JOURNAL OF TRAFFIC AND TRANSPORTATION ENGINEERING (ENGLISH EDITION) 2016; 3 (1): 16–27

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/jtte

Original Research Paper

Vehicle and pedestrian safety impacts of signal timing optimization in a dense urban street network

Arash M. Roshandeh [a], *Zongzhi Li* [b,*], *Shengrui Zhang* [c], *Herbert S. Levinson* [d], *Xi Lu* [b]

[a] *Department of Engineering and Public Works, City of Alpharetta, GA 30009, USA*
[b] *Department of Civil, Architectural and Environmental Engineering, Illinois Institute of Technology, Chicago, IL 60616, USA*
[c] *School of Highway, Chang'an University, Xi'an 710064, China*
[d] *Herbert S. Levinson Transportation Consultant, New Haven, CT 06492, USA*

ARTICLE INFO

Article history:
Available online 14 January 2016

Keywords:
Signal
Optimization
Safety
Vehicle
Pedestrian
Empirical Bayesian analysis

ABSTRACT

Intersection signal timing optimization is expected to affect both traffic mobility and safety. However, in safety impacts analysis, the existing studies mainly focus on estimating changes in vehicle crashes without addressing the influence of pedestrian related crashes. This study aims to simultaneously assess the overall impacts of vehicle and pedestrian crashes caused by signal timing optimization in dense urban street networks. An empirical Bayesian analysis method was introduced to estimate the safety impacts of intersection signal timing optimization in an urban street network in terms of vehicle-to-vehicle and vehicle-to-pedestrian crashes at intersections, as well as single and multiple vehicle crashes on street segments. A computational experiment was performed to apply the proposed method to the Chicago central business district that includes 875 signalized intersections and 2016 roadway segments. Results show that vehicle-to-vehicle and vehicle-to-pedestrian crashes at intersections are decreased in different crash severity levels and types, especially for angle and rear-end ones after signal timing optimization. Similar results are found for multi-vehicle rear-end crashes on street segments. These indicate that intersection signal timing optimization in dense urban street networks has a potential for improving traffic mobility, vehicle and pedestrian safety at intersections, and vehicle safety on street segments.

© 2016 Periodical Offices of Chang'an University. Production and hosting by Elsevier B.V. on behalf of Owner. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

* *Corresponding author*. Tel.: +1 312 567 3556; fax: +1 312 567 3519.
E-mail address: lizz@iit.edu (Z. Li).

Peer review under responsibility of Periodical Offices of Chang'an University.
http://dx.doi.org/10.1016/j.jtte.2016.01.001

2095-7564/© 2016 Periodical Offices of Chang'an University. Production and hosting by Elsevier B.V. on behalf of Owner. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Every year, many crashes occur in the nation's highway network and a significant portion of them takes place in urban areas. Although the trend of fatal crashes in the United States has been decreasing due largely to safety programs in the context of engineering, enforcement, education, and emergency response, traffic safety still is a problem in the society. Owning to land scarcity, high project costs, and concerns of traffic disruption during the project construction, expanding the capacity of the urban street network is particularly challenging. Conversely, efficient utilization of urban areas' existing capacity has become the focus to potentially mitigate traffic congestion.

In the past several decades, significant progress has been made to develop new traffic stream models by accounting for the interdependency and connectivity of possible factors and their contribution to network modeling in different scales. Using more detailed approaches for characterizing the traffic flow, density, and speed relationships the accuracy of vehicle delay estimation could be improved to identify effective delay mitigation measures (Abbas et al., 2007; Mulandi et al., 2010; Sun et al., 2003). In addition, a number of research studies have developed pedestrian walking models to analyze the behaviors of pedestrians walking along sidewalks and crossing intersections (Antonini et al., 2006; Hoogendoorn and Bovy, 2004; Robin et al., 2009).

Recently, Roshandeh et al. (2014) developed a method for intersection signal timing optimization in an entire urban street network stemmed from the kinematic wave theory by simultaneously minimizing vehicle and pedestrian delays in each signal cycle over a 24 h period. A computational experiment revealed its strength for a wide range of practical applications, particularly due to its potential for addressing both vehicle and pedestrian delays in a holistic manner. Meanwhile, the impacts of this model on vehicle and pedestrian safety need to be evaluated. As such, the current study applies an empirical Bayesian (EB) before-after analysis method to investigate the effects consequences of traffic mobility improvements on vehicle-to-vehicle and vehicle-to-pedestrian crashes at intersections and vehicle crashes on street segments in dense urban street networks.

1.1. *Related work*

The impacts of traffic mobility and safety caused by altering the intersection traffic control in aspects of using signal coordination, green extension, and green time countdown devices, extending the cycle length of existing signals, increasing speed limits, and installing new signals have been studied since the 1970's (Moore and Lowrie, 1976; Short et al., 1982; Zeeger and Deen, 1978). Pant et al. (2005) found the advantages of using green extension at closely spaced high-speed intersections in terms of crash reduction. In particular, it was reported that a 3 s green extension could reduce vehicle conflicts by 37 percent during the a.m. peak period. Lum and Halim (2006) found that installing green signal countdown devices for driver's warning could reduce red-light running violations by 65 percent and thus could potentially reduce vehicle crashes. A Federal Highway Administration (FHWA) study conducted by Sabra et al. (2010) revealed that cycle length had the most significant impact on the total number of crashes at intersections and further noted that adopting a longer cycle length could reduce all types of movement conflicts. Pirdavani et al. (2010) evaluated safety conditions at 4-leg signalized intersections and found that increasing speed limits had detrimental impacts on safety. In another recent study, Stevanovic et al. (2013) analyzed the impacts of signal timing optimization on crash risks using a 12-intersection corridor and concluded that the number of movement conflicts could reduce by 7 percent after the treatment. However, pedestrian safety was not considered.

Some researchers have developed statistical models to explicitly analyze the correlation between crash occurrences and signal timing design features. Chin and Quddus (2003) introduced a random effect negative binomial model to analyze the relationship between crash occurrences and the geometric, traffic and control characteristics of signalized intersections in Singapore and concluded that traffic volumes on intersection approaches and the number of phases used for each signal cycle were among the most significant variables affecting the crash frequency. Guo et al. (2010) developed Poisson and negative binomial Bayesian statistical approaches to model the crash data from 170 signalized intersections in Florida and confirmed that the intersection size, and traffic volumes by turning movement, and coordination of signal plans for adjacent intersections had significant impacts on intersection safety. Agbelie and Roshandeh (2015) applied a random-parameter negative binomial model and found that the increase of the number of signal phases and approach lanes would yield the increase of the crash frequency at the majority of the intersections. Behnood et al. (2014) developed a latent class multinomial logit severity model and identified that traffic signal controls would decrease minor injury (i.e., crashes not ended up with fatality) and property damage only (PDO) for female drivers younger than 31 years old and alcohol-impaired.

1.2. *Aim*

Traffic mobility and safety are viewed to be correlated with each other. The improvement of mobility at an isolated intersection or on a roadway segment may or may not positively affect safety performance. The existing methods and models dealing with various aspects of signal timing designs such as signal coordination, green extension, and longer cycle length, are effective in terms of improving the mobility of isolated intersections, major corridors, and urban street networks. However, the interaction of mobility and safety performance, which can account for both vehicles and pedestrians in a large urban street network, has not been well studied. The current paper endeavors to fill this gap and apply an EB method to assess the overall safety impacts of signal timing optimization (i.e., treatment) in an urban street network.

The remainder of this paper is organized as follows: Section 1 elaborates on the proposed methodology, including a

Download English Version:

https://daneshyari.com/en/article/292758

Download Persian Version:

https://daneshyari.com/article/292758

Daneshyari.com