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Original Research Paper

Traffic recovery time estimation under different flow regimes in traffic simulation

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ABSTRACT

Incident occurrence and recovery are critical to the smooth and efficient operations of freeways. Although many studies have been performed on incident detection, clearance, and management, travelers and traffic managers are unable to accurately predict the length of time required for full traffic recovery after an incident occurs. This is because there are no practical studies available to estimate post-incident recovery time. This paper estimates post-incident traffic recovery time along an urban freeway using traffic simulation and compares the simulation results with shockwave theory calculations. The simulation model is calibrated and validated using a freeway segment in Baltimore, MD. The model explores different flow regimes (traffic intensity) and incident duration for different incident severity, and their effects on recovery time. A total of 726 simulations are completed using VISSIM software. Finally, the impact of congestion and incident delay on the highway network is quantified by a regression formula to predict traffic recovery time. The developed regression model predicts post-incident traffic recovery time based on traffic intensity, incident duration, and incident severity (ratio of lanes closure). In addition, three regression models are developed for different flow regimes of near-capacity, moderate, and low-traffic intensity. The model is validated by collected field data on two different urban freeways.

1. Introduction

Freeway congestion is a major problem in many urban areas. Congestion on freeways is classified to recurring and non-recurring. Recurring congestion is from normal peak-hour travel. Non-recurring congestion is from random and unpredictable incidents and events that impede the flow of traffic, such as lane blockage from accidents, disabled vehicles, or natural phenomena. These non-recurring incidents can make large delays that contribute significantly to the total congestion experienced by travelers. Delays are influenced by the nature and frequency of incidents and the traffic intensity before the incident. Accurate estimations of congestion delay

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and its components are important for effective traffic management. Traffic management decisions will be largely influenced by the nature and type of congestion experienced. Traffic management strategies should be emphasized if the accrued delay is largely from recurrent congestion, and the incident management strategies should be applied if the delay is largely incident related (Skabardonis and Geroliminis, 2004).

A literature search is conducted to find past researches related to incident delay estimation and recovery time. The obtained information indicates that most of the available studies utilized the analytical model of queuing analysis (Garib et al., 1997; Giuliano, 1989; Lindley, 1987; Morales, 1986; Olmstead, 1999; Sullivan, 1997) and shockwave analysis theory (Hadi et al., 2007; Knoop, 2010). While these methodologies remain popular, others have concluded that these approaches underestimate the actual queue dissipation time and, ultimately, the full system recovery time (Chien and Chowdhury, 2000; Li et al., 2006). Although these analytical models can reasonably estimate the average delay, they seriously underestimate the standard deviation of delay and the expected total delay in the dynamic traffic networks.

Delay is one of the most important indicators to measure the impacts of incidents. Several methods (queuing and shockwave) are available in the literature for incident-induced delay estimation on freeway networks. The deterministic queuing model (DQM) is one of the most widely used methods and also supported by the Highway Capacity Manual (TRB, 2010).

DQM and shockwave theory are often used to evaluate the characteristics of queue formation and dissipation. DQM is based on assumptions regarding arrival patterns, departure characteristics, and queue disciplines. The queue discipline that most readily assumed for traffic-oriented queues is the first-in, first-out (FIFO).

A shockwave means a discontinuity of flow or density and occurs when cars change speed abruptly. A sudden reduction of the freeway capacity creates backups and queuing, and results in the shockwave effect. The sudden reduction of capacity results from either recurring or non-recurring congestion. The bottleneck results in speed reduction, and the point at which this change occurs can be noted by the brake lights on the vehicles.

According to Skabardonis and Geroliminis (2004), simulation models can be applied to analyze incident impacts without simplifying assumptions which is required by analytical techniques. Furthermore, most previous studies have only estimated the queue dissipation time, and had no standard formulation for full traffic recovery time (TRT) estimation. Therefore, traffic managers in different areas have postulated that post-incident TRT exceeds the actual duration of an incident by a fixed factor. For example, this factor is postulated to be four and ten in Maryland and California, respectively (Chang et al., 2006). While that idea is clearly refutable because the recovery time is a function of the prevailing traffic intensity, it does have some element of truth regarding the relatively longer period of traffic recovery and the actual duration of the incident. In this study, TRT is defined as the time when post-incident traffic flow has returned to pre-incident conditions.

It is usually difficult to accurately predict the length of time required for full traffic recovery after an incident. The probabilistic nature of most non-recurring incidents makes it difficult to collect accurate empirical data to establish a mathematical relationship between incident duration and TRT for different flow regimes or traffic intensity values. The duration of most non-recurring incidents is usually unknown because of one's inability to determine the exact time of occurrence. Microscopic simulation allows for generation of pseudo-incidents for a variety of traffic-flow scenarios. These pseudo-incidents can facilitate a controlled study on the ramifications of delay to highway incident response.

A typical time-density-speed graph of incidents is presented in Fig. 1 to show the difference between queue dissipation and full traffic recovery. The upper line segment in the graph represents the density curve in vehicle per mile (vpm), while the downward slope of the line represents the queue discharge during the traffic stabilization period prior to the onset of full TRT, or pre-incident conditions. The lower line represents the speed curve in miles per hour (mph). The first section is the pre-incident normal condition. The incident begins at T1 and ends at T2. Queue dissipation starts at T2 and ends at T3. Full traffic recovery happens at T4. The time between T1 and T2 is the incident duration when an incident happens, lanes are closed until the incident is cleared and lanes would be re-opened. During the incident, density increases and speed decreases since one or more lanes of the freeway are blocked. After the incident ends, recovery begins and traffic dissipates. Although the queue is dissipated at T3, the traffic is not stabilized. Full incident recovery is achieved when pre-incident conditions are observed, after queue dissipation at T4. The authors considered both speed and density for traffic recovery. Density is a more accurate indicator for traffic congestion along freeways, as freeways can be heavily congested even at free flow speeds.

Computer simulation models have become increasingly important in the analysis, design, and management of transportation/traffic infrastructure and operations. This is particularly true for delay impact, delay analysis, incident detection, and incident management, which form the complex and frequently changing traffic conditions. Since it is expensive and difficult to analyze such situations through empirical methods (due to the large amount of data required), simulation models are often used. In most cases, only limited, if any, field tests are feasible, because of prohibitively high costs and lack

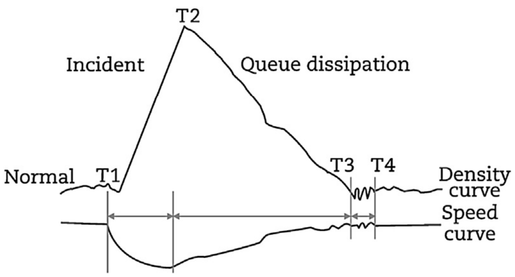

Fig. 1 – Typical time-density-speed graph of incidents and traffic recovery.