Case Studies on Transport Policy 4 (2016) 122–132

Contents lists available at ScienceDirect

Case Studies on Transport Policy

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

Assessing spatial and temporal effects due to a crash on a freeway through traffic simulation

Srinivas S. Pulugurtha*, Srinivas Sujith Balaram Mahanthi

Civil & Environmental Engineering Department, The University of North Carolina at Charlotte, 9201 University City Boulevard, Charlotte, NC 28223-0001, USA

ARTICLE INFO

Article history:
Received 9 July 2015
Received in revised form 6 November 2015
Accepted 13 December 2015
Available online 17 December 2015

Keywords:
Crash
Simulation
Travel time variation
Upstream
Distance
Fatal
Injury

ABSTRACT

The focus of this paper is to simulate, evaluate and assess spatial and temporal effects in travel time variation and upstream distance or length of upstream links affected due to a crash. Traffic simulations were conducted for different conditions in VISSIM 5.30™ to obtain travel times at various points upstream of the crash location, over time, along a freeway corridor. Travel time variation between fatal crash condition and no crash condition (baseline condition) and between injury crash condition and no crash condition (baseline condition) were computed and compared to evaluate the effect of a crash on a freeway. Results obtained showed that fatal crash on freeways has an effect under low, moderate, and high traffic volume conditions, whereas injury crash has an effect only under moderate and high traffic volume conditions. The travel time variation and upstream distance affected due to a fatal crash on the right-most lane was generally higher than fatal crash on the left-most lane. The trends remained fairly consistent irrespective of the lane on which an injury crash occurred. The upstream distance affected due to a fatal crash varied from 1.5 miles to ~7.5 miles based on traffic volume and lane on which the fatal crash occurred. It varied from ~0.5 miles to 7 miles due to an injury crash and traffic condition. Queue may start dissipating at least 15 min after blocked lanes are re-opened for normal traffic flow depending on the type of crash, traffic volume and lane in which the crash occurred. The results and findings from this research can be applied to emulate dynamic message signs over time and space so as to alert the motorists about the length and duration of congestion depending on the severity of crash and lane on which the crash occurred.

1. Introduction

According to the National Highway Traffic Safety Administration (NHTSA, 2010) of the United States Department of Transportation (USDOT) traffic safety facts, in the year 2010, over 30,000 fatal, 1.5 million injury and 5.5 million total crashes occurred in the United States. In the city of Charlotte, North Carolina, during the same year, over 200 fatal and 22,000 injury crashes were reported. The most common types of collisions on freeways are rear-end, ran-off road and sideswipe collisions. The main factors that contributed to the above collision types are failure to reduce speed when the vehicle in front reduces speed, improper lane change, speeding, and inattentive driving (NHTSA, 2010).

Accommodating and addressing the safety of system users on freeways is vital as associated damages and economic losses are substantial in nature. Crashes occurring in congested conditions are less severe and more likely to be rear-end collisions (Zhou and Sisiopiku, 1997; Chang and Xiang, 2003; Golob et al., 2008). The highest charges on freeway segments are associated with crashes on congested roads during non-peak travel hours (Rothenbeg et al., 2007). Moreover, crashes during uncongested conditions are more severe and may result in relatively high travel time variation.

A majority of safety related research in the past focused on identification of high crash locations and understanding the causes of crashes to improve safety. Likewise, considerable research was done to understand the effect of traffic volume or travel demand on congestion. However, not many focused on understanding the effect of crashes on traffic delay and travel time variation (at and upstream of the crash location) over time and space.

Crashes on freeways not only cause severe damage but also induce vehicle delays along the road network. When a crash occurs

* Corresponding author at: Civil & Environmental Engineering Department, Infrastructure, Design, Environment, & Sustainability (IDEAS) Center, The University of North Carolina at Charlotte, 9201 University City Boulevard, Charlotte, NC 28223-0001, USA. Fax: +1 704 687 0957.

E-mail addresses: sspulugurtha@uncc.edu (S.S. Pulugurtha), sujithk.dba@gmail.com (S.S. Balaram Mahanthi).

http://dx.doi.org/10.1016/j.cstp.2015.12.001

on a freeway, one or two lanes are blocked (closed) temporarily depending on the type of crash. This results in a temporary reduction in capacity and an increase of vehicle delays on the road network. The total delay would be high when a crash occurs during peak hours (high traffic volume) than when compared to off-peak hours (low traffic volume). However, the variation in travel time (function of difference between travel time under a certain condition and travel time under no crash or off-peak condition) may not follow the same trend. The effect of a crash on travel time variation further depends on the time of occurrence, severity of the crash, the number of vehicles involved in the crash, traffic volume (existing and short-term future), geometric conditions, and the lane on which it occurred.

When a lane or two lanes are blocked due to a crash, queues are formed in the upstream direction. The formation of queue and the effect on traffic delay over time can be examined using travel time variation as a measure. At the same time, the dissipation of queue from the blocked location takes place in the upstream direction. In general, the rate of dissipation of queue is faster than the rate of formation of queue. Therefore, the difference in travel time variation could be higher for the upstream segments some time after the crash (example, 75 min after a fatal crash than 60 min after the fatal crash) due to queue building in the upstream direction but dissipating at a faster rate in the same direction. In case of a severe crash and multiple lanes are blocked for an extended period, the queue and delay could extend further and result in an additional delay under congested conditions.

Therefore, there is a need to examine the effect of a crash on travel time variation on upstream segments over time and space. The spatial and temporal effects need to be evaluated and assessed by traffic condition, crash severity, and the lane (say, right-most or left-most lane) on which the crash has occurred. This research deals with the travel time variation (defined as variation in travel time due to a crash when compared to normal no crash traffic flow condition during the same time interval) and affected upstream distance (based on links with travel time variation) caused due to a fatal or injury crash to study their effect on travel time delay. The objectives of the research are:

1. to simulate and evaluate the effect of a fatal or injury crash, occurring on different lanes, on travel time variation and upstream distance affected along a corridor;
2. to examine the role of traffic volume on upstream distance affected from the blocked section and the duration of travel time variation (congestion); and,
3. to evaluate and assess the queue formation and dissipation pattern over time.

2. Literature review

In the past, research was conducted to calculate travel time variation and travel time delay, as well as to quantify congestion. NCHRP Report 618 discusses the use of cost effective performance measures such as travel time delay, variation and reliability (NCHRP, 2008). The report specifies the minimum number of observations required to obtain a desired confidence level to calculate the mean delay and travel time.

Non-recurring congestion due to crashes and other incidents also play a major role on congestion. Al-Deek et al. (1995) developed a methodology to estimate freeway incident congestion on I-880 in California where extensive loop and incident data are available. Time-space domain was determined for each incident using shockwave analysis, which was used to define the congestion boundaries of an incident and to decide whether the incident should be analyzed as isolated or as a multiple-incident case. Traffic speed and traffic counts upstream and downstream of the incident location were used to compute incident delay on each segment during small time periods, and then used to quantify cumulative incident delay.

Garib et al. (1997) developed two statistical models, one to estimate incident delay and another to predict incident duration. The incident delay models showed that up to 85% of variation in incident delay can be explained using incident duration, the number of lanes affected, the number of vehicles involved, and traffic volume before the incident. The incident duration prediction model showed that 81% of variation in incident duration can be predicted by the number of lanes affected, the number of vehicles involved, truck involvement, time of day, police response time, and weather condition.

Güner et al. (2012) developed a stochastic dynamic programming formulation for dynamic routing of vehicles in non-stationary stochastic networks subject to both recurring and non-recurring congestion. They also proposed alternative models to estimate incident induced delays. Their results looked promising when the algorithms were tested in a simulated network of South-East Michigan freeways using historical data from the MITS Center and Traffic.com. Findings from their study indicate that 50% of all travel time delays are attributable to non-recurring congestion sources such as incidents.

Mansoureh et al. (2011) simulated the post-incident traffic recovery time along a freeway and compared the results with shockwave theory calculations. Their results showed that a higher post-incident recovery time is estimated for traffic to return to pre-incident travel conditions using the simulation method than when using the shockwave theory. They also showed that the recovery time increases proportionally as traffic intensity builds.

Most of the research on non-recurring congestion was conducted using the data collected by agencies. A few authors such as Pulugurtha et al. (2002); Martin et al. (2011) used traffic simulation software to analyze the effect of incidents on transportation system performance in the past. Pulugurtha et al. (2002) explored the features available in CORSIM and VISSIM traffic simulation software to simulate and analyze the effect of incidents. They neither calibrated the model nor focused on travel time variation or upstream distance affected due to a crash. Martin et al. (2011) worked on an analysis of freeway incidents on the Salt Lake Valley freeway network. Different types of incidents were analyzed using VISSIM simulation software. Their analysis focused on incident induced freeway delays and also looked at other parameters such as vehicle throughput, travel times and network-wide delays.

Researchers have also attempted to integrate recurring and non-recurring congestion components to quantify congestion in the past. Pulugurtha and Pasupuleti (2010) developed a methodology to estimate travel time and its variations, travel delay index due to crashes and their severity, congestion score, and reliability of each link in the network for the city of Charlotte, North Carolina. The congestion scores for recurring and non-recurring congestion were combined to evaluate the reliability of each link.

Data from loop detectors or other sources could be captured to model the affect of a crash at a location on travel time variation or other measures within its vicinity. However, crashes are random, comparatively rare events, and may occur at any point on the network. Several other factors could also play a role on real-time travel times along a corridor. Understanding the effect of a crash using simulation approach would help forecast variation over time (short-term) due to the same, minimize complexities that arise due to the presence of several other variables, and better plan to emulate dynamic message signs and influence travel patterns over space and time. Using a simulation approach to model the effect of