Transportation Research Part F 21 (2013) 159–172

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

The impact of waiting time and other factors on dangerous pedestrian crossings and violations at signalized intersections: A case study in Montreal

Marilyne Brosseau [a], Sohail Zangenehpour [b], Nicolas Saunier [a,*], Luis Miranda-Moreno [b]

[a] Department of Civil, Geological and Mining Engineering, Polytechnique Montréal, C.P. 6079, succursale Centre-Ville, Montréal, Québec H3C 3A7, Canada
[b] Department of Civil Engineering and Applied Mechanics, McGill University, Macdonald Engineering Building, 817 Sherbrooke Street West, Montréal, Québec H3A 2K6, Canada

ARTICLE INFO

Article history:
Received 2 September 2011
Received in revised form 28 May 2013
Accepted 15 September 2013

Keywords:
Pedestrians
Violations
Crossing behavior
Signalized intersections
Safety

ABSTRACT

Pedestrian violations of traffic signals and dangerous crossings at intersections are common. The objective of this study is to determine the impact of pedestrian waiting time at an intersection on the proportion and type of pedestrian violations and dangerous crossings. The amount of waiting depends on signal phasing, time of arrival, and the presence of a pedestrian signal. Thirteen intersections with similar geometry and traffic conditions but different maximum waiting times, seven of which had a pedestrian signal, were observed over at least 2 h to collect crossing information. Data was collected manually for the main analysis and complementary video data was used for validation.

Several factors were identified as having an impact on the proportion of pedestrian violations. In accordance with the literature, age, sex, group size, pedestrian flow and pedestrian signals are associated to pedestrian violations. In addition, other factors were identified in this research, such as maximum waiting time (red phase). It was also determined that an intersection clearing time had an impact on violations and on the proportion of dangerous crossings committed. Also, pedestrians' speeds depended on the type of crossing. The results underline the importance of providing pedestrian signals including countdown displays, which is significantly and negatively linked to dangerous violations and crossings. The results also highlight the importance of pedestrian maximum waiting time as well as clearing time. When designing cycle and phase lengths, particular attention should be paid to pedestrian waiting times that are positively correlated to violations. Minimizing waiting times for pedestrians is expected to reduce dangerous pedestrian behaviors at signalized intersections.

1. Introduction

Pedestrian safety in urban areas is an issue of growing concern. Pedestrian injuries represent an important proportion of total traffic-related injuries in Canada. Between 2004 and 2006, pedestrians represented about 13% of traffic fatalities with an average of 363 pedestrians killed each year (Transport Canada, 2010). In Canadian cities like Montreal, intersections are the most critical roadway elements with a high concentration of vehicle–pedestrian crashes – approximately 60% of pedestrians injuries happened at intersections in this city (Morency and Cloutier, 2005). This is not surprising, given the fact that intersections are where pedestrians are exposed to motorized traffic and are the most vulnerable. They are even more

* Corresponding author. Tel.: +1 (514) 340 4711x4962; fax: +1 (514) 340 3981.
E-mail address: nicolas.saunier@polymtl.ca (N. Saunier).

1369-8478/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.trf.2013.09.010

vulnerable when crossing outside of an intersection crosswalk or during a red-light phase at a signalized intersection, since other road users will not expect their encounter.

To enhance pedestrian safety, local authorities are seeking a combination of appropriate interventions, often referred to as the 3 E's – engineering, enforcement and education. This reflects the fact that traffic-related pedestrian injuries can be the result of one or multiple contributing factors including human behavior, road design, and built environment. Many recent studies have highlighted the important role of road and built environment factors on pedestrian safety (Elvik, 2009; Harwood et al., 2008; Miranda-Moreno et al., 2011). Some studies have also demonstrated the importance of human factors. A few past works have investigated the factors associated with risky behavior of pedestrians, such as red-light violations – (Guo, Gao, Yang, & Jiang, 2011; Li & Fernie, 2010; Lipovac, Vujanic, Maric, & Nesic, in press; Ren, Zhou, Wang, Zhang, & Wang, 2011; Rosenbloom, 2009; Van Houten, Ellis, & Kim, 2007). While pedestrian–vehicle encounters rarely lead to collisions, pedestrian violations are an important factor in pedestrian fatalities. For instance, pedestrian violations contribute to 13% of the pedestrian fatalities in Canada, (Transport Canada, 2010). Pedestrian violations include crossing outside of designated markings, failure to yield to vehicles and crossing during a red-light phase. In the literature, violations have been associated with individual characteristics (age and gender) (Guo et al., 2011; Rosenbloom, 2009; Tiwari, Bangdiwala, Saraswat, & Gauray, 2007; Yagil, 2000; Zhuang & Wu, 2011), personal attitudes such as attitude towards subjective norms and social conformity (Evans & Norman, 1998; Moyano Diaz, 2002; Zhou, Horrey, & Yu, 2009), level of pedestrian density, group size (Rosenbloom, 2009; Zhuang & Wu, 2011), vehicular traffic conditions (Wang, Guo, Gao, & Bubb, 2011; Yagil, 2000; Yang, Deng, Wang, Li, & Wang, 2005), waiting time duration (Li & Fernie, 2010; Tiwari et al., 2007; Van Houten et al., 2007), length of the crossing (Cambon de Lavalette et al., 2009; Cinnamon, Schuurman, & Hameed, 2011), weather conditions (Li & Fernie, 2010; Yang et al., 2005), land use (Cinnamon et al., 2011; Zhuang & Wu, 2011) and trip purpose (Guo et al., 2011). These findings suggest that interventions to address traffic-rule violations should include enforcement and education actions as well as engineering countermeasures, such as the appropriate design of road geometry and traffic controls.

Despite the growing literature on this subject, very few empirical studies exist on effects of the maximum waiting time (red phase), pedestrian time of arrival at an intersection (moment during a phase at which the pedestrian arrived at an intersection approach), and the presence of a pedestrian signal, in particular in the North American context. Past studies have not classified and modeled violations according to the moment of the crossing with respect to the pedestrian signal. Previous studies have involved a very small sample of intersections in the analysis. Also, the use of video data for validation has been little explored.

This paper presents an analysis of pedestrian violations and dangerous crossings at signalized intersections and their relationship with factors such as maximum waiting time, time of arrival, and the presence of a pedestrian signal. These factors have been rarely studied simultaneously and this study adds to the previous ones by examining wait times based on arrival time during the cycle. Moreover, the sample of studied intersections is one of the largest considered in studies of this type. A discrete choice modeling approach is used to model violation types. In addition, video data is collected for two intersections and processed for validation.

The background of this work is presented in the next section. It is followed by a description of the proposed methodology, the presentation and discussion of the experimental results, and the conclusion.

2. Background

Factors associated with pedestrian crossing behavior have been widely studied. These factors are related to the individual characteristics, environment, and other pedestrians' and road users' behavior, and may have combined effects. Studies have determined that men have a tendency to commit more violations than women (Moyano Diaz, 2002; Rosenbloom, 2009; Tiwari et al., 2007; Yagil, 2000) and young adults tend to violate a traffic light more often than other age groups. As people age, they are less likely to take risks while crossing the road, due in part to their decreasing mobility (Guo et al., 2011; Zhuang & Wu, 2011). The people surrounding a pedestrian will also affect her or his crossing behavior. The larger the group of pedestrians, either traveling together or waiting at an intersection, the less likely a pedestrian is to violate the traffic control (Rosenbloom, 2009; Zhuang & Wu, 2011). Teenagers, however, are more likely to violate traffic control in a larger group: Rosenbloom (2009) suggests that teenagers traveling with their peers tend to take bigger risks for reasons such as social acceptance. The trip purpose is also likely to impact the decision to commit violations. People traveling to work or school are more likely to commit violations than people traveling leisurely (Guo et al., 2011).

A pedestrian's decision to violate traffic signalization will also be affected by the characteristics of the intersection. Factors such as the presence of a pedestrian signal (Cambon de Lavalette et al., 2009; Markowitz, Sciortino, Fleck, & Yee, 2006) and of countdown displays (Lipovac et al., in press) have been proven to reduce the proportion of violations. Research has also been undertaken on the waiting duration. Van Houten et al. (2007) examined the relationship between pedestrian waiting time and violations at two signalized midblock crosswalks. Minimum vehicle green time, i.e. pedestrian minimum waiting time, was manipulated from 30 s to 1 and 2 min, and it was found that violation rates increased when the waiting time increased. Similar conclusions were drawn from a study at seven intersections in India (Tiwari et al., 2007). Recent studies have also been done in China. Based on observations at five intersections, Wang et al. (2011) found that people who had violated the traffic signal had a slightly smaller waiting time threshold on average; in a more recent study and using survey data, Ren et al. (2011) studied crossing behaviors at signalized intersections in three cities. They found that the largest