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Pedestrian safety under permissive left-turn signal control

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ABSTRACT

At intersections with permissive only signal control, pedestrians will move at the phase with the parallel through vehicular movement and the permissive left-turn movement. The left-turn vehicles have to yield to both opposing vehicles and pedestrians at the crosswalk. Under such complicated driving conditions, collision risks rise if left-turn vehicles make misjudgments and fail to yield to the pedestrians. In this research, driving-simulation based experiments were conducted for identifying and assessing the impacts of the factors that contribute to the collision between the left-turn vehicles and the pedestrians during the permissive left-turn phase. The results of this study showed that the percentage of left-turn trucks and the pedestrian volume has significant impacts on the pedestrian safety under permissive left-turn signal control.

Introduction

For the intersections with permissive only or protected/permissive left-turn (PPLT) control, pedestrians will move at the permissive phase with the parallel through vehicular movement. This requires left-turn vehicle to yield to both opposing vehicles and pedestrians prior to selecting an appropriate gap. Pedestrian accident risks are increased in such complicated driving conditions if left-turn vehicles make misjudgments and fail to yield to the pedestrians. The year 2002 National Highway Traffic Safety Administration's pedestrian crash facts show that a pedestrian is killed or injured in an intersection crash every 16 min, and pedestrian involved crashes occur far more often with left-turning vehicles than with right-turning and straight through vehicles, partly because drivers are not clearly able to see pedestrians on the left.

The existing signal design guidelines on left-turn operations mainly focus on the traffic conditions at the intersections. Few of them give particular considerations on the pedestrian safety problems in the determination of the most appropriate left-turn control mode for an intersection. For example, the exiting warrants for PPLT control are developed mainly based on the left-turn and the opposing through traffic volumes, while the pedestrian volumes and other pedestrian safety related factors, such as the pedestrian volume, the presence of big vehicles, the intersection geometric conditions and the sight distance of the left-turn drivers, have not be explicitly taken into account by these existing signal design guideline. To fill this gap, this research is to investigate the pedestrian safety under the permissive left-turn signal control. For this purpose, the driving-simulation based experiments were conducted to identify and assess the impacts of the factors that contribute to the crashes between left-turn vehicles and pedestrians during the left-turn permissive phase. After that, a survey was conducted

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to the participated drivers to get the subjective assessment of the pedestrian safety at different intersections with various traffic and geometric conditions.

Based on the results of the driving-simulation based experiments and survey, recommendations were provided regarding when the permissive left-turn signal control should not be used due to the potential risk to pedestrians. The results of this study can help the traffic engineers better understand the pedestrian safety issues related to the left-turn movements and choose the best left-turn signal time control mode for the intersections. Thus, it will reduce the causalities and property damages due to the conflicts between the crossing pedestrians and the left-turn vehicles.

Literature review

The literature review focus on the contributing factors to the collisions between left-turn vehicles and pedestrians during the permissive left-turn phase. Besides the traffic signal control methods, the pedestrian safety under left-turn permissive phase will also be affected by following factors: (1) pedestrian volume, (2) traffic conditions, (3) intersection geometric features, and (4) others. Following is a brief discussion about the findings from literature regarding the impacts of these factors.

Pedestrian volume

Theoretically, more pedestrians crossing the intersection will cause the left-turn vehicle more difficult to find an enough gap in the pedestrian flow to make a safe left-turn. However, previous researches (Zaidel et al., 1987 and Zegeer et al., 1982) have also found that it is safer for pedestrian to cross the intersection in a group. It may be due to the fact that a big group of pedestrians cannot be hidden by the visual impediment of the driver turning left. In addition, drivers may be more cautious during the left-turn maneuver at intersections where a high number of pedestrians are present since these drivers expect pedestrians in their path. Therefore, it is not a simple linear relationship between the pedestrian volume and the likelihood of pedestrian and left-turn vehicle accidents. The most risky situation may occur when the pedestrian volume is within a certain range.

Traffic conditions

Left-turn vehicle volume: previous research found that left-turn vehicle volume is an important influencing fact on the pedestrian accidents. When the left-turn volume is high, the drivers will become more aggressive and try to make permissive turns even if the time gap in the opposing traffic is relative small, which will cause they fail to yield to the pedestrians.

Opposing vehicle volume: at two-way/two-way intersections, drivers making a left-turn usually have to let oncoming vehicles from the opposite approach pass before performing the maneuver. Lord (1994) observed that while the driver was waiting for a gap long enough to turn, the majority of pedestrians usually had the time to cross the intersection. As a result, when the driver could finally turn left, there were very few pedestrians or no pedestrians at all in the crosswalk. Therefore, the risk to pedestrians may also be a function of the number of vehicles coming from the opposite approach.

Truck volume: large size vehicle, such as trucks, at intersections pose special risk and potential damage to pedestrians. In general, truck turning left has a wide turning path and will cross up to two lanes of traffic, bike lanes, and a crosswalk. If other vehicles, bikers, or pedestrians aren't paying attention and attempt to cross in front of the truck, a tragic collision may occur. In addition, trucks have extended blind spots on their left side, making it more difficult for truck drivers to see cars next to them and pedestrians in crosswalks.

Intersection geometric features

Quaye et al. (1993) attempted to develop accident models for predicting the pedestrian accidents and left-turning traffic at signalized intersections. The models showed that T-intersections were generally more dangerous to pedestrians (for a pedestrian flow above100 ped/hr). This result was also supported by Lord (1996), in which traffic conflict technique was used to evaluate the intersections studied by Quaye et al. (1993). It may be because, in these types of intersections, there are no opposing traffics, left-turn drivers are less cautious when they make turns during the permissive phase, which might cause they fail to yield to the pedestrians who are crossing the intersections during the same phase.

Besides the factors listed above, there are several other factors, such as the lighting and weather conditions, crosswalk marking, pavement surface condition, curb extensions, driver's age, driving experiences, and pedestrian's age, will also affect the risk of accidents between the pedestrian and left-turn vehicles. This study will focus on the impacts of pedestrian volume, traffic conditions and intersection geometric features.

Experimental design

In this study, the driving simulator based experiments were conducted to investigate the risk of collisions between pedestrians and left-turn vehicles during the permissive left-turn phase. In the driving simulator test, the driving performance measures of participants passing through different types of intersections with different pedestrian volumes, traffic and geo-