Splitter-Island on Pedestrian Safety at Roundabout

Subjects: Transportation

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Traffic accident statistics have traditionally been used to assess traffic safety. This method has severe limitations when used to investigate the impact of a particular feature of traffic facilities on safety at a microscopic level. Most previous research on surrogate safety measures (SSMs) had, on the other hand, focused on studying the safety of traffic operation conditions.

Keywords: pedestrian safety ; splitter-island ; safety performance ; surrogate safety measures

1. Introduction

Investigating the impact of a certain feature of traffic facilities on safety can provide a deeper understanding of safety conditions. The geometry of traffic facilities has a direct link to safety and traffic operation. Traditional accident-based analysis has severe limitations when investigating the effect of a certain feature of traffic facilities on safety at a microscopic level [1][2][3]. Nowadays, researchers and practitioners are widely employing a surrogate approach to assess the impact of new traffic designs and investigate safety-related issues by using real-world data extracted from videography and/or traffic safety simulation [4]. Although the SSM approach is an applicable tool to evaluate the effect of specific traffic facilities on safety, most previous research related to SSMs has focused on studying the safety performance and operational efficiency of overall traffic facilities in general [5]. The effect of individual features of traffic facilities on safety has received far less attention in the literature. The U.S. *National Cooperative Highway Research Program Reports on Roundabouts: An Information Guide* (NCHRP), defined a splitter-island as the key feature of roundabouts that enhances pedestrian safety at crosswalks and traffic operations by providing shelter for pedestrians, assisting control of entry speeds, and guiding traffic onto the roundabout [6]. This raised or painted area in the approach constitutes a separate and opposite traffic direction, providing deflection for entering and/or exiting vehicles, and accessible space for pedestrians crossing at two stages. Therefore, it is anticipated that a splitter-island would have a substantial impact on safety and operational efficiency, and their performance effectiveness could be evaluated by analyzing pedestrian-vehicle conflict behaviour through SSMs.

Following a partial amendment to the Japan Traffic Act in 2012, approximately 140 modern roundabouts were built [7]. Roundabouts are still uncommon in their number due to extensive landscaping requirements, particularly in the central-island and splitter-island alignments, as well as the limited space in densely populated residential, urban, and suburban areas of Japan. However, the reason for converting signalized intersections to roundabouts is to increase mobility during disasters such as earthquakes and tsunamis that occur more frequently in Japan [8]. The absence of a splitter-island is considered a defect in terms of geometry, and some roundabouts in Japan have some kind of such geometric issues. For example, some have unnecessarily wide circulatory roadways, and others lack apron steps [9]. Although the U.S. Guide on roundabouts (NCHRP) recommends that a splitter-island should be designed for all approaches of single roundabouts, the Towa-cha roundabout in Nagano prefecture of Japan does not have splitter-islands on two approaches due to limited space. The Towa-cha roundabout layout is illustrated in **Figure 1**. The figure shows that the Towa-cha roundabout is constructed with no splitter-islands in crosswalks C-C and D-D on the minor street approaches. Although road traffic is highly regulated, and rules of priority are consistently obeyed in Japan, users claim they still feel confused when crossing these types of traffic facilities [10], and it is even further frustrating to cross roundabouts without splitter-islands.

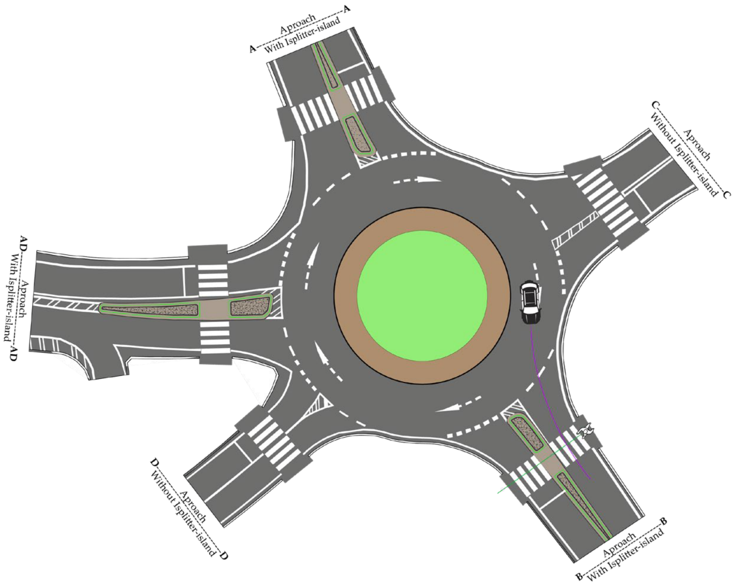

Figure 1. The Towa-cha roundabout layout.

Consequently, it is not clear how the absence of a physical splitter-island impacts pedestrian safety when crossing a crosswalk. More specifically, the effect of a splitter-island on pedestrian safety has not been comprehensively studied due to limited cases, particularly in the Japanese traffic environment.

Using SSMs, the impact of individual features of a traffic facility was reflected in 67 traffic users conflicts. Pedestrian-vehicle conflict behaviour was evaluated by measuring kinematic parameters such as speed, longitudinal acceleration, and deceleration. Particle tracking velocimetry (PTV) software was used to measure the traffic users' kinematic parameters at microscopic levels for a more accurate determination of the impact of splitter-island on pedestrian safety. Among SSMs, Post-encroach-time (PET), minimum time to collision (TTC_{min}), maximum speed (MaxS), and maximum deceleration to safety time (maxDST) are the most applicable to analyze the conflict severity of pedestrian-vehicle conflict crosswalks [1][3][5]. SSMs, including PET, TTCmin, MaxS, and DST, were employed to analyze and compare safety performance between the presence of a splitter-island (PS) and the absence of a splitter-island (AS).

2. Impact of Traffic Control Devices, Law Enforcement Programs and Surface Marking on Pedestrian Safety

Several past studies have explored how traffic control devices and road markings affect pedestrians' crossing decisions. Navarro et al. [4] investigated the safety effectiveness of converting a two-way-stop sign to an all-way-stop sign using an observational before-and-after approach. The authors found that all-way-stop intersections significantly reduced vehicle speed and increased PET time. Another study by Turner et al. [11] had the same result and concluded that active signage systems are quite effective in decreasing vehicle speeds and improving safety performance because of pedestrians' willingness to give way. Temporary traffic control devices that are featured on pedestrian walking paths should be flexible or energy-absorbing to moderate the injury outcome of a potentially vulnerable crash [12].

Li et al. [13] used SSMs to analyze the impact of law enforcement cameras on pedestrians' risk perception and driver behaviour at non-signalized crosswalks. The result showed that the cameras had a positive influence on reducing drivers' aggressiveness and conflict severity. Arhin et al. [14] conducted a statistical comparison to study the impact of different traffic enforcement programs on pedestrian-vehicle safety at four signalized intersections using SSM variables. The result indicated that enforcement measures have a significant impact on pedestrian safety.

Surface markings are often listed amongst meaningful contributors to traffic safety. Suzuki et al. [8] investigated vehicle movement by conducting driving experiments at five Japanese roundabouts; the results showed that coloured surface marking significantly reduces the necessary deceleration rate before crosswalks. The presence of parallelogram-shaped pavement markings were effective in decreasing approaching speeds at areas of intersection, and reduce both the severity and frequency of crashes at pedestrian crosswalks [15]. The safety effectiveness of newly designed crosswalk markings was evaluated by Bian et al. [16]. The results indicate that newly designed crosswalk markings are highly effective and influence drivers' behaviour more than standard crosswalk markings, no matter where pedestrian-vehicle conflict occurs. Hussain et al. [17] investigated the effect of two traffic control strategies, namely an advanced variable message sign, LED lights, and surface markings, on driver behaviour at high-speed uncontrolled crosswalks. The authors used a driving simulator in the presence or absence of a pedestrian and concluded that both traffic control strategies were effective in reducing vehicle speed. Mukherjee and Mitra [18] studied illegal crossings of 55 signalized intersections in Kolkata city, India. They concluded that illegal crossing is highly associated with defects and/or the absence of surface markings at crosswalks.

3. Impact of Distracted and Violating Behaviour of Pedestrians on Safety

Many researchers, for example, [18][19][20], are aware of the negative impact of distracted and violating pedestrian behaviour on safety, and it is believed that both factors increase the risk of pedestrian-vehicle conflict severity at crosswalks.

Distracted behaviour is defined as walking while simultaneously engaged in other activities, such as using technological devices, eating or drinking, and conversing with other people [21]. Thompson et al. [22] randomly recorded the behaviour of 1102 pedestrians crossing at 20 high-risk intersections. The authors observed that nearly one-third (29.8%) of all pedestrians engaged in some kind of distracting activity. Gruden et al. [23] conducted an eye-tracking study to investigate digital distraction and pedestrian reaction time at roundabout crosswalks, and reported an 84% increase in reaction time and slight rise in crossing time when using a phone. In another study, Mohammed [24] studied distracted pedestrian behaviour at 23 midblock crosswalks to determine the relationship between distraction type, road cross-sections, and other in-person factors and pedestrian walking speed. The author found that crossing with headphones increased walking speeds, using other forms of distraction decreased walking speeds, while using cellphones when crossing had no effect.

According to Raoniar and Maurya [25], pedestrian waiting time has a direct effect on reducing the likelihood of an oncoming pedestrian signal violation. The authors observed that red light signals were more often violated by oncoming pedestrians when neighbours were doing the same in Kolkata city, India. Wu et al. [26] developed a real-time safety model to investigate red-light running violations in the city of Nanjing, China. The results showed that pedestrian red-light running is statistically significantly associated with pedestrian volume, the ratio of males to females, the proportion of pedestrians on phones talking, pedestrian waiting time, green ratio, signal type, and length of the crosswalk. Gong et al. [27] reported a significant correlation between pedestrian violation rate and cycle length, crosswalk length, crossing time, vehicle headway, and age category by conducting an observational and questionnaire case study in Lanzhou City, China.

4. Impact of Geometric Features on Pedestrian Safety

Most past studies have applied the accident-based/traditional safety approach to investigating the impact of overall traffic facilities on traffic safety. As an alternative, surrogate approaches are commonly applied to study the safety effectiveness of engineering treatments of traffic facilities. There are similar investigations of the effectiveness of geometric features (i.e., road slop, cross-section, deceleration/acceleration lane, pavement friction, lane configuration, road shoulder, etc.) on vehicular traffic safety that apply different surrogate approaches [3][28][29][30][31].

Through SSMs, studies have been conducted to investigate the impact of certain geometric features of traffic facilities on pedestrian safety using SSMs. Candappa et al. [32] investigated the pedestrian safety effectiveness of raised crosswalks at roundabout entrances in a quasi-experimental before-and-after study. Results showed a significant reduction in mean approaching speed, reduction in total crossing time, and increased crossing compliance, and pedestrians perceived a more convenient safety crossing compared to the post-treatment. Chaudhari et al. [33] evaluated pedestrian safety at urban midblock crosswalks using different SSMs (vehicle crossing speed, PET, yielding compliance, and conflict rate). The authors concluded that the severity of crosswalk conflicts depends on the street type and land use, that dangerous conflict occurs more at high-speed multilane road crosswalks due to increasing approaching speed and decreasing PET time, and that the PET time for light vehicles is shorter than for heavy vehicles. Zhu et al. [34] developed a novel agent-based framework for evaluating pedestrian safety at unsignalized crosswalks. The authors targeted mid-block crosswalks with refuge islands for the experimental study using relevant behavioural measures, and a sensitivity analysis of the proposed framework showed that the probability of serious conflicts increased with the longer reaction time of drivers and small safety margin time, when visual obstacles exist near crosswalks. Yoshioka et al. [9] proposed a risk index by combining the invisibility probability and the crash impact as a performance measure for evaluating the impact of geometric features of roundabouts on safety and concluded that larger invisibility probability increased with a smaller entry angle and a decrease in deviation angle was associated with greater crash impact.

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