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Evaluating the safety impacts of the number and arrangement of lanes on freeway exit ramps

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ABSTRACT

The primary objective of this study is to evaluate the impacts of the number and arrangement of lanes on freeway exit ramps on the safety performance of freeway diverge areas. The research team collected crash data at 343 freeway segments in the state of Florida. Four different types of exit ramps were considered in this study. They were defined as type 1, type 2, type 3, and type 4 exit ramps respectively. Cross-sectional comparison was conducted for comparing crash frequency, crash rate and crash severity between different types of freeway exit ramps. Crash prediction models were developed to identify the factors that contribute to the crashes reported at selected freeway segments and to provide quantified information regarding the safety impacts of different freeway exit ramps. It was found that the ramp and freeway AADT, posted speed limit on freeway, deceleration lane length, right shoulder width, and the type of exit ramp significantly affected the safety performance of freeway diverge areas. The study demonstrated the safety benefits of using lane-balanced exit ramps. Based on the crash prediction models, replacing a type 1 exit ramp (lane-balanced) with a type 2 exit ramp (not lane-balanced) will increase crash counts at freeway diverge areas by 68.33%. Replacing a type 3 ramp (lane-balanced) with a type 4 ramp (not lane-balanced) will increase crash counts at freeway diverge areas by 32.20%.

1. Introduction

The number and arrangement of lanes used by traffic to exit freeways is an important consideration in freeway exit ramp design. Based on the number and arrangement of lanes, freeway exit ramps can be classified into different types. Drivers exiting freeways need to make decisions and execute maneuvers such as lane change or lane merge prior to the exit ramp in order to access crossroads at the interchanges. Different types of exit ramps require drivers to make distinctive decisions to complete related maneuvers both for exiting and continuing with the freeway. As a result, different exit ramps may have different impacts on the safety and operational performance of freeway diverge areas.

During the past several decades, numerous studies have studied the safety performance of freeway exit ramps (Bared et al., 1999, 2005; Lord and Bonneson, 2005; Bauer and Harwood, 1998; Khorashadi, 1998; McCartt et al., 2004; Garber and Fontaine, 1999; Bonneson, 2005; Janson et al., 1998; Cirillo et al., 1969; Batenhorst and Gerken, 2000). Previous researchers have developed several crash prediction models to relate crash frequency at ramp sections and deceleration lanes to different explanatory variables such as traffic volumes and ramp design elements. However, none of these studies has focused on the impacts of the number and arrangement of lanes used by traffic to exit freeways.

In previous studies, the types of freeway exits are usually defined by ramp configurations. Bauer and Harwood (1998) studied the relationship between traffic crashes and highway geometric design elements and traffic volumes for interchange ramps and speed change lanes. The statistical modeling approaches used in that research included Poisson and negative binomial regression. Several models were developed to predict crashes on ramp sections and speed change lanes. The variables that were included in crash models included mainline freeway AADT, ramp AADT, area type (rural/urban), ramp type (on/off), ramp configuration, right shoulder width, and lengths of ramp and speed-change lane. Among these variables, it was found that ramp AADT explained most of the variability in the accident data. Crash frequency increases with the increase of the ramp AADT. The crash prediction model for the deceleration lane is given by:

$$y = (X_1)^{1.04} \exp(-9.73 - 1.21X_2 + 0.09X_3) \quad (1)$$

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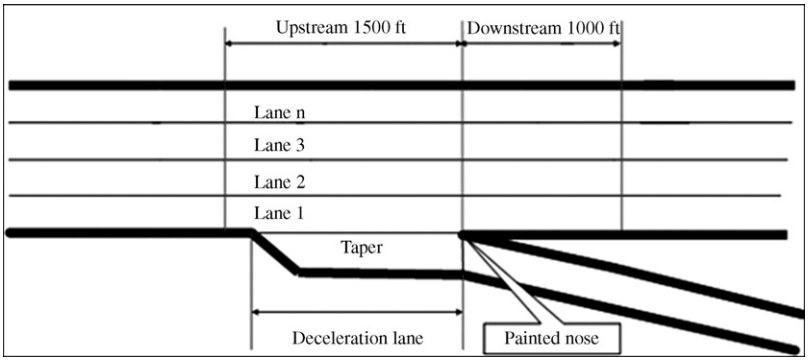

Fig. 1. Type 1 exit ramp.

where y is the expected number of total crashes in a 3-year period on the deceleration lanes, X_1 the ramp AADT (veh/day), X_2 a dummy variable for area type (=1 if the area type is rural, 0 otherwise), and X_3 denotes the right shoulder width.

Bared et al. (1999) developed a model to estimate the crash frequency for entire ramps as a function of ramp AADT, mainline freeway AADT, deceleration lane length and ramp configurations. The focus of that study is on the safety effects of the lengths of acceleration and deceleration lanes. The ramp configurations considered in that study included diamond, parclo loop, free-flow loop, and outer connecter. The model shows that crash frequency on freeway ramps increases with the increase of ramp and freeway AADT and decreases with the increase of the deceleration lane length. Sensitivity analysis results show that a 100 ft increase in deceleration lane length will result in a 4.8% reduction in crash frequency. The final crash prediction model is given as follows:

$$N = (RAADT)^{0.78}(FAADT)^{0.13}\ \exp(-7.27 + 0.45DIA + 0.78PAR - 0.02FF + 0.69OC - 0.37RUR + 0.37DECEL - 2.59SCLEN + 1.62RLEN) \quad (2)$$

where N is the expected number of total accidents in a 3-year period on entire ramp combined with speed-change lane, *RAADT* the ramp AADT (veh/day), and *FAADT* is the mainline freeway AADT for the direction of travel in which the ramp is located (veh/day). *DIA*, *PAR* and *FF* are dummy variables defined for diamond ramp, parclo loop ramp, and free-flow ramp respectively, *DECEL* the dummy variable for off/on ramp (=1 if the ramp is an off ramp, 0 otherwise), *SCLEN* the speed change lane length (miles) and *RLEN* is the ramp length (miles).

Until recently, the safety impacts of the number and arrangement of lanes on freeway exit ramps have not been well studied or documented. No clear guidelines, neither federal nor state, are currently available in selecting the number and arrangement of lanes on freeway exit ramps to improve safety at freeway diverge areas. In the current engineering practice, the number and arrangement of lanes on freeway exit ramps are often determined by joint consideration of the basic number of lanes on freeway and the lane balance theory.

The basic number of lanes on freeway is mainly determined by the freeway traffic demand. It is recommended that a certain consistency should be maintained in the number of lanes provided along any route of arterial corridor (AASHTO, 2001). Based on the lane balance theory, the number of approach lanes on a freeway at exits should be equal to the number of lanes beyond the exit, plus the number of lanes on the exit, minus one. In addition, the travelled way of the freeway should be reduced by not more than one traffic lane at a time (AASHTO, 2001). In practice, due to various restrictions, lane balance at freeway exits, sometimes, cannot be achieved. It is generally believed that lane-balanced exit ramps have better safety performance than those not balanced (AASHTO, 2001). However, the safety benefits have not been demonstrated by previous studies.

The primary objective of this study is to evaluate and compare the impacts of various types of exit ramps on the safety performance of freeway diverge areas. The types of exit ramps are defined by the number and arrangement of lanes used by traffic to exit freeways. Four different types of exit ramps were considered in this study. For convenience, they were defined as type 1, type 2, type 3 and type 4 exit ramps respectively. The definition of each type of exit ramp is illustrated in Figs. 1–4 and their characteristics are briefly described as follows:

- Type 1 exit ramp is a single lane exit ramp with tapered design. Vehicles on freeway can weave to the outer lane of freeway by

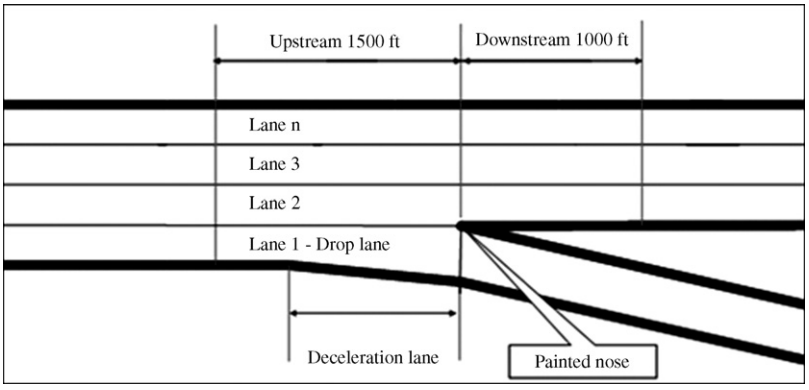

Fig. 2. Type 2 exit ramp.