Comparison of Two Pedestrian Behavior Models during Flashing Green Time for Signalized Intersection in a Safety Simulator

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1. Introduction

Pedestrian behaviors at signalized crosswalks mainly include reaction to signal and vehicles, crossing paths and speed profiles, all being important for safety evaluation at intersections. With comparison to the behaviors during pedestrian green (PG), pedestrian clearing behavior during pedestrian flashing green (PFG) is supposed to be given more safety concern. In brief, PFG is provided as much as the clearance time for pedestrians who start entering into the crosswalk at the end of PG to complete crossing. Although Japanese Traffic Law regulates that pedestrians should not enter the crosswalk during PFG, some pedestrians rush into the crosswalks even after the onset of PFG, which may cause higher probability to get conflicts with left-turn vehicles.

For safety assessment, microscopic simulation is often used in practice as an analysis tool. However, existing simulation software, intended for mobility assessment, simplifies the traffic flow and fails to enable a reliable safety evaluation. The models described in this paper are one part of a comprehensive research project aimed at closing this gap. The objective of this study is to analyze the differences of two pedestrian behavior models during PFG in a safety simulator in terms of pedestrian speed and conflicts with left-turn vehicles.

2. Pedestrian Behavior Models

Generally, there are two kinds of assumptions in previous studies. One assumes that all pedestrians choose to go at PG and PFG, which to some extent regards PFG as part of PG[1]. The other assumes that some of the pedestrians choose to stop at the edge of crosswalk while others choose to rush into the crosswalk based on their decisions when approaching[2]. Accordingly, two kinds of pedestrian behavior models are established, which are referred to as GPB (*Go Pedestrian Behavior*) model and SGPB (*Stop-Go Pedestrian Behavior*) model in this paper, respectively.

(1) GPB Model

According to the simulation model developed by Zhang et. al[1], it is assumed that pedestrians decide to stop when signal phase is red, while choose to go at both PG and PFG. This model simplifies the pedestrian behavior during PFG just the same as during PG, which indicates that pedestrians do not conduct any particular behavior after the onset of PFG. In this model, pedestrian speed (v_p) is estimated by assuming normal distribution, which is further a function of crosswalk geometry, pedestrian demand, pedestrian origin-destination and the defined pedestrian signal intervals. The speed model is represented by Equation (1).

$$v_p = NormalRandom(\mu, \sigma) \tag{1}$$

where μ and σ are linear regression functions of the length of crosswalk and the pedestrian demand. The coefficients of these parameters are given by Zhang et. al[1].

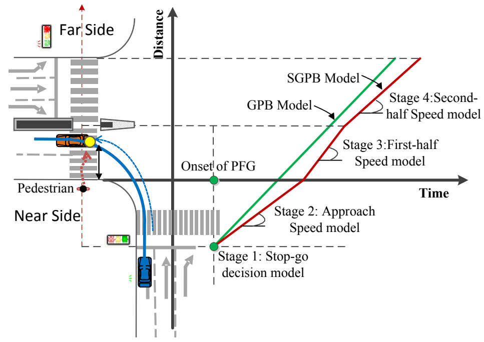


Fig.1 Pedestrian behaviors of two models

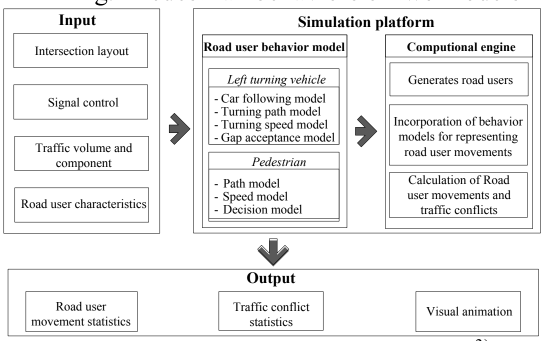


Fig.2 The basic structure of simulation[3]

(2) SGPB Model

During PFG interval, pedestrian crossing behavior is separated into four stages as illustrated in Fig.1. First of all, pedestrians decide to stop or go when approaching crosswalk at the onset of PFG. Stop-Go model is shown as in Equation (2). And then according to the decision, pedestrians will conduct different behaviors on the next stage. If pedestrians decide to go, pedestrian speeds are calculated dependent on whether the pedestrian is on the sidewalk, first-half crosswalk or second-half crosswalk[2]. The basic form of the three speed models is given by Equation (3).

a. Stop-Go Decision Model

$$\Pr(go) = \frac{\exp(V)}{1+\exp(V)} \tag{2}$$

where V is a linear function of distance to crosswalk, speed and movement direction.

b. Speed distribution model

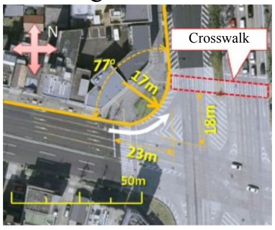
$$\Pr(v_p = x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \exp\left(-\frac{x-\gamma}{\beta}\right)(x-\gamma)^{\alpha-1} \tag{3}$$

where α , β and γ are linear functions of distance to crosswalk, previous speed and pedestrian demand. $\Gamma(\alpha)$ is a Gamma function[2].

3. Simulation Experiment

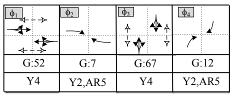
In order to assess the corresponding pedestrian safety, two models are incorporated into a traffic safety simulator[3] to enable the comparison. The basic structure of the simulation is shown in Fig.2. And the interface of simulation is shown in Fig.3.

Fig.3 The interface of simulation[3)]



Time	Turning volume	Pedestrian near-side	Pedestrian far-side
1/18/2008 9:00-12:00	284 (veh/h)	96 (peh/h)	64 (peh/h)

(a)Traffic Volumn



(b)Traffic Signal Phase

Fig.4 Experimental intersection

4. Data analysis

The selected site for simulation is Nishi-osu intersection which is a key multilane intersection in Nagoya City as shown in Fig.4. The conflict between left-turning vehicles from the westbound approach and pedestrians at the north crosswalk is chosen for analysis. The first-half speed and Post-Encroachment Time (PET) are utilized to analyze the differences between two models. Herein, PET is defined as the time difference between left turning vehicle and the nearest pedestrian passing the conflict point.

(1) Pedestrian speed during PFG

Pedestrian speeds from bi-direction on the first-half crosswalk during PFG are selected for analysis. It is found that the pedestrian speed distributions in GPB model and SGPB model are significantly different at the 95% confidence level as shown in Fig.5. The speeds by SGPB model are higher than those by GPB model, which is logical since SGPB model assumes that pedestrians will go faster on the first-half crosswalk if he/she decides to go during PFG.

(2) PET during PG and PFG

To better reflect the probability of conflict between left-turning vehicles and pedestrians, only those PET less than 10s are selected for analysis. Fig.6 presents the PET distributions given by both models. It is found that two means of PET distributions are significantly different at the 95% confidence level. Apparently, the PET distribution by SGPB model is shifted to the right side compared to that by GPB model, which means the PET values become larger after implementing SGPB model into the simulator. It's attributable to several reasons. Firstly, in this simulation case, since left turning vehicles will pass the crosswalk by accepting lag/gap in pedestrian flow[4)], most of the pedestrians can go through the conflict area first. Therefore, when pedestrians go faster, the difference between arriving times of vehicle and pedestrian at the conflict point will become larger, which is characterized by larger PET values. Secondly, higher pedestrian speeds indicate that pedestrians stay on crosswalk for shorter time, which decreases the probability of conflicts.

Based on the aforementioned results, it can be seen that simulation can generate significantly different results if choosing these two kinds of pedestrian behavior models. On the other hand, it implies that GPB model and SGPB model can lead to different safety assessments. Therefore, shorter as PFG duration at signalized intersections, it is necessary to select a more precise model through validation based on large amounts of real data; otherwise it will cause considerable errors when adopting simulation approach to evaluate pedestrian safety performance.

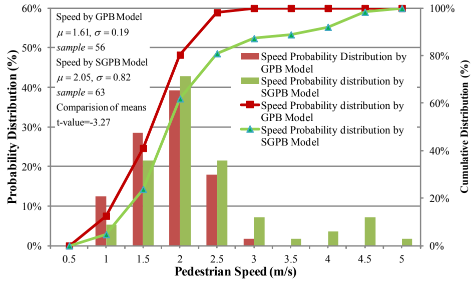


Fig.5 Pedestrian speed distribution on the first-half crosswalk during PFG

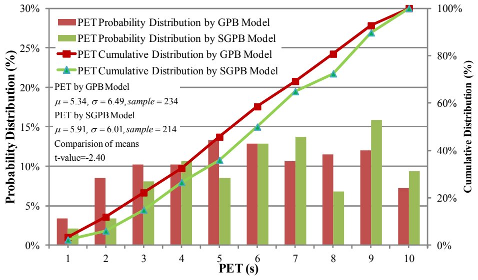


Fig.6 PET distribution during PG and PFG

5. Conclusion and future work

Two pedestrian behavior models during PFG are implemented in a traffic safety simulator. One of the models assumes no differences of pedestrian behavior between PG and PFG. The other model assumes there are three kinds of pedestrian behavior after the onset of PFG, which is different from that during PG. Simulation experiments show that pedestrian speed and PET are significantly different according to T-test, which suggests that implementing these two different assumptions will lead to different safety assessment results. Therefore, towards the future development of simulation, it is quite necessary to calibrate and validate these two models as well as the comparison of observed PET in different geometry and traffic conditions.

Acknowledgement

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