Driving Simulator Study of J-Turn Acceleration/ Deceleration Lane and U-Turn Spacing Configurations

tech transfer summary

J-turns are an innovative geometric design that reduce the severity of crashes at intersections between a major highway and a minor road.

Objective

The objective of this project was to develop data-driven design guidance for J-turns through the evaluation of three design parameters: J-turn lane configuration, U-turn spacing, and minor road signage.

Background

A J-turn, also known as a restricted crossing U-turn (RCUT) or superstreet, is an innovative geometric design that helps to improve the safety of intersections between a major highway and a minor road. With this design, the minor road through and left-turn movements are prohibited from crossing the major highway directly; instead, vehicles are forced to make a U-turn. Thus, crossing conflicts are eliminated and are replaced with merging conflicts.

Safety studies have shown that J-turns reduce severe crashes by about 64 percent. The longer travel through the U-turn does increase travel times—but not significantly. J-turns have been implemented in Maryland and North Carolina for many years and are being implemented and studied in other states as well.

Problem Statement

Despite the increased adoption of J-turns in many states, research-based guidance for several J-turn design parameters is still lacking. Existing guidance uses certain values out of convenience. For example, some guides recommend for the spacing between the minor road approach and the U-turn to be 660, 1,320, or 2,640 ft because they correspond to 1/8, 1/4, and 1/2 mi.; no empirical studies were conducted to show the safety effects of such spacing.

Research Description

The researchers used the ZouSim, a driving simulator housed at the University of Missouri, to examine three design parameters—J-turn lane configuration, U-turn spacing, and minor road signage—in an effort to provide research-based guidance on the design of J-turns.

The research team investigated nine separate design scenarios involving the following different lane configurations: U-turn spacing, signage styles, and traffic volumes. Thirty people from wide ranging demographics participated in this study.

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MTC RESEARCH PROJECT TITLE
Investigation of Rural J-Turn Design Factors Using the ZouSim Driving Simulator

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The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC). Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.

MTC's research focus area is State of Good Repair, a key program under the 2012 federal transportation bill, the Moving Ahead for Progress in the 21st Century Act (MAP-21). MTC research focuses on data-driven performance measures of transportation infrastructure, traffic safety, and project construction.

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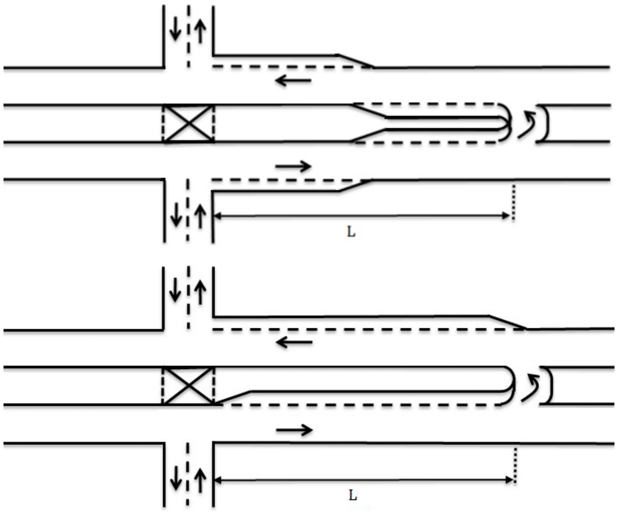


X in the center of each intersection represents prohibition of the through and left-turn movements from the minor approaches

J-turn design considerations showing acceleration and deceleration lanes (top) and full deceleration lanes (bottom)

Several performance measures were derived from the simulator experiments: speed differential, time-to-collision (TTC), lane-change locations, vehicle trajectory plots, and missed U-turns. Performance measure results were analyzed using applicable statistical methods. Additionally, regression models were developed for TTC versus standardized explanatory variables.

The two signage styles investigated in this study were diagrammatic (i.e., bird's-eye view, which can include the U-turn movement) and directional (i.e., directing the minor road traffic to the major road where other signage continues to guide the traffic).

Key Findings

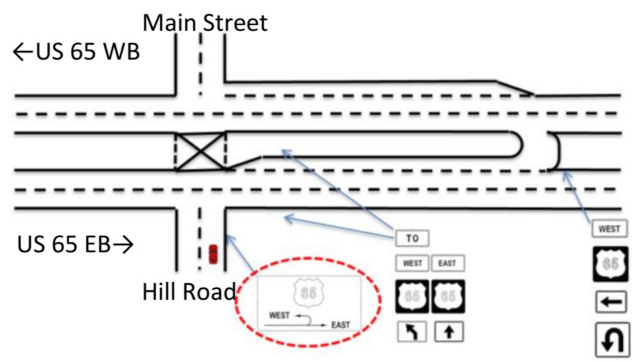
The simulator study results were consistent with post-simulator survey results. Both the simulator and survey results favored the acceleration/deceleration (AD) lane design due to smaller speed differentials, safer TTCs, and higher survey ratings. Vehicle trajectory plots generated from the trials also showed that drivers traveled differently on the AD lane versus the deceleration lane only (DF) configurations.

The 1,000 versus 2,000 ft U-turn spacing results were similar for the DF lane configuration, while safety results improved with longer U-turn spacing for the AD lanes. With the DF design, U-turn spacing greater than 1,000 ft was not found to provide any noticeable improvement in safety. The practical design guidance is to use the AD lane configuration over the DF.

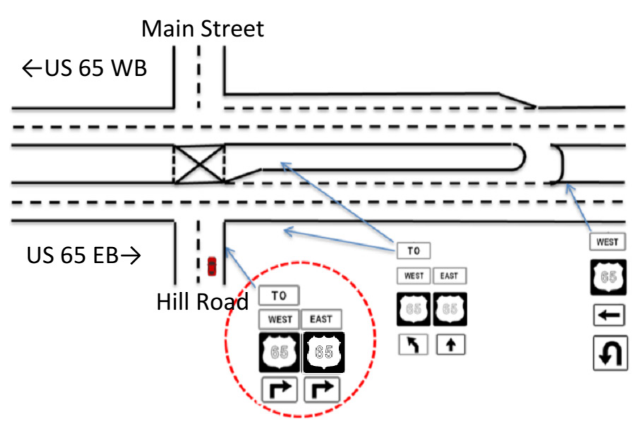
Even though survey results showed a slight preference for the directional style over the diagrammatic for signage, the simulator results did not vary between the two signage styles. However, a significant number of drivers missed the U-turn in the simulator results.

Speed differential results showed a relationship between lane configuration and U-turn spacing and that lane configuration was the most important design factor. Regression models were developed for TTC versus standardized explanatory variables. The coefficient for lane configuration was 0.714, while the coefficient for U-turn spacing was only 0.0938. TTC results showed a statistically significant difference ($p=0.0243$) of 66.3 percent more total safety-critical TTC values with the DF lane configuration compared to the AD lane.

Average lane-change locations were much shorter for the DF lane design compared to the AD lane design. The difference in lane-change locations was also verified visually from vehicle trajectory plots generated from simulator output. Post-simulator surveys produced results that were consistent with the simulator study results showing a preference for AD lane design and longer spacing.



Diagrammatic-style signage on minor road shows the bird's eye view, which includes the U-turn movement



Directional-style signage on minor road only directs the traffic to the major road, where other signage continues to provide guidance

Implementation Readiness and Benefits

Ultimately, the research results add to the knowledge of this innovative geometric design and present guidance for lane configuration, U-turn spacing, and signage. These findings can be incorporated into a guide to assist roadway designers in the deployment of this low-cost safety countermeasure for intersections.

For example, it was found that the AD lane configuration design is recommended over the DF lane configuration. Thus, when possible, acceleration lanes should be provided at J-turn sites. With the AD lane design, longer spacing improved safety. Locations with high traffic demand should especially consider longer lengths such as 2,000 ft.

If the DF lane design is used, 1,000 ft spacing is adequate, but such a design is not suited for locations with high traffic volumes and small traffic gaps.

Diagrammatic and directional signage performed about equally. A public educational campaign about J-turn deployment could help to improve driver understanding and to reduce the instance of missed U-turns.

A strong media and public information campaign could be employed when J-turns are implemented in communities unfamiliar with their operation. An agency can consider using additional signage to guide left-turn and through traffic on the minor road to reinforce the single signage on the minor road.