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A driving simulator study of driver performance on deceleration lanes

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ABSTRACT

Deceleration lanes are important because they help drivers transition from high-speed lanes to low-speed ramps. Although they are designed to allow vehicles to depart the freeway safely and efficiently, many studies report high accident rates on exit ramps with the highest percentage of crashes taking place in deceleration lanes.

This paper describes the results of a driving simulator study that focused on driving performance while approaching a divergence area and decelerating during the exiting maneuver. Three different traffic scenarios were simulated to analyze the influence of traffic volume on driving performance. Thirty drivers drove in the simulator in these scenarios while data on their lateral position, speed and deceleration were collected. Our results indicate there are considerable differences between the main assumptions of models generally used to design deceleration lanes and actual driving performance. In particular, diverging drivers begin to decelerate before arriving at the deceleration lane, causing interference with the main flow. Moreover, speeds recorded at the end of the deceleration lane exceed those for which the ramp's curves are designed; this creates risky driving conditions that could explain the high crash rates found in studies of exit ramps. Finally, statistical analyses demonstrate significant influences of traffic volume on some aspects of exiting drivers' performance: lower traffic volume results in elevated exiting speed and deceleration, and diverging drivers begin to decelerate earlier along the main lane when traffic volume is low. However, speeds at the end of the deceleration lane and the site of lane changing are not significantly influenced by traffic volume.

1. Introduction

Freeway deceleration lanes and exit ramps are designed to allow vehicles to depart the freeway safely and efficiently. They have long been required in highway interchanges, and planning authorities have employed them when designing new high-speed intersections or when upgrading existing intersections. At both interchanges and intersections, deceleration lanes are built to improve traffic flow conditions by reducing interruptions, increasing capacity and improving safety. However, safety problems can be expected if drivers are forced to reduce speed in the main traffic lanes or if they are forced to decelerate too quickly. This interference may result in traffic conflicts that increase the probability of crash occurrence as demonstrated by the high accident rates reported in previous investigations of freeway exit ramp safety (Harwood and Graham, 1983; Oppenlander and Dawson, 1970; Twomey et al., 1992). Although automotive technology and vehicle design have evolved significantly, deceleration lane safety problems have not been adequately addressed, as demonstrated by recent crash analyses (McCartt et al., 2004; Chen et al., 2009).

Thus, the identification of factors contributing to crashes at freeway divergence areas is obviously a crucial objective for improving the safety of freeway off ramps. According to several crash prediction models proposed over the years, these factors may include the following: the geometric characteristics of the freeway, particularly the deceleration lane; the environmental and traffic conditions; the features of the vehicle; and, of course, the driver's behavior during the exiting maneuver. These models are calibrated and validated by onsite observations, and they relate crash frequency at the ramp to different explanatory variables such as traffic flow and ramp geometry. Nevertheless, there are no guidelines or research results that provide designers with clear and updated criteria for appropriate deceleration lane geometries that are based on real driving behavior and the influence that design variables have on driving behavior. Considering the small body of literature in this area of road design, further research is required to gain a deeper comprehension of the relationship between driving performance and deceleration lane features. Particular attention should be paid to traffic flow because it is a key factor in road safety (e.g., Bauer and Harwood, 1997; Khorashadi, 1998; Chen et al., 2009).

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