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Research Article

The Impact of Uncertainty on Pedestrians' Decision to Start Roadway Crossing during the Clearance Phase

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Clearance phase at signalized crosswalks is an important parameter of pedestrians' safety because it helps them to complete the crossing before the green signal for vehicles. However, there is the issue of pedestrian decision as to whether to cross if they arrive at the crosswalk during the clearance phase, which represents a violation in many countries. Due to the proof that pedestrian violations multiply the risk of traffic accidents, in this study, the tendency of pedestrians to commit violations during the clearance time has been researched. With the aim of proposing the design of the pedestrian traffic lights, which could decrease the frequency of pedestrian violations, the comparison of pedestrians behaviour at crosswalks with and without a countdown timer during the clearance time was made, based on the data collected in the video recording. Chi square independency test showed that there is a statistically significant difference in the behaviour of pedestrians during the clearance time, depending on the existence of the timer, as well as the fact that pedestrians behave in a safer manner if there is no clearance time shown on the timer. The total delay rate on the roadway during the red signal, which was the consequence of starting the crossing during the clearance time or subsequent violations, was 1.3 times higher at the crosswalks with the countdown timer. This research was unique because for the first time, two-phase pedestrian crossings on the roadway with the median refuge island in the sense of clearance time were analysed, in spite of the previous proof that pedestrians are more likely to commit violations during the red signal in that kind of roadway. Another novelty in the research was pedestrians following till the end of crossing, due to the possibility of subsequent violations. With the means of binary logistic regression, different factors which affect pedestrians' behaviour during the clearance time have been determined and they differ depending on the existence of the timer. At the pedestrian crosswalks with the timer, contributing factors have been determined, such as gender, the number of waiting pedestrians, distractions, arrival time, and age. If there is no timer, the contributing factors are the following: the number of crossing pedestrians, distractions, group, position of pedestrians in relation to the vehicle, the number of traffic lanes, and age. Based on the obtained results, a new design of the pedestrian traffic lights was proposed.

1. Introduction

Globally, pedestrians account for 23% of all fatal outcomes in road accidents [1]. Pedestrians are vulnerable road users as they have no physical protection when they come in contact with a vehicle, and also because the vehicles are much bigger [2]. These two factors lead to severe bodily injury or death of the vulnerable pedestrians when compared with motorists and the passengers in a vehicle.

According to the research of Ulfarsson et al. [3], pedestrians are found to be at fault for 59% of the accidents due to attempts of illegal crossings at signalized intersections. Every illegal crossing of the roadway by pedestrians will not always result in a road accident. However, the risk of

accidents due to illegal crossing of pedestrians increases by about 8 times in comparison with those that are not caused by illegal crossings [4].

An important parameter of safety of pedestrians at signalized intersections is the clearance time because it helps pedestrians to complete the roadway crossing. The design of the clearance time differs depending on the country. In the USA, it is designed as Flashing Do not Walk; in Germany, New Zealand, and Australia as a Flashing Red Man; in Japan and China it is in the form of a Flashing Green Man [5, 6]. In the Republic of Serbia, the design of the clearance time for pedestrians depends on the existence of the countdown timer, and it is shown as a Red Man with the remaining time till start of the red signal in the form of orange numbers, or just Red Man on traditional traffic lights without the timer (see Figure 1).

Traffic regulations regarding the meaning of the clearance time also differ depending on the country. Namely, in Canada, the law is more flexible since it allows pedestrians to judge their ability to cross the roadway for the remaining time. In other words, if a pedestrian starts and finishes the crossing during the clearance phase, that would not be considered a violation [7]. On the other hand, in countries like Japan, China, as well as the Republic of Serbia, it is forbidden for pedestrians to start crossing during the clearance phase, regardless of the remaining time till the red signal. Generally, clearance phase is defined as the time which enables pedestrians who have already started the crossing to finish it before the start of the green light for the vehicles. In countries with stricter regulations, the beginning of roadway crossing by pedestrians even in the first second of the clearance time represents a violation.

Considering the fact that pedestrians are found to be at fault in the highest percentage of accidents in which they are killed or injured [3], as well as the fact that the risk of traffic accidents occurrence is multiple higher due to their violations [4], in this study one type of pedestrian violations has been researched. Concretely, the topic of this study is the pedestrian violations during the clearance time at signalized crosswalks, as well as their comparison on the crosswalks with and without the countdown timer. It is also important to determine how uncertainty caused by the lack of information on available time at crosswalks without the countdown timer affects pedestrians' tendency to start roadway crossing during the clearance phase.

Apart from the stated, other factors have also been researched, which can be contributing to the tendency of pedestrians to start roadway crossing during the clearance phase. The selection of the examined factors has been conducted after a more detailed literature review.

The sections, Literature review, Materials and methods, Discussion, and Conclusion, follow.

2. Literature Review

The behaviour of pedestrians arriving at the crosswalk during the clearance time has been the subject of several research studies, the results of which have been described in the following section.

Lee and Lam [8] found that the borderline between the decision of the pedestrians who arrive during the clearance phase whether to cross the roadway or to wait is approximately equal to the half of the clearance time duration (borderline is 6 s for the clearance time of 13 s). According to their results, most pedestrians arriving at the crosswalk during the first 7 seconds of the clearance time decide to cross the roadway, while 50% of the pedestrians arriving during the last 6 seconds do not cross the crosswalk.

Wanty et al. [9] found that 23% of all pedestrians arriving at the crosswalk during the clearance time decide to cross the roadway.

According to Koh et al. [10], 34% of all pedestrians and cyclists arriving at the crosswalk in the last 5 seconds of the clearance time decided to wait for the beginning of the green signal, while all the pedestrians and cyclists who arrived earlier decided to cross the roadway.

According to the study conducted by Ma et al. [11], the tendency of some pedestrians arriving at the crosswalk during the clearance time to cross the roadway depends on their age, that is, these authors have found that 92.7% of the pedestrians younger than 50, who arrive at the crosswalk with the countdown timer showing the clearance time, decide to cross the roadway. With the pedestrians older than 50, this percentage is significantly lower (12.4%).

It was found in the analyses of the behaviour of children pedestrians at signalized intersections in school zones, conducted by Fu and Zou [12], that 6.9% of them decide to start the crossing during the clearance time.

According to Zhuang et al. [6], 85.2% of pedestrians decided to start the crossing during the clearance time, while a lower percentage of pedestrians decided to wait (14.8%). 79% of pedestrians did not finish the crossing during the clearance time, but the red light started and they crossed 41% of the roadway width during the clearance time.

The results of the previous studies are consistent regarding the general tendency of pedestrians to start the roadway crossing during the clearance phase.

Apart from the stated, the behaviour of pedestrians arriving at the crosswalk during the clearance time can be even more complex since there is a possibility that pedestrians start the crossing during the red signal, although they decided to wait immediately after the arrival during the clearance time. These results, regarding the tendency of pedestrians towards subsequent violations have been reported by Schmitz [13].

The comparative analysis of the behaviour of pedestrians during the clearance time at signalized crosswalks with and without the countdown timers has been the topic of four research studies, the results of which were contradictory.

Xiong et al. [14] and Fu and Zou [12] have not succeeded in proving significant differences in the behaviour of pedestrians at signalized crosswalks with and without the timer during the clearance time, but Wanty et al. [9] have determined the statistically significant difference. After the installation of the countdown timer on the traffic lights, the percentage of pedestrians who started the roadway crossing during the clearance time has significantly increased. Ma et al. [11] found a significant difference for one age group of

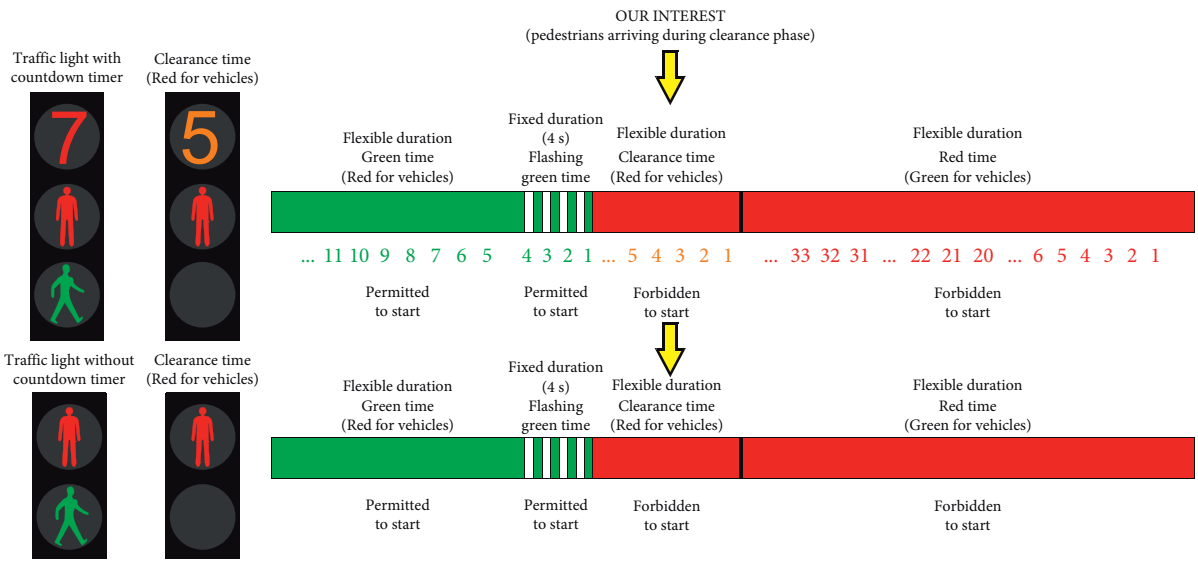

Figure 1: Design of pedestrian traffic lights with and without the countdown timer at the study sites.

pedestrians, that is, Ma et al. [11] reported that with the pedestrians younger than 50 there is not any significant difference in the percentage of pedestrians who start the crossing during the clearance time at the intersections with and without the timer (92.7% with the timer and 94.5% without the timer). On the other hand, with the pedestrians older than 50, this difference is more significant and it is 29.8% (12.4% and 42.2% at the crosswalks with and without the timer, respectively). Xiong et al. [14] concluded that the existence of the countdown timer at pedestrian traffic lights has a weak impact on the behaviour of pedestrians during the clearance time, considering that the difference in the percentage of the pedestrians who cross at the crosswalks with and without the timer is only 1.9%. Fu and Zou [12] reached similar conclusions, differing only in the percentage of children pedestrians (0.7%) who decide to cross the roadway during the clearance time (6.2% of the pedestrians at crosswalks with the timer as opposed to 6.9% of the pedestrians at crosswalks without the timer). It is important to mention that Fu and Zou [12] only researched the behaviour of children pedestrians, without considering other age groups.

In the literature, a large number of contributing factors regarding the behaviour of pedestrians during the clearance time has been identified, such as age [6, 11], distractions, the pedestrian position in relation to the vehicles (pedestrian is closer or farther from the vehicle), required speed of the pedestrian to complete the crossing during the clearance time, as well as the number of pedestrians crossing the roadway at the moment when the observed pedestrian arrives at the intersection [6]. Zhuang et al. [6] reported that with the increase of pedestrian age the probability of whether they will decide to cross during the clearance time decreases. Unlike Zhuang et al. [6], in the research of Ma et al. [11], the focus was on the comparison of the pedestrians at crosswalks with and without the timer, where it was found that older pedestrians are more likely to commit violations if there is no timer on the traffic lights. According to Zhuang et al. [6], pedestrians who are distracted are 4.9 times less likely to commit violations during the clearance time in comparison to the pedestrians without distractions. The results of the research imply that pedestrians commit violations by starting the roadway crossing during the clearance time if they are farther from the vehicle. The tendency of pedestrians to violations decreases with the increase of the required speed of their movement [6]. Also, a higher pedestrian tendency to start the crossing during the clearance time has been reported, if at the moment of their arrival at the crosswalk there are other pedestrians who are already crossing the roadway [6].

It can be concluded that not many authors have dealt with the issue of the factors affecting the decision of the pedestrians to start the crossing during the clearance time. The results reported by Koh et al. [10] imply the impact of gender, a group belonging, number of traffic lanes, waiting time, and vehicle flow on the frequency of violations committed by pedestrians at signalized intersections. However, in the mentioned study, there is neither a clear difference between pedestrians and cyclists, nor between earlier start and late finish. Therefore, it is not known which factors concretely relate to the clearance phase.

The risk factors in the road transport are countless, and fuzzy logics and multi-criteria decision-making can be used for their ranking [15].

For the reason of a small number of the existing studies dealing with the behaviour of pedestrians during the clearance time, the search of the contributing factors of pedestrians has been expanded onto the other types of violation at signalized intersections and crosswalks. The waiting time is the most commonly reported predictor of the pedestrian crossings during the red signal [7, 16, 17]. The group has also been reported as the one affecting the way pedestrians move within a group showing lower tendency to cross the roadway during the red light [10, 16, 18].

Pedestrians' waiting time is one of the key indicators of level-of-service (LOS) at signalized intersections. In HCM (2010) (Highway Capacity Manual), the level of service was defined by means of a six-level scale, from A to F, whereby A is the highest and F is the lowest level of service. The average pedestrians' delay that is lower than 10 s belongs to the level of service A, while waiting longer than 60 s represents the level of service F. When pedestrians wait for a long while, they become impatient and start behaving in a risky manner.

In their analyses of pedestrians' crossings during the red signal at intersections, Zhang and Deng [17] divided these crossings into the active ones (where a pedestrian first starts the crossing) and the conformity crossing during the red light (where a pedestrian follows other pedestrians who have already started the crossing). Different contributing factors have been found depending on the type of behaviour, whereby the number of pedestrians who cross during the red light has been identified as the one which affects the conformity crossings, while the waiting time and the number of waiting pedestrians affect the active crossings. According to Faria et al. [19], the probability that the observed pedestrian will cross the roadway is 1.5–2.5 times higher if the other pedestrians are already crossing. Similar tendencies towards violation increasing in the presence of other violators have been reported by Afshari et al. [21].

There are also other research studies where it was found that the behaviour of an observed pedestrian is conditioned by the behaviour of other pedestrians present. The existence of pedestrians who wait for the change of the red signal primarily affects the female pedestrians, as the frequency of their risky behaviour decreases [21]. Rosenbloom [22] reached similar conclusions, in the sense that the existence of pedestrians who wait for the beginning of the green signal reduces the probability of crossings during the red signal.

With the increase of the length of the crossing (the roadway width, the length of the crosswalk, the number of traffic lanes) the number of the pedestrians who decide to cross the roadway during the red signal decreases [16, 23, 24].

On the basis of the conducted literature review, it can be concluded that the pedestrian's process of decision-making whether to commit the violation is generally complex as it depends on a large number of factors. Apart from this, the complexity of the pedestrians' decision-making is increased due to their subjectivity when assessing the elements important for safe roadway crossing (speed and stopping distance of the oncoming vehicle[25], vehicles' speed [26].

2.1. Stimulus for Research. As it can be concluded on the basis of the conducted literature review, not many authors have dealt with the behaviour of the pedestrians arriving during the clearance phase, especially the contributing factors related to the decision of the pedestrians' roadway crossing during this phase. Apart from this, even fewer authors dealt with the comparison of the behaviour of pedestrians during the clearance time at the traffic lights with and without the countdown timer. The results of the research with the described aim are contradictory since Xiong et al. [14] and Fu and Zou [12] did not find a statistically significant difference. On the other hand, Wanty et al. [9] found a statistically significant difference, while Ma et al. (2016) reported a statistically significant difference only in the behaviour of pedestrians of a certain age group. Contradictions in previous studies are one of the motives for this research.

Despite the findings that the existence of the median refuge island affects the increase of the number of violations committed by pedestrians [23, 27, 28], there is no research on the behaviour of pedestrians during the clearance time on the roadway with a median refuge island. This research study is unique for it deals with crossing the roadway with median refuge islands by pedestrians during the clearance time, and it takes into consideration two-phase pedestrian crossings.

Apart from that, this research also includes subsequent pedestrian violations (the pedestrians who first decided to wait during the clearance time but later crossed the roadway during the red signal), which is a possibility reported by Schmitz [13]. This research is unique because it takes into consideration both two-phase crossings of pedestrians during the clearance time and the comparative analysis of pedestrian behaviour depending on the existence of the countdown timer.

3. Materials and Methods

3.1. Study Sites. The research was conducted at four signalized crosswalks in the city of Novi Sad, two with the countdown timer, and two without it. Before the video recording of the location started, their selection was conducted in accordance with a few criteria. For obtaining comparable data, the most important selection criterion of the location was the existence of "pairs" of signalized crosswalks with similar characteristics. In other words, the chosen locations were with a similar length of the crosswalk with and without the timer, similar length of the duration of the clearance time at crosswalks with and without the timer, etc. The existence of the median refuge island has been reported as the factor which affects the increase of the number of pedestrian violations [23, 27] because it motivates them to use two-phase crossings. Latest studies imply the same tendencies [28, 29]. For the mentioned reasons, one of the criteria for the choice of the location for the research was the existence of the median refuge island. The existence of a larger number of pedestrians was also one of the criteria for the choice of the signalized crosswalks; therefore, the chosen locations are those with a higher degree of attraction.

After defining the criteria, the locations were visited in order to select those locations that meet all criteria. The determination of some of the criteria (countdown timer existence; the number of traffic lanes and the existence of median refuge island; the duration of the green, red, and the clearance time at pedestrian traffic lights with the countdown timer) has been conducted visually. On the other hand, the duration of the green, red, and clearance time on pedestrian crossings without the countdown timer has been determined using a stopwatch. The other criteria, including the roadway width, crosswalks width, and median refuge

islands width, have been established by using the measuring wheel. In the first phase of the research, 7 potential research locations were chosen. Then, there was a pilot research which meant creating a 15-minute video recording at all 7 potential locations. After the creation of the video recording, their review was carried out for determining the possibility of the extraction of all data necessary for the analysis. Apart from this, from the created video recordings, the counting of the arriving pedestrians was conducted. Four out of seven potential locations were chosen with the largest number of pedestrians. At these four chosen locations, there was also the best visibility of all data necessary for the analysis (seconds on the timer, perceptibility on the sidewalk on the other side of the roadway in relation to the recording camera, etc.), based on the possibility of setting the camera at certain positions.

The characteristics of the chosen study locations are given in Table 1.

According to the regulations of the Republic of Serbia, during the Flashing Green Light, pedestrians are allowed to start roadway crossing. It is important to mention that the duration of the Flashing Green Light is always 4 s. The clearance time is a time interval between the completion of the Flashing Green Light for pedestrians and the beginning of the green light for vehicles, both at the traffic lights with and without the countdown timer. Apart from the mentioned, pedestrians are forbidden to start crossing the roadway from the moment of clearance time start.

Illustration of the pedestrian traffic lights with and without the timer and the timing plan for pedestrian signals is shown in Figure 1.

3.2. Procedure. The research was conducted by video recording of the chosen locations. When setting video cameras, special attention was paid to their positions; thus, they were set such that they were not noticed by the pedestrians who were the subjects of the research. The research was conducted in May 2021, and it lasted for 4 days (13th, 14th, 19th, and 20th May). It is important to emphasize that the research was conducted in the morning on working days.

During all research days the weather was sunny. The total duration of the video recordings made at all locations was 1,080 minutes.

After the creation of the video recordings, they were reviewed and the data necessary for the analysis were extracted.

The data were analysed in the software packages IBM SPSS Statistics v.23 and Microsoft Excel.

This research has been approved by the ethics committee of the Faculty of Technical Sciences in Novi Sad.

3.3. Participants. It is important to note that the data extracted from the video recordings were only about the pedestrians arriving at the crosswalk during the clearance time. The pedestrians arriving at the crosswalk in other phases, including red, green, and flashing green light were not the subject of this study; therefore, they were not considered.

A total of 743 pedestrians arriving at the crosswalk during the clearance time were captured in the video recordings.

The pedestrians crossing the roadway diagonally were not included in the research for the reason that their stay on the roadway is longer compared to the crossings at approximately a right angle. The pedestrians who started running several metres before the crosswalk, which resulted in their stepping onto the roadway in the last seconds of the green light, and not during the clearance time, were not considered. The total number of pedestrians at all locations who were excluded from the analysis after the selection was 64.

The pedestrians used for the analysis were divided into 6 age groups. The classification of pedestrians by age was done by subjective assessment based on video reviews. Due to the possibility of error occurrence during the subjective evaluation of the pedestrian age, wider age limits were defined, in 10-year intervals. The arrival moment of pedestrians at the crosswalk in this article represents the moment when the observed pedestrians arrived at the edge of the roadway or the moment when they stopped in the immediate vicinity of the roadway. Pedestrian distractions were not classified by the type (the pedestrian eats, drinks, uses the mobile phone, pushes a baby carriage, has walking difficulties, carries luggage, takes a pet for a walk), and they have been observed and analysed as a whole.

4. Results

4.1. Comparison of Pedestrian Behaviour (with and without Countdown Timer). The total number of pedestrians arriving at all observed crosswalks during clearance time and used for the analysis was 679, out of which, 315 pedestrians were recorded at the crosswalks with the countdown timer, while the rest (364) pedestrians were registered at crosswalks without the timer.

Table 2 shows the descriptive statistics of the examined factors by the type of crosswalks. Apart from that, the table shows the percentage of waiting pedestrians and those who cross the roadway during the clearance time at crosswalks with and without the countdown timer. At crosswalks with the timer, 65.7% of pedestrians started the roadway crossing during the clearance time. On the other hand, at crosswalks without the timer, this percentage is significantly lower and it is 22%.

Chi-Squared test of independence was used for examining the influence of the existence of the timer on the behaviour of arriving pedestrians at the crosswalk during the clearance time. Chi-Squared test showed a statistically significant relation between pedestrian behaviour and the existence of the timer at the pedestrian traffic lights $\chi^2(1, N = 679) = 130.59$, $p < 0.001$. According to Cohen criterion [30], if the value of Phi is 0.1, the influence is low, and for the value 0.3 the influence is medium, and if the value of the coefficient is 0.5, the influence of the researched factor is high. The results of this analysis show that the influence of the existence of the countdown timer on the behaviour of pedestrians during the clearance time is between medium and high, since Phi = 0.442.

Table 1: Summary of key characteristics of study locations.

		Pair 1		Pair 2	
		Location 1	Location 3	Location 2	Location 4
Number of traffic lanes		4	4	6	6
Crosswalk geometry	Width (m)	5	5	5	5
	Length (m)[a]	17.5	13.5	20	19.5
	Median refuge island	Yes	Yes	Yes	Yes
	Island width (m)	4.5	1.5	2	1.5
Design characteristics	Countdown timer	Yes	No	Yes	No
	Green time duration (s)	16	17	13	11
	Flashing green time duration (s)	4	4	4	4
	Clearance time duration	7	7	8	10
	Red time duration (s)	63	50	65	49

Note. [a]the crosswalk length (traffic lanes width + median refuge island width).

Table 2: Descriptive statistics.

Category variables	Levels	With countdown timer				Without countdown timer			
		Cross		Wait		Cross		Wait	
		Number	%	Number	%	Number	%	Number	%
Gender	Males	97	71.9	38	28.1	35	25.0	105	75.0
	Females	110	61.1	70	38.9	45	20.1	179	79.9
Age	<20	15	93.8	1	6.3	2	6.1	31	93.9
	21–30	89	96.7	3	3.3	38	29.0	93	71.0
	31–40	69	87.3	10	12.7	11	15.9	58	84.1
	41–50	22	47.8	24	52.2	8	19.0	34	81.0
	51–60	12	23.1	40	76.9	16	28.6	40	71.4
	>60	0	0.0	30	100.0	5	15.2	28	84.8
Distractions	No	204	73.4	74	26.6	73	23.7	235	76.3
	Yes	3	8.1	34	91.9	7	12.5	49	87.5
Group	No	154	73.7	55	26.3	72	27.0	195	73.0
	Yes	53	50.0	53	50.0	8	8.2	89	91.8
Pedestrian position	Closer to the vehicles	142	64.3	79	35.7	33	18.5	145	81.5
	Further from the vehicles	65	69.1	29	30.9	47	25.3	139	74.7
	Total	207	65.7	108	34.3	80	22.0	284	78.0
Continuous variables		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of crossing pedestrians		1.5	2.0	1.64	1.87	1.99	2.59	1.46	1.93
Number of waiting pedestrians		0.4	0.8	1.38	1.34	0.20	0.56	0.31	0.59
Arrival time (second of the clearance time)		4.7	1.8	4.03	1.68	6.11	2.33	5.43	2.25

All pedestrians arriving at the signalized crosswalk during the clearance time are divided into two groups: pedestrians starting the crossing immediately after arriving and pedestrians waiting after arriving and not starting the crossing during the clearance time. The pedestrians who arrive and start the crossing during the clearance time, and cross in continuity, can finish the crossing during the clearance time or after its completion. The other group of pedestrians is characterised by the possibility of subsequent violations, despite the fact that they decided to wait at the first place. The tendency towards subsequent violations was also reported by Schmitz [13], which can be explained by the fact that pedestrians become impatient if they wait for too long [31], that is, waiting pedestrians during the clearance time can also cross during the red signal or they can start the crossing during the red signal and finish during the green signal (if they start crossing in the last seconds of the red signal).

Considering the existence of the median refuge island at all study sites, pedestrians could cross the roadway in continuity or in two phases, with waiting at the median refuge island. All previously described combinations of the roadway crossings can be performed in continuity or in two phases. Due to a higher complexity of two-phase crossings, there are additional crossing possibilities in this group. Pedestrians can start the crossing during the clearance time, wait at the median refuge island, and finish it during the red signal (pedestrians wait for traffic gap) or during the green signal (pedestrians wait for the start of the green light).

The only behaviour which is in accordance with the law represents the beginning and the end of the pedestrians' crossing during the green signal, while all previously described crossings represent violations. A summary of all roadway crossings by pedestrians and violations are given in Table 3. During the analysis of violations, their percentage was calculated for crosswalks with and without the

Table 3: Types of pedestrians' roadway crossings and delay rate.

Crosswalk type	Pedestrian behaviour	Type of crossing	Light at the traffic lights at the moment of the crossing start and finish	Number of cases	Total cases	% of cases	Rate of pedestrian delay on the roadway during the red signal (sec/ped)
With countdown timer	Wait	Crossings in continuity	Green start-green finish	77	108	24.4	5.27 (c)
			Red start-red finish	0		0	
			Red start-green finish	10		3.2	
		Two-phase crossings	Red start-red finish (**a**)	19		6	
			Red start-green finish (**b**)	2		0.6	
	Cross	Crossings in continuity	Clearance start-clearance finish	27	207	8.6	
			Clearance start-red finish	122		38.7	
		Two-phase crossings	Clearance start-red finish (**a**)	51		16.2	
			Clearance start-green finish (**b**)	7		2.2	
Without countdown timer	Wait	Crossings in continuity	Green start-green finish	266	284	73.1	4.05 (d)
			Red start-red finish	11		3	
			Red start-green finish	0		0	
		Two-phase crossings	Red start-red finish (**a**)	4		1.1	
			Red start-green finish (**b**)	3		0.8	
	Cross	Crossings in continuity	Clearance start-clearance finish	12	80	3.3	
			Clearance start-red finish	43		11.8	
		Two-phase crossings	Clearance start-red finish (**a**)	12		3.3	
			Clearance start-green finish (**b**)	13		3.6	

a Waiting for the traffic gap at the median refuge island. **b** Waiting for the green light at the median refuge island. **c** The total pedestrian delay of violators on the roadway during the red light at crosswalks with the timer (seconds)/total number of violators at crosswalks with the timer. **d** The total pedestrian delay of violators on the roadway during the red light at crosswalks without the timer (seconds)/total number of violators at crosswalks without the timer.

countdown timer separately, as there were different numbers of pedestrians in the groups.

Based on Table 3, it can be concluded that the highest percentage of pedestrians (38.7%) committed the violation in the form of starting during the clearance time, and finishing during the red signal, when crossing the roadway in continuity. On the basis of the analysis of crossings in continuity at the intersections with the countdown timer, it was also reported that most pedestrians who start the crossing during the clearance time finish it during the red signal (almost half of the pedestrians [10]; 79% of pedestrians [6]). The described tendency was found in our research study as well. Simultaneously, with these violations, there was the highest difference (26.9%) between the pedestrian behaviour depending on the countdown timer existence. The following violations (16.2%) were two-phase crossings where pedestrians started the crossing during the clearance time and finished during the red light. It actually means that 16.2% of pedestrians started the crossing during the clearance time, stopped at the median refuge island, waited for a traffic gap, and then crossed the other half of the roadway during the red signal. The difference between pedestrian behaviour depending on the countdown timer existence, with the described violations, was 12.9%, and there are more violations if there is a countdown timer.

Based on Table 3, it can be noticed that almost all types of violations are more prevalent at crosswalks with the timer. The exceptions are two-phase clearance start-red finish crossings, as well as the red start-green finish crossings, but the percentage of these violations in the total structure is small.

It is important to separate the crossings in continuity completed during the clearance time. Those are the pedestrians who increased their speed so as to finish the crossing before the green light for vehicles. Although according to the regulations in the Republic of Serbia this behaviour is considered a violation, a high percentage of these violations imply more positive outcomes, due to the shorter delay of pedestrians on the roadway during the red signal. The percentage of start and finish of the crossings during the clearance time was 5.3% higher at the crosswalks with the countdown timer, which is expected, as the information on available time for the crossings motivates pedestrians to accelerate their walk.

In order to show pedestrian risk exposure, their delay rate on the roadway during the red signal was determined (Table 3) by the types of crosswalks. The rate was calculated as the ratio between the total time spent on the roadway during the red signal due to committed violations and the total number of the pedestrians who committed the violations, by the types of crosswalks (with and without the timer). The delay rate, both for the crossings on the crosswalks with the countdown timer and on those without them, is related to violators only. It is important to mention that during the calculation of the delay rate during the red light for the crossings in continuity, the time pedestrians need to cross the median refuge island was subtracted.

The results of this research showed that violators reached 1.3 times higher delay rate on the crosswalks with the timer (5.27) in comparison with those without the timer (4.05).

4.2. Contributing Factors Affecting the Decision of Pedestrians Whether to Cross. Considering the determined statistically significant difference in the behaviour of pedestrians on crosswalks with and without the timer, two models were formed.

Binary logistic regression was performed to assess the influence of the investigated factors on the probability as to whether the pedestrians will start roadway crossing during the clearance time on the signalized crosswalks with and without the countdown timer. For the category variable "age," the Chi-Square independency test was used. Both models contain 9 independent variables: gender, number of pedestrians crossing the roadway and waiting at the moment when the observed pedestrian arrives at the crosswalk, distractions, group, the moment of the pedestrian arrival at the crosswalk (expressed in seconds of the clearance time), the position of the pedestrian in relation to the vehicle, number of traffic lanes, and age.

Both models are given in Table 4. The values from the model 2, which represent the crossings of pedestrians on crosswalks without the countdown timer, are shown in brackets.

4.3. Model Development (Crosswalks with and without Countdown Timer). The whole model 1 (with all predictors) was statistically significant, χ^2 (8, $N = 315$) = 131.7, $p < 0.001$, which means that the model differentiates between the pedestrians who cross the roadway during the clearance time (crossing pedestrians) and the pedestrians who wait (waiting pedestrians). The whole model explains between 34.2% and 47.2% of the variance in the behaviour of pedestrians and precisely classifies 80.6% of the cases. As it can be seen in Table 4, four independent variables gave a unique, statistically significant contribution to model 1 (gender, number of waiting passengers, distractions, and pedestrians' arrival time). The strongest predictor is pedestrians' arrival time at the observed crosswalk, the probability quotient of which is 1.20. It indicates that pedestrians arriving at the crosswalk at the start of the clearance time (higher available time for roadway crossing) 1.20 times more often crossed than the pedestrians arriving at the crosswalk in the last seconds of the clearance time, when all other factors in the model are equal. The following predictors with the probability quotient of 0.50, 0.42, and 0.02 are the factors gender, number of waiting pedestrians, and distractions, respectively. Probability quotient for the factors gender, number of waiting pedestrians, and distractions is lower than 1.

The probability that female pedestrians will decide to cross is 0.50 times lower in comparison with male pedestrians, when all other factors are equal. With the increase of the number of waiting pedestrians at the moment when the observed pedestrian arrives at the crosswalk, the probability that the pedestrian will start the crossing during the clearance time decreases. In other words, for every additional waiting pedestrian, the probability is that the observed pedestrian 0.42 times will less often decide to cross. Regarding distractions, with the distracted pedestrians, the probability of starting to cross during the clearance time is 0.023 times lower in comparison with the pedestrians who do not have distractions.

Chi-square independency test showed statistically significant relation between the age of pedestrians and their behaviour at crosswalks with the timer ($\chi^2(5, N = 315) = 167.28$, $p < 0.001$), whereby the influence of this factor is high (Cramer's $V = 0.729$).

Also, in the case of nonexistence of the countdown timer, the whole model (model 2) is statistically significant, χ^2 (8, $N = 364$) = 43.8, $p < 0.001$, which means that in this model two types of pedestrians can be distinguished, those who cross the crosswalk during the clearance time and those who wait. The model on the whole explains between 11.3% and 17.4% of the variance in the behaviour of pedestrians and precisely classifies 78.3% of cases. Five independent variables gave a unique statistically significant contribution to the model (number of crossing pedestrians, distractions, group, position of the pedestrian in relation to the vehicle, and the number of traffic lanes). The strongest predictor of pedestrian crossings during the clearance time is their position in relation to the vehicle, whose probability quotient is 1.88. That means that pedestrians who are farther from the vehicle 1.88 times more often decide to cross during the clearance phase in comparison to the pedestrians who are closer to the vehicles, when all other factors in the model are equal. The following predictor with a probability quotient of 1.21 is the factor of the number of pedestrians crossing the roadway at the moment when the observed pedestrian arrives at the crosswalk, and with the increase of this factor, the probability that the pedestrian will cross the roadway during the clearance phase also increases. Concretely, for each additional crossing pedestrian, the probability that the observed pedestrian will do the same increases by 1.21 times. Then, there are the probability quotients of 0.47, 0.37, and 0.24 for the factors, namely, the number of traffic lanes, distractions, and group, respectively.

The probability that pedestrians will decide to cross is 0.47 times lower on the roadway which consists of 6 traffic lanes in comparison with the roadway which has 4 lanes. The probability of pedestrians' decision to cross during the clearance phase is related to those who have distractions and who cross in the group decreases (0.37 and 0.24 times, respectively).

Chi-Squared independency test showed statistically significant relation between the age of pedestrians and their behaviour at crosswalks without the timer ($\chi^2(5, N = 364) = 19.37$, $p < 0.005$), with the mean influence of the factor of age (Cramer's $V = 0.231$).

The obtained results regarding the age of pedestrians and their tendency to start the crossing during the clearance time are also shown in Figure 2. Regarding crosswalks with the timer, there is approximately a regular trend of decrease in the tendency to cross with the increase of the age of pedestrians. The exception are pedestrians younger than 20, since it was found that they have a lower tendency to cross (93.8% of all pedestrians who arrived during the clearance time crossed the roadway), compared to the next age group, aged 20–30 (96.7%).

Table 4: Predictors of pedestrians' choices estimated by binary logistic model and the chi-square test.

Factors	*B*	S.E.	Wald	df	Sig.	Exp (B)
Gender*	−0.70 (−0.13)	0.34 (0.28)	4.29 (0.19)	1 (1)	0.038 (0.660)	0.50 (0.88)
Number of crossing pedestrians (*)	−0.02 (0.19)	0.09 (0.08)	0.03 (5.25)		0.859 (0.022)	0.99 (1.21)
Number of waiting pedestrians***	−0.87 (−0.25)	0.17 (0.27)	27.95 (0.92)		0.000 (0.338)	0.42 (0.78)
Distractions*** (*)	−3.78 (−0.99)	0.66 (0.46)	33.21 (4.77)	1 (1)	0.000 (0.029)	0.02 (0.37)
Group (***)	−0.30 (−1.45)	0.36 (0.41)	0.67 (12.77)	1 (1)	0.413 (0.000)	0.74 (0.24)
Arrival time*	0.18 (0.13)	0.09 (0.07)	3.87 (2.96)		0.049 (0.085)	1.20 (1.13)
Position relative to the vehicles (*)	0.34 (0.63)	0.35 (0.30)	0.94 (4.50)	1 (1)	0.331 (0.034)	1.40 (1.88)
Number of lanes (*)	−0.31 (−0.76)	0.33 (0.35)	0.88 (4.77)	1 (1)	0.349 (0.029)	0.73 (0.47)
Constant	1.55 (−1.72)	0.48 (051)	10.36 (11.64)	1 (1)	0.001 (0.01)	4.71 (0.18)
Age*** (**)		$\chi^2 = 167.3$ (19.4)		5 (5)	0.000 (0.002)	

Note. model 1-with countdown timer; (model 2-without countdown timer).

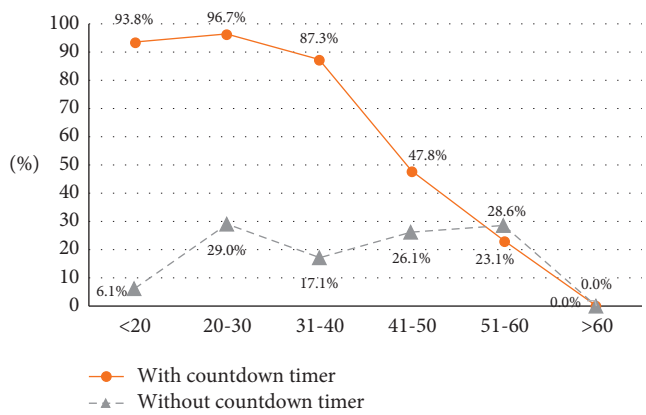

Figure 2: Percentage of the start of roadway crossing during the clearance time by the age, for both types of crosswalks.

As it can be seen in Figure 2, at crosswalks without the timer, the tendency towards crossing during the clearance time depending on the age of pedestrians is not clear, that is, the exceptions are pedestrians younger than 20, aged 31–40, as well as 51–60. The last age group (51–60 years) showed a significant tendency because they were the only ones who committed a higher percentage of this type of violations at crosswalks without the timer (28.6%) in comparison with the crosswalks with it (23.1%).

Regarding the difference in the behaviour at crosswalks with and without the countdown timer, depending on age, younger pedestrians showed a significant difference, whereby they are more likely to cross during the clearance time at crosswalks with the timer.

5. Discussion

5.1. Comparison of Pedestrian Behaviour (Crosswalks with and without Countdown Timer). By means of Chi-Squared independency test, a statistically significant difference in the behaviour of pedestrians arriving during the clearance time to the crosswalk with and without the timer was found. The results showed that pedestrians are more likely to start the roadway crossing if there is the countdown timer on the traffic lights (65.7% of all pedestrians that arrived at crosswalks with the timer decided to cross, while at the crosswalks without the timer this percentage was 22%). Four studies have been found where the behaviour of pedestrians during the clearance time depending on the existence of the timer was analysed, but these results are not completely consistent with the results of this research (for example [12, 14]). The results of this research were consistent with the results conducted by Wanty et al. [9] because it was found that the existence of the countdown timer which shows the clearance time statistically significantly increases the pedestrians' tendency to start the crossing. Ma et al. [11] did not find any significant difference in the behaviour of pedestrians younger than 50 years arriving during a signal change interval at intersections with and without the timer in Shangai, but they did find difference in behaviour with pedestrians older than 50. Analyzing the behaviour of children pedestrians during the clearance time in the zones of schools in the city of Jinan, Fu and Zou [12] did not find a significant difference in their behaviour depending on the existence of the timer. However, it is important to note that the target group of Fu and Zou [12] were children pedestrians, which implies significant methodological differences in studies.

It is very important to distinguish key differences in regulations regarding clearance time, that is, all three research studies were conducted in China, where the clearance time means Flashing Green Signal, whereby starting of the crossing is not allowed. On the other hand, in the Republic of Serbia, starting roadway crossing during the Flashing Green Man is allowed, but it is forbidden after its end in 4 seconds (see Figure 1). Considering the design of traffic lights in the

Republic of Serbia, at the moment of arrival at the crosswalk, the pedestrian actually does not have any information that he or she arrived during the clearance time at the traffic lights without the countdown timer because there is no visual difference between the symbols (both the clearance and red phase are shown in the form of the red light). On the other hand, if there is a countdown timer on the traffic lights, the pedestrian is informed that they arrived to the crosswalk in the clearance phase. Apart from this, the results of the survey conducted by Ma et al. [11] imply that pedestrians do not have the knowledge on the purpose of the clearance time–85% of their respondents think it is allowed to start crossing the roadway during the clearance time. Also, Robertson and Carter [32] found that only around one half of the pedestrians understood the purpose of the clearance time. These findings suggest the possibility that pedestrians who cross the crosswalk with the timer actually do not know it is not allowed, due to the existence of the information on the remaining time for crossing.

Hence, different target groups, regulations, traffic lights design, and pedestrian ignorance in relation of regulations [11, 32] are potential reasons for inconsistent result.

In this article, the structure of crossings by the type was also found (Table 2), as well as the structure of different violations (Table 3), depending on the existence of the timer. In the total structure of violations, most were those in continuity which started during the clearance phase at crosswalks with the timer, with a rate of 38.7%. The difference with this type of violation is also the highest when the crosswalks with and without the timer are compared (25.9% of pedestrians started the crossing during the clearance time, and finished during the red phase at crosswalks without the timer). These results can be explained by the tendency of pedestrians to overestimate their capabilities [33–35], thinking that they can finish the crossing in the available time shown on the countdown timer. Apart from this, the potential reason for these results can be the existence of uncertainty at crosswalks without the countdown timer, which discourages pedestrians to start the crossing. In other words, if on the traffic lights there is no information on the available time for crossing, the probability of pedestrians' decision to cross the roadway decreases, due to the uncertainty regarding the duration of the clearance phase.

The following 16.2% violations at crosswalks with timers are two-phased crossings which started during the clearance time, and finished during the red signal. It means that the percentage of the pedestrians who crossed the second part of the roadway (from the median refuge island to the end of the roadway) did that during the red signal. Clearance start-red finish violations during the two-phase crossings were significantly less represented at crosswalks without the timer (3.3 %).

It is interesting to mention the violations of pedestrians who started and finished the crossing during the clearance time (8.6% at crosswalks with the timer and 3.3% without the timer). Although this behaviour of pedestrians is characterized as a violation, it is not essentially risky behaviour because these pedestrians did not stay on the roadway during the red signal. This type of violation represents the only more important "positive" behaviour of pedestrians at crosswalks with the countdown timer. This tendency of pedestrians can be explained with the fact that the information on the timer helps pedestrians to finish their crossing during the clearance time because it motivates them to increase their speed [11], and it is consistent with the results reported by Xiong et al. (2015).

The time of stay of pedestrians on the roadway during the red signal is expressed by the delay rate. The results of this research have shown that pedestrians have achieved 1.3 times higher delay rate crossing the crosswalks with the countdown timer in comparison with the crosswalks without it. These results imply that the uncertainty in the concrete case positively affects the behaviour of pedestrians.

5.2. Contributing Factors Affecting the Decision of Pedestrians on Starting the Crossing during the Clearance Time. Since it was found by means of Chi-Squared test that there is a statistically significant difference in the behaviour of pedestrians who arrive at the signalized crosswalk with and without the timer, two models were formed in order to determine the behaviour predictors (Model 1-with the countdown timer; Model 2-without the countdown timer).

The results showed that the behaviour predictors are different depending on the type of the crosswalk.

The strongest predictor of crossings in model 1 represents the time of the arrival of pedestrians at the crosswalk (given in the seconds of the clearance time). Higher values of the arrival time imply longer available time for finishing the roadway crossing by pedestrians. The results regarding this factor are logical, considering the fact that it was found that crossing probability increases due to the increase of the available time for crossing. The results of this study are consistent with the study conducted by Koh et al. [10] who found that all pedestrians and cyclists arriving at the intersection during the last 5 seconds of the clearance time decided to wait for the green light, and all pedestrians arriving earlier crossed the roadway. There is an indirect consistency of our results with those reported by Zhuang et al. [6] who found that there is a lower tendency of pedestrians to start crossing during the clearance time, if the required speed at which they would finish the crossing is higher. The results indicate that there are similar tendencies in the behaviour of pedestrians since the probability of pedestrians crossing during the clearance time in both cases increases, if there is longer available time for the crossing (by the results of this study), which certainly requires lower speed (by the results of [6]). Previously mentioned studies [8, 10] were conducted at crosswalks with the timer. On the other hand, the arrival time of pedestrians at the crosswalk without the timer (model 2) was found to be insignificant. Analyzing the behaviour of pedestrians at signalized crosswalks in Hong Kong, Lee and Lam [8] emphasised the borderline of 6 s over which most pedestrians decided to cross the roadway, and below which more than 50% of them did not cross the roadway. This indicates the significance of the

factor of the pedestrians' arrival time. However, on the basis of the described methodology by the author, clear conclusions about the possible timer existence at the study sites cannot be reached. Anyway, it seems that information on the available time for roadway crossing can also have negative effects because, according to the results of this research, it increases of the probability of committing violations.

The authors who dealt with the crossings of pedestrians during the red signal most commonly reported waiting time as a contributing factor [7, 16, 17], and with its increase the tendency to violations also increases. However, in this article, the expected waiting time (the time of waiting for the start of the green signal) was not analysed because it is in direct relation with the time of arrival of pedestrians at the crosswalk. In other words, for the pedestrians arriving during the clearance phase, the time of waiting for the start of the green signal represents the summation of the time of duration of the red signal and the remaining clearance time.

The factor of gender has been found statistically significant in the model 1, but not in the model 2. When speaking about the roadway crossings during the clearance time, Zhuang et al. [6] and Fu and Zou [12] found that the gender is not statistically significant, unlike Aghabayk et al. [36] whose results are consistent with the results of our research, both in terms of gender significance and in terms of higher tendency of males to cross. On the other hand, Koh et al. [10] found that gender is significant, as well as that male pedestrians and cyclists are more likely to commit violations, which is consistent with the results of this study. Analyzing two-phase crossings during the red signal, Zhu and Sze [37] also reported that male pedestrians are more likely to commit violations in comparison with the female pedestrians.

In model 1, a statistically significant factor was the number of the waiting pedestrians at the moment when the observed pedestrians arrive at the crosswalk, while in model 2, the number of the pedestrians who cross the crosswalk was found to be significant. Zhuang et al. [6] dealt with the mentioned factors, and their impact on the pedestrians' decisions as to whether to start the roadway crossing during the clearance time or not. Analyzing the impact of these factors on the behaviour of pedestrians at crosswalks with the timer, the mentioned authors established the significance of the number of crossing pedestrians on the behaviour of the observed pedestrian but not the significance of the waiting pedestrians. Inconsistency of our results and the ones reported by Zhuang et al. [6] could be explained by different types of crossings, that is, Zhang and Deng [17] found that the number of pedestrians who cross during the red light affects conformity violations, while the number of waiting pedestrians affects active ones. The social factor in the sense of behaviour of other pedestrians, generally, was reported by other authors [19, 22, 37].

The influence of the group, by the results of this study, exists only in model 2. The authors who dealt with the behaviour of pedestrians during the clearance time identified the group as a contributing factor [10], in the way that belonging to the group decreases the tendency of pedestrians to commit violations, which is consistent with the results of this research. Zhu and Sze [37] conducted their research on the roadway with the median refuge island, which is similar to the research locations of this study, whereby they also identified the group as the contributing factor affecting the pedestrians' crossings during the red signal.

Distractions were identified as the contributing factor in both models. Pedestrians who have distractions showed a lesser tendency to starting roadway crossing during the clearance time. These results are consistent with the results of Zhuang et al. [6] who not only dealt with the clearance phase but also with the results of the authors whose subject of study was the behaviour of pedestrians during the red signal [38].

Apart from the distractions, age was also identified in both models as the contributing factor affecting the decision of pedestrians as to whether to cross the roadway or not during the clearance time. Regarding crosswalks with timers, there is an approximately regular trend of decreasing the tendency towards the crossings during the clearance time with the increase of pedestrian age, which is consistent with the results reported by Zhuang et al. [6]. Zafri et al. [39] reached similar conclusions in terms of older pedestrians who have a lower tendency towards risky rolling gap crossings.

The tendency of pedestrians towards crossings on crosswalks without the timer is more complex due to the nonexistence of a clear trend, which can be explained by a small sample within certain age groups, as well as with the fact that pedestrians were categorized into different age groups by the subjective assessment. Anyway, the only age group which is more likely to cross during the clearance time on crosswalks without the timer is the 51–60 year age group. These tendencies of pedestrians older than 50 were also reported by Ma et al. (2016), since a higher percentage of the pedestrians from this age group started the crossing on the crosswalk without the timer (42.2% on the crosswalks without the timer, 12.4% with the timer). On the other hand, opposite to Ma et al. [11], a higher difference between the tendency towards crossings between crosswalks with and without the timer have been determined, and with younger pedestrians. The reason for these results could be the fact that younger pedestrians overestimate their capabilities [33, 35], believing that within the available time during the clearance phase, shown on the timer, they can finish their crossing, while on the traditional traffic lights such information does not exist.

The position of pedestrians in relation to the vehicles (closer to vehicles or farther from them) and the number of traffic lanes have been found as the significant factors only in model 2. The position of pedestrians was found to be a contributing factor by Zhuang et al. [6] in the way that pedestrians were more likely to start crossing during the clearance time if they are farther away from the vehicle, which is consistent with the results of this research.

The results of this study also showed that pedestrians have higher tendencies to cross the roadways with four lanes, in comparison with the roadway consisting of six lanes.

Similar results were reported in previous studies [10, 16, 23, 24].

5.3. Study Limitations. This research had several limitations. Firstly, there is not an equal number of pedestrians by age categories, to accidental arrivals of pedestrians to the observed crosswalks.

Also, the distractions were analysed in a group, without individual considerations, depending on their type (a pedestrian takes a pet for a walk, uses the mobile phone, carries the luggage, etc.), which represents a research lack.

The following lack refers to the unequal duration of the red light at the researched locations. Taking into account other criteria during the choice of study locations, including the roadway width, the existence of the median refuge island, etc., crosswalks with identical cycles were not found.

Apart from this, the research was conducted only in sunny weather conditions, which represents another lack and model limitation.

5.4. Practical Implications. Since in this article it was found that there are higher tendencies of pedestrians to starting the crossing within the clearance time, if there is a countdown timer on the traffic lights, a proposal is the new design of traffic lights with a combination of the traditional (without the countdown timer) and the contemporary one (with the timer). On the basis of the obtained results, it was suggested to exclude only the clearance time on countdown timers. Apart from this, there is the possibility of the introduction of the message with the inscription "DON'T START," instead of the timer during the clearance phase. It is important to mention that the suspension or change of the timer functioning showing green or red signal is not suggested since it is not the subject of this article. Within this article, some benefits were also found at the crosswalks with the timer (a higher percentage of pedestrians managed to finish the crossing within the clearance time at the crosswalks with the timer than without it). However, the difference in this percentage is small and it is only 5.5%, while on the other hand there are a significantly higher percentage of pedestrians who did not succeed in finishing the crossing during the clearance time at crosswalks with the countdown timer (38.7%). In other words, the proposed design of the traffic lights may affect the decrease of a smaller percentage of efficiency, but safety benefits would be achieved.

6. Conclusions

In summary, in the article, it was found that there is a higher tendency of the pedestrians who arrived during the clearance time, to cross the crosswalks with the timer, and which were separated by the median refuge island. Also, it was found that there is generally a higher tendency for violations at crosswalks with the countdown timer, which means that a higher uncertainty discourages pedestrians to start the roadway crossing. The results of this research are completely consistent with the research conducted by Wanty et al. [9], and partially consistent with the research of Ma et al. (2016). On the other hand, the results of this research are inconsistent with the results of studies conducted by Xiong et al. [14] and Fu and Zou [12] since the mentioned authors did not find any significant difference in the behaviour of pedestrians depending on the existence of the countdown timer. As it has been previously explained in the Discussion section, different target groups, regulations, traffic lights design, and pedestrian ignorance in relation to regulation are potential reasons for the inconsistent results.

In this article, different influencing factors were found regarding the tendency of starting the roadway crossing during the clearance time, depending on the type of the crosswalk. Regarding crosswalks with the timer, the following factors were determined: gender, number of waiting pedestrians, distractions, arrival time, and age. Influential factors at crosswalks without the timer are the number of crossing pedestrians, distractions, group, position of pedestrians in relation to the vehicle, number of traffic lanes, and age. Regarding results of this study in terms of contributing factors, they are mostly consistent with the results of previous studies.

In relation to the study results, the measures which would possibly lead to the decrease of the pedestrian tendency to commit violations at signalized crosswalks with median refuge islands were proposed.

The study had several limitations, including unequal number of pedestrians by age categories, group analysis of the distractions, unequal duration of the red signal for pedestrians at the researched locations, and the fact that the research was conducted only in sunny weather conditions.

The study limitations indicate the directions for future research studies. In order to have data on age groups completely comparable, it is necessary to have similar samples. In further research studies, it is planned to conduct a more thorough analysis of the influence of distractions to pedestrian behaviour during the clearance time, in accordance with the classification of distractions made by Aghabayk [36]. Considering the highlighted limitations of the model and its applicability only in sunny weather conditions, similar studies should be conducted in other weather conditions, which is the recommendation for further research.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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