allowed to enter a specific yard block or zone during a pre-specified time-window, typically in the range of 1–4 h. Quotas are set based on yard crane availability. They are also set to avoid potential conflicts with other operations in a certain yard block or zone, such as vessel operations, warehouse operations, rail operations, and customs inspections. From the trucker's perspective, once the quota for the desired time-window is reached, he needs to choose a different time-window for the appointment. It is evident that the quotas set by the terminal operators can have a significant impact on terminal and drayage operations. To this end, many studies have sought to determine the optimal quotas for TAS (e.g., Huynh and Walton (2005), Huynh (2009); Chen et al. (2011); Chen et al. (2013a); Chen et al. (2013b); Zhang et al. (2013)). Other studies have sought to understand the impact of TAS on drayage scheduling (e.g., Namboothiri and Erera (2008); Shiri and Huynh (2016)). However, to date, no studies have developed a TAS that seeks to minimize the impact on drayage scheduling. Given that each drayage firm has a number of timing constraints imposed by customers and the network travel time varies day to day (Torkjazi et al., 2017), any additional timing constraint imposed by the TAS will make it even more difficult for drayage operators to make deliveries or pickups on time. Thus, an effective TAS must consider not only the capacity and constraints of the terminal but also that of the drayage firms.

The objective of this paper is to develop a new mathematical model for the TAS that seeks to minimize the drayage cost when determining the appointment time-window(s) for a truck, as well as the truck's gate queuing time. The gate queuing time is minimized when the appointment quotas (and hence truck arrivals) are distributed evenly throughout the day. To determine the right balance between reducing drayage cost and gate queuing time, different weights associated with these two cost components are evaluated. To our knowledge, this is the first paper that proposes to design a TAS that explicitly takes into account truck tours. The TAS model is formulated as a mixed integer nonlinear problem (MINLP) and can be solved using the Lingo commercial software. Given the combination of linear and non-linear constraints, and integer and real decision variables, the proposed TAS model is a MINLP.

The rest of the paper is organized as follows. Section 2 provides a summary of closely related studies to provide context for the contributions of this work. Section 3 provides the problem description and formulation, followed by Section 4 which presents the proposed solution methodology. Section 5 discusses the experimental results. Lastly, Section 6 provides a summary of the study and concluding remarks.

2. Literature review

As mentioned previously, a number of studies have sought to develop methodologies to determine the optimal quotas for TAS or assess the effectiveness of TAS. A comprehensive review of TAS can be found in the work of Huynh et al. (2016). The following review focuses on studies that examined the impact of TAS on drayage and truck emissions. Table 1 shows summary of TAS literature reviews. While previous studies on TAS have considered truck queuing, emissions, terminal resources, and the impact of shifting a truck's desired appointment, there has been no study that explicitly considered the effect of truck's schedule of jobs in determining the terminal appointment time-windows on drayage operation cost. The notion of considering drayage scheduling in designing the TAS is partially addressed in the work of Phan and Kim (2015, 2016). In the earlier study (2015), the authors proposed an iterative

Table 1
Summary of the TAS literature review.

Author(s) (year)	Study country						TAS design						Solution method						
	US*	CA*	CN*	CL*	FR*	H*	Q*	Y*	E*	A*	D*	C/I*	Queuing system		Simulation model		Qn*	Opt*	
													S*	NS*	AG*	DE*		Ex*	Hu*
Morais and Lord (2006)	✓	✓					✓		✓	✓			✓				✓		
Huynh and Walton (2008)							✓						✓			✓		✓	
Huynh (2009)	✓						✓			✓			✓			✓			
Guan and Liu (2009a,b)	✓						✓						✓					✓	
Zhao and Goodchild (2010)						✓	✓	✓											✓
Chen and Yang (2010)			✓				✓	✓	✓		✓		✓						✓
Chen et al. (2013a)			✓				✓	✓						✓					✓
Chen et al. (2013b)	✓						✓		✓		✓			✓					✓
Zhang et al. (2013)			✓				✓	✓						✓					✓
Zehendner and Feillet (2014)					✓		✓							✓		✓			✓
Schulte et al. (2015)				✓			✓		✓		✓	✓	✓			✓			
Phan and Kim (2015)						✓	✓	✓				✓		✓				✓	
Phan and Kim (2016)						✓	✓	✓			✓	✓		✓				✓	
Schulte et al. (2017)				✓			✓	✓	✓	✓	✓	✓						✓	
Current study	✓						✓	✓		✓	✓			✓				✓	

*US: United States; *CA: Canada; *CN: China; *CL: Chile; *FR: France; *H: Hypothetical; *Q: Quotas considerations; *Y: Yard considerations; *E: Environmental considerations; *A: Assessment of existing TAS methods; *D: Drayage firms considerations; *C/I: Collaborative/Iterative TAS; *S: Stationary; *NS: Non-Stationary; *AG: Agent-Based; *DE: Discrete-Event; *Qn: Quantitative; *Opt: Optimization; *Ex: Exact; *Hu: Heuristic.