Proceedings of the 10th International Conference on Civil Structural and Transportation Engineering (ICCSTE 2025)
July, 2025 | Imperial College London Conference Center, London, United Kingdom
Paper No. 196
DOI: 10.11159/iccste25.196

Road Safety Audits in Croatia – Experiences to Date

Marko Šoštarić[1], Marko Ševrović[1], Juraj Vertlberg[1], David Gruhonjić[1]
[1]Faculty of Transport and Traffic Sciences, University of Zagreb
Vukelićeva 4, 10000 Zagreb, Croatia
fpz@fpz.unizg.hr

Abstract **-** Road infrastructure is one of the key factors influencing road safety. Accordingly, the transport profession faces a growing need for safer road infrastructure each year. According to the National Road Safety Plan of the Republic of Croatia for the period 2021–2030, human, in combination with the road infrastructure, is a potential cause of approximately 35% of all serious road accidents. The solution lies in adopting "forgiving roads," which aim to accommodate driver errors while preventing or reducing the severity of traffic accidents. Road Safety Audits are one of the procedures aimed to achieve this goal. They were recognized and introduced through Directive 2008/96/EC of the European Parliament and the Council of 19 November 2008 on road infrastructure safety management. Authorized road safety auditors from the Faculty of Transport and Traffic Sciences, together with their audit teams, have conducted over 50 road safety audits in Croatia and abroad since the introduction of the road safety audit process. This paper presents the key results and conclusions derived from RSAs conducted. Analysis of the results of road infrastructure audits revealed that 5% of identified findings are high-risk, 30% are medium-risk, 64% are low-risk and 1% have no risk. The most common categories of identified issues fall into four groups: design elements, traffic signage, traffic light systems, and passive safety systems. Experience to date shows that over 75% of the auditors' findings are accepted by clients, with an 88% acceptance rate for proposals related to high-risk findings. The most common reasons for rejecting findings are increases in project costs and the need to amend location permits or construction documents that have already been obtained or are in progress. Based on the identified results, there is a clear potential for improving the current road design practices in Croatia.

Keywords**:** road safety, road safety audit, road design, risk assessment

1. Introduction

Road safety is a pressing issue worldwide, with approximately 1.19 million people dying as a result of road traffic accidents annually and 20 to 50 million people sustaining various types of injuries [1]. The annual cost of fatalities and injuries which were sustained in traffic accidents is around 3.6 trillion US dollars, which is 3.7% of the global GDP [2]. When it comes to the Republic of Croatia, despite a significant reduction in the number of road deaths, the country has seen 274 deaths and more than 14 thousand injuries of various severities in 2023 [3]. Since multiple countries are not seeing a quick enough reduction in the number of accidents and fatalities, the Stockholm Declaration [4] has additionally highlighted the importance of working on achieving the road safety goals set for 2030, which include the reduction of road deaths and injuries by at least 50%, as well as other goals.

Since road infrastructure is an important factor contributing to the occurrence of road traffic accidents, it is important to design roads which are safe, but also "forgiving". The concept of "*forgiving roads*" implies that drivers' and vehicles' errors are inevitable, and that roads and roadsides should be designed in a way that drivers can correct their errors to avoid an accident. However, if the error cannot be corrected, the road and its environment should be designed in a way that the consequences of the accident are minimal [5]. To enhance road safety in its area and to regulate procedures regarding road infrastructure safety management, the European Union published Directive 2008/96/EC, which regulates key road safety procedures, such as road safety impact assessments (RSIA), road safety audits (RSA), the network safety management (NSM) and road safety inspections (RSI) [6]. This directive was updated with the Directive (EU) 2019/1936, which includes new terms such as network-wide road safety assessments (NWRSA), has bigger focus on vulnerable road users as well as enhanced transparency and reporting [7].

One of the methods used to minimize the consequences of road traffic accidents and to improve road safety is to conduct road safety audits (RSA). Road safety audit can be defined as formal, systematic, independent assessment of the potential road safety issues associated with a new road design or road improvement design. RSAs are carried out by a multidisciplinary

audit team comprising two or more experienced and qualified road safety engineers who are not part of the design team [8]. Also, RSAs are considered as a useful process for identifying potential road safety improvements in any part of the project's lifespan including all its stages: planning, design, construction, or the as-built stage (exploitation) [9]. Once the road is built, proactive RSAs should be conducted periodically to ensure that potential issues are addressed before an accident happens [10]. RSAs were first widely conducted in the United Kingdom, after which many countries adopted this concept as well, such as Australia, Canada, Denmark, Sweden, Germany, India, Malaysia, Singapore etc.

2. Road Safety Audits in Croatia

The previously mentioned Directives of the European Union made obligatory all member states to regulate activities regarding procedures for improving road infrastructure safety and road safety audits. To align with European directives, the Croatian *Ministry of the Sea, Transport, and Infrastructure* adopted the Regulation on Activities and Procedures for Improving Road Infrastructure Safety and Road Safety Audits [11]. This regulation defines activities aimed at improving the road infrastructure safety, as mandated by the Roads Act. These activities encompass all stages of road planning, design, construction, and maintenance. They include road network safety assessments, road safety impact assessments, road safety audits, management of road safety data, and the preparation of accident reports.

The regulation also defines the scope and the methodology for conducting Road Safety Audits. Under the current regulation, the road safety audit process is carried out in four stages: Preliminary Design RSA (RSA1), Main Project/Detail Design RSA (RSA2), RSA of Built Road Infrastructure – before opening to traffic (RSA3), and Post-Opening RSA (RSA4). The first stage involves auditing the preliminary design before initiating the process of obtaining a location permit. The main project/detail design is audited depending on the level of detail in the project documentation, in accordance with specific regulations. This RSA must be conducted before initiating the process of obtaining a building permit. This stage takes place prior to opening the road to traffic and before conducting the technical inspection of the infrastructure. This RSA is conducted within one year of the road being opened to traffic.

After analysing project documentation (pre-construction RSAs) or conducting on-site field surveys (post-construction RSAs), the Audit Team prepares findings and recommendations, for improvement measures. Additionally, each identified issue is assigned a risk level (high, medium, low), which indicates the probability of severe or minor road traffic accidents occurring. These comprehensive procedures ensure that road infrastructure safety is thoroughly evaluated and improved at every stage, ultimately reducing the risk of road traffic accidents and enhancing overall safety for all road users.

3. Road Safety Audit Experiences

The team of authorized road safety auditors from the Faculty of Transport and Traffic Sciences at the University of Zagreb has conducted over 50 road safety audits in Croatia and abroad, along with their audit teams. Figure 1 shows the distribution of audits per stage.

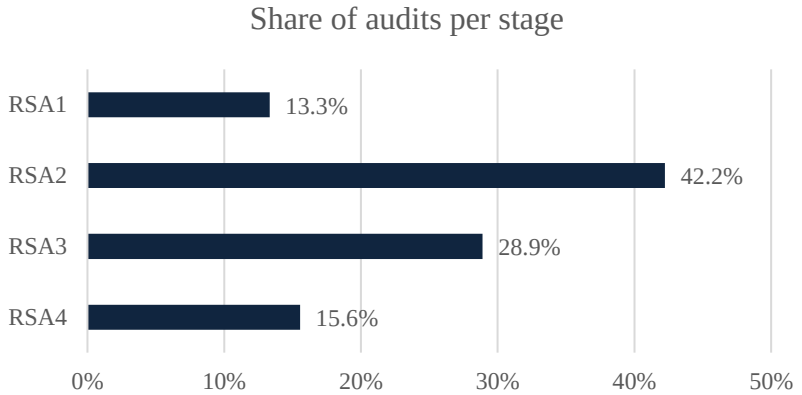

Fig. 1: Share of road safety audits per stage

The majority of the RSAs conducted pertain to the design stage, with preliminary design and main project/detail design RSAs accounting for 55% of all RSAs. Post-construction RSAs contribute to 29% of all RSAs, while 16% of the RSAS are related to the post-opening stage.

All RSAs are made of individual findings and recommendations, with most RSAs having more than one finding or recommendation. Figure 2 shows the distribution of findings per stage.

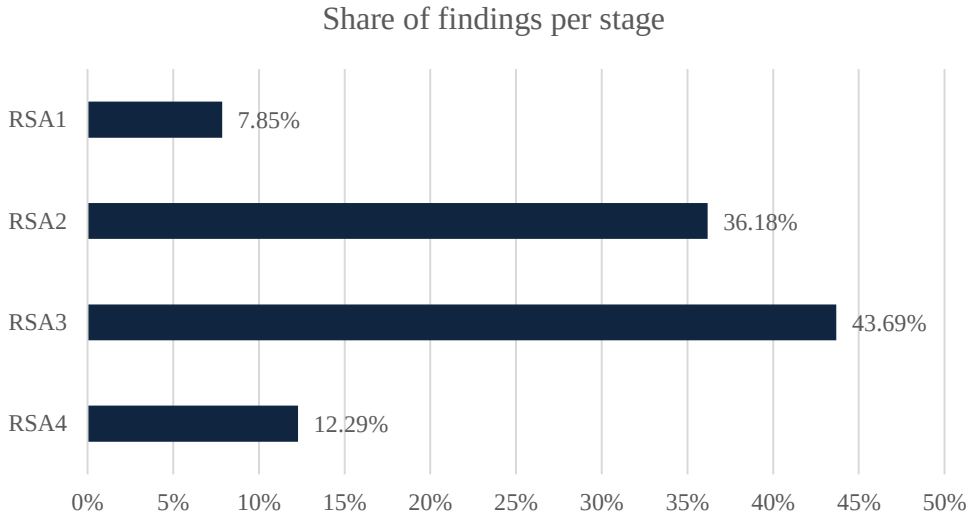

Fig. 2: Share of findings of RSAs per stage

Indeed, the majority of findings were identified either in the main project/detailed design stage (RSA2) (36%) or in the post-construction stage-before the opening to traffic (RSA3) (44%). Figure 3 shows the distribution of findings according to risk.

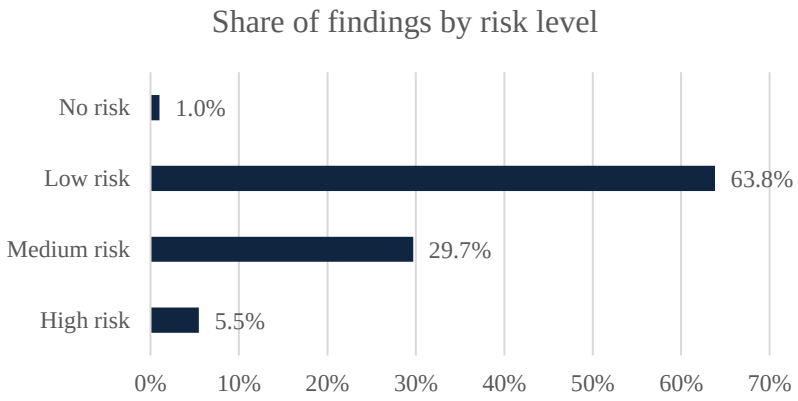

Fig. 3: Share of findings of road safety audits by risk level

As can be seen, most of the findings were labelled as low-risk findings (64%), medium-risk findings account for 30%, high-risk findings have a share of 5%, while 1% of findings have no risk.

The most common categories of identified findings fall into the following four groups:

- Design elements,
- Traffic signage,
- Traffic light systems,

- Passive safety systems.

The most common findings pertain to traffic signalisation (51%), especially vertical road signs. The second common group of findings refers to design elements (28%), followed by passive safety systems (18%) and traffic light systems (3%).

3.1. Design Elements

The most frequent issues regarding road design elements include aspects that directly affect road safety and are interconnected, forming key road safety factors. Among these issues, horizontal and vertical alignment elements stand out as one of the most common ones. Their dimensions often enable significantly higher operating speeds (85^{th} percentile speed) compared to the defined design speed. According to RSAs4 conducted (post-opening of roads), this type of design typically results in a large deviation between operating speeds and speed limits, thereby increasing the risk of serious road traffic accidents. Additionally, frequent findings include insufficient stopping and overtaking sight distance and inadequate turning radii in intersection zones, which allow for higher turning speeds than intended.

3.2. Traffic Signage

The most common issues regarding traffic signage include:

- Lack of chevron signs,
- Misalignment of horizontal and vertical traffic signs,
- Excessive signalisation that may confuse drivers,
- Inconsistencies between speed limit signs and the surrounding traffic environment.

Understanding these issues is crucial for creating a safer road environment. For instance, the absence of signs marking sharp curves can pose a serious hazard, as drivers are deprived of critical information about upcoming conditions, especially when significant speed reductions are needed before entering the curve. Misaligned horizontal and vertical signage can confuse drivers, while inconsistent or redundant signage can lead to information overload, diverting attention and increasing the likelihood of traffic violations. Therefore, traffic signage should be designed unambiguously and precisely to provide clear and consistent information to drivers, contributing to improved road safety.

3.3. Traffic Light Systems

Common issues regarding traffic light systems significantly impact the efficiency and road safety. These issues include:

- Mismatched signal stage durations with expected traffic loads and flow distribution,
- Insufficient clearance time between conflicting signal groups,
- Inadequate synchronization of traffic lights at connected intersections.

Mismatched signal stage durations often result in longer waiting times and therefore traffic congestions, while insufficient clearance time increases the risk of vehicle collisions. Poor synchronization of traffic lights at connected intersections complicates traffic management and causes unnecessary delays. Addressing these issues is crucial for improving traffic flow and road safety.

3.4. Passive Safety Systems

Issues regarding passive safety systems frequently involve key components such as guardrails, terminals, and crash cushions. Common issues include adherence to only minimal legal requirements for installing guardrails and their insufficient lengths at lateral hazard locations. These issues often result in guardrails being too short or installed at too few locations. The most common problems with guardrails include insufficient containment levels and inappropriate working widths. Insufficient containment level limits a guardrail's ability to prevent vehicles running off the road,

potentially leading to severe consequences. Inadequate working widths reduce the effectiveness of guardrails in protecting vehicles and drivers from hitting lateral hazards.

Issues with terminals and crash cushions often involve improper installation or complete absence. Proper installation is is critical to their functionality, as these elements are designed to extend the stopping distance of vehicles, thereby preventing preventing sudden deceleration. Their absence or improper installation significantly increases the severity of road traffic accidents. Proper implementation, maintenance, and monitoring of these components are essential for ensuring a safe traffic system.

3.5. Additional Findings

On average, road safety audits identify slightly less than nine findings per RSA. It is important to note that the number of findings largely depends on the complexity and spatial scope of the project being audited. Additionally, fewer issues are identified in projects that underwent RSAs in earlier stages, as well as for high-risk findings.

Regarding the acceptance of findings by Clients/Designers, experience shows that 76% of them were fully accepted and necessary changes were made, 9% were partially accepted while 15% were not accepted. Figure 4 shows the acceptance rate of findings, categorised by risk levels.

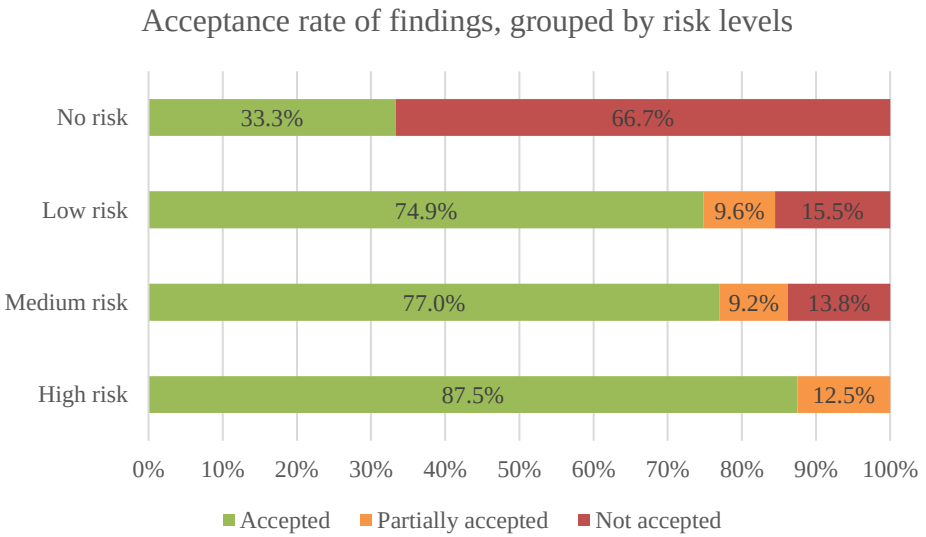

Fig. 4: Acceptance rate of the findings of road safety audits, grouped by risk levels

The highest acceptance rate is for high-risk findings (88%). Some high-risk findings were only partially accepted, but no high-risk findings were completely declined. A high acceptance rate can be observed for low- and medium-risk findings as well, with 75% and 77% of findings being fully accepted and 10% and 9% of findings being partially accepted. Some findings were not accepted at all in these risk groups, amounting to 16% and 14% respectively. Findings labelled as no-risk have a low acceptance rate, but it should be noted that there are only 3 such findings, out of which one was accepted (33%) and two were not (67%). Findings are often rejected due to unexpected project cost increases that were not accounted for in the budget, as well as the need to revise location permits or construction documents that are already obtained or being finalized. This analysis highlights the importance of early-stage RSAs and proper planning to address potential issues and ensure safer road infrastructure.

4. Conclusion

Road Safety Audits offer a proactive and practical approach to identifying and improving the safety of road infrastructure at any stage of its lifecycle. Regular application of RSAs encourages and mandates safety analysis during the planning,

development, construction, and maintenance of road infrastructure. RSAS also encompass all road users, with a particular emphasis on vulnerable road users, such as pedestrians, cyclists, etc.

The fact that, on average, 35% of identified findings in conducted road safety audits are classified as high or medium risk, and that 76% of improvement measures for identified findings are fully accepted by Clients/Designers, that there is significant potential for further integrating road design processes into the function of road safety. and based on previous experiences with the characteristics of identified findings, the need for systematic education of designers and road infrastructure managers in new trends and best practices of safe design is undeniable.

Furthermore, it is essential to develop guidelines for safe design that will enable designers and road infrastructure managers to more easily access education and provide professional advice during the design process of various road infrastructure elements from a road safety perspective. On top of that, in line with the above and global best practices, it is necessary to conduct RSAs at all stages of significant road infrastructure reconstruction and new construction projects, in accordance with the Regulation on Activities and Procedures for Improving Road Infrastructure Safety and Road Safety Audits. This practice will help to avoid significant undesirable social and financial costs associated with correcting potentially unsafe elements of road infrastructure.

5. References

[1] World Health Organization. (2023, December 13). Road traffic injuries [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

[2] iRAP. (2025). iRAP Safety Insights Explorer [Online]. Available: https://irap.org/safety-insights-explorer/

[3] Croatian Ministry of Internal Affairs, *Bulletin on Road Traffic Safety 2023*. Zagreb: Ministry of Internal Affairs, 2024.

[4] International Road Federation, *Stockholm Declaration on Road Safety*. Stockholm: 3rd Global Ministerial Conference on Road Safety.

[5] iRAP. (2025). Forgiving Roads Concept [Online]. Available: https://toolkit.irap.org/safer-road-treatments/forgiving-roads-concept/

[6] European Parliament and the Council of the European Union, *Directive 2008/96/EC on road infrastructure safety management*. Brussels: Official Journal of the European Union, 2008.

[7] European Parliament and the Council of the European Union, *Directive (EU) 2019/1936 amending Directive 2008/96/EC on road infrastructure safety management*. Brussels: Official Journal of the European Union, 2019.

[8] Vardaki, S., Papadimitriou, F. and Kopelias, P., "Road safety audit on a major freeway: implementing safety improvements," *Eur. Transp. Res. Rev.*, vol. 6, pp. 387-395.

[9] Owers, R. S., and Wilson, E. M., *Safety analysis without the legal paralysis: The road safety audit program (No. MPC Report No. 02-129)*. Laramie, WY: University of Wyoming, 2001.

[10] Zahran, E.-S., Tan, S. J., Tan, E. H. A., Mohamad Asri Putra, N. A., Atiqah, B., Yap, Y. H., and Abdul Rahman, E. K., "Spatial analysis of road traffic accident hotspots: Evaluation and validation of recent approaches using road safety audit," *Journal of Transportation Safety & Security*., vol. 13(6), pp. 575–604.

[11] Ministry of Sea, Transport and Infrastructure, *Regulation on Activities and Procedures for Improving Road Infrastructure Safety and Road Safety Audits*. Zagreb: Official Gazette of the Republic of Croatia, 2022.