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Driving simulator evaluation of drivers' response to intersections with dynamic use of exit-lanes for left-turn

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ABSTRACT

With the worsening of urban traffic congestion in large cities around the world, researchers have been looking for unconventional designs and/or controls to squeeze more capacity out of intersections, the most common bottlenecks of the road network. One of these innovative intersection designs, known as the exit-lanes for left-turn (EFL), opens up exit-lanes to be used by left-turn traffic with the help of an additional traffic light installed at the median opening (the pre-signal). This paper studies how drivers respond to EFL intersections with a series of driving simulator experiments. In our experiments, 64 drivers were recruited and divided into two groups. One group is trained to use the EFL while the other group is not. In addition, four scenarios were considered with different sign and marking designs and traffic conditions in the experiments. Results indicate that drivers show certain amount of confusion and hesitation when encountering an EFL intersection for the first time. They can be overcome, however, by increasing exposure through driver education or by cue provided from other vehicles. Moreover, drivers unfamiliar with EFL operation can make a left turn using the conventional left-turn lanes as usual. The EFL operation is not likely to pose any serious safety risk of the intersection in real life operations.

1. Introduction

Facing with geometric limitations to expand intersections with heavy traffic demand, researchers have been looking for unconventional intersection designs to squeeze more capacity out of an intersection with oversaturated traffic conditions (Hummer, 1998b, a; Xuan et al., 2011; El Esawey and Sayed, 2013). One of these innovative intersection designs, as shown in Fig. 1, is to use some of the opposing through-lanes for left turns, which is known as the exit-lanes for left-turn (EFL) intersection design (Zhao et al., 2013).

The EFL intersection is proposed to increase the throughput of left-turn traffic in congested intersections with heavy left turn volumes and no space to add more left-turn bays. The function of lanes in the mixed-usage-area is variable. These lanes can be used as opposing through-lanes or left-turn lanes during different periods of a signal cycle. At the upstream of the intersection, there is a pre-signal and a median opening. Some of the left-turn vehicles can drive into the mixed-usage-area at the signalized median opening then turn left at the intersection using lanes in the mixed-usage-area when they receive green light. This increase of the number of left-turn lanes could shorten the left turn phase, hence releasing green time for use by other conflicting movements, which in turn increases the capacity of the intersection.

Fig. 2 shows how the EFL system would operate during one signal cycle. The pre-signal starts its cycle by giving the red to the left-turn vehicles while the left-turn phase of the cross-street is green. The pre-signal turns green for left-turn vehicles a few seconds after the cross-street left-turn green terminated. Then, some of the left-turn vehicles can drive into the mixed-usage-area from the median opening and queue at the intersection stop line. The left-turn vehicles could discharge more efficiently by using either left-turn lanes in the approach or the mixed-usage-area lanes during the left-turn phase. The pre-signal turns red a few seconds earlier than the start of the opposing-through green.

In an earlier study (Zhao et al., 2013), an optimization model for the EFL control has been formulated, in which the geometric

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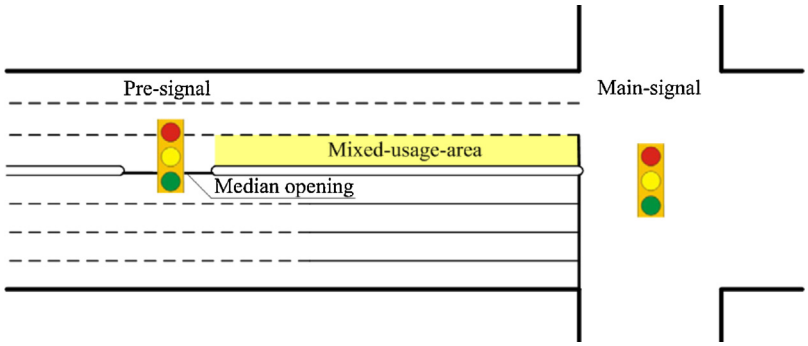

Fig. 1. Exit-lanes for left-turn (EFL) control concept.

layout, main-signal timing and pre-signal timing were integrated. The EFL control could increase the capacity of an intersection with promising preliminary results especially under high left-turn demand compared with conventional intersection control. The highest improvement is about 50%. Moreover, the EFL control could be applied to one or multiple legs simultaneously, thus it is particularly useful for intersections with unbalanced left demand and degree of saturation among different travel directions. Generally, an additional leg using the EFL control leads to about 7% increase in intersection capacity.

Despite the promising results, it is not clear how drivers would respond to such an unconventional intersection when it is implemented in real life and if the benefits would fully materialize. For example, a left-turn driver unfamiliar with EFL operation might queue at the median opening at the upstream of the approach without driving into the mixed-usage-area when the pre-signal turns green, then blocks other left-turn drivers. At this point, careful driver behavior studies and adequate driver education have to be carried out before EFL control is perfected and implemented in the field. The current study was intended to understand motorist

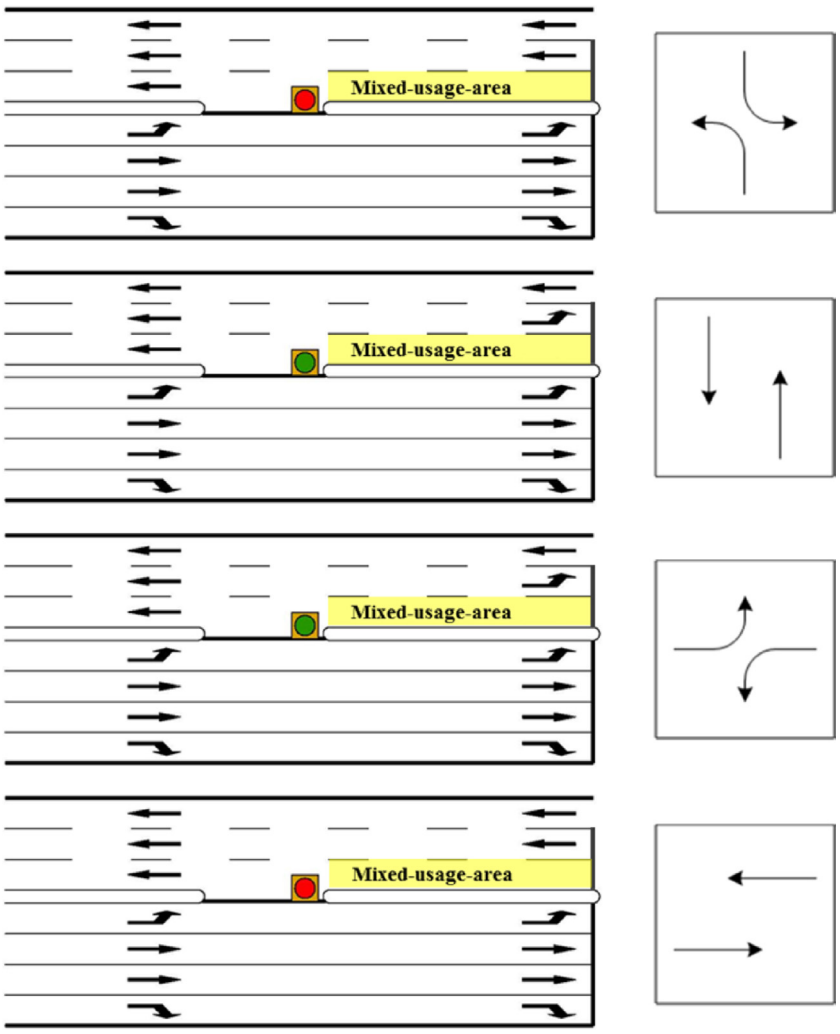

Fig. 2. Operating process of EFL control.