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THE INFLUENCE OF TRAFFIC SIGNAL TYPE ON PEDESTRIAN BEHAVIOUR AND SAFETY IN SCHOOL ZONES

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Abstract: As a vulnerable category of road users, pedestrians are often exposed to conflict situations, even when crossing the road at designated pedestrian crossings. Pedestrian safety depends on their behaviour and compliance with traffic signals, as well as the behaviour of drivers and their attitude towards this category of road user. This study analysed the behaviour of pedestrians crossing the road at signalised pedestrian crossings in school zones. Particular attention was paid to the influence of the type and mode of operation of traffic lights on pedestrian safety, and on the occurrence of irregular behaviour when crossing the road. Additionally, the analysis includes the traffic conditions and characteristics of the observed locations. The results indicate that the appropriate selection and setting of traffic lights can significantly impact pedestrian behaviour, reducing the occurrence of irregular road crossings and improving pedestrian safety in school zones.

Keywords: Pedestrians, traffic signals, pedestrian behaviour, school zones.

1. INTRODUCTION

Pedestrian safety is a significant issue in traffic safety because pedestrians are the most vulnerable road users. They face a significantly higher risk of injury and fatality in the event of a collision with a motor vehicle than other road users. Most accidents involving pedestrians occur while they are crossing the road, and these accidents often have more severe consequences than other types of traffic accident. Signalised pedestrian crossings are fundamental to regulating the interaction between pedestrians and vehicular traffic. Their primary function is to separate pedestrian and vehicle flows temporally, thereby creating conditions for safe road crossing. However, the effectiveness of this type of regulation depends significantly on the behaviour of road users themselves, specifically the extent to which pedestrians adhere to traffic signal indications.

According to research by Ding et al. (Ding et al., 2024), traffic accidents involving pedestrians can occur when pedestrians cross the road in accordance with traffic signals, as well as when accidents result from pedestrians violating traffic rules. Pedestrians' non-

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compliance with traffic rules is highlighted as a leading cause of accidents, with disregard for traffic signals undermining the purpose of controlled crossings. The most frequently cited reasons for rule violations include haste on the part of the pedestrian, long red-light durations and the pedestrian's assessment that the road can be crossed safely due to low traffic volume (Dağlı et al., 2024).

In addition to pedestrian behaviour, the decision-making process when crossing the roadway can be influenced by the characteristics of the traffic signal system in use In urban environments, alongside traditional traffic lights, systems that provide pedestrians with additional information, such as countdown traffic signal. So too are systems where pedestrians activate the signal by pressing a button. These various technical solutions can affect how waiting time is perceived, when the decision to start crossing is made, and compliance with traffic signals.

This paper presents the results of a study of pedestrian behaviour at signalised crossings in Novi Sad. The research was based on direct field observations of three crossings with different types of traffic signal systems. The primary objective was to determine pedestrian behaviour when crossing the road, with a specific focus on compliance with traffic signals and the frequency of irregular crossings, i.e. crossing against the red light. Particular attention was paid to comparing the observed locations based on their signal types: traditional traffic signals, countdown traffic signals, and push-button traffic signals. This study is particularly significant because it was conducted in school zones, where some of the most vulnerable road users, children, are present.

2. LITERATURE REVIEW

Traffic signals are one of the most important elements of traffic regulation at pedestrian crossings with. Their main function is to separate conflicting traffic flows and ensure the safe crossing of pedestrians. Modern traffic systems use different types of traffic signals, which vary in how they operate and the level of information they provide to pedestrians. This paper's research was conducted at pedestrian crossings regulated by three types of traffic light: traditional traffic signals, countdown traffic signals, and push-button traffic signals. A review of the scientific literature reveals that there is no consensus on which type of signal is safest for regulating pedestrian crossings. Some researchers have concluded that countdown displays negatively affect pedestrian behaviour (Fu & Zou, 2016; McTiernan et al., 2012; Schmitz, 2011). Conversely, certain studies show that installing countdown displays reduces the number of irregular pedestrian crossings (Schattler et al., 2007; Eccles et al., 2004; Pešić et al., 2012; Washburn et al., 2006; Chai et al., 2017). A survey in Greece found that most respondents (95.5%) preferred a numerical countdown system to traditional traffic signals for controlling pedestrian traffic. Furthermore, 91% believed that installing such displays would improve safety and help pedestrians adjust their walking speed while crossing. Push-button pedestrian signals have received the least research attention, and the results show that practical issues arise with this method of traffic control. For example, pedestrians unfamiliar with how these signals operate sometimes attempt to cross during the red phase for pedestrians without activating the signal, thereby increasing the risk of traffic accidents. Furthermore, pedestrians may press the button but then not wait for the green light, crossing the roadway while the signal is still red. In such instances, the system continues to display a red light for vehicles, causing them to remain stopped unnecessarily after the pedestrian has finished crossing. This issue leads to increased fuel consumption, higher exhaust emissions and longer vehicle delays (ITF, 2024).

Due to conflicting views in the scientific literature and the fact that pedestrian behaviour depends on spatial, traffic and signal-related characteristics, further research is needed.

3. RESEARCH METHODOLOGY

The study of pedestrian behaviour was conducted using direct field observations at three signalised pedestrian crossings within the city of Novi Sad.
Data collected during the study included the pedestrian flow, the number of compliant and non-compliant crossings of the roadway and the traffic volume. In addition, traffic accident data for the observed locations from 2019 to 2024 was analysed to assess the safety level at the crossings in question.

The study was conducted on a working day between 8:00 a.m. and 4:00 p.m., simultaneously at three locations:

- Location 1: Futoška Street, near the "Mihajlo Pupin" Electrical Engineering School and the "Branko Radičević" Elementary School
- Location 2: Bore Prodanovića Street, near the "Petefi Šandor" Elementary School
- Location 3: Dimitrija Avramovića Street, near the "Ivo Lola Ribar" Elementary School

Special attention was paid to the type of traffic signal used when choosing locations. A push-button traffic signal was installed at the location in Futoška Street, a countdown traffic signal was installed at the location in Bore Prodanovića Street, and a traditional traffic signal was installed at the location in Dimitrija Avramovića Street. In addition to the type of traffic signal, the basic signal parameters were analysed, such as cycle length, the duration of the green light for pedestrians, and the ratio of green time to cycle length (g/C). Previous research has shown that these signal parameters can significantly impact waiting times and pedestrians' decisions about crossing the road.

3.1. Research results

Analysis and systematisation of the collected data revealed that the location with the highest traffic volume was Futoška Street. During the observation period, a total of 12,824 vehicles and 6,331 pedestrians were recorded. Compared to the other two locations, Futoška Street is characterised by significantly higher volumes of both motorised and pedestrian traffic. Futoška Street has four traffic lanes. The total cycle duration is 130 seconds, while the duration of the green light for pedestrians is 16 seconds.

Bora Prodanović Street has two traffic lanes. The total cycle duration is 90 seconds, and the pedestrian phase lasts 29 seconds. This location recorded the lowest number of pedestrians — 1,731 in total — along with 3,763 vehicles, during the same period. Compared to the other two locations, the lowest number of pedestrians was recorded at this crossing.

Dimitrija Avramović Street has two traffic lanes. The traffic light cycle is designed to last 60 seconds, while the green pedestrian light lasts for 22 seconds. During the research period, a total of 1,989 vehicles and 2,884 pedestrians were recorded.

The following figure shows the total number of pedestrians and vehicles at each observation point.

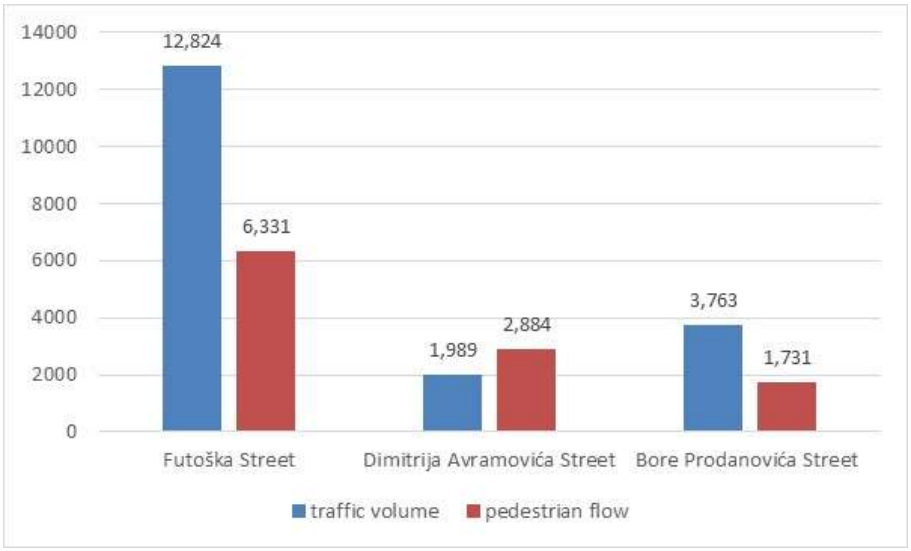


Fig. 1. Traffic volume and pedestrian flow at the observed locations

Among the observed pedestrian crossings, the largest number of irregular crossings of 3915 in total was recorded at the pedestrian crossing in Futoška street. At the location in Dimitrija Avramovića Street, 852 irregular crossings were registered, while in Bore Prodanovića Street, 156 irregular crossings were recorded. Bringing the number of irregular roadway crossings into a relative relationship with the total number of crossings, it follows that at the pedestrian crossing in Futoška Street, as many as 61.8% of crossings are irregular, at the pedestrian crossing in Dimitrija Avramovića Street, 29.5% of crossings are irregular, while only 9% of irregular crossings were recorded in Bore Prodanovića Street (Figure 2).

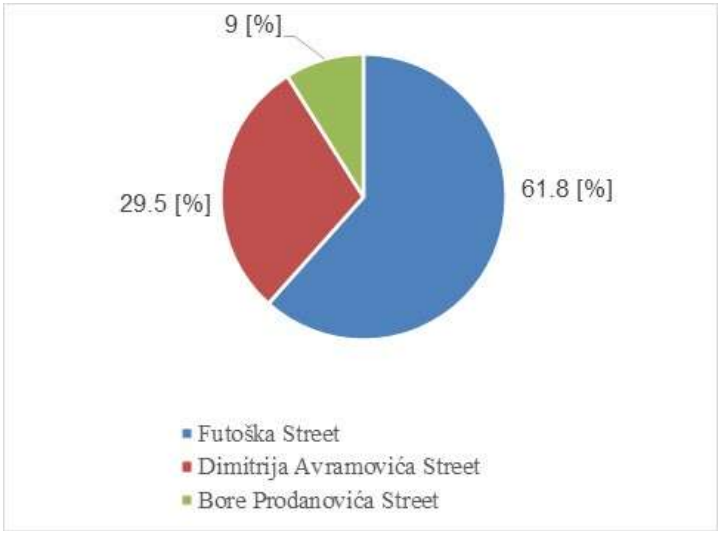


Fig. 2. Percentage of irregular crossings at the observed locations

Between 2019 and 2024, a total of nine traffic accidents involving pedestrians occurred at the observed locations. Of these, five took place on Futoška Street, three on Bore Prodanovića Street, and one on Dimitrija Avramovića Street.

4. DISCUSSION

The results obtained indicate differences in pedestrian behaviour across the observed locations. The highest number and proportion of irregular crossings were recorded at the pedestrian crossing on Futoška Street (61.8%), while the lowest proportion was observed on Bore Prodanovića Street (9%). When interpreting these results, it is important to note that the locations differ in terms of not only the type of traffic signal control, but also other characteristics such as pedestrian and vehicular traffic volumes, the number of traffic lanes and signal phase durations. One parameter that may be linked to the observed differences in pedestrian behaviour is the ratio of pedestrian green time to total signal cycle duration. The lowest value for this ratio was recorded on Futoška Street (0.12), compared to 0.32 on Bore Prodanovića Street and 0.37 on Dimitrija Avramovića Street. The location with the shortest green time relative to the cycle duration exhibited the highest proportion of irregular crossings. Conversely, the location on Bore Prodanovića Street, which had a more favourable ratio of green time to cycle duration, recorded the lowest proportion of irregular crossings. These results suggest a potential correlation between the duration of the pedestrian crossing interval and pedestrian behaviour, indicating that a shorter interval may increase the likelihood of crossing during a red signal.

The way information regarding signal changes is conveyed can also influence pedestrian behaviour. The pedestrian crossing on Futoška Street has a push button traffic signal with countdown display. While this provides pedestrians with information on the remaining time of the signal phase, the very short duration of the green light relative to the total cycle length may prevent them from crossing properly. Pedestrians arriving during the red phase, for example, may decide to start crossing before the signal actually turns green, anticipating a long wait for the green light. Conversely, the traffic light with a display on Bora Prodanović Street positively influences pedestrian behaviour, as the wait time for a signal change is significantly shorter. This information reduces uncertainty and makes it easier for pedestrians to decide to wait for the green signal before crossing. In contrast, pedestrians at the standard traffic light on Dimitrije Avramović Street lack information about how long they have to wait for the signal to change. Consequently, they may decide whether to cross based on their assessment of current traffic conditions and their own estimation of the wait time. Despite having the most favourable ratio of green time to cycle duration (0.37), this location recorded a 30% rate of improper crossings. This indicates that the duration of the green phase alone is insufficient to explain pedestrian behaviour, and that other characteristics of the signalling and the location itself must also be considered.

The observed data on motorised traffic volume indicates that its impact on pedestrian behaviour cannot be viewed in isolation. The highest traffic volume and proportion of irregular crossings were recorded on Futoška Street. While one might expect a higher volume of traffic to reduce the likelihood of irregular crossings due to fewer available gaps between vehicles, the results do not confirm such a simple correlation. At the same time, other location-specific factors cannot be overlooked, primarily the high number of traffic lanes and the very low ratio of pedestrian green time to total signal cycle duration. Consequently, this study does not permit the identification of a single dominant cause of irregular pedestrian behaviour.

The data on traffic accidents at the observed locations indicates that the safety conditions need to be examined further, particularly since all of the analysed pedestrian crossings are situated in school zones. Overall, the research findings demonstrate that pedestrian behaviour at signalised crossings cannot be explained by the type of traffic signal control alone. The ratio of green signal duration to total cycle length, how pedestrians are informed about signal phase changes, traffic volume and the location's specific characteristics must all be considered. Consequently, rather than identifying a single factor that independently determines pedestrian behaviour, the results point to the need for a comprehensive assessment of conditions at signalised pedestrian crossings.

5. CONCLUSION

This study analysed the behaviour of pedestrians at three signalised crossings in Novi Sad that were located near educational institutions and that employed different types of traffic signal systems. The study aimed to determine the frequency of non-compliant crossings and examine the relationship between pedestrian behaviour and factors such as signal type, parameters and traffic volume.

The analysis of the results revealed a correlation between the duration of the pedestrian green light relative to the total signal cycle length and the frequency of non-compliant crossings. Specifically, less favourable signal parameters were associated with a greater likelihood of pedestrians beginning to cross during the red signal. The results also suggest that providing additional information about signal phase duration, such as a countdown display, can influence pedestrians' decisions about whether to cross the road. However, the observed differences cannot be attributed solely to the type of traffic signal system employed, since the locations under study also differ in terms of other traffic and spatial characteristics.

Based on the results obtained, it can be concluded that installing traffic lights at a pedestrian crossing does not guarantee a high level of safety in itself. Selecting the appropriate type of signalisation and designing the signal parameters properly are crucial, primarily in terms of the ratio between the duration of the pedestrian green signal and the total cycle length. Providing clear information to pedestrians is also important.

In addition to technical and infrastructural measures, improving safety requires continuous pedestrian education and the enforcement of traffic rules. This education should focus on fostering proper attitudes and habits, and encouraging safe behaviour among all road users. This is particularly relevant for school-age children, who need to develop correct traffic behaviour habits from an early age.

Future research should encompass a larger number of locations and times of day, as well as a more detailed analysis of the factors influencing pedestrians' decisions to cross the roadway. This would enable the impact of traffic signal types and parameters on pedestrian behaviour to be determined more reliably and measures to be defined for enhancing their safety.

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