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PEDESTRIANS' CROSSING SPEED AND INFLUENTIAL FACTORS

Key Words

Pedestrians;
Speed;
Road crossing;
Influential factors

Abstract

The pedestrians' behavior and their speed while crossing the road was the subject of interest of the numerous studies in previous years, for a few reasons. In order to improve the pedestrians' safety, better understanding of the pedestrians movement characteristics during roadway crossing is necessary. Also, pedestrians' crossing speed is the input data for the signalized intersection cycle determination, in term of the pedestrians green cycle duration. Thus, in this paper is performed literature review, some of the influential factors are identified, and previously reported results about pedestrians' speed differences are compared and detailed discussed.

1. INTRODUCTION

According to the Global Status Report on Road Safety, the number of road traffic deaths reached 1.35 million in 2016. Road traffic injuries are now the leading cause of death for children and young adults aged 5–29 years, and 8th leading cause of death for people all ages. Particularly risky are vulnerable road users, including pedestrians, cyclists and two-wheelers. Globally, pedestrians represent 23% of all road traffic deaths [1], which leading to the conclusion that described problem is obvious.

Zeger et al. [2] reported non-significantly different crash rates between marked and unmarked crosswalks on two-lane and multi-lane roads while investigated pedestrians behavior in 30 cities across the United States. In contrast with this, there is some findings that risk of the collision is significantly higher during unmarked roadway crossing by pedestrians compared to the crossing at marked crosswalks [3]. However, in order to cross the road safely in both cases (marked crosswalks and unmarked roadway crossings) pedestrians are faced with a complex task to estimate oncoming vehicles moving in term of their distance [4-6], and speed [7]. Pedestrians crossing speed is also an important factor which affects safe or risky road crossing in term of pedestrians vehicles time-spatial interactions during illegal and non-signalized crosswalks crossings.

On the other hand, pedestrians speed is the key factor for pedestrians green cycle duration on the signalized intersections. A better understanding of pedestrians crossing speed can reduce vehicle time losses and provide pedestrians safety, at the same time.

Thus, in this paper will be investigated pedestrians crossing speed in term of its value, but also will be identified some influential factors and tendencies for speed variations among pedestrians, based on the previous findings.

In this paper are presented some studies which investigated pedestrians crossing speed in the various traffic conditions mentioned above (signalized crosswalks crossings, non-signalized crosswalks crossing and unmarked roadway crossings).

2. BASIC FINDINGS REPORTED IN PREVIOUS STUDIES

Tarawneh [8] conducted research on the 27 crosswalks at 12 signalized intersections in the city of Amman (Jordan). Based on the collected data from nearly 3500 pedestrians crossing, the author found some factors affecting the moving speed of the pedestrians, such as age, gender, group size and street width.

Analysis of the results collected during TCRP-NCHRP reported by Fitzpatrick et al. [9] also identifies some influential factors on pedestrians speed. The data set included data from 42 sites in the 7 states across USA (Arizona, California, Maryland, Oregon, Texas, Utah, and Washington) with a sample size of 2522 pedestrians. Authors investigated the potential gender, age, group size, vehicle volume, speed limit and median refuge influence on pedestrians' speed. Results of this study that all the described factors, except gender, are statistically significant, but the practical difference is reported only at age, group size and vehicle volume. Authors found factor gender non-significant, in contrast with previous research made by Tarawneh [8].

Montufar et al. [10] conducted 8 months duration study in the city of Winnipeg (Canada) with a purpose to identify potential pedestrians speed differences during normal walking and road crossing on signalized intersections, taking into account age and gender of the pedestrians and the season effects (winter or summer). Based on the 1792 pedestrians moving observations (1104 during the summer and

668 during the winter), they found statistically significant differences between normal walking speed and crossing speed, regardless of age and gender. Older pedestrians walk faster when they are crossing the road (1.36 m/s on average) than when they are walking normally (1.14 m/s on average). There are also clear differences between the average walking speeds of older male and female pedestrians. Older males walk faster than older females in both, normal walking conditions and crossing conditions, no matter of the season. Like it can be concluded from the described above, age and gender differences have also been reported.

The most of the studies we found are focused on pedestrians' speed while crossing the signalized crosswalks. There is some study [11] that makes a comparison between the pedestrian's speed during signalized and non-signalized crosswalks crossings. They conducted research on 4 locations in Kuala Lumpur (Malaysia), with a total sample size of 1579 crossing observations. The results showed that there is a significant difference of pedestrians crossing comparing these two types of crosswalks and authors concluded that the average pedestrians' speed on the signalized crosswalks (1.31 m/s) is lower from the one on non-signalized (1.39 m/s). Their results also indicate that there are pedestrians' gender and age impact on crossing speed, while the influence of factors lighting (daytime or nighttime) and race don't exist.

While investigated pedestrians illegal road crossing on the 4 overpass locations in Izmir (Turkey) with various speed limits (50 km/h and 70 km/h) Demiroz et al. [12] found that pedestrians' speed during illegal road crossings is influenced by gender and speed limit. By analyzing the speed of 345 pedestrians they found that pedestrians moving faster while crossing the road with a higher speed limit, probably because feel more risky. In contrast with Tarawneh [8] Demiroz et al. [12] reported a non-significant connection between pedestrians crossing speed and group size. Their finding showed that the average crossing speed of individuals pedestrians was 1.21 m/s, while groups' speed found to be 1.20 m/s.

Based on the 2694 pedestrians crossing observations on the 8 signalized crosswalks in Izmir (Turkey) Onelcin and Alver [13] identified age, gender, group size, but also age and group size interaction as influential factors on pedestrians crossing speed. They also found that items carrying affects the pedestrians crossing speed. Pedestrians without any items have reached an average crossing speed 1.32 m/s, while the pedestrians with some kind of item were moving with 1.28 m/s on average, which indicates that items carrying affects the reduction of pedestrians crossing speed.

Muley et al. [14] investigated the pedestrians speed at 3 signalized crosswalks in the city of Doha (Qatar) in term of crosswalks length influence on the pedestrians' entry speed, crossing speed and exit speed. Results of their study showed that crosswalks length affects all investigated pedestrians speed (entry, crossing and exit), which is similar to the results reported by Tarawneh [8] who found that pedestrians' speed is correlated with street width. Both of them concluded that pedestrians' speed is higher on the longer distances.

According to Guo et al. [15] factors age, gender and group size affects the pedestrians crossing speed. The research was conducted on the two-stage pedestrian signalized crosswalk in Zibo City in China with a sample size of 1025 crossing observations in total. Different from others, this authors investigated the potential impact of two-staged crossing (first and the second phase on the roads where directions are separated by middle island) and also the pedestrians moving direction on theirs crossing speed. Results showed that there is no statistical significance in pedestrians' speed depending on moving direction, but it is significantly depending on the crossing stage. Pedestrians speed was higher during second stage crossing (1.59 m/s on average) comparing with the first one (1.31 m/s on average).

Shaaban [16] also reported age, gender, group size and items carrying differences while investigated pedestrians road crossing on the 3 signalized intersections in Doha (Qatar), with a sample size of 1423 crossings in total. In contrast with all previous studies which identified gender as influential factors, he found that females moving faster while crossing the road, compared with males. According to Shaaban [16], speed of younger pedestrians and pedestrians individuals is higher than the older ones and pedestrians in the group, respectively, which is in line with previous findings.

Table 1. Summary of the pedestrians speed influential factors

References	Sample size	FACTORS								
		Gender	Age	Group size	Road width	Traffic volume	Crosswalk type	Items carrying	Speed limit	Walking type
Tarawneh, 2001	nearly 3500	+	+	+	+	/	/	/	/	/
Fitzpatrick et al., 2006	2522	-	+	+	/	+	+	/	+	/
Montufar et al., 2007	1792	+	+	/	/	/	/	/	/	+
Goh et al., 2012	1579	+	+	/	/	/	+	/	/	/
Demiroz et al., 2015	345	+	/	-	/	/	/	/	+	/
Onelcin & Alver, 2017	2694	+	+	+	/	/	/	+	/	/
Muley et al., 2018	211	/	/	/	+	/	/	/	/	+
Guo et al., 2019	1025	+	+	+	/	/	/	/	/	+
Shaaban, 2019	1423	+	+	+	/	/	/	+	/	/

*(„**+**“ Affects pedestrians' speed), („**-**“ Do not affects pedestrians' speed), („**/**“ Not investigated)

Like it can be seen from Table 1, the most frequently investigated potential factors are gender, age and group size, respectively. Those factors are also the most frequently confirmed, so their influence on pedestrians crossing speed will be detailed discussed below.

3. ANALYSIS OF PEDESTRIAN'S SPEED DIFFERENCES DEPENDING ON INFLUENTIAL FACTORS

3.1. Gender as an influential factor

Numerous studies have investigated pedestrians' gender influence on their speed while crossing the road [8-13,15,16]. All the mentioned studies have been confirmed the gender influence, except Fitzpatrick et al. [9]. Results from almost all described studies showed that males pedestrians are moving faster while crossing the road comparing to female pedestrians. There is only one exception study which reported the opposite speed tendency in term of pedestrians gender [16]. Results from those studies have been extracted and presented graphically on figure 1. Since Montufar et al. [10] investigated pedestrians' normal (during sidewalks moving) and signalizes crosswalk crossing, it is important to note that we take into considerations only road crossing speeds. The slowest pedestrians' speed for both genders has been reported by Demiroz et al. [12], while the fastest crossing pedestrians speed was found by Montufar et al. [10]. These results are surprising, considering that Demiroz et al. [12] explored illegal pedestrian road crossings on the overpass locations, so it was expected faster moving.

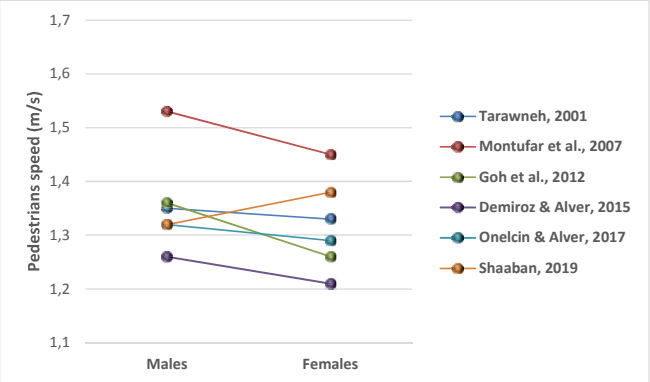

Figure 1. Pedestrians' crossing speeds depending on gender

3.2. Age as an influential factor

The results of all studies analyzed in this paper [8-11,13,15,16] showed that the slowest pedestrians are the oldest ones, which is not surprising considering their limited sensory and psychomotor abilities.

The problem with the comparison of age-related pedestrians' speed characteristics was various defined age categories by the authors. For example, Montufar et al. [10], defined only two age categories, such as younger (between 20 and 64 years) and older pedestrians (65 years and older). On the other hand, Tarawneh [8], defined five age categories (<20; 21-30; 31-45; 46-65; >65 years). Since the most analyzed studies contained three age groups, we made the comparative analysis

with this number of age groups (younger, adult and older), respecting the years of the age categories suggested by previous authors.

Other problem is in relation to pedestrians age determination, thus the methodology of most studies contained pedestrians age characteristic extraction from the video records, so the accuracy of determined pedestrians age depends on the authors' subjective abilities.

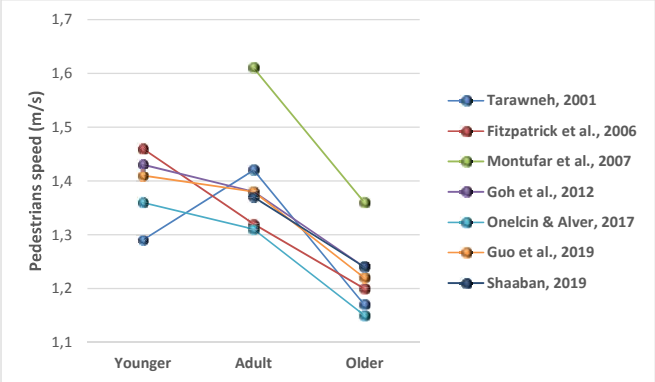

Figure 2. Pedestrians' crossing speeds depending on age

From figure 2 it can be seen that there are clear speed reduction tendencies with age increasing. An exception is results reported by Tarawhen [8], who found that adults crossed the road faster than younger pedestrians, in contrast with other studies. The only one exception in term od speed value is noticed in the study conducted by Montufar et al. [10], who reported higher speed for both adult and older pedestrians, compared with other authors.

3.3. Group as an influential factor

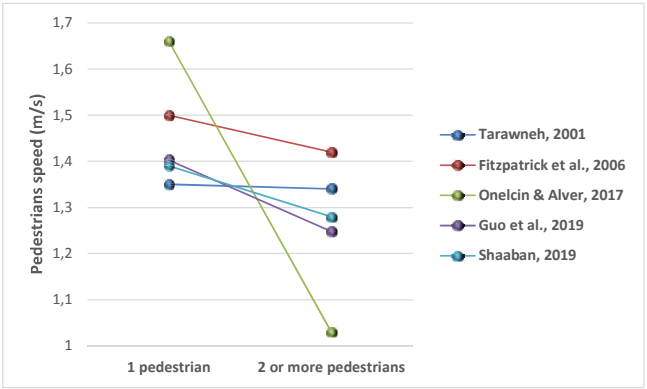

Figure 3. Pedestrians' crossing speeds depending on group

From figure 3 it can be seen that the results of all studies showed that pedestrians cross the road slower while they are moving in a group. Results reported by Onelcin and Alver [13] differ from the other studies in term of speed values. They reported the highest speed of individual pedestrian (1.66 m/s), and the slowest for group od pedestrians (1.03 m/s), comparing with other studies.

3.4. Summary of the pedestrians speed values

In table 2 is presented the descriptive statistics of the pedestrians' speed values depending on factors, including all the results of the studies analyzed in this paper.

Table 2. Descriptive statistics for pedestrians' speed value depending on influential factors

Factors	Categories	PEDESTRIANS SPEED (m/s)			
		Mean	**SD**	**Min**	**Max**
GENDER	**Males**	1.36	0.08	1.26	1.53
	Females	1.32	0.08	1.21	1.45
AGE	**Younger**	1.39	0.06	1.29	1.46
	Adult	1.4	0.09	1.31	1.61
	Older	1.23	0.06	1.15	1.36
GROUP	**1 pedestrian**	1.46	0.11	1.35	1.66
	2 or more pedestrians	1.26	0.13	1.03	1.42

Also, previously reported results are extracted and analyzed using paired t-test (factors gender and group) and ANOVA test (factor age). The input data were the averaged speed values reported by analyzed studies [8-16], with respect on speed differences between pedestrian categories.

Table 3. Paired T-test and ANOVA test results

	Mean (Pairs)	**95% CI**		**t (F)**	**Sig. (2-tailed)**
		Lower	**Upper**		
Paired T-test					
GENDER	0.037	-0.022	0.096	1.601	0.170
Paired T-test					
GROUP	0.197	-0.111	0.505	1.778	0.150
ANOVA					
AGE	/	/	/	9.537	**0.002***

*(α=0.05)

Paired T-test showed that there is no statistically significant difference between male and female speed (Sig.=0.17), as well as individual pedestrians comparing with pedestrians in a group (Sig.=0.15) On the other side, there is statistically significant crossing speed differences between the younger, adult and older

pedestrians. Post-hoc Tukey test indicates that older pedestrians speed is significantly slower than the other ones.

4. CONCLUSION

Like it is described above, the most frequently investigated and also confirmed pedestrians crossing speed influential factors are gender, age and group size, which indicates that their influence is obvious. Although the authors of the previous studies reported statistically significant speed differences between males and females pedestrians, such as individuals versus pedestrians in a group, we found non-significant speed differences based on average pedestrians' speed reported by previous authors. On the other hand, we found statistically significant speed differences between age groups, primarily at the older pedestrians' speed.

It is important to note that all the analyzed studies treated only normal pedestrians crossing, leaving out of the analysis some extreme movements, such as slow-moving or running. The purpose of normal pedestrians crossing extraction is taking into consideration the highest percent of the pedestrian's movements and their speeds. Since pedestrians speed plays an important role in the green cycle length determination on pedestrians signals on the signalized intersections, it must include tendencies for pedestrians' speed variations as much as possible, with the aim to provide pedestrians safe road crossings. On example, all the analyzed studies in this paper reported that older pedestrians speed is significantly lower than the other ones, thus this facts also need to be considered for green cycle length determination. On the other hand, if the signalized intersections are located in the area with a higher percentage of the younger pedestrians (on examples university areas), designers should take into consideration younger pedestrians ability to move faster and determine the green cycle in accordance, to minimize unnecessary vehicle time losses.

One more interesting finding in this term is pedestrians' speed differences depending on road width [8], i.e crosswalk length [14]. This findings are underinvestigated, but can also be very important factors for green cycle length determination. Thus, the detailed examination of the road width influence on the pedestrian's speed during signalized crosswalk crossings is a suggestion for future research.

Also, there are some findings [9,12] that pedestrians crossing speed varies depending on road speed limits on the non-signalized crosswalks, which also requires more intention in the future, primarily because of pedestrians safety improvement.

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