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Evaluating Capacity and Delay for Signalized Arterials with Freight Deliveries

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Abstract

Freight deliveries on signalized urban streets are known to cause lane blockages during delivery. Traffic congestion associated with urban freight deliveries has gained increasing attention recently as traffic engineers and planners are tasked with finding solutions to manage increasing demand more sustainably with limited road capacity. The goal of this research is to evaluate two models for quantifying the capacity and delay effects of a lane blocking freight delivery on a signalized urban street. The two methods are: an all-or-nothing model similar to methodology used in the Highway Capacity Manual 2010 (HCM2010) and a detailed analytical model consistent with kinematic wave theory. The purpose is to provide insight on the use of these tools for analysis of urban freight delivery policy. The results of the two models are compared with each. A simulation of 8th Avenue in New York was created based on freight delivery conditions from a recorded six-hour period, and the simulated results confirm the effect of delivery location on capacity and delay. The results show that the methods from the HCM2010 to account for the effects of buses stopping for passengers provide only a coarse representation of the capacity and delay effects of urban freight deliveries. The more detailed approach that accounts for the dynamics of queuing provide closed form analytical formulas for delay and capacity that can account for varying locations of deliveries, long delivery durations, and different impacts on different lane groups.

Keywords: Urban Freight Delivery, Signalized Arterial, Capacity, Delay, Highway Capacity Manual (HCM)

1 Introduction

Freight deliveries are known to disrupt traffic on urban arterials. Traffic congestion associated with urban freight deliveries has gained increasing attention in recent years as traffic engineers and planners are tasked with finding solutions to manage increasing demand in a more sustainable way with limited road capacity. Although trucks make up only a small percentage of vehicular traffic (6% of vehicles on urban freeways), they incur a greater proportion of the total cost of delays (26% of total cost) (Eisele et al., 2013). Emerging discussion of policies to shift deliveries to off hours are intended to mitigate the impacts of on traffic congestion.

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The effects of truck deliveries in urban networks can be generally separated into two categories: 1) the effect of heavy vehicle in the traffic stream on the flow of vehicles, and 2) the effect of truck delivery stops on traffic flow when lane blocking occurs. The first category of effects has been analyzed more extensively in the literature. Some studies have made use of traffic simulations to account for the effect of trucks in the traffic stream (Benekohal and Zhao, 2000; Ukkusuri et al., 2015). Other studies have made use of empirical field measurements along with calibrated traffic simulations (Skabardonis et al., 2014). A significant synthesis of the effects of heavy vehicles in the traffic stream was published in NCFRP Report 31 (Dowling, et al., 2014). The report summarizes the effect of trucks on mid-block arterials speeds and presents improved methods for calculating truck passenger car equivalent factors for capacity analysis of signalized intersections. These methods do not account for blockages caused by parked trucks.

The effect of freight delivery stops that block lanes of traffic on arterial capacity and intersection delays has received less attention in the literature. Han et al. (2005) conducted a GIS-based investigation of the extent and order of magnitude of double parking disruptions for pickup and deliveries across the U.S. Other recent studies have considered the problem of truck parking for deliveries from the perspective of the carrier (Kawamura et al., 2014; Tipagornwong and Figliozzi, 2015; Zou et al., 2015). Other studies have identified many of the characteristics of delivery patterns and businesses on urban streets (Cherrett et al., 2012; Ahrens et al., 1977). Very few investigations of the effect of parked trucks on intersection capacity have been conducted, and they have not provided a comprehensive analytical approach for estimating capacity and delay (Habib, 1981).

A growing body of research has investigated policies to encourage the schedule of deliveries in urban areas during off-peak hours (Holguin-Veras, Wang, et al., 2006; Palmer and Piecyk, 2010; Su and Roorda, 2014; Fioravanti et al., 2015). Although a major motivation for off-hour delivery programs is to reduce traffic congestion, most of the analysis focuses on the experience from the perspective of agencies or the delivery drivers, who are able to travel at greater speeds during lower traffic periods (Holguin-Veras, Perez, et al., 2006; Holguin-Veras et al., 2008; Silas and Holguin-Veras, 2009). The challenge is to convince receivers to schedule off-hour deliveries, which in many cases requires paying an employee of a store to stay after normal business hours or make special arrangements for the delivery to be made in the absence of someone to receive the delivery (Holguin-Veras et al., 2007). Programs to reduce traffic congestion by managing urban freight are limited (Crainic et al., 2004; Yannis et al., 2006). A trial off-peak delivery program in New York City paid businesses approximately $2000 to receive shipments during off-hours rather than normal business hours for a month; carriers were paid $300 to participate in the trial (Holguin-Veras et al., 2011). Evaluations of the congestion and reliability effects of the off-hour delivery program in New York required extensive simulation analysis but did not include the impact of lane blocking during delivery (Ukkusuri et al., 2015). Being able to quantify the effects of urban freight deliveries on the performance of signalized streets would be useful for evaluating urban freight delivery policies that may attempt to reduce, relocate, or reschedule urban freight deliveries.

The goal of this research is to develop models for the effect of freight deliveries on capacity and vehicle delay on a signalized urban street based on fundamental traffic flow theory. The 2010 Highway Capacity Manual (HCM2010) does not provide any guidance for urban freight deliveries, but double parked delivery vehicles may have a similar effect as two types of lane blockages: buses stopping to board and alight passengers, and vehicles making parallel parking maneuvers. This paper presents a modification of the existing HCM2010 methodology in which a stop either blocks an entire lane or has no effect. This is compared with a more detailed model of capacity and delay using kinematic wave theory (Lighthill and Whitham, 1955; Richards, 1956).

The paper is organized as follows. First, a simple method for calculating capacity and delays based on the HCM2010 methodology for accounting for stopping buses if presented. A model for arterial capacity based on kinematic waver theory is then presented, followed by a procedure for calculating intersection delay based on the dynamics of queuing when a delivery vehicle blocks part of the street upstream of a signalized intersection. A comparison of the two methods reveals that the HCM2010

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