ANA TRPKOVIĆ, M.Sc.[1]
(Corresponding author)
E-mail: a.trpkovic@sf.bg.ac.rs
MARINA MILENKOVIĆ, M.Sc.[1]
E-mail: marina.milenkovic@sf.bg.ac.rs
MILAN VUJANIĆ, Ph.D.[1]
E-mail: m.vujanic@sf.bg.ac.rs
BRANIMIR STANIĆ, Ph.D.[1]
E-mail: b.stanic@sf.bg.ac.rs
DRAŽENKO GLAVIĆ, Ph.D.[1]
E-mail: drazen@sf.bg.ac.rs
[1] University of Belgrade,
Faculty of Transport and Traffic Engineering,
Vojvode Stepe 305, 11000 Belgrade, Republic of Serbia

Safety and Security in Traffic
Preliminary Communication
Submitted: 18 Mar. 2016
Accepted: 16 Nov. 2016

THE CROSSING SPEED OF ELDERLY PEDESTRIANS

ABSTRACT

The population of elderly people is rapidly growing and in terms of safety, senior pedestrians represent one of the most vulnerable group. The pedestrian crossing speed is a significant input parameter in traffic engineering, which can have effect on pedestrians' safety, especially of older population. The objective of this study was to determine the value of the crossing speed of elderly pedestrians (65+) for different types of urban crossings. The research was conducted at ten intersections in the city of Belgrade, Serbia, using the method of direct observation and a questionnaire for collecting data. The data were analysed in the statistical software package IBM SPSS Statistics. The results showed that elderly pedestrians walk slower and the crossing type significantly influenced the speed of older population. The order of crossing types in relation to the measured speed is ranked as follows, from the lowest to the highest speed value: unsignalized, signalized, signalized with pedestrian countdown display, signalized with pedestrian island and pedestrian countdown display and finally signalized crossing with pedestrian island. According to the questionnaire results, the elderly recognize the importance of implementing pedestrian counters. This indicates the necessity to provide safe street crossing for the elderly using the corresponding engineering measures.

KEY WORDS

elderly pedestrians; crossing speed; pedestrian crossing type; safety;

1. INTRODUCTION

In the Republic of Serbia, people older than 65 comprise 18% of the total population and also 25% of the total number of fatalities in traffic. In other words, each fourth traffic fatality involves an older person [1]. According to the statistical indicators of traffic safety in Serbia, almost half of the casualties, (49%) within this age group, are pedestrians [1].

Traffic accidents involving pedestrians have become a significant safety problem all over the world. According to previous research, the risk of participating in a traffic accident while crossing the street increases with age [2]. Also, traffic accidents including older pedestrians are more frequent in urban areas [3] and at intersections [4]. The CEMT [5] added that older pedestrians were more involved in crashes within built-up areas than outside them, that they tended to be at fault in their collisions, and that collisions were often due to their inability to handle complex traffic situations. Compared to their younger counterparts, old pedestrians exhibit declining walking skills, with a walking speed decrease, less stable balance, less efficient wayfinding strategies, and a greater number of unsafe road crossing behaviours. These difficulties are linked to age-related changes in sensorial, cognitive, physical, and self-perception abilities [6].

One of the basic reasons why pedestrians older than 65 account for more traffic accidents than younger pedestrians, is related to their walking speed while crossing the street [7]. Generally, older pedestrians walk more slowly than younger pedestrians [8]. Fitzpatrick et al. [9] analysed the speed of 2,445 pedestrians at 42 locations in seven countries and found out that older pedestrians moved significantly slower than younger pedestrians. The mean walking speed of older pedestrians varies in the studies from 0.97 m/s to 1.4 m/s, and the 15^{th} percentile walking speed is between 0.67 m/s and 1.2 m/s [8].

Tarawneh [10] studied the walking speeds of pedestrians at different walking locations and he found out that pedestrians walked the fastest at pedestrian crossings. Analysing the elderly crossing speed at different types of intersections, Coffin & Morrall [11] found out that at unsignalized intersections older pedestrians walked slower than at signalized intersections. Stollof et al. [8] studied the walking speed of pedestrians who were crossing the street at traditional signalized intersections and signalized intersections with pedestrian countdown displays. The walking speed of older pedestrians was higher at the intersections with pedestrian countdown displays (1.46 m/s) than at traditional signalized intersections (1.40 m/s). Analyzing the walking speed of pedestrians before and after the installation of countdown displays at 8 intersections, York et al. [12] found that after the installation of countdown displays the speeds of pedestrians increased by 3% to 10% depending on the location. Schmitz [13] examined the effect of countdown displays on pedestrian safety and crossing efficiency. It was noticed that the countdown display increased the pedestrian crossing speed by 0.61 m/s at two intersections in Lincoln (USA).

On the other hand, pedestrian crossing safety is highly dependent on the intersection design and crossing facilities. Infrastructure improvements are an important part of road safety enhancements that increase the walking and cycling safety and decrease fatalities [14]. Zegeer [15] and Davies [16] proposed that street facilities, such as adequate pedestrian crossing facilities, pedestrian refuges, curb build-outs, standard footways, tactile paving surfaces and traffic calming, could enhance pedestrian safety. Bernhoft and Carstensen [17] analysed preferences and behaviour of older pedestrians and cyclists by means of a questionnaire. It was found that older pedestrians appreciated pedestrian facilities more than the younger ones, and were also more influenced by the fact that an action was illegal. Asadi-Shekari et al. [18] conceptualized the pedestrian safety index (PSI), which evaluates the facilities along the streets for pedestrians. The pedestrian safety enhancements stated that using this method could enhance the safety of older and disabled pedestrians who suffer most from the lack of facilities.

By reviewing literature, it was concluded that different studies had analysed the value of walking speed of older population from various aspects at urban intersections. However, few studies dealt with the impact of different crossing types on elderly pedestrian speed. So far, this kind of research has not been conducted in Serbia and this paper represents one of the first attempts to examine this topic in local conditions. The main objectives of this study were to determine the crossing speed of elderly pedestrians at specified types of pedestrian crossings in local conditions, and differences in speed values related to the defined crossing types. Also, gender and age distinctions in crossing speed were determined, as well as the percentage of violators on crosswalks. In addition, older pedestrians' perception of safety at each of the observed crossing types was examined.

2. RESEARCH METHODOLOGY

2.1 Materials and methods

The research focuses on investigating the crossing speed of older pedestrians at urban intersections. It was conducted in the city of Belgrade, Serbia, according to the defined methodology. In this study, the crossing walking speed is defined as the speed at which pedestrians walk when crossing an intersection. The term "old" refers to the users older than 65 years of age. The method of direct observation and questionnaire was used for collecting data.

Pedestrian crossings are classified in five different categories. Depending on the geometric characteristics and the applied traffic regulation measures at intersections, the following types have been defined: unsignalized, signalized, signalized with a pedestrian countdown display (signalized with PCD), signalized with a pedestrian island (signalized with PI) and signalized with a pedestrian countdown display and a pedestrian island (signalized with PCD and PI).

The research was conducted at ten selected sites, on a sample of elderly pedestrians (n=1,073, 65+) in two time intervals of the day (morning - after 9 AM and afternoon - after 5 PM). For each of the crossing types, the measuring of speed was performed at two representative intersections. The selected pedestrian crossings are located in the vicinity of potentially attractive places for older population, i.e. near marketplaces, hospitals and cultural attractions. In terms of safety, the selected locations can be defined as potentially "dangerous" for the observed age category. Five out of ten selected crossings are located along the main arterial street in Belgrade and represent all of the previously defined types. Other intersections are located at the sites in or near the city centre and they have similar geometric and management characteristics.

The measurement was performed using the technique of manual data collection, i.e. measuring and noting the values of the crossing time at the defined locations on the prepared recording sheets. The necessary lengths and current traffic signal plans were previously recorded at the locations concerned. The crossing time of older pedestrians was measured using a stopwatch and noted down on the recording sheets. The pedestrian crossing time was measured from the moment when the pedestrian left the sidewalk with at least one foot and started crossing the street. The measurement ended at the moment when the pedestrian left the crosswalk with both feet and stepped onto the sidewalk. Pedestrian crossing speed values were obtained by computation.

In addition, data on the "efficiency" in crossing the street were also collected. The researchers noted the information about the signal light on the pedestrian display at the beginning and ending of the crossing for each recorded user. Thus, the number of violators was also obtained, i.e. the number of elderly pedestrians who started crossing during the red light interval.

A short questionnaire was conducted on a sample of older pedestrians, which represents part of the total recorded population. The respondents willing to participate were asked to answer a few questions after having crossed the street. Their responses were recorded in the prepared questionnaire. The five-point Likert scale was used for the formulation of answers. The respondents gave their perception of the available time for street crossing, the subjective feeling of safety while crossing the street, the importance of pedestrian islands and/or PCD devices. They also had the possibility to indicate the most important problems while crossing the street.

2.2 Statistical analysis

The database was formed in Microsoft Office Excel v.2010 program. The data were analysed in the statistical software package IBM SPSS Statistics v. 21, and the standard methods of descriptive and analytic statistics were applied. The normality of distribution was tested by the inspection of histogram and by the Kolmogorov-Smirnov test. Since the distributions of all continual variables did not statistically significantly deviate from the normal distribution, parameter methods were used. The arithmetic mean, median and the 15th percentile, i.e. the absolute (n) and relative frequencies (%), were used for the description, and Pearson's χ^2 test, independent samples T-test and one-factor analysis of variance (ANOVA) were used for estimating the significance of the difference. The null hypothesis (H_0) was set up by saying: there is no statistically significant difference between the groups; and the working hypothesis (H_a) saying: there is a statistically significant difference between the groups. The threshold of the statistical significance was set up at 5%. Thus, if $p \leq 0.05$, H_0 is rejected and H_a is accepted. If $p>0.05$, H_0 is accepted.

According to the objectives of the paper, one main (H1) and four additional (H2,H3,H4,H5) hypotheses are defined:

H1. The walking speeds of older pedestrians differ statistically significantly on pedestrian crossings at different intersection types.

H2. Older pedestrians' speed differs statistically significantly according to the defined age categories within the observed group

H3. There is a statistically significant difference between the crossing speed of older male and female pedestrians.

H4. There is a statistically significant difference in the efficiency of older pedestrians' crossing according to the observed intersection types.

H5. There is a statistically significant difference in the subjective feeling of safety of older pedestrans according to the pedestrian crossing type.

3. RESULTS

3.1 Crossing speed results

The results of this research have shown that the average crossing speed of older pedestrians is 1.1 m/s and the 15th percentile speed is 0.88 m/s. The Kolmogorov-Smirnov test was used for estimating the normality of the crossing speed distribution and the obtained result is close to the limiting value of normality estimation (p=0.026). Considering the sample size it can be concluded that the pedestrian crossing speed has normal distribution (*Figure 1*).

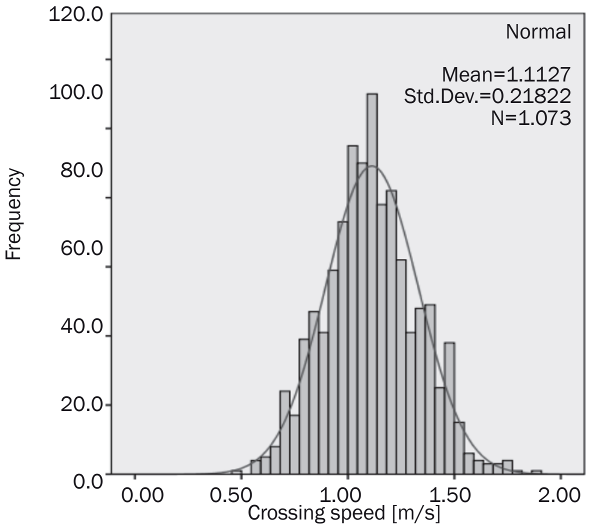

Figure 1 – Speed distribution

Table 1 shows the crossing speed values for older men and women. The independent samples T-test was used for estimating the significance of the difference in crossing speeds of pedestrians of male and female gender, and it determined that there was no statistically significant difference in the speed of older male and female pedestrians (t=-1.614; p=0.104).

Table 1 – The speed of older pedestrians according to gender

	Gender	*n*	Mean	SD
Crossing speed [m/s]	Female	505	1.0603	0.21667
	Male	568	1.0988	0.25199

The analysis of the effect of the pedestrian age on the crossing speed was conducted in the study and it was analysed only for the interviewed pedestrians. In order to eliminate the statistically significant difference in the number of pedestrians per age groups, the difference in the mean value of two pedestrian groups (those aged from 65 to 70 and those over 70) was considered. The independent samples T-test determined that the pedestrians aged 65-70 moved statistically significantly faster while crossing the street than the pedestrians older than 70 (t=5.432; p<0.001). The crossing speed values for these age groups are shown in *Table 2*.

Table 2 – The speeds of older pedestrians according to age groups

	Age Group	*n*	Mean	SD
Crossing speed [m/s]	65-70	199	1.12	0.21
	>70	156	0.99	0.24

Following the general analysis of the speed of older pedestrians (for the total sample), the paper considered the speed of older pedestrians according to different types of intersections. *Table 3* gives the amounts of mean values of the speeds, as well as the 15th percentile speeds for each pedestrian crossing type.

One-factor analysis of variance (ANOVA) refers to the continuous variable representing the speed of older pedestrians and the categorical variable representing pedestrian crossing type. ANOVA determined that there was a statistically significant difference between the mean values of pedestrian speeds according to the observed pedestrian crossing types (F(4.1068)=30.911; p<0.001). Speed dispersion according to pedestrian crossing types is represented in *Figure 2*.

The subsequent Tukey Post-hoc test defined the differences in mean values for each pair of intersections (*Table 4*). The results showed that at unsignalized intersections the pedestrians walked statistically significantly slower than pedestrians at other types of intersections (p<0.005), while pedestrians at signalized intersections with pedestrian islands walked statistically significantly faster than pedestrians at all other pedestrian crossing types (p<0.005). It was also found that pedestrians at signalized intersections with pedestrian countdown displays and pedestrians at signalized intersections with countdown displays and pedestrian islands walked faster than the pedestrians at traditional signalized intersections. However, these differences were not statistically significant (p>0.005).

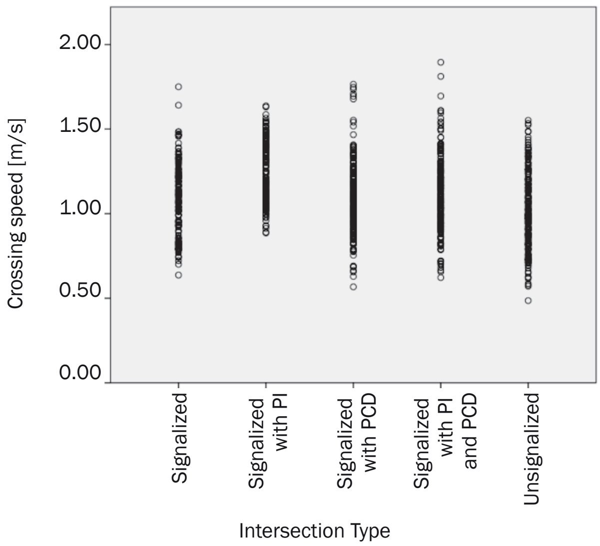

Figure 2 – Speed dispersion

The paper also considered the efficiency of pedestrian crossing according to the observed pedestrian crossing types. In this paper the term “efficient crossing” is defined as the street crossing, from curb to curb, which started at the green light and finished at the green light. *Table 5* shows the results which indicate the percentage of the pedestrians who efficiently crossed the street depending on the pedestrian crossing type. *Table 5* shows that the most efficient pedestrians were those at signalized intersections with pedestrian countdown displays (82.4 %), then those at signalized intersections with pedestrian islands (40.5 %) and finally those at intersections with both countdown displays and islands (18.3 %). The least efficient pedestrians were those at standard signalized intersections (12.2 %). This difference in the efficiency in crossing of pedestrians according to the observed pedestrian crossing types was statistically significant (χ^2=378.721; p<0.001). *Table 5* also shows that older pedestrians made the biggest number of violations at signalized intersections with an island (17.0 %) and at signalized intersections with both an island and a countdown display (16.4%).

Table 3 – The speeds of older pedestrians according to the observed pedestrian crossing types

Pedestrian crossing type	Crossing speed [m/s]				
	n	Mean	Median	15th percentile	SD
Signalized	164	1.08	1.08	0.82	0.22
Signalized with PI*	247	1.22	1.17	1.05	0.17
Signalized with PCD**	210	1.11	1.10	0.90	0.21
Signalized with PI and PCD	220	1.12	1.10	0.91	0.21
Unsignalized	232	1.02	0.99	0.77	0.22

Pedestrian island (PI); Pedestrian countdown displey (PCD)*

Table 4 – Tukey Post-hoc test of the significance of difference in the mean values of pedestrian speeds for each pair of intersections

Pedestrian crossing type		Mean Difference (I-J)	*p*
Signalized	Signalized with PI	-0.15*	0.000
	Signalized with PCD	-0.03	0.589
	Signalized with PI and PCD	-0.04	0.364
	Unsignalized	0.06*	0.045
Signalized with PI	Signalized	0.15*	0.000
	Signalized with PCD	0.11*	0.000
	Signalized with PI and PCD	0.11*	0.000
	Unsignalized	0.20*	0.000
Signalized with PCD	Signalized	0.03	0.589
	Signalized with PI	-0.11*	0.000
	Signalized with PI and PCD	-0.01	0.996
	Unsignalized	0.09*	0.000
Signalized with PI and PCD	Signalized	0.04	0.364
	Signalized with PI	-0.11*	0.000
	Signalized with PCD	0.01	0.996
	Unsignalized	0.10*	0.000
Unsignalized	Signalized	-0.06*	0.045
	Signalized with PI	-0.20*	0.000
	Signalized with PCD	-0.09*	0.000
	Signalized with PI and PCD	-0.10*	0.000

**The mean difference is significant at the 0.05 level*

Table 5 – The efficiency of street crossing by older pedestrians according to the considered pedestrian crossing types

	Crossing efficiency							
	Started at the green light and finished at the green light		Started at the green light and finished at the flashing green light		Started at the green light and finished at the red light		Violation	
	n	%	*n*	%	*n*	%	*n*	%
Signalized	20	12,2%	64	39,0%	70	42,7%	10	6,1%
Signalized with PI	100	40,5%	48	19,4%	57	23,1%	42	17,0%
Signalized with PCD	173	82,4%	11	5,2%	15	7,1%	11	5,2%
Signalized with PI and PCD	40	18,3%	8	3,7%	135	61,6%	36	16,4%

** Value of Pearson's chi-square test: χ^2=378.721; p<0.001*

3.2 Questionnaire results

The questionnaire analysed the attitudes of 355 older pedestrians. The interviewees gave their opinions on the available time for street crossing, the subjective feeling of safety while crossing the street, the importance of pedestrian islands and/or PCD devices. The results of this analysis are presented below.

The subjective feeling of available time

The results have shown that there is a statistically significant difference between the considered pedestrian crossing types and the subjective feeling of the respondents regarding the subjective feeling of time which they had at their disposal for walking over the pedestrian crossing (F=5.581; p<0.001). According to the respondents' answers, the signalized intersection is defined as the poorest in this sense (p<0.005). The users believe that they are given the longest time at intersections with PCD.

The subjective feeling of safety while crossing the street

The results have shown that there is a statistically significant difference between the considered pedestrian crossing types and the subjective feeling of the respondents regarding safety while walking across the pedestrian crossing (F=6.168; p<0.001). The users felt the safest at intersections with PCD, i.e. it was determined that there was a statistically significant difference in the subjective feeling of safe crossing between the intersection with PCD and other pedestrian crossing types ($p<0.005$), except for the intersection with a pedestrian island ($p=0.132$). Safety was evaluated as the poorest at the traditional signalized intersection.

To which extent a countdown display enables/would enable easier and safer street crossing

The results have shown that there is a statistically significant difference between the considered pedestrian crossing types and the evaluation of the importance of implementing a PCD device in terms of easier and safer street crossing ($F=12.051$; $p<0.001$). The users expressed the most favourable opinions on this issue at the crossings with PCD devices. The difference between the intersection with a PCD and other pedestrian crossing types was statistically significant ($p<0.005$), except for the signalized intersection with a pedestrian island and a PCD ($p=0.138$).

To which extent a pedestrian island enables/would enable easier and safer street crossing

The results have shown that there is a statistically significant difference between the considered pedestrian crossing types and the evaluation of the importance of the existence of a pedestrian island in terms of easier and safer street crossing ($F=10.785$; $p<0.001$). It is interesting that the users ranked this measure least favourably at the intersections with pedestrian islands, while at other pedestrian crossing types they stated that implementing a pedestrian island would lead to easier and safer street crossing to a certain degree.

4. DISCUSSION

The conducted research determined the value of the 15th percentile speed of older pedestrians for the entire sample, as well as the value of this parameter for the defined pedestrian crossing types. The fifteenth percentile speed is the generally accepted value used for determining the signal plan for pedestrians [19]. Fifteen percent of pedestrians walk at this speed or slower than this speed (the 15th percentile speed). This measure is analogous to the most measures of the 85th percentile used commonly in traffic engineering and designing street and road networks. For the entire sample, the value of the 15th percentile speed of older pedestrians amounted to 0.88 m/s. Having in mind that, reviewing the relevant literature, Stollof et al. [8] determined that the 15th percentile walking speed of older pedestrians was between 0.67 m/s and 1.219 m/s, it can be concluded that the results of this research are in concordance with the results of the previous research. The US Institute of Transportation Engineers (ITE) [19] suggested the speed of 0.75 m/s at the location with the higher share of older people. The crossing speeds given in HCM [20] were based on the share of the elderly in the total share of the pedestrians who used the facility. The speed of 1.2 m/s was recommended for the crossings with less than 20% of the elderly, and the speed of 1.0 m/s for the values above 20%. The US Manual on Uniform Traffic Control Devices from 2003 [21] recommended the standard value of 1.2 m/s. In 2009, the US MUTCD updated the walking speed used for design to be 0.91 m/s, to provide more inclusive service for pedestrians. Also, the next update for the Canadian MUTCD in 2015 included the range of 0.8 m/s to 1.0 m/s for a pedestrian walking speed [22]. It is common practice in Serbia to use the crossing speed of 1.2 m/s in traffic engineering calculations. Previous results have indicated that 1.2 m/s is not sufficient for slower pedestrians, especially older pedestrians and pedestrians using mobility devices. On the basis of the above mentioned, it can be concluded that there are large variations in the stated speeds in different countries and that there is a general need to define these values for local conditions.

This research results have also shown that older female pedestrians walk more slowly than older male pedestrians. Dahlstedt [23] reported that older women were slower than older men by 0.15 m/s on the average at normal walking speed. Generally, previous research concluded that women walked statistically significantly slower than men [24-26]. The paper also conducted the analysis of the effect of the pedestrian age on the crossing speed. The results of this analysis have shown that the pedestrians aged 65-70 walk significantly faster while crossing the street than the pedestrians older than 70. These results are in accordance with previous research which also determined that the older people walk slower.

This research defined the values of the 15th percentile speeds of older pedestrians for the selected pedestrian crossing types. The research results have shown that there is a statistically significant difference in the values of crossing speed of older population in relation to the pedestrian crossing type. Older pedestrians walk slowest at unsignalized intersections, which can be explained by the fact that there is no time limitation for street crossing, as opposed to signalized intersections. Thus, it can be assumed that this speed value is the most approximate to the normal walking speed of older people and therefore its values are lower than the measured crossing speeds at other types of signalized intersections. The fact that unsignalized crossings are unsafe, i.e. that pedestrians are only visually but not temporally protected, did not prompt older pedestrians to increase their speed while crossing the street. The speed of older pedestrians at unsignalized intersections highlights the necessary application of the engineering measures at the crossings where a higher percentage of this age category can be expected. Analyzing the speeds at unsignalized and signalized crossings, Coffin & Morrall [11] and Gates et al. [7] also found that at unsignalized intersections older pedestrians walked slower than at signalized intersections.

At signalized intersections pedestrians are forced to adjust their speed to the management and infrastructure parameters, so the measured speeds are significantly higher than the values of this parameter at unsignalized intersections. The results of this research showed that older pedestrians moved faster at signalized intersections with PCD than at standard intersections. However, this difference was not statistically significant. Previous research has generally determined that the existence of counters at signalized intersections has effect on the increase of pedestrian speed [8, 12-13].

Older pedestrians walked fastest at signalized intersections with a pedestrian island, which is directly related to the crossing length and the available time. At signalized intersections with PCD, with or without a pedestrian island, the speed is statistically significantly lower than at signalized intersections with a pedestrian island. These values are the consequence of countdown displays, which enables pedestrians to adjust their walking speed to the time at the PCD display. The walking speed of older pedestrians at traditional intersections is the lowest in comparison to other studied types of signalized intersections, but it is still significantly higher than the speeds recorded at unsignalized intersections.

When it comes to signalized intersections, this paper also studied the percentage of violations, as well as the efficiency of pedestrians regarding the defined pedestrian crossing types. The smallest number of violations was recorded at intersections with PCD, where only 5.2% of older pedestrians started walking at the red traffic light. These are followed by standard signalized intersections with 6.1% violators, while a high percentage of violations (approximately 17%) was recorded at the remaining two types of signalized intersections with a pedestrian island. This leads to the conclusion that in some cases the existence of the pedestrian island "encourages" pedestrians, even the elderly ones, to behave in an illicit manner. The results of a study also conducted in Serbia have shown that a countdown display reduces the total number of violators [27]. Xu et al. [28] summarized that the infrastructure of the pedestrian crossing facilities (such as physical layout, presence of refuge island or guardrail) had influential effects on pedestrian compliance with pedestrian signals. Koh et al. [29] found that the variables that contributed to the probability of violating were the number of crossing lanes, being accompanied or not, gender, crossing length, accepted waiting time, standing position of the subject, the number of passing vehicles and the number of violating pedestrians. The island itself cannot represent the cause of the unallowed behaviour. However, correlated with the total crossing length and the existing signal plan, it could have a negative effect on the behaviour of pedestrians. The efficiency of crossing, i.e. the percentage of those who started and completed walking within the green light interval, is the highest at signalized intersections with PCD and it amounts to as much as 82.4%. Similar findings were obtained by Stollof et al. [8] who determined that a higher percentage of pedestrians successfully completed pedestrian crossing under the countdown signal than in the traditional scenarios. This clearly highlights the importance of the application of PCD devices at signalized crossings. Older pedestrians at traditional signalized intersections were least efficient, with only 12.2% of those who managed to cross the street within the permitted time, which is in this case the consequence of the inadequate signal plan for the observed age category.

According to the questionnaire results, it can be seen that the pedestrians interviewed at the intersections with PCD unarguably recognize the importance of the counters for easier and safer street crossing, while at other intersections they are not equally aware of the advantages of implementing PCD devices. It is interesting that the importance of implementing a pedestrian island was ranked lowest by the users interviewed at the crossings with the island. At other intersections, the users thought that an island would facilitate the crossing. These results are in accordance with the previous discussion. The general subjective feeling of safety while crossing is the highest at intersections with PCD, and the lowest at traditional signalized intersections, which is directly related to the recorded crossing "efficiency". In their paper, Bonneau et al. [30] found that pedestrians, primarily older pedestrians, felt safer if there was a pedestrian counter display at signalized intersections. Similarly, York et al. [12] determined that pedestrians felt safer when using a pedestrian crossing after the implementation of a pedestrian counter. It should be emphasized that older pedestrians do not perceive unsignalized crossings as less safe in relation to the other defined crossing types, which is confirmed by the results of measuring the speed values. In this regard, the use of engineering measures, as well as other available means (campaigns, education), should raise the awareness of drivers and pedestrians of all age groups, particularly the elderly, at these crossings.

The limitation of the paper refers to the small sample of different crossing types included in the analysis (two intersections per each observed pedestrian crossing type). Increasing the number of pedestrian crossings per types would certainly reduce the potential effect of the specificities of the observed pedestrian crossings.

Although the research sample consisted of 1,073 older pedestrians (*n*=1,073, 65^{+}), any further research, as well as increasing the sample size, would definitely contribute to the accuracy and reliability of the obtained results. The planned directions of the future study include additional research.

5. CONCLUSION

The pedestrian speed represents one of the most important parameters used in designing and managing pedestrian facilities. Also, it has a significant influence on traffic safety and efficiency. This study has researched the stated parameter for elderly pedestrians in Belgrade, Serbia. The obtained results are in accordance with the global research and confirm many of the previous finding in other countries.

The main contribution of the research has been to determine the speed value of older pedestrians at urban crossings and to examine the impact of defined crossing types on the crossing speed of the elderly. According to the results, it could be concluded that older people are mostly unable to cross the street safely due to their slower pace. The study has found that there is a significant impact of the crossing type on the crossing speed of the ageing population. Also, it has been shown that pedestrians' perception of safety depends on the crossing type, respecting the intersection geometric characteristics and available crossing time for this age group. These findings indicate the need for applying the corresponding engineering measures which would enable safer street crossing for older population. It should be generally recommended to use the value of the 15^{th} percentile speed of older pedestrians in traffic engineering applications. It is important to underline that the value of the 15^{th} percentile speed of pedestrians of all age categories differs significantly from the value of the 15^{th} percentile speed of older pedestrians. In accordance with this fact, it is recommended that engineering calculations should use the value of the 15^{th} percentile speed of older pedestrians at the places where their share is proportionally higher. The implementation of PCD devices is considered to be an adequate and favourable measure at all places with an increased share of the elderly. An additional measure could be the use of personalized cards for this age category which would allow extra green interval time at all signalized intersections, e.g. "Green Man+". Special attention should be directed towards unsignalized intersections where it is necessary to apply infrastructure and/or management improvements: the application of different colours and materials, platforms, non-standard vertical signalization, the application of fluorescent flags for pedestrians, warning pedestrian display, etc.

Directions for further research should focus on determining the normal walking speed of older population in local conditions and comparing the results with the obtained crossing speed values. Considering signalized intersections, it would be important to examine the reaction time of the elderly on pedestrian crossings. Also, the total population of older pedestrians includes those who have not performed their walking due to limited psychological and physical abilities, or due to any other reason for deciding not to start walking. This group was not included in the conducted study and should be treated in further research.

In general, the study highlights the need for improving the level of safety and existing traffic conditions for older population at urban crossings.

Asist. **ANA TRPKOVIĆ**, Mast.inž.saobr.[1]
E-mail: a.trpkovic@sf.bg.ac.rs
Asist. **MARINA MILENKOVIĆ**, Mast.inž.saobr.[1]
E-mail: marina.milenkovic@sf.bg.ac.rs
Prof. dr. **MILAN VUJANIĆ**[1]
E-mail: m.vujanic@sf.bg.ac.rs
Prof. dr. **BRANIMIR STANIĆ**[1]
E-mail: b.stanic@sf.bg.ac.rs
Vanr. prof. dr. **DRAŽENKO GLAVIĆ**[1]
E-mail: drazen@sf.bg.ac.rs
[1] Univerzitet u Beogradu, Saobraćajni fakultet
Vojvode Stepe 305, 11000 Beograd, Republika Srbija

BRZINA HODA STARIJIH PEŠAKA NA PEŠAČKIM PRELAZIMA

REZIME

Populacija starijih ljudi u svetu se veoma brzo uvećava, a u pogledu bezbednosti u saobraćaju, stariji pešaci predstavljaju jednu od najranjivijih grupa. Sa druge strane, brzina pešaka je značajan ulazni parametar u saobraćajnom inženjerstvu, koji može uticati na njihovu bezbednost, naročito onih starijih. Cilj ovog istraživanja bio je da utvrdi vrednosti brzina starijih pešaka (65+) na različitim tipovima pešačkih prelaza u urbanom okruženju. Istraživanje je sprovedeno na deset raskrsnica u gradu Beogradu, u Srbiji, korišćenjem metode neposrednog osmatranja i ankete korisnika. Podaci su analizirani u statističkom softverskom paketu IBM SPSS Statistics. Rezultati su pokazali da se stariji pešaci kreću sporije, kao i da tip prelaza značajno utiče na brzinu seniora. Redosled tipova prelaza u odnosu na izmerene brzine je sledeći, u poretku od najmanje ka najvećoj vrednosti brzine: nesignalisan, signalisan, signalisan sa brojačem, signalisan sa pešačkim ostrvom i brojačem i na kraju, signalisan sa pešačkim ostrvom. Prema rezultatima ankete, može se uočiti da su seniori prepoznali značaj primene brojača na pešačkim prelazima. Prethodno navedeno ukazuje na potrebu da se omogući bezbedan prelazak ulice za starije korisnike korišćenjem odgovarajućih inženjerskih mera.

KLJUČNE REČI

stariji pešaci; brzina prelaska; tip pešačkog prelaza; bezbednost;

REFERENCES

[1] RTSA. Traffic Safety for Older People, Fact sheet. Road Traffic Safety Agency, Belgrade, Republic of Serbia; 2015.

[2] Keall MD. Pedestrian exposure to risk of road accident in New Zealand. Accident Analysis and Prevention. 1995;27(5):729-740.

[3] Transport Canada. Pedestrian Fatalities and Injuries 1988-1997, Fact Sheet. Ottawa, Ontario: Transport Canada; 2001.

[4] Hauer E. The safety of older persons at intersections. Transportation in an Aging Society 2. Washington, DC: Transportation Research Board; 1988. p. 194-252.

[5] OECD. Ageing and transport: Mobility needs and safety issues. Organisation for Economic Co-operation and Development, Paris, France; 2001.

[6] Tourniera I, Dommes A, Cavallo V. Review of safety and mobility issues among older pedestrians. Accident Analysis and Prevention. 2016;91:24-35.

[7] Gates TJ, Noyce DA, Bill AR, Van Ee N. Recommended walking speeds for timing of pedestrian clearance intervals based on characteristics of the pedestrian population. Transportation Research Record 1982. Washington: Natl Acad Sci; 2006. p. 38-47.

[8] Stollof ER, McGee H, Eccles KA. Pedestrian Signal Safety for Older Person. Washington, DC: AAA Foundation for Traffic Safety; 2007.

[9] Fitzpatrick K, Brewer MA, Turner S. Improving Pedestrian Safety at Unsignalized Crossings. TCRP D-08, NCHRP 3-71; 2005.

[10] Tarawneh MS. Evaluation of Pedestrian Speed in Jordon with Investigation of Some Contributing Factors, Journal of Safety Research. 2001;32(2):229-236.

[11] Coffin A, Morrall J. Walking speed of elderly pedestrians at crosswalks. Transportation Research Record. 1995;1487:63-67.

[12] York I, Ball S, Beesley R, Webster D, Knight P, Hopkin J. Pedestrian Countdown at Traffic Signal Junctions (PCaTS) – Road Trial. Project Record: TfIL2481. Transport Research Laboratory; 2011.

[13] Schmitz JN. The effects of pedestrian countdown timers on safety and efficiency of operations at signalized intersections. Civil Engineering Theses, Dissertations and Student Research, University of Nebraska-Lincoln; 2011.

[14] Moeinaddini M, Asadi-Shekari Z, Sultan Z, Zaly Shah M. Analyzing the relationships between the number of deaths in road accidents and the work travel mode choice at the city level. Safety Science. 2015;72:249-254.

[15] Zegeer CV, Stutts JC, Huang H, Zhou M. Analysis of elderly pedestrian accidents and recommended countermeasures. Transportation Research Record. 1993;1405:56-63.

[16] Davies DG. Research, Development, and Implementation of Pedestrian Safety Facilities in the United Kingdom. Federal Highway Administration; 1999.

[17] Bernhoft IM, Carstensen G. Preferences and behaviour of pedestrians and cyclists by age and gender. Transportation Research Part F. 2008;11:83-95.

[18] Asadi-Shekari Z, Moeinaddini M, Shah MZ. Pedestrian safety index for evaluating street facilities in urban areas. Safety Science. 2015;74:1-14.

[19] Manual of Transportation Engineering Studies. Washington, DC: Institute of Transportation Engineers; 2000.

[20] Highway Capacity Manual. Washington, DC: Transportation Research Board; 2010.

[21] Manual on Uniform Traffic Control Devices for Streets and Highways. Washington, DC: U.S. Department of Transportation; 2003.

[22] Montufar J, Rempel G, Klassen S. Pedestrian Walking Speed for Traffic Operations and Safety in Canada. Transportation Association of Canada; 2013.

[23] Dahlstedt S. Walking speeds and walking habits of elderly people. International Conference on Transport for the Elderly and Handicapped. Cambridge: Loughborough University of Technology; 1978. p. 243-249.

[24] Knoblauch RL, Pietrucha MT, Nitzburg M. Field studies of pedestrian walking speed and start-up time. Transportation Research Record. 1996;1538:27-38.

[25] Wilson DG, Grayson GB. Age-related differences in the road crossing behaviour of adult pedestrians. Transport and Road Research Digest. LR 933. Crowthorne: Transport and Road Research Laboratory; 1980.

[26] Avineri E, Shinar D, Susilo Y. Pedestrians behaviour in cross walks: The effects of fear of falling and age. Accident Analysis and Prevention. 2012;44(1):30-34.

[27] Lipovac K, Vujanic M, Maric B, Nesic M. The influence of a pedestrian countdown display on pedestrian behavior at signalized pedestrian crossings. Transportation Research Part F. 2013;20:121-134.

[28] Xu Y, Li Y, Zhang F. Pedestrians' intention to jaywalk: automatic or planned? A study based on a dual-process model in China. Accid. Anal. Prev. 2013;50:811-819.

[29] Koh PP, Wong YD, Chandrasekar P. Safety evaluation of pedestrian behaviour and violations at signalised pedestrian crossings. Safety Science. 2014;70:143-152.

[30] Belanger-Bonneau H, Lamothe F, Rannou A, Joly MF, Bergeron J, Breton JG, Laberge Nadeau C, Maug U. Project d'experimentation et d'e´valuation d'une signalisation numerique pietionnie`re: Le de´compte visuel. Montreal, Canada: Unite´ de Sante´ Publique, Hopital du Sacre´-Coeur de Montre´al, Centre de Recherche sur les Transport; 1994. French