TECHBRIEF

Simulator Assessment of Alternative Lane Grouping at Signalized Intersections

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This document is a technical summary of the Federal Highway Administration report, *Simulator Assessment of Alternative Lane Grouping at Signalized Intersections* (FHWA-HRT-19-025).[1]

Introduction

Throughput at signalized intersections with high left-turn demand is a common cause of bottleneck for traffic flow. Dynamic lane-grouping strategies offer cost-effective methods for increasing operational efficiency within existing rights of way. Previous traffic simulations suggest that reversible left-turn lanes can significantly increase throughput at intersections where left-turn demand is high.[2,3] However, the operational benefits offered by reversible-turn-lane designs depend on safe and proper use by drivers.

Because reversible lanes make use of existing infrastructure and are time-of-day dependent, they require clear and adaptive signs and signals to indicate the active or closed status of a reversible lane and control alternative lane assignment during active periods. Reversible-lane designs may also expose drivers to novel or unfamiliar situations, such as sharing a lane with opposing traffic waiting at the far side of the intersection. In these cases, appropriate signs can mitigate unsafe driving behaviors and driver discomfort or confusion. In addition, improved signs and markings may aid in minimizing issues observed at existing reversible-lane interchanges, such as incorrect or missed turns and lane changes within the intersection.[4]

Research

Two experiments were conducted in a highway driving simulator to evaluate driver behavior and sign comprehension during reversible-lane operations compared to conventional-lane operations. Several key behaviors were measured to evaluate safe and efficient use of reversible-lane interchanges, including lane choice, sign comprehension, and appropriate navigation of reversible lanes. Conventional versions of the

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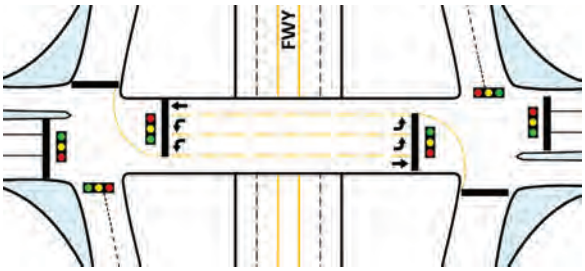
interchanges were simulated to provide a basis of comparison for driving performance. The signs used in these studies were chosen based on feedback obtained from a panel of subject-matter experts. A previous unpublished sign study provided further evidence that the chosen signs were comprehensible and clear to drivers.[1]

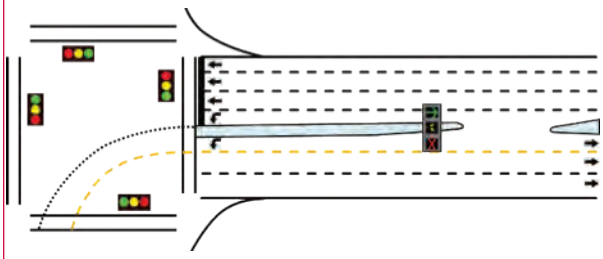
The experiments tested the dynamic reversible left-turn (DRLT) lane at diamond interchanges and the contraflow left-turn (CLT) lane at signalized intersections. The DRLT lane design replaces back-to-back left-turn lanes with reversible lanes that span the entire distance between interchange nodes. In a CLT lane intersection, a gap in the median allows drivers turning left to queue in a lane that is normally used by opposing through traffic. This design provides an additional left-turn lane without widening the roadway. These designs are illustrated in figure 1.

Figure 1. Reversible left-turn lane configurations.



Source: FHWA.

A. DRLT lane design.

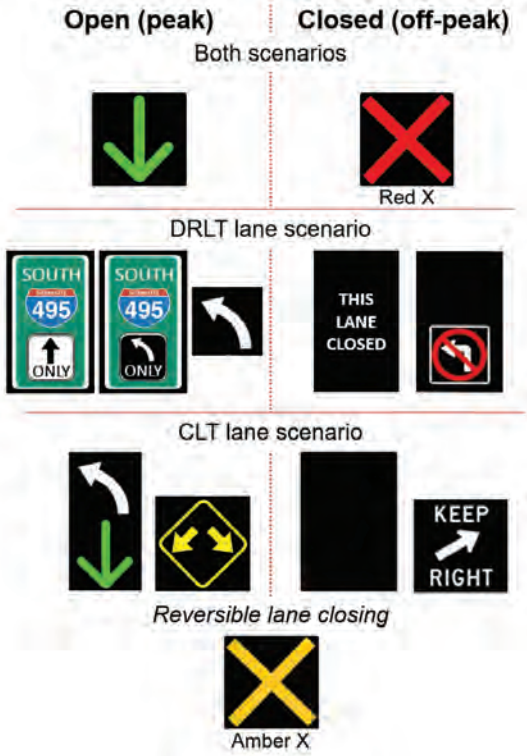


Source: FHWA.

B. CLT lane design.

A total of 192 participants completed the experiments. The researchers administered questionnaires after the experimental drives to collect feedback on the signs and markings used in the simulation. Figure 2 shows the changeable-message signs (CMSs) and symbols used to indicate the status of the reversible lanes.

Figure 2. CMSs and symbols used for reversible lanes.



Source: FHWA.

Results and Conclusions

Performance data collected during the simulated drives and self-reported questionnaire responses were used to evaluate driver behavior and comprehension of the reversible-lane designs and associated signs. Results showed that drivers used both versions of the reversible left-turn lane safely and with

[1]From an unpublished 2017 internal report by Inman, V. and Jackson, S. entitled *Dynamic Reversible Lane Human Factors Laboratory Study.*

frequency high enough to potentially improve throughput during periods of high traffic volume.

Overall, sign comprehension was high, as evidenced by compliant driving behavior and questionnaire responses. Participants used an incorrect lane in a small number of trials (up to 8 percent). No participants were observed entering a closed CLT lane signed with a red X. However, participants followed a simulated car into a CLT lane that was transitioning from open to closed in 5 percent of trials. Otherwise, participants consistently conformed to the intended meaning of signs and symbols, despite some reports of confusion or uncertainty regarding safe operations of the reversible lane or difficulty describing the meaning of a symbol.

In both experiments, participants in a through lane could arrive at the intersection during a red signal and be faced with opposing reversible-lane traffic occupying their lane across the intersection. This scenario had several undesirable effects on participant behavior, including delayed acceleration from the stop bar (up to 0.60 s). In addition, drivers in reversible lanes were observed making lane changes within the intersection in as many as 15 percent of trials after observing traffic occupying their lane across the intersection. The probability of making a lane change decreased with repeated exposure, presumably as participants became more familiar with reversible-lane operations. Although simulated traffic was seldom present ahead or to the right of the participants, inappropriate lane changes in an intersection are often considered unsafe and may endanger drivers.

Participants' uncertainty, as indicated by lane changes, was also reflected in their open-ended questionnaire responses. Forty percent of participants who drove through CLT intersection scenarios reported that confusion caused by the unfamiliar design of the CLT lane geometry influenced their hesitation to use the reversible left-turn lane.

The lane used to approach the CLT intersection and the amount of traffic present in the left-turn lanes were shown to affect participants' decisions to use the reversible left-turn lane. In the DRLT lane interchange, participants who originated in the left through lane used the reversible lane in 35 percent of trials. When less traffic was present in the CLT lane compared to the nonreversible left-turn lane, participants used the CLT lane in 48 percent of trials. This probability increased to 58 percent on the second exposure to a condition in which the CLT lane was empty and the queue in the nonreversible left-turn lane was long.

Questionnaire responses again corroborated observed behavior regarding motivation to use the reversible lane. When asked to report on the factors that influenced their willingness to enter and use the CLT lane, several participants described a desire to gain a time advantage by using a turn lane occupied by fewer vehicles.

Recommendations

The signs and symbols used in this study are recommended for on-road deployment.

Strategies that may be explored to encourage driver comfort and proper use of the reversible lanes include the following:

- Posting advance guide signs describing reversible-lane operations upstream of an intersection.
- Altering stop bars (e.g., raising, embedding, or milling the footprint) to make them visible only to nonreversible traffic.
- Installing low-profile raised curbs or flexible delineator posts along reversible-lane markings to discourage lane changes.

References

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Researchers—This study was performed by Stephanie Roldan (ORCID: 0000-0002-1849-2934) and Vaughan Inman of Leidos. Tracy Gonzalez (ORCID: 0000-0003-2672-1343) of Leidos performed statistical analyses. The study is under contract number DTFH61-13-D-00024 and used FHWA's Highway Driving Simulator at the Turner-Fairbank Highway Research Center in McLean, VA.

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