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MEASURES TO IMPROVE LEVEL CROSSING SAFETY

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Abstract: This paper examines key measures to improve traffic safety at level crossings, which remain critical points of conflict between rail and road transport. It analyzes current infrastructure challenges, driver behavior, and technological advancements. The study proposes a comprehensive approach combining physical upgrades, such as modern barriers, LED signaling, and grade separation with innovative solutions, including automated warning systems and AI-powered surveillance. Ultimately, implementing these integrated measures can significantly reduce accident rates, prevent fatalities, and ensure smoother traffic flow at level crossings.

Keywords: Level crossing safety, traffic management, accident prevention.

1. INTRODUCTION

In recent years, approximately 850 fatalities resulting from railway accidents have occurred within the European Union (EU), with around 27% of these taking place at level crossings (Watson & Bayyati, 2021). Numerous scientific publications are dedicated to assessing and analyzing safety at level crossings, as well as to exploring new approaches and measures to enhance it.

Improving traffic safety at level crossings is a significant aspect of transport operations globally. Accidents at level crossings often result in severe consequences, including fatalities, injuries, and substantial economic losses. Consequently, various measures have been developed to enhance safety and reduce the number of accidents at these locations (Evans, 2004; Yeh & Multer, 2008).

One of the most effective engineering solutions for improving safety at level crossings is their elimination through grade separation, where rail and road traffic are separated by constructing overpasses or underpasses. This solution eliminates conflicts between trains and road users and is therefore considered the safest option. However, such projects require significant financial investment and can be difficult to implement in densely populated urban areas due to spatial and economic constraints (Mok & Savage, 2005).

A widely implemented safety measure is the installation of active warning systems at level crossings. Active protection systems typically include flashing lights, audible alarms, and automatic barriers that activate as a train approaches the crossing. These systems provide clear warnings to road users and significantly reduce the risk of accidents compared to passive crossings that rely solely on signs and road markings (Yeh & Multer, 2008). Research has shown that drivers react earlier and more appropriately when active warning devices are present.

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Improvements to road infrastructure and traffic control also play a vital role in enhancing safety at level crossings. These measures include improved signaling, better pavement markings, the installation of stop lines, and increased visibility around crossings through the removal of vegetation or other obstructions. Additional measures, such as rumble strips, can alert drivers and encourage them to reduce speed when approaching crossings (Rudin-Brown et al., 2013). Although these measures cannot entirely prevent violations, they provide additional warning signals to road users.

Technological advancements have also introduced Intelligent Transport Systems (ITS) to improve safety at level crossings. These systems incorporate train detection technologies, vehicle detection systems, and communication systems that provide real-time warnings to road users or traffic control centers. Some systems can detect obstacles or vehicles trapped on the tracks and send warnings to railway operators or approaching trains (Larue et al., 2015).

In addition to technological and engineering measures, education and awareness-raising programs are important for improving safety at level crossings. Public awareness campaigns aim to inform drivers, pedestrians, and cyclists about the risks associated with level crossings and to encourage compliance with traffic regulations and warning signals. Educational programs are particularly important for frequent users of level crossings and young drivers, who may underestimate the risks associated with these locations (Freeman & Rakotinariny, 2015).

Furthermore, regulatory enforcement and traffic control play a significant role in level crossing safety. Strict enforcement of traffic regulations, including penalties for ignoring warning signals or bypassing barriers, can discourage risky behavior. The use of surveillance cameras and automated enforcement systems at level crossings can also improve compliance with traffic rules (Larue et al., 2015). Data analysis and safety monitoring are increasingly being used to identify high-risk crossings and prioritize safety improvements. By analyzing accident statistics, traffic conflicts, traffic volumes, and environmental conditions, decision-makers can identify the highest-risk locations and implement targeted interventions (Evans, 2004).

The paper presents a selection of measures derived from the Study on Traffic Safety at Level Crossings in the Autonomous Province of Vojvodina.

2. CONCEPT FOR IMPROVING TRAFFIC SAFETY AT LEVEL CROSSINGS

Level crossings represent critical intersection points between rail and road infrastructure, inherently carrying a high risk of severe accidents, fatalities, and socio-economic losses. Despite continuous advancements in transport engineering, traditional safety measures often fall short due to human error, infrastructure limitations, and growing traffic volumes. By integrating modern infrastructure upgrades with innovative technologies, this conceptual approach aims to minimize conflicts between trains and road users, optimize traffic flow, and significantly reduce accident rates.

Building upon these established challenges, developing an effective strategy requires a holistic view of the safety ecosystem. Taking into account global best practices, the specific operational characteristics of the traffic safety system, and previous efforts to improve safety at level crossings, certain priority areas for action can be identified.

Key priorities should focus on:

- Strengthening the strategic framework: A dedicated program for improving traffic safety at level crossings could be developed. This program should define the system's operational foundations, including problem identification, organizational structures, actionable measures, and funding mechanisms, thereby ensuring a long-term societal commitment to the issue.

- Developing a unified information system: Databases relevant to traffic safety serve as a crucial foundation for defining problems and monitoring the effectiveness of interventions. Addressing these issues requires integrating diverse data, such as traffic accidents and their consequences, road and rail infrastructure elements, equipment specifications, and traffic volume and composition, into a single system to enhance operational effectiveness.
- Strengthening institutional capacity: The efficiency of relevant authorities contributes significantly to resolving traffic safety issues. Institutional capacities can be enhanced by advancing human resource skills, updating knowledge bases, and streamlining operational procedures through the implementation of strategic documents.
- Raising public awareness: The human factor remains the dominant variable in traffic safety. Strengthening community awareness fosters a deeper understanding of individual roles and responsibilities within the traffic safety system. Through targeted educational programs, public campaigns, and media outreach, overall social awareness can be elevated to improve safety compliance.
- Promoting the application of modern technology: A crucial step toward modernizing safety lies in the adoption of advanced technical solutions and equipment. Because the legislative, economic, and business environments decisively influence these deployment conditions, fostering a supportive institutional structure is essential for the wider adoption of modern technology.
- Monitoring regulatory implementation and updates: Defining clear norms of conduct and updated regulations (standardization) is essential for efficient, organized, and safe traffic operations. These norms establish the baseline requirements that all road users and operators must meet to ensure safe participation in the transport network.

3. SELECTED MEASURES FOR IMPROVING LEVEL CROSSING SAFETY

A range of technical measures has been developed with the aim of:

- Improving driver awareness regarding the approach to a level crossing and train visibility;
- Preventing unsafe behavior and traffic violations at level crossings;
- Reducing vehicle speeds when approaching a level crossing.

The selection of measures to improve traffic safety at level crossings should be based on the identification and analysis of risk factors affecting traffic safety at these locations. Particular attention should be given to the characteristics of road and railway infrastructure, existing level crossing protection systems, visibility conditions, and road user behavior. In this context, the implementation of additional technical measures can contribute to the timely recognition of hazards, reduce the risk of driver non-compliance with traffic regulations, and create safer conditions for crossing railway tracks.

The Study on Traffic Safety at Level Crossings in the Autonomous Province of Vojvodina (ADOMNE and MHM Project, 2026) examined various technical solutions aimed at improving level crossing visibility, providing timely warnings to drivers, and influencing their behavior when approaching a crossing. The installation of rumble strips on the road surface (Fig. 1) provides additional tactile and audible warnings to drivers, while traffic light signals (Fig. 2) provide clear indications of the need to stop. The use of variable message signs (VMS; Fig. 3) offers an additional means of attracting drivers' attention and emphasizing potential hazards when approaching a level crossing.

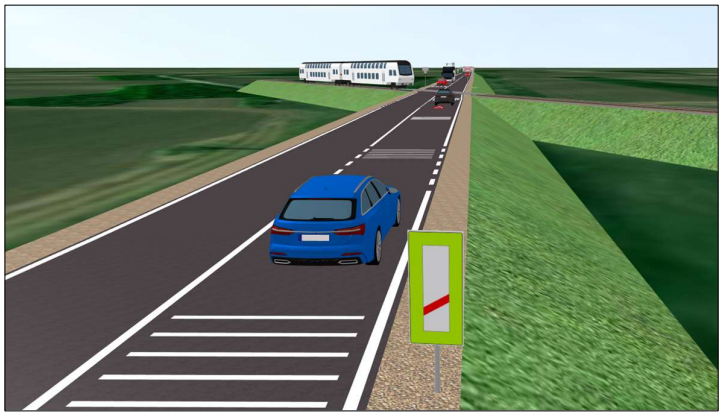


Fig. 1 Rumble strips on the approach to a level crossing (ADOMNE and MHM Project, 2026)



Fig. 2 Light signal device (traffic light) for regulating traffic at a level crossing (ADOMNE and MHM Project, 2026)



Fig. 3 Variable message sign warning of an approaching level crossing (ADOMNE and MHM Project, 2026)

In addition to the aforementioned solutions, particular attention should be paid to the appropriate selection, placement, and visibility of traffic signs and road markings on approaches to level crossings. Combining standard traffic signs and road markings (Fig. 4) with additional warning signs (Fig. 5) can improve the timely recognition of hazards and encourage drivers to adjust their speed and exercise greater caution. The selection and combination of individual measures should be based on the specific characteristics of each level crossing, including visibility conditions, road geometry, the existing level crossing protection system, and traffic volumes, in order to achieve an appropriate level of traffic safety.

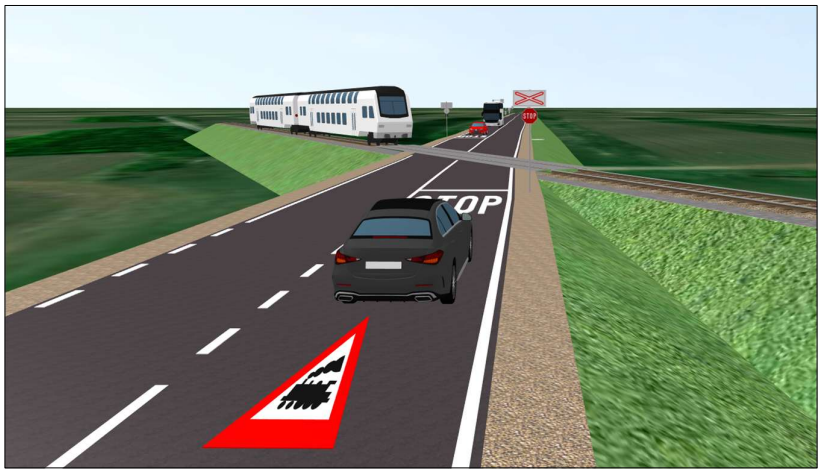


Fig. 4 Traffic signaling at the approach to a level crossing
(ADOMNE and MHM Project, 2026)

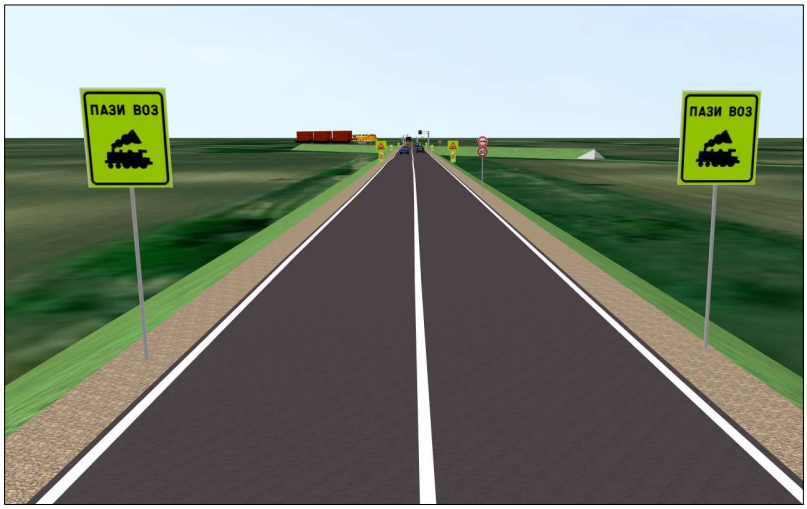


Fig. 5 Traffic signs warning of an approaching level crossing
(ADOMNE and MHM Project, 2026)

The technical solutions presented illustrate examples of measures that may be considered when improving traffic safety at level crossings. Their implementation requires a prior assessment of existing conditions and the identification of specific safety issues, taking into account the technical and operational characteristics of each crossing. It is particularly important that the proposed solutions comply with applicable technical regulations and the requirements of the relevant road and railway infrastructure managers.

4. CONCLUSION

Level crossings represent one of the most critical points of interaction between road and rail transport systems. While they facilitate connections between road networks and railway corridors, they also introduce significant safety risks and operational constraints. Traffic accidents at these locations often have severe consequences due to the immense mass and speed of trains, as well as their limited braking capabilities.

Improving traffic safety at level crossings begins with fundamental measures regarding visibility, road user behavior, and traffic control. Several key interventions can significantly enhance safety performance:

- Upgrading warning systems: Installing or modernizing flashing lights, audible alarms, and automatic barriers to provide drivers with clear and timely warnings;
- Enhancing visibility: Managing vegetation, improving illumination, and ensuring that traffic signs is visible from a greater distance;
- Optimizing road markings: Implementing stop lines, rumble strips, and high-visibility reflective paint to encourage drivers to reduce speed;
- Implementing speed control: Reducing approach speeds through targeted signage and traffic-calming measures where necessary;
- Raising public awareness: Educating road users about the inherent risks associated with crossings and promoting compliant behavior;
- Ensuring regular maintenance: Keeping signaling systems, active barriers, and road surfaces in optimal operating condition;
- Evaluating grade separation: Constructing overpasses or underpasses in high-traffic or high-risk zones as the most effective long-term solution.

These measures achieve optimal results when implemented collectively, addressing both infrastructure design and human behavior. Upgrading infrastructure, strictly enforcing traffic regulations, and expanding public education can significantly reduce accident rates at level crossings.

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