

TRAFFIC SAFETY IN ROAD CONSTRUCTION ZONES IN THE REPUBLIC OF SERBIA

Tijana Ivanišević^{1,a}, Aleksandar Trifunović^{2,b}, Svetlana Čičević^{2,c}, Aleksandar Zunjic^{3,d}, Slobodan Mitrović^{2,e}, Vedran Vukšić^{4,f}

¹Academy of Professional Studies Šumadija, Department in Kragujevac, Serbia

²University of Belgrade, Faculty of Transport and Traffic Engineering, Belgrade, Serbia

³University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia

⁴P.E. "GSP Belgrade", Belgrade, Republic of Serbia

^a tijana.ivanisevic@mail.com, ^b a.trifunovic@sf.bg.ac.rs, ^c s.cicevic@sf.bg.ac.rs, ^d azunjic@mas.bg.ac.rs,

^e cobaja@sf.bg.ac.rs, ^f vedran.vuksic@gsp.co.rs

Abstract Today's times are characterized by increased mobility of people, primarily by road traffic. The number of zones where roadworks are carried out is continuously increasing, so the number of risky situations in which drivers can find themselves is also increasing. Roadwork zones represent high-risk conditions in traffic, both for road users and construction workers. This paper presents and analyses data on road crashes and their consequences in roadwork zones, including the analysis of four typical roadwork situations that could pose a risk for traffic participants. The obtained results can be used to prevent similar accidents in the future in road construction zones.

Keywords: Traffic safety; road construction zones; road maintenance; injury prevention; safety measures.

1. INTRODUCTION

Traffic in Serbia, as well as in the whole world, records a constant increase, which results in an increase in the intensity of traffic, an increase in the degree of motorization and an increase in travel time, which will initiate the construction, maintenance and rehabilitation of roads in the coming period. With such an expectation, it is not acceptable that there is a deterioration in safety and a reduction in traffic flow in the zones where roadworks are carried out [1-3].

Roadwork zones constitute traffic situations that are unexpected and unusual for most road users. The number of zones where roadworks are carried out is continuously increasing, so the number of high-risk situations, in terms of road safety, in which road users and construction workers can find themselves, is also increasing [4].

Road crashes that occur in roadwork zones are accompanied by property damage, fatalities and injured road users, as well as construction workers, so it is necessary that the zones where roadworks are carried out be equipped with appropriate traffic signs, devices and equipment for traffic regulation and provision of information for safer traffic.

2. ROAD SAFETY INDICATORS IN ROADWORK ZONES

The data on road crashes in Serbia are collected by the Ministry of Internal Affairs (MIA), but monitored and analyzed by the Road Safety Agency. In the integrated database on the characteristics of road crashes, there are no data on the number of road crashes that occurred in roadwork zones. The

reason why this type of road crashes is not registered can be found in the Road Crash Investigation Report itself. Namely, in the listed types of road crashes found in the Report, there is no 'checkbox' or any other option to record road crashes that occurred in roadwork zones.

While most high-income countries have teams of experts for road crashes, many countries, such as Serbia, rely on investigations carried out by the members of the traffic police. Improving the Report, and thus the database would enable the analysis of data related to identification as well as management of the number and consequences of road crashes that occurred in roadwork zones.

Bearing in mind the presented problem, this paper analyses and presents the indicators and characteristics of road crashes that occurred in roadwork zones in Virginia in the period from 1996 to 1999. Research has shown that the number of road crashes during roadworks increased by an average of 26% compared to the same section of the road in the same period of the previous year when the roadworks were not carried out. Also, the number of road crashes increases by 88% during long-term periods of roadworks compared to the period when they were not carried out [5].

In the total number of road crashes that occurred in roadwork zones, road crashes with property damage (61%), casualties (38%) and fatalities (1%) are the most common.

The most common types of road crashes in roadwork zones are collisions with a vehicle (52%), collisions with a stationary object on the road (13%), collisions with a stationary object off the road (12%), side collisions while moving (11%), collisions at an angle (4%) and other (8%).

The temporal distribution of road crashes that occurred in roadwork zones indicates that the largest number of road crashes (213) occurred in the period from 1 p.m. to 4 p.m., the highest percentage of fatalities (1.8%) was recorded in the period from 10 p.m. to 6 a.m., the highest percentage of injured road users (44.1%) was recorded between 10 a.m. and 1 p.m., while the highest percentage of property damage (68.9%) was recorded between 4 p.m. and 7 p.m.

3. LEGISLATION FOR ROADWORK ZONES

Serbian legislation prescribes a framework for safe traffic in roadwork zones. The legal framework consists of the Rulebook on Traffic Signs, Signals and Road Markings, the Law on Public Roads and the Law on Road Safety, which define responsibilities and measures for safe traffic in roadwork zones [6].

The Law on Public Roads defines the liability of companies that manage roads that may arise as a result of untimely roadworks, i.e. due to the performance of roadworks contrary to the prescribed technical conditions and method of performance [7].

If the obstacles and the damage cannot be cleared immediately, the company that manages the road has to set up appropriate traffic signs and secure the location where the roadworks are carried out, which will enable the safe and smooth flow of traffic without time losses caused by traffic jams, as defined in the Law on Road Safety [7].

According to the Law on Road Safety, the Technical Traffic Regulation project must be prepared for the installation of temporary traffic signs, except in cases of emergency roadworks that do not last longer than 24 hours, which would fully define the temporary traffic signs that would be installed in roadwork zones, so that road users are not misled and that there are no time losses, but also so as not to endanger the safe and smooth flow of traffic [7].

During maintenance works or other construction works that do not last longer than 24 hours, certain measures should be taken immediately to eliminate disturbances and ensure the safe flow of traffic. Such measures do not require a Technical Traffic Regulation project [7].

Temporary traffic signs that are used to mark roadworks are defined by the Rulebook on Traffic Signs, Signals and Road Markings, and must be implemented in the right places – around, in front of, and behind the place where the roadworks are carried out. Temporary traffic signs serve the purpose of timely warning drivers of the danger, providing the necessary information about the danger, directing the flow of traffic, and protecting road users and construction workers at the location of the roadwork, all to ensure safe traffic [8].

Traffic signs, markings and equipment in the roadwork zones are installed based on the traffic flow plan, which is approved by the authorized body. The traffic flow plan is designed by qualified and authorized designers, which is defined in the Law on Road Safety [8].

4. EMERGENCE OF A DANGEROUS SITUATION IN ROADWORK ZONES

A large number of road crashes that occurred in roadwork zones were caused by inadequate safety of the roadwork zone, bad traffic routing, poorly conveyed messages and information to road users through temporary traffic signs in the work zone.



Figure 1. An example of poor regulation and direction of traffic in the roadwork zone.

Although a legal framework has been defined in Serbia, ensuring the safe flow of traffic in roadwork zones, the reality on the roads indicates a significant problem with the correct installation of temporary traffic signs and, therefore, with the regulation and direction of traffic in the roadwork zones.

The procedure for issuing approval for the installation of temporary traffic signs in roadwork zones requires a Technical Traffic Regulation project, which is in accordance with the current Rulebook on Traffic Signs, Signals and Road Markings.

Namely, even if the Technical Traffic Regulation project has to be in accordance with the Rulebook on Traffic Signs, Signals and Road Markings, large differences were observed during the installation and, therefore, during the project design by the designers. The designers sometimes use too many and sometimes too few traffic signs. Traffic signs that do not meet the criteria defined by the current Serbian legislation in terms of shape, dimensions, colour and method of placement are often placed in roadwork zones. Namely, traffic signs that are supposed to inform and warn road users that they are approaching a place where roadworks are carried out are often placed directly in front of the work site, on the dirt or road surface, simply leaning on another object or placed down on the road.

Bearing in mind all of the above, the problem of installing temporary traffic signs on the road can be solved by applying the Standard Solutions for traffic regulation.

The Standard Solutions for traffic regulation in the roadwork zones define the traffic signs as well as the distance at which they are placed in relation to the place where the roadworks are carried out.

4.1. Example no. 1

The plan for marking and securing the roadwork zone in a built-up area (50 km/h) when two-way traffic is not possible is presented. This is a typical solution for cases when the length of the roadwork zone is small, i.e. up to 50 meters, and traffic flows in one traffic lane. The first traffic signs are placed at a distance of 50 to 100 meters from the place where the roadworks are carried out, whereby the traffic participant is timely and adequately informed about the speed limit, the roadworks, the narrowing of the roadway, the right of way, etc.

Bearing in mind that traffic signs I-19 roadworks and II-30 speed limit are placed at a distance of 50 to 100 meters from the place where the roadworks are carried out, the stopping distance of vehicles at a speed of 50 km/h would be 76.01 m. In the street where the roadworks are carried out, traffic signs intended to warn and notify road users must be placed at a distance of at least 76.01 m. In the event that roadworks and speed limit traffic signs are placed at a distance greater than 76.01 m, drivers would be able to stop their vehicle by normal deceleration, that is, to adjust their driving to the traffic conditions. In this case, if a road crash were to occur on the part of the road managed by the roadwork company, the company would not be held accountable for the creation of a dangerous situation and the occurrence of the crash.

If the first traffic signs intended to warn and inform road users about a change in the traffic regime were placed at a distance of less than 76.01 m, drivers would be forced to adjust their driving to the traffic conditions by forced braking, thus becoming exposed to a dangerous situation by forced braking, because there is a possibility that the vehicle moving behind them will catch up with them, which can lead to a road crash. If, in this case, a road crash was to occur on the part of the road managed by the roadwork company, the company would be held accountable for the creation of a dangerous situation and the occurrence of the crash.

The stopping distance of the vehicle at a speed of 50 km/h, at a normal deceleration of 2 m/s^2 and with a reaction time of 2 s, would be:

$$S = 13.89 \cdot 2 + 13.89^2 : 2 : 2$$

$$S = 27.78 + 48.23 = 76.01 \text{ m}$$

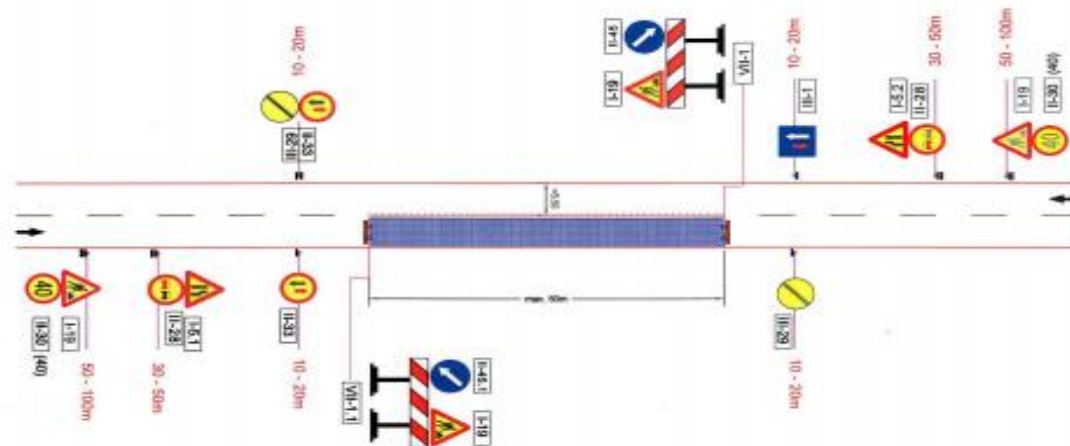


Figure 2. Example no. 1.

4.2. Example no. 2

The plan for marking and securing the roadwork zone outside a built-up area on the road with two traffic lanes, where a speed of 80-100 km/h is allowed (with alternating traffic management using traffic signs) is presented. This is an example of a typical solution for the case when the roadwork zone is longer than 50 meters. Traffic flows in one traffic lane, as regulated by traffic signs. The first traffic sign is placed at a distance of 400 meters from the place where the roadworks are carried out, whereby the road users are timely and adequately informed that they are approaching the roadwork zone, after which they receive information through traffic signs about speed limits, overtaking prohibitions, traffic lights, etc.

Bearing in mind the vehicle's stopping distance of 167.87 m at a speed of 80 km/h, as well as the fact that the traffic sign I-19 roadworks is located at a distance of 400 meters from the place where the roadworks are carried out, road users have time to adapt their driving to the conditions of safe traffic in the roadwork zone, and in the event of a road crash, the company that manages the road would not be held responsible for the creation of a dangerous situation and the occurrence of the crash.

The stopping distance of the vehicle at a speed of 80 km/h, at a normal deceleration of 2 m/s^2 and with a reaction time of 2 s, would be

$$S = 22.22 \cdot 2 + 22.22^2 : 2 : 2$$

$$S = 44.44 + 123.43 = 167.87 \text{ m}$$

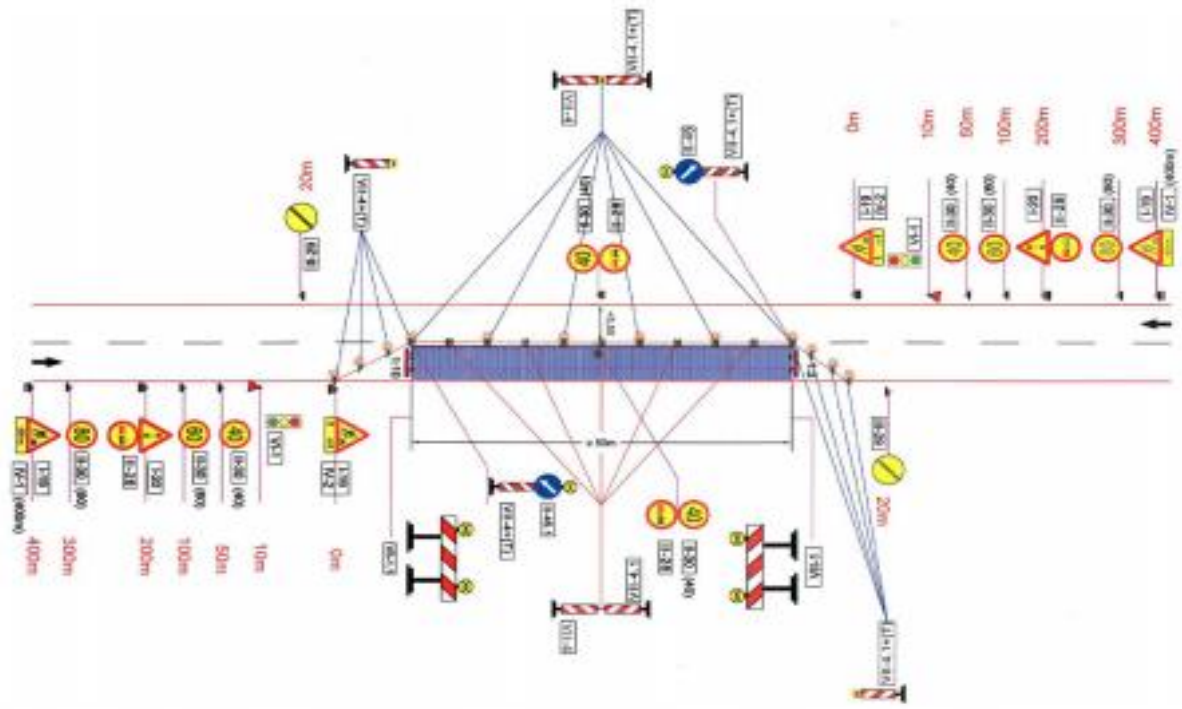


Figure 3. Example no. 2.

4.3. Example no. 3

The plan for marking and securing the roadwork zone outside a built-up area on the road with two traffic lanes, where a speed of 80-100 km/h is allowed (with alternating manual traffic management with flags) is presented. This is an example of a typical solution for the case when the roadwork zone is longer than 50 meters. The traffic flows in one traffic lane, and the construction workers who regulate the traffic in daytime conditions must be properly marked for better visibility on the road and be equipped with a radio connection, considering that the length of the roadwork zone is more than 50 meters. With the traffic sign I-19 roadworks placed at 400 meters, road users receive the information that they are switching from the normal traffic regime to the traffic regime in the roadwork zone.

Bearing in mind that the stopping distance of the vehicle at a speed of 100 km/h is 248.5 m and that the traffic sign I-19 roadworks is located at a distance of 400 meters from the place where the roadworks are carried out, road users have time to adjust their driving to the conditions of safe traffic in the roadwork zone, and in the event of a road crash, the company that manages the road would not be held accountable for the creation of a dangerous situation and the occurrence of the crash.

The stopping distance of the vehicle at a speed of 100 km/h, at a normal deceleration of 2 m/s² and with a reaction time of 2 s would be

$$S = 27.78 \cdot 2 + 27.78^2 : 2 : 2$$

$$S = 55.56 + 192.93 = 248.5 \text{ m.}$$

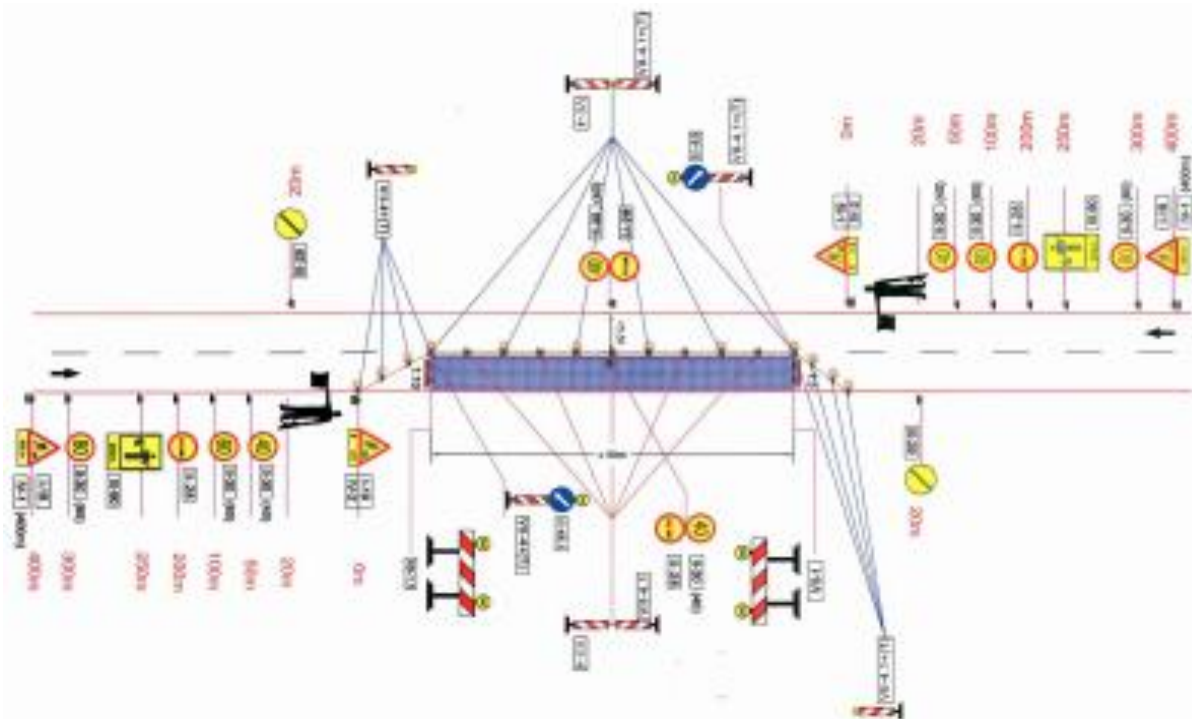


Figure 4. Example no. 3.

4.4. Example no. 4

The plan for marking and securing the roadwork zone on a highway, with complete closure of the highway lanes and with traffic flowing on the opposite roadway, is presented. This is an example of a typical solution for the case when the roadwork zone is longer than 50 meters. At a distance of 800 meters, road users receive information through the traffic sign I-19 roadworks that they are approaching a roadwork zone, after which they receive information about the speed limit (60 km/h), overtaking prohibition, and information on the flow of traffic in the roadwork zone.

The stopping distance of the vehicle at a speed of 120 km/h would be 344.4 m, and bearing in mind that the traffic sign I-19 roadworks is located at a distance of 800 meters from the place where the roadworks are carried out, road users have time to adapt their driving to the conditions of safe traffic in the roadwork zone and in the event of a crash, the company that manages the road would not be held accountable for the creation of a dangerous situation and the occurrence of the crash.

The stopping distance of the vehicle at a speed of 120 km/h, at a normal deceleration of 2 m/s^2 and with a reaction time of 2 s, would be

$$S = 33.33 \cdot 2 + 33.33^2 : 2 : 2$$

$$S = 66.66 + 277.7 = 344.4 \text{ m}$$

No marking or inadequate marking of the roadwork zones on the road constitutes an imperceptible, sudden, dangerous and unexpected obstacle for road users in the road lane, which may result in a dangerous situation and a road crash.

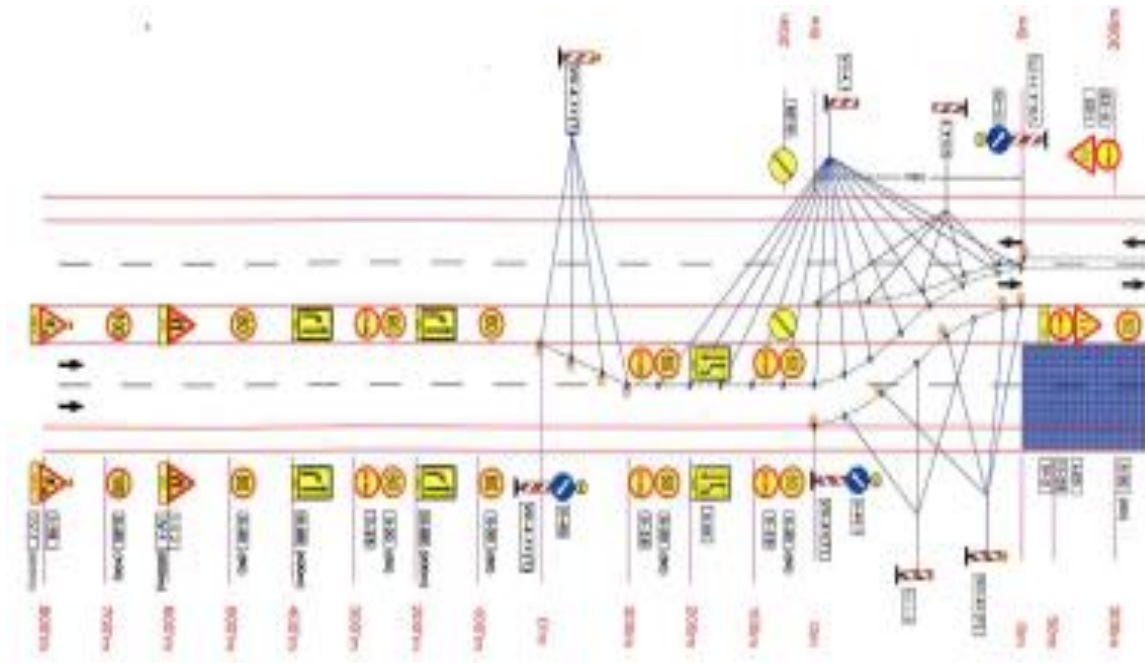


Figure 5. Example no. 4.

The analysis of road crashes that occurred in the roadwork zones due to a suddenly arising dangerous situation, which drivers could not avoid in time, predict, or have a reason to expect, indicates that the circumstance that created the dangerous situation is the cause of the road crash. Namely, if a road crash occurred as a result of a dangerous situation in which drivers were placed due to poor traffic management and poorly transmitted messages and information through temporary traffic signs in the roadwork zone, any fault related to the creation of a dangerous situation and the occurrence of the crash lies on the company that manages the road and the responsible Technical Traffic Regulation project designer.

The Law on Public Roads defines the liability of a company that manages the road for damage caused to public road users due to the failure to perform specific works, i.e. due to the performance of those works contrary to the prescribed technical conditions and method of their performance [6].

Considering all of the above, the company that manages the road is obliged to ensure the safe and smooth flow of traffic for road users, whereas drivers, i.e. road users, have no reason to expect unmarked or inadequately marked roadwork zones. In the event of a road crash, any breach of the legal regulations by the company that manages the road will make the company and its responsible persons accountable for the creation of a dangerous situation and the occurrence of the crash.

5. CONCLUSION

Roadwork zones constitute traffic situations that are unexpected but fairly common for most road users. A large number of road crashes that occurred in roadwork zones were caused by inadequate safety of the roadwork zone, bad traffic routing, and poorly conveyed messages and information to road users through temporary traffic signs in the work zone.

The legal regulations of the Republic of Serbia define the rights, obligations, duties, responsibilities and activities of companies that manage roads, traffic designers, and contractors. Namely, the company that manages the road is obliged to ensure the safe and smooth flow of traffic for road users, while drivers, that is, road users, have no reason to expect unmarked or inadequately marked roadwork zones.

Identifying the causes of road crashes is one of the most important steps in defining the problem, taking specific measures and identifying priorities, all with the aim of increasing road safety in roadwork zones. By informing drivers in time and using new technologies [10, 11], a large number of traffic accidents could be prevented, both on the territory of Serbia [12] and around the world.

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References

- [1] Ivanišević, T., Ivković, I., Čičević, S., Trifunović, A., Pešić, D., Vukšić, V., and Simović, S., 2022, The impact of daytime running (LED) lights on motorcycles speed estimation: A driving simulator study. *Transportation research part F: traffic psychology and behaviour*, 90, pp. 47-57.
- [2] Simović, S., Ivanišević, T., Trifunović, A., Čičević, S., and Taranović, D., 2021, What affects the e-bicycle speed perception in the era of eco-sustainable mobility: a driving simulator study. *Sustainability*, 13(9), 5252.
- [3] Ivanišević, T., Trifunović, A., Čičević, S., Pešić, D., Simović, S., Zunjic, A., Duplakova, D., Duplak, J. and Manojlović, U., 2023, Analysis and Determination of the Lateral Distance Parameters of Vehicles When Overtaking an Electric Bicycle from the Point of View of Road Safety, *Applied Sciences*, 13(3), p.1621.
- [4] Cvetanović, A., and Banić, B., 2008, *Handbook for road workers*, Academic thought, Belgrade.
- [5] Garber, N., and Zhao, M., 2002, Crash Characteristics at Work Zones, Virginia Transportation Research Council.
- [6] Technical recommendation for roadworks markings, 1992, Federal Institute for Standardization.
- [7] Law on Road Safety, "Official Gazette of RS", no. 41/2009, 53/2010, 101/2011, 32/2013, 55/2014, 96/2015, 9/2016, 24/2018, 41/2018, 41/2018, 87/2018, 23/2019 and 128/2020.
- [8] Rulebook on Traffic Signs, Signals and Road Markings, "Official Gazette of RS", number 85/17 and 14/2021.
- [9] Law on Public Roads, "Official Gazette of RS", number 101/2005, 123/2007.

- [10] Cicevic, S., Trifunovic, A., Mitrovic, S., & Nešic, M., 2017, The usability analysis of a different presentation media design for vehicle speed assessment. In: Zunjic A. (Ed.) *Ergonomic Design and Assessment of Products and Systems*, pp. 195-220, Nova Science Publishers, Inc. New York.
- [11] Trifunović, A., Čičević, S., Lazarević, D., Dragović, M., & Čučaković, A., 2019, Challenges and promises of mobile devices usage for spatial visualization skills assessment in technical drawing for engineering course. In *ICGG 2018-Proceedings of the 18th International Conference on Geometry and Graphics: 40th Anniversary-Milan, Italy, August 3-7*, pp. 1740-1750, Springer International Publishing.
- [12] Pešić, A., Stephens, A. N., Newnam, S., Čičević, S., Pešić, D., & Trifunović, A., 2022, Youth Perceptions and Attitudes towards Road Safety in Serbia. *Systems*, 10(5), 191.