Transportation Research Part B 84 (2016) 1–30

Contents lists available at ScienceDirect

Transportation Research Part B

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

Optimal location of advance warning for mandatory lane change near a two-lane highway off-ramp

Siyuan Gong, Lili Du*

Department of Civil, Architectural and Environmental Engineering, Illinois Institute of Technology, 3201 South Dearborn Street, Chicago, IL 60616, USA

ARTICLE INFO

Article history:
Received 4 July 2015
Revised 2 December 2015
Accepted 2 December 2015
Available online 29 December 2015

Keywords:
Mandatory lane change
Optimal lane change zones
Time delay
Shock wave

ABSTRACT

Improper mandatory lane change (MLC) maneuvers in the vicinity of highway off-ramp will jeopardize traffic efficiency and safety. Providing an advance warning for lane change necessity is one of the efficient methods to perform systematic lane change management, which encourages smooth MLC maneuvers occurring at proper locations to mitigate the negative effects of MLC maneuvers on traffic flow nearby off-ramp. However, the state of the art indicates the lack of rigorous methods to optimally locate this advance warning so that the maximum benefit can be obtained. This research is motivated to address this gap. Specifically, the proposed approach considers that the area downstream of the advance warning includes two zones: (i) the green zone whose traffic ensures safe and smooth lane changes without speed deceleration (S-MLC); the start point of the green zone corresponding to the location of the advance warning; (ii) the yellow zone whose traffic leads to rush lane change maneuvers with speed deceleration (D-MLC). An optimization model is proposed to search for the optimal green and yellow zones. Traffic flow theory such as Greenshield model and shock wave analysis are used to analyze the impacts of the S-MLC and D-MLC maneuvers on the traffic delay. A grid search algorithm is applied to solve the optimization model. Numerical experiments conducted on the simulation model developed in Paramics 6.9.3 indicate that the proposed optimization model can identify the optimal location to set the advance MLC warning nearby an off-ramp so that the traffic delay resulting from lane change maneuvers is minimized, and the corresponding capacity drop and traffic oscillation can be efficiently mitigated. Moreover, the experiments validated the consistency of the green and yellow zones obtained in the simulation traffic flow and from the optimization model for a given optimally located MLC advance warning under various traffic regimes. The proposed approach can be implemented by roadside mobile warning facility or on-board GPS for human-driven vehicles, or embedded into lane change aid systems to serve connected and automated vehicles. Thus it will greatly contribute to both literature and engineering practice in lane change management.
© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Lane change decision represents the tactical driving decision in a trip. It determines which lane the vehicle will move on in the near future. According to the circumstantial factors that trigger the intention of a lane-change, drivers' lane-change behaviors can be mainly classified into two types. (i) Discretionary lane change (DLC), which intends to improve his/her driving conditions. It is not required and usually happens according to drivers' habits. (ii) Mandatory lane change (MLC), which is forced because of

* Corresponding author. Tel.: +1 312 567 3426.
E-mail addresses: sgong1@hawk.iit.edu (S. Gong), ldu3@iit.edu (L. Du).

http://dx.doi.org/10.1016/j.trb.2015.12.001
0191-2615/© 2015 Elsevier Ltd. All rights reserved.

unavoidable conditions, such as the end of a merging lane, and exit of off-ramp (Ahmed 1999; Halati et al 1997; FHWA 1998). Clearly, MLC is more trackable than DLC from a system point of view. This study thus is interested in developing strategic lane change guidance for MLC at off-ramp. The proposed research is motivated by several motivations below.

First of all, many existing studies have indicated that traffic congestion often happens at the diverge bottleneck due to low capacity at off-ramp lane. This congestion will propagate to upstream branch and blocks traffic flow further (Daganzo, 1999; Munoz and Daganzo, 2002; Cassidy et al., 2002; Jin and Zhang, 2005; Jin, 2009; Ahn et al., 2010). Moreover, recent research recognized that lane change maneuver is one of the main triggers of negative effect nearby off-ramp. For example, Leclercq et al. (2007) validated that relaxation phenomenon[1] resulting from lane change maneuvers nearby on-ramp and off-ramp will cause traffic delay to surrounding vehicles, which will make a driver (a lane-changer or a follower) become more aggressive after this relaxation phenomenon (Zheng et al. 2013). Jin (2010, 2013) captured the capacity drop and jam densities, which are closely related to lane change maneuvers nearby both on-ramp and off-ramp. More generally, both researchers and engineers have noticed that improper lane change maneuvers will disrupt traffic streams, induce traffic oscillation and traffic breakdown, and even cause traffic congestion and accidents (Jula et al., 2000; Mauch and Cassidy, 2002; Laval and Daganzo, 2006; Ahn and Cassidy, 2007, Li and Ouyang, 2011, Zheng, 2014). Therefore, strategic guidance and management for lane change maneuvers around off-ramp are needed to promote both lane change safety and traffic efficiency, which thus motivates the proposed study.

In recent years, companying with the development of advanced sensing and communication techniques, a plenty of on-board lane change assistant systems such as collision avoidance system and automotive lane change aid (Talmadge et al., 2000; Vahidi and Eskandarian, 2003; Schofield, 2005; Ardelt et al., 2012; Park, 2012) have been developed. These systems are able to provide warning information about nearby vehicles' movement or location to improve the safety of a lane change maneuver once it starts. But they still suffer from avoiding rush lane change maneuvers due to two shortcomings. First, they cannot inform vehicles when and where to start the lane change intention, which is one of the key components to affect lane change decision and behavior (Choudhury, 2002). Hurry lane change maneuvers will happen more often if a lane change starts closer to an off-ramp (Hou et al, 2012). The existing on-board lane change aid systems usually rely on individual drivers' experience to decide when and where to start the lane change intention, thus the optimality even the properness cannot be guaranteed since they may not be able to accurately aware the local traffic condition. Second, they cannot sustain traffic efficiency since the effect of a lane change maneuver on traffic flow is not considered in these lane change aid systems. Thus, more comprehensive lane change guidance is needed.

Current lane change warning/management usually applies roadside advance warning. They will provide advance warning for off-ramp, lane merge, and lane division at a fixed point, such as "½ mile for Exit 41A" (FHWA, 2009). It is expected that vehicles will start lane change intention if needed once they see these warnings. Since the fixed signpost does not count traffic condition variation, it is usually unknown/uncertain to both traffic managers and drivers where is the best spot to locate the advance warning, which triggers the lane change intention so that we can obtain the maximum benefit, especially for new drivers or drivers who are not familiar with the trips. As a result, improper lane change behavior happens frequently in the vicinity of an off-ramp.

This negative effect of MLC maneuvers around work zone obtained more attentions than highway off-ramp in literature. Quite a few studies (Tarko et al., 1999; Mccoy and Pesti, 2001; Michigan DOT, 2004; Radwan, Zaidi, Harb 2011) proposed lane change management strategies around work zones, including early merge, late merge, and dynamic merge strategies. Engineering experiments indicated that early merge, which suggests lane merges at a location further away from a work zone, is effective under light traffic condition; late merge, which suggests lane merges at a location closer to a work zone, will minimize the queue length resulting from lane closure at work zone under congested traffic condition; and dynamic merge proposes a technique which alternatively uses early and late merge according to traffic flow condition. However, most of the proposed work applies engineering experiences rather than rigorous methods to determine the location of the advance warning for either early merge or late merge strategy. Thus, the best benefits of the systematic lane change management strategies may not be obtained. In addition, the proposed strategies for work zones cannot be directly used to manage the MLC maneuvers nearby the area of a lane division or off-ramp since they cause traffic flow variations different to the situation around work zones (Jin, 2009; Ahn et al., 2010; Radwan, Zaidi, Harb, 2011). The state of the art indicates that we are still lack of rigorous methods to guide MLC maneuvers nearby highway off-ramp, even though real-time traffic condition can be well detected.

Motivated by the above views, this study focuses on guiding MLC maneuvers in the vicinity of off-ramp on a two-lane highway segment with one entrance and one exit. All lane change maneuvers discussed hereafter in this paper imply MLC maneuvers without a particular specification. Our simulation experiments (see Fig. 8) show that neither the advance warning for the lane change is given too early nor too late can result in minimum time delay, given all the vehicles need to exit at the off-ramp follow the warning to start their lane change intentions. This study thus seeks to locate an optimal spatial lane change zone for vehicles to start and then perform lane change maneuvers upstream to the exit so that enough safe lane change opportunities are sustained for individual vehicles, while traffic delay resulting from lane change maneuvers is minimized.

More exactly, the proposed approach separates the downstream area of the advance warning into two zones: (i) the green zone (immediate downstream of the advance warning) whose traffic ensures safe and smooth lane change without speed deceleration (S-MLC); (ii) the yellow zone (immediate downstream to the end of the green zone) whose traffic leads to rush lane

[1] Relaxation phenomenon: Lane changers will accept very short spacing as they enter the target lane and then "relax" to a more comfortable spacing (Laval and Leclercq, 2008).

Download English Version:

https://daneshyari.com/en/article/1131640

Download Persian Version:

https://daneshyari.com/article/1131640

Daneshyari.com