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Impact of Bottleneck Merge Control Strategies on Freeway Level of Service

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Abstract
Freeway work zones typically mandate lane closures that often induce bottlenecks. Merge maneuvers and the accompanying increase in the rate of lane changes at these bottlenecks can become problematic resulting in undesirable mobility and safety impacts. Traditionally, merge control strategies are deployed to mitigate such impacts. Literature sources indicate that available merge control strategies fall into one of four categories, namely: (i) late merge control, (ii) early merge control, (iii) mainline merge metering, and (iv) temporary ramp metering. However, little is known about the proper criteria for selecting and implementing one of the available merge control strategies. In addition, the impact of the various control strategies on freeway *Level of Service* (LOS) is currently under-researched. The purpose of this study is to evaluate the operational impacts of the above-mentioned freeway merge control strategies. The goal is to provide work-zone-aware LOS indicators that would help transportation agencies in selecting the most appropriate merge control strategy to minimally impact the freeway operations. In order to meet the research goals and objectives, this study used the CORSIM micro-simulation platform to evaluate impacts of various merge control strategies at a freeway study corridor in Birmingham, AL. The 2010 Highway Capacity Manual methods for calculating LOS were considered and modifications were proposed to align the calculated LOS with the assessed impacts of each merge control strategy. This study is significant for its contribution to providing transportation researchers and professionals with tools and methods to evaluate freeway LOS under work zone conditions and assisting them in mitigating the adverse impacts of work zones on traffic operations.

Keywords: Traffic Flow; Traffic Congestion; Bottlenecks; Level of Service (LOS); Simulation

1 Introduction

Freeway work zones typically mandate lane closures that often induce bottlenecks. Merge maneuvers and the accompanying increase in the rate of lane changes at these bottlenecks can become problematic thus resulting in undesirable mobility and safety impacts. Traditionally, merge control

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strategies are deployed to mitigate such impacts. Recently, the authors reviewed seventeen key articles of literature through which they identified four merge control strategies that can be used for managing traffic at freeway bottleneck locations (Ramadan and Sisiopiku, 2015). These strategies are:

i. Late merge control, which is designed to encourage drivers to remain in their lanes until they reach the merge point at the lane closure taper;
ii. Early merge control, which is designed to encourage drivers to merge into the open lane(s) sooner than they would;
iii. Mainline merge metering, which is similar to late merge control; however, a traffic meter similar to that of a ramp meter is installed right at the merge point or closure tapper to regulate merge maneuvers; and
iv. Temporary ramp metering, which utilizes a temporary local ramp meter on an on-ramp at a work zone with lane reductions or cross-overs.

Additionally within the same study, Ramadan and Sisiopiku (2015) conducted a national survey of practice by directly soliciting responses from maintenance managers and engineers from all State Departments of Transportation on merge control practices at work zones. Responses from 27 States revealed that the most commonly used strategy is early merge control, followed by late merge control. Mainline merge control and temporary ramp metering are not being used by any of the State agencies surveyed. Another significant finding is that most agencies (79%) attributed their choice of bottleneck merge control strategies to earlier experience within their agency with minimal or nearly no consideration of operational or safety impacts. Such gap between practice and research had to be investigated further in an effort to motivate State agencies to choose appropriate bottleneck merge control strategies based upon mobility and/or safety considerations in the future.

This study considered the LOS as a well-established indicator for mobility. Using a freeway segment from Birmingham, AL as a testbed and the CORSIM micro-simulation model as a platform, four merge control strategies were simulated under varying traffic demand conditions and the impact of each strategy on LOS was studied in detail. As discussed in Chapter 26 of the 2010 *Highway Capacity Manual* (HCM) (TRB, 2010), the current HCM methods cannot estimate the impacts of the presence of an incident/work zone. Density is the key indicator for freeway LOS, thus a Density Index (I_D) was developed as the percentage density change that might be expected after implementing a given bottleneck merge control strategy at a specific site. Microscopic simulation results were used to estimate density as a function of percentage peak traffic at the work zone location under various merge control strategies.

2 Study Design

2.1 Study Site Characteristics

A case study of a section of I-65 in Birmingham, Alabama was considered. The study segment extends from exit 247, where it intersects with Valleydale Road, to exit 261, where it intersects with Interstate 20/59 (I-20/59), and was used as the basis for this simulation study. The study segment, shown in Figure 1, typically has three 12-ft (3.66 m) lanes per mainline direction, with auxiliary lanes added at ramps locations. The posted speed limit on the study segment is generally 60 mph (96.6 km/h) with an advisory speed limit of 45 mph (72.45 km/h) on ramps. The 2014 *Annual Average Daily Traffic* (AADT) for this specific section was 122,510 veh/day, with peak traffic typically occurring on weekdays between 7:00 am and 9:00 am.

Examination of *Alabama Department of Transportation* (ALDOT) traffic data yielded that off-peak traffic represents 13.43% of the peak traffic. Accordingly, the spectrum between 13.43% and 100% represents the variations in traffic throughout any given day. Hence, 10 even intervals were considered to simulate the impact of the considered merge control strategies, namely: 100%, 90.38%, 80.76%,