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Safety evaluation of pedestrian behaviour and violations at signalised pedestrian crossings

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ABSTRACT

Pedestrians being the most vulnerable road users, take up about one in every four road deaths in Singapore. Of all pedestrian fatal accidents, 22% occurred at signalised pedestrian crossings though they are time-separated designated facility for pedestrians to cross the road. As such, it is important to examine crossing behaviour of pedestrians at these locations to further enhance their safety. Violators, in particular, have higher risks of encountering traffic conflicts or accidents. Violating behaviour of pedestrians is studied and a relationship is established with dependent variables such as waiting time, the number of conflicting traffic lanes, conflicting vehicular traffic volume and personal characteristics of the pedestrian. The outputs obtained from the study can be used for predicting violations, identifying countermeasures and establishing realistic micro-simulation modelling to further enhance safety at these crossings. Recommendations on enhancing design for pedestrian crossings shall be made where possible.

1. Introduction

Signalised pedestrian crossings are designated channels for pedestrians to get to the other side of the road by stopping the conflicting motorised vehicles. They are typically located at junctions where two or more roads meet or in the middle section of roads (usually known as mid-block crossings). Traffic signals are provided at pedestrian crossings if the conflicting vehicular traffic is heavy and time-separation is needed for safe crossing. If road users obey the rules of the traffic signals strictly with alertness, conflicts (and hence accidents) between road users can be minimised. However, sometime if a person is affected by his or her personal needs (e.g. being late for a meeting) or due to weather conditions (e.g. heavy rain), he or she may take a risk in order to get to his or her destination quickly. That is, he or she may choose to violate the signals and cross the road earlier when he or she perceives it is safe. The perceived safe time gap by a pedestrian could sometimes be misjudged or the violation act is unexpected by a motorist, such that it results in an accident. Therefore, it is important to understand the likely conditions that induce a pedestrian to violate the signals.

From recent 2009–2011 Traffic Police accident statistics (SPF, 2013), it was found that 22% of the pedestrian fatal accidents occurred at signalised pedestrian crossings. Of which, one in three such accidents occurred during the Red Man (RM) phase. The average age of the killed pedestrians is 52 years old. If these pedestrians were to obey the traffic signals, the chances that they become victims of road traffic accidents would be reduced. Examining the overall concentration of pedestrian accidents (number of accidents/hr) at signalised pedestrian crossing revealed that there is a higher chance of accident occurring during peak hours compared to off-peak hours. Accident records that the present research team had access to could not readily identify detailed behaviour and hence it would be useful to analyse behaviour via video footages obtained unobtrusively.

In Singapore, there are mainly two types of signalised pedestrian crossings namely, at the junctions or mid-blocks. Most of the pedestrian crossing signals are attached with countdown-to-red pedestrian timers which start to count down after 6 or 10 s of Steady Green Man (SGM) as SGM changes to Flashing Green Man (FGM) and the counters blinked together with the Green Man during the last five seconds (LFGM). In essence, the counter displays the amount of time left to RM onset. At a typical signalised pedestrian crossing at a junction, during the Green Man phase (GM = SGM + FGM + LFGM), pedestrians still have to look out for errant left turning vehicles (at junction without slip road which is a channel that cuts across the corner of the road, and is not under the control of the traffic signal) and right turning vehicles (during permissive filtering right turn movement). (It is useful to note that Singapore is a left hand traffic country where motorists drive on the left side of the road). According to Singapore Road Traffic Act,

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it is an offence for a pedestrian to cross during the RM phase (Road Traffic Act, 1982). At every traffic light pole, there is an information plate reminding pedestrians of appropriate behaviour at the different phases.

This study utilises unobtrusive video recording to analyse pedestrian crossing behaviour and violations at signalised pedestrian crossings. The findings could be utilised to address problems of when and why pedestrians cross the streets without adhering to traffic regulations. The results of this study shall also be used to build up the basic pedestrian behavioural model for microscopic simulation programme and also be useful for planning, management and facility design of pedestrian traffic. Furthermore, as most cyclists are also using the pedestrian crossings to cross the roads, the study includes some aspects of cyclist crossing behaviour as well.

1.1. Violating behaviours

Violations could be seen as a proxy indication of unacceptable level of service at a signalised pedestrian crossing. If many violations are observed at a crossing, it could mean that the crossing is not performing to its fullest and some measures (e.g. widening of crossing, lengthening GM time) could be done to improve the situation. A pedestrian would generally want to cross where it is convenient in order to get to his or her destination with as little delay as possible (Daff and Cramphorn, 1994). Apart from this basic principle of walking, there are many other reasons why a pedestrian sometimes chooses to cross the road during RM signal. They could be divided into three main groups namely, personal characteristics, situational conditions and environmental conditions.

1.1.1. Effects of personal characteristics

Previous experience of successful violations at the same location may increase a higher chance of violating again (Xu et al., 2013). When one is in a hurry and/or when it is perceived as safe (i.e. there is little or no conflicting traffic), he or she also has a higher tendency to cross earlier (Chen et al., 2011). Other times, it could be due to following the crowd behaviour. Ho (2003) found in a local study that male pedestrians were more likely to start illegally than female pedestrians and that adult group had the highest proportion of illegal crossers compared to young and elderly groups.

1.1.2. Effects of situational conditions

Yagil (2000) found that the presence of other pedestrians is related to the unsafe crossing behaviour of women while the traffic volume affected that of men. The passing motorised traffic volume has an effect on available gaps and hence the likelihood of one to cross illegally (Guo et al., 2011; Xu et al., 2013; Koh and Wong, 2014).

1.1.3. Effects of environmental conditions

Xu et al. (2013) summarised that infrastructure of the pedestrian crossing facilities (such as physical layout, presence of refuge island or guardrail) have influential effects on pedestrian compliance to pedestrian signals. Many found that crossing length is also an important factor (Supernak et al., 2013; Yang and Sun, 2013).

Pedestrian countdown timers are found to increase the number of late starters who managed to finish crossing before RM (Levasseur et al., 2012) and to increase the crossing speeds of pedestrians (Schmitz, 2011).

Evans and Norman (1998) found that perceived behavioural control component of the Theory of Planned Behaviour emerged as the strongest predictor of road crossing intentions. That is, when the behaviour is seen to be easy to perform, the person is more likely to engage in potentially hazardous road safety behaviour.

Wang et al. (2011) found that the probability of compliance (using Weibull distribution) decreases with longer waiting duration (or commonly known as delays) and the covariates that influence crossing behaviour include personal characteristics (age, gender, safety awareness), traffic conditions (pedestrian flow rate, group size, red signal time, vehicular traffic volume) and trip characteristics (trip purpose). It was also found that about half of the pedestrians would not wait longer than 40 s. Brosseau et al. (2012) used logistic regression to model and identify factors that influenced the proportion of the types of crossings (dangerous violations, non-dangerous violations and dangerous legal crossings). The presence of pedestrian signal type, countdown pedestrian signal, group size, gender, age, pedestrian flow and maximum waiting time were found to have significant influencing effect on the models. Instead of presenting different models for different crossing behaviours, Zhou et al. (2013) used a multinomial logit with latent variables to differentiate between different violator types. A non-parametric baseline duration model was introduced by Guo et al. (2011) to model pedestrian waiting duration and the various variables such as personal characteristics, traffic conditions and trip features. Factors that involved pedestrians' subjective willingness were found to play an important role in street crossing behaviour.

If the reasons for violating could be better understood, appropriate countermeasures could be recommended and it can indirectly enhance safety. This forms the motivation of the study which used an unobtrusive observation method to correlate the propensity of violations with various contributing factors.

The paper is structured in two different parts. The first part offers the observation and analysis of crossing behaviour at the signalised crossings. This includes late crossings, incomplete crossings, crossing outside demarcated area and crossing speeds. The second part presents the modelling of contributing factors (in terms of personal characteristics, situational conditions and environmental conditions) on the propensity of violations.

2. Experimental setup

2.1. Data collection

Seven stretches of signalised pedestrian crossings near to transit stations [*Site;* see Table 9 (later)] were selected in the study (see Table 1). The study locations were geographically well-spread across the nation-wide road network. The types of crossings [*LType*] included cross junctions (3), T junctions (2) and mid block (2) pedestrian crossings (see Fig. 1). This is to cover different settings of motorised vehicular exposure to the pedestrians. The crossings have wide range of pedestrian and cyclist interactions and the crossing widths [*XingWidth*] and lengths [*XingLength*] vary from 2.8–6.2 m to 15–26 m, respectively. All the crossings have countdown-to-red pedestrian timers. Video cameras were used to capture footages of crossing behaviour of pedestrians from a vantage point (tied to an extended pole attached to a nearby lamp post) during the evening peak period. The coverage of the video included the waiting area at two ends of the crossing, the crossing and traffic signal. The deployment period was done during non-raining weekday (exclude Friday) evening peak hours (between 5 and 7 pm) with at least one hour uninterrupted recording per location.

2.2. Data reduction

The subjects were categorised by singles, pairs or groups, depending on their proximity with one another, travelling speeds and trajectories (see Fig. 2). This resulted in 12 subject types [*SubjectType*] namely, pedestrian without walking hindrance,