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Safety effects of the separation distances between driveway exits and downstream U-turn locations

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Abstract

Using U-turns as alternatives to direct left-turns is an important access management treatment which has been widely implemented in the United States to improve safety on multilane highways. The primary objective of this study is to evaluate the safety effects of the separation distances between driveway exits and downstream U-turn locations. To achieve the research objective, crash data reported at 140 street segments in the state of Florida were investigated. The selected sites were divided into three groups based on the separation distances. *t*-Tests and proportionality tests were performed for comparing crash frequency, crash type, and crash severity between different separation distance groups. Negative-binomial models were developed for examining the factors that contribute to the crashes reported at selected sites. The data analysis results show that the separation distances significantly impact the safety of the street segments between driveways and downstream U-turn locations. A 10% increase in separation distance will result in a 3.3% decrease in total crashes and a 4.5% decrease in the crashes which is related with right-turns followed by U-turns. The models also show that providing U-turns at a signalized intersection will result in more crashes at weaving sections. Thus, if U-turns are to be provided at a signalized intersection, a longer separation distance shall be provided.

Keywords: Access management; U-turn; Separation distance; Negative binomial model; Proportionality test

1. Introduction

During the past decades, more and more states and local transportation agencies have recognized the safety benefits of using U-turns as alternatives to direct left-turn movements from driveways, and have started installing restrictive medians and directional median openings on multilane highways. In 1993, the Florida Department of Transportation (FDOT) mandated that all new or reconstructed major arterials with design speeds over 64.4 km/h (40 mph) be designed with restrictive medians. In the state of Florida, directional median openings and restrictive medians are installed on some major arterials to prohibit direct left-turn access from driveways onto major arterials. As a result, drivers wishing to make direct left-turns would, instead, make right-turns followed by U-turns (RTUT) at downstream median openings or signalized intersections.

A typical RTUT procedure requires five steps: (1) Drivers stop and wait at a driveway; (2) Make a right-turn onto the major road when a suitable gap is available from left-side through traffic; (3) Accelerate to the operating speed of the major road, weave to the inside lane, and decelerate to a stop at the exclusive left-turn/U-turn bay; (4) Wait until the signal turns green (if U-turns are accommodated at a signalized intersection) or when there are suitable gaps in the major road traffic stream (if U-turns are accommodated at a median opening) to make U-turns; (5) Accelerate to the operating speed of the major street through traffic. Using U-turns as alternatives to direct left-turns from a driveway reduces conflict points at unsignalized intersections and separates conflict areas. Thus, it simplifies driving tasks and has the potential to improve safety on multilane highways (TRB, 2003).

In past several years, numerous studies have evaluated the safety impacts of using U-turns as alternatives to direct left-turns. In response to the safety concerns with regard to providing U-turns at median openings, Potts et al. (2004) analyzed crash

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data at 481 conventional full median openings and 187 directional median openings and found that the crashes related to U-turn and left-turn maneuvers at median openings occurred very infrequently. In urban arterial corridors, median openings experienced an average of 0.41 U-turn plus left-turn crashes per median opening per year. In rural arterial corridors, median openings experienced an average of 0.20 U-turn plus left-turn crashes per median opening per year. Based on these limited crash frequencies, the researchers concluded that U-turns do not constitute a major safety concern at median openings.

Carter et al. (2005) examined U-turn crash history at 78 signalized intersections and found that 65 sites did not have any collisions involving U-turns in a 3-year study period. U-turn collisions at the remaining 13 sites ranged from 0.33 to 3.0 crashes per year. Based on the crash data analysis results, Carter and Hummer concluded that U-turns do not have a large negative safety effect on signalized intersections.

Lu et al. compared the safety performance of two driveway left-turn treatments, including direct left-turns from driveways and right-turns followed by U-turns at downstream median openings or signalized intersections (Lu et al., 2001a,b, 2004, 2005). The research team examined crash history at 258 sites with a total of 3913 crashes reported during a 3-year time frame. It was found that using right-turns followed by U-turns at median openings as an alternative to direct left-turns from driveways reduce crash rate by 26% and injury/fatality rate by 32% for 6-lane arterials. Lu et al. also used conflict techniques to compare the safety performance of different driveway left-turn alternatives. Traffic conflict data were collected at 16 sites in central Florida. The conflict data analysis results showed that indirect left-turns are generally safer than direct left-turns from driveways. On average, vehicles making RTUT at a median opening generate 47% fewer conflicts than those making direct left-turns from a driveway (Dissanayake et al., 2002). Vehicles making RTUT at a signalized intersection generate 26% fewer conflicts than those making direct left-turns from a driveway (Lu et al., 2004).

Even though numerous studies have evaluated the safety performance of right-turns followed by U-turns, none of them has focused on the impacts of the separation distances between driveway exits and downstream U-turn locations. As shown in Fig. 1, the separation distance between a driveway exit and the downstream U-turn location consists of three parts, including a weaving section, a transition section, and a left-turn/U-turn bay. It was found that the separation distances between driveway exits and downstream U-turn locations greatly impact the weaving patterns of RTUT (Cluck et al., 1999).

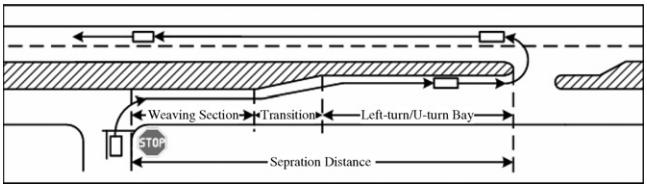

Fig. 1. Definition of separation distance.

In practice, if the major road traffic volume is low, drivers can easily find a suitable gap in all through traffic lanes, make a direct entry into the lane next to the median, decelerate and stop at the left-turn/U-turn bay. During peak periods, however, with the increases of the major road traffic volume, it becomes more difficult to find a simultaneous large gap in all through traffic lanes. In this condition, some drivers at the driveway will select a suitable gap in the right most lane to join the major street traffic stream, weave to the inside lane, decelerate and then stop at the left-turn/U-turn bay. If the separation distance is too short, however, drivers do not have enough maneuvering space to weave to the inside lane and have to stay at the driveway to wait for a simultaneous gap in all through lanes. With the increase of waiting delay at the driveway, some drivers start losing their patience and tend to accept too small gaps in the major road traffic stream. This, sometimes, will lead to the increased probability of having angle/right-turn crashes and rear-end crashes between right-turning vehicles and major street vehicles.

So far, there are no widely accepted standards, regulations or guidelines for determining the minimum or optimal separation distance to facilitate driver use of RTUT. In Michigan, left-turns are prohibited at some signalized intersections on major urban/suburban arterials to allow two-phase signal control at signalized intersections. A U-turn crossover is provided at about 201 m (660 ft) away from the signalized intersection to allow drivers to make U-turns (Levinson et al., 2000). This design concept is also called "Michigan U". The AASHTO Green Book (AASHTO, 2001) recommends that the minimum spacing between a median crossover and the signalized intersection with a "Michigan U" design should be between 122 m (400 ft) and 183 m (600 ft).

The most relevant study regarding the separation distances between driveways and U-turn locations was conducted by Zhou et al. in 2003. Researchers of that study developed an analytical model for determining the optimal location of mid-block U-turn median openings on 6-lane divided roadways. It was found that the average delay for U-turns will significantly decrease and the capacity of U-turns will increase if the U-turn median opening is located at an optimal location downstream of driveway. The recommended distances between driveways and downstream U-turn median openings vary from 140 m to 340 m. Zhou et al.'s study provided very useful information about the optimal locations of U-turn median openings on 6-lane divided roadways. However, the study was focused on the situation in which U-turns are provided at a specially designed mid-block U-turn median opening. The study has not considered the situation in which vehicles making U-turns at a signalized intersection. In addition, Zhou et al.'s study is focused on the operational effects of the separation distances. The study did not consider the crashes that may occur at the weaving sections while drivers were making RTUT.

To determine the optimal separation distances between driveway exits and downstream U-turn locations, the safety and operational impacts of the separation distance should be carefully studied. The objective of this study is to evaluate how the separation distances between driveway exits and downstream U-turn locations impact the safety performance of vehicles making