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The crossing speed and safety margin of pedestrians at signalized intersections

Pelin Onelcin[a,*], Yalcin Alver[a]

[a]*Ege University, Civil Engineering Department, Izmir, Turkey*

Abstract

Pedestrians are the vulnerable part of the road users worldwide. A significant number of pedestrian fatalities occur in road traffic accidents each year. Hence, to minimize the pedestrian-vehicle accidents it is important to optimize the signal timings according to pedestrians' crossing speeds and delays at signalized intersections and to understand the pedestrians' safety perception. This paper investigates the pedestrians' crossing speeds, delays and gap perceptions at six signalized intersections in Izmir, Turkey. The crosswalk where the pedestrian density is high at each intersection was selected for observations. Each intersection was observed on weekdays during afternoon peak (12.30-13.30) and evening peak (17.00-18.00) hours using video cameras. In total, 2,694 pedestrian crossings were observed. The average crossing speed is found to be 1.31 m/s and the average 15th percentile crossing speed is found to be 1.07 m/s. Existing delay models are compared with the observed delays and the results showed that none of the models give good results to explain the observed delays and a new model is needed. Speed limit and position*speed limit interaction revealed significant effects on safety margin.

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Keywords: Pedestrians' crossing speed; safety margin; signalized intersection

1. Introduction

No matter which type of transportation mode is chosen by the people, walking is a part of that trip. Hence, each person is a pedestrian during some part of his/her trip. In this paper, the results of an observational study at

* Corresponding author. Tel.: +90-232-388-6026; fax: +90-232-342-5629
E-mail address: onelcinpelin@gmail.com

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signalized intersections are presented. Pedestrians' walking speed, delay and safety margins are given and interpreted in terms of pedestrian safety.

Pedestrians' crossing speed varies for each country. The pedestrian walking speed is given as 1.2 m/s in Highway Capacity Manual (HCM) 2010 (Transportation Research Board, 2010). The number of elderly pedestrians affects the recommended walking speed. For more than 20% elderly pedestrians the crossing speed is given as 1.0 m/s. The Manual on Uniform Traffic Control Devices (MUTCD 2003) recommends a crossing speed of 1.21 m/s. In Turkey the design walking speed is given as 1.4 m/s by Turkish Standards Institution (TSI, 2012). This value is considerably high especially for elderly pedestrians.

In Australia Bennett et al. (2001) found the average crossing speed to be 1.24 m/s. In Jordan, Tarawneh (2001) recommended an average 15^{th} percentile speed of 1.11 m/s. They found that pedestrians who crossed in groups had a higher crossing speed than individuals, the younger pedestrians had a higher crossing speed than the elderly pedestrians, and males walked faster than females. In India, Chandra and Bharti (2013) and in Canada, Montufar et al. (2007) also found that males walked faster than females. Gates et al. (2006) conducted a study in Wisconsin and observed that the individuals walked faster than the pedestrians who crossed in groups. They recommended a 1.2 m/s walking speed.

At signalized intersection not only vehicles but also pedestrians experience delays. Pedestrian phases usually consist of green, clearance and red phases. During red phases pedestrians are not allowed to walk but are allowed to walk during green phase. On the other hand, during clearance phase if pedestrians are already on crosswalk they are required to speed up and if those who are not yet on crosswalk are not allowed to enter the crosswalk. Flashing red or flashing Don't Walk are usually used for clearance phases (Li et al., 2005). The signalized intersection investigated in this paper had green, red and all red signals for pedestrians.

Pedestrian delay estimation is based on uniform arrival rates and fixed pedestrian timing in HCM 2010 (TRB, 2010). The model developed by Braun and Roddin (1978) assumed uniform pedestrian arrival rate, complete signal compliance, fixed cycle length, and no pedestrian actuation.

Virkler (1998) indicated that there are times when pedestrians do not comply with signal rules to minimize their delays. Data was collected at 18 crosswalks in Brisbane, Australia. Pedestrians who crossed during green signal, pedestrians who entered the crosswalk during the clearance interval, pedestrians who entered the crosswalk during the red interval, and the delay of all pedestrians were observed. By modifying the equation developed by Braun and Roddin (1978) they used 69% of the clearance interval for entering the crosswalks.

Li et al. (2005) developed a model for pedestrian delays in developing cities like Xi'an, China. The authors noted that the models currently used in developed countries do not take into account the delay that pedestrians may encounter during the green signal. They found that the average delay of pedestrians during the green signal was 1.9 s. In Turkey, pedestrians experience delays during green signal as well.

Pedestrians making illegal crossings either cross against the lights or away from the lights (Lange et al., 2011). Safety margins for pedestrians who crossed illegally (within the 25 m from the crosswalk) were measured in this study. Safety margin is defined as the difference between the time a pedestrian crosses the traffic and the time the next vehicle arrives at the crossing point by Chu and Baltes (2001). This definition is adopted for the present study.

Age was found to be a predominant factor in the gap perception studies. Oxley et al. (1997) investigated the age related differences in crossing actions and found that elderly pedestrians made less safe choices compared to the young pedestrians despite they left longer gaps because the elderly pedestrians underestimated their crossing times. The study of Connelly et al. (1998) only investigated the gap thresholds of 48 school children whose ages ranged from five to twelve. About one third of the children took into account both distance and the speed of the oncoming vehicle. Oxley et al. (2005) conducted two experiments to investigate the effect of age in selecting safe time gaps in a simulated road-crossing task. Lobjois and Cavallo (2007) focused on the effect of age, vehicle speed, and time constraints on gap acceptance decisions. Their experiments are similar to the experiments of Oxley et al. (2005). Elderly participants accepted lower time gaps at higher speeds. The young-old group had a safety margin between 0–2 s while the old-old group had a negative safety margin of up to -10 s. A negative sign indicates underestimated time required crossing the road. Dommes et al. (2012) used simulator-based training for a group of 20 pedestrians whose age ranged from 65 to 83 to reveal if any training could change the perception of elderly pedestrians for selecting adequate gap for safe crossing. The results of the training showed that elderly participants adopted higher safety margins, made more safe decisions, and made fewer unsafe decisions on the post-tests than pre-test. Lobjois

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