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Security of railway crossings in the Slovak Republic and its impact on traffic accidents

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Abstract

This article focuses on the analysis of securing railway crossings in the Slovak Republic and its impact on the prevention and extent of the consequences of road accidents in road and rail vehicle clashes. The first part examines the correlation between economic and transport relations and statistical data on the development of traffic indicators in the EU. Furthermore, traffic accidents and the provision of railway crossings in the Slovak Republic are analyzed from a technical and legislative point of view. In the last part, the model example is used to calculate the impact of changing the interlocking safety equipment at the intersection of road and rail communications to traffic accidents in terms of socio-economic benefits.

Keywords: rail transport, safety, railway crossing, accidents

Introduction

Economics and transport are closely linked and mutually determining sets of processes. Affordable, secure and capacity-adequate infrastructure creates the conditions for efficient investment allocation, economic growth and stimulates mobility and the emergence of induced traffic. At the same time, transport is an inherent part of production, distribution and transport processes in both freight and passenger transport.

Conversely, a well-established and sustainable transport system is a precondition for a booming economy. The global expansion of world markets and the effort to optimize the costs of moving people and goods bring legitimate requirements for the qualitative and quantitative characteristics of the transport system.

Transport is experiencing a growing trend in post-crisis years in the EU as a result of re-economic growth, rising living standards for citizens and good economic condition. These factors make it increasingly commonplace within the common market for the transport system by the population and commerce to ensure mobility in the required range and quality.

Statistics from Eurostat show that from 2010 to 2016 there was an increase of 1,57 %[1] in the level of automotive traffic (number of passenger cars per 1 000 inhabitants) within the European Union. This phenomenon indicates the increasing intensity of vehicles on the roads and the increased volume of transport performance in road transport. The range of train kilometers in rail transport has increased by almost 26,5 %[2] over this period.

As the volume of traffic performance in both passenger and freight transport is increasing, there is a need for all relevant stakeholders (builders and infrastructure managers, transport vehicle manufacturers, transport operators, training and education organizations, safety and licensing organizations, authorities, legislators) to address the issue of smooth, safe and environmentally friendly transport.

An important issue in addition to solving the problems associated with a modern, high-capacity infrastructure providing sufficient conditions to meet the needs of population and goods mobility and sufficient room for efficient transport system setup is a security issue.

From this point of view, all modes of transport represent separate closed systems which, while taking into account limited conditions, are not subject to the operational and safety settings of other transport systems. However, in the case of modes of transport operating on roads, there may be a level or interchange that shows the potential for collision, namely:

- The level crossing of road and rail communication,
- The fly-over crossing of water and rail or road communication.

The fly-over crossing of water and rail or road communication can be collision dependent on the technical solution of the intersection. In this case, the technical solution and the local conditions are decisive. Usually, the crossing is solved with a sufficient margin for the movement of the vehicles to avoid collision situations.

The fly-over crossing of road and rail traffic is collision-free unless an incident occurs on any of the communications (traffic accident, cargo release, leakage, etc.), mostly in the case of high-altitude roads such as road overpass or railway bridges over the road.

The highest probability of a traffic accident is at the point of level crossing of road and rail communication. To prevent the occurrence of these adverse events, the level crossings are provided with high-level interlocking devices. The method of securing a rail crossing depends on local traffic, urban, and other specific conditions at the intersection point. The area of road safety in connection with the provision of railway crossings is addressed not only by transport infrastructure managers and design, production and deployment companies but also by police forces, state institutions, and transport authorities.

Despite the apparent increase in the number of cars and transport performance, the number of people killed on rail crossings in the EU is decreasing (see Table 1). The values listed in the table include fatal accidents when a train collides with road vehicle, pedestrian or cyclist.

Table 1. Number of deaths in rail transport in the EU

Rail transport	2010 [persons]	2017 [persons]	Difference [%]
Total	1 270	977	- 23,10
Out of: at railway crossing	371	298	-19,70

Source: [3]

Evidence that transport safety is one of the priority topics of great concern within the EU is not only the decreasing amounts of fatal accident statistics but also the fact that safety is given due consideration in all relevant EU strategy papers part of the theme of transport. One example is the White Paper - A Roadmap to a Single European Transport Area[4], one of the indicators being stated as: 'By 2050, reducing the number of fatal accidents to almost 0, by 2020 by half'. To meet the set measurable indicators, individual member states should take effective measures, the effectiveness and positive impact of which is subsequently assessed.

The accident rate in the Slovak Republic

Competencies and responsibilities for securing railway crossings belong to the administrators of rail and road infrastructure of intersected roads.

In the Slovak Republic, the railway infrastructure is managed by Slovak Railways (Železnice Slovenskej republiky, further as ŽSR); in road transport, depending on the category of road, the Slovak Road Administration (Slovenská správa ciest), the Regional Road Administration, or towns and municipalities.

Railway crossings fall under the management of ŽSR, which operates 3,626 km of tracks and 2,102 railway crossings[5] (as of 2017), i.e., approximately 1 crossing to 1.7 km of the railway line.

The method and the type of security device used at the intersection of road and rail depend on:

- the type of railway line,
- the type of road,
- vision conditions and
- local conditions.

Requirements for minimum level crossing safety are stipulated in the ŽSR regulation: "ŽSR Z 12 Crossings and Crossovers"[8]. Based on the number of crossed rails, the road communication group and the line speed, there exists the recommended safeguarding of existing or reconstructed crossings.

Basic categorization of railway crossing facilities in the Slovak Republic divided into active, i.e., equipped with a crossover device, and passively, i.e. marked with traffic signs only, is shown in *Table 2*.

Table 2. Number and type of interlocking security plants in the SR

year	2017
Total	**2 102**
Passive crossing (not secured)	1 032
Active crossing (secured)	1 070
Out of:	
Mechanical ramps	50
Permanently locked rail crossings	43
Mechanical crossing device	8

Light crossing interlocking plants	969

Source: [5]

Numbers of individual types of interlocking security plants are determined by historical, legislative and technical factors specific to the Slovak Republic.

According to the type of traffic accident on the railway crossing (from the view of road traffic), it is possible to define 10 categories, namely:

- collision with a running non-train vehicle,
- collision with a parked/stopped vehicle,
- collision with a fixed obstacle,
- collision with a pedestrian,
- collision with wildlife animal,
- collision with a domestic animal,
- collision with the train,
- collision with a tram,
- accident,
- another type of accident.

The following table compares the number of crossings accidents by category of the level of rail crossing security category, resulting in fatal and severe accidents in 2017 and 2018 (train collision accidents with road vehicle, pedestrian or cyclist). It is clear from the Slovak Police Force's statistics on accidents at rail crossings that in 2017, the proportion of accidents (in categories: train collision with a road vehicle, train collision with a pedestrian or train collision with a cyclist) was approximately 12% at the active and 49% at the passive interlocked crossings from all registered accidents.

Table 3. Number of accidents and deaths on railway crossings in Slovakia

	2017	2018
Number of accidents at crossings	**50**	**48**
Out of:		
PZS – Z	5	5
PZS	28	29
PZM	0	
K	17	14
Accidents resulting in injuries		
Death injuries	**6**	**15**
Out of:		
K	1	4
PZS	2	10
PZS – Z	3	1
PZM	0	0
Severe injuries	**13**	**14**
Out of:		
K	2	1
PZS	7	13
PZS – Z	4	0
PZM	0	0

Source:[7]; Legend: PSZ – Z – crossing with traffic lights and ramps, PZS – crossing with traffic lights without ramps, PZM – mechanically equipped crossing, K – passive (unsecured) crossing

It is clear from the presented data that there was only a small year-on-year change in the total number of accidents on railway crossings, the most significant number of accidents occurring on light crossing facilities without ramps, but this phenomenon is also influenced by the total number of light signaling devices on ŽSR lines, of which these are absolute majority (see Table 2). An important factor is also the intensity of road transport on the intersected roads and the extent of transport performance in rail transport on individual lines equipped with this kind of road safety equipment.

Modernization of a crossing interlocking system can have a positive impact on the occurrence of traffic accidents related to a train (tram) collision with a road vehicle, pedestrian or cyclist; other categories of traffic accidents are not affected by the replacement of the interlocking equipment - a higher level of crossing safety does not create a presumption of a lower incidence of traffic accidents in these categories.

In this context, it is not possible to generalize the number of accidents on active and passive crossings, as based on the normative and real operating ratios that make a significant difference in the extent of traffic performed on highway intersections with higher category railways (with higher line speed and more tracks).

Statistical data show that there was a significant increase in fatal injuries in 2018, especially on crossings with traffic lights with no ramps, which, according to legislation, should be applied at road crossing points or lower-class railway lines, where there is no assumption of a large volume of realized transport performance. The influencing factor may be the absence of barriers, the failure to observe the warning signal but also the psychological factor of drivers who know the extent of rail transport and therefore do not pay increased attention when crossing the railway tracks.

Figure 1 shows the number of accidents on secured and unsecured rail crossings in 2017 and 2018.

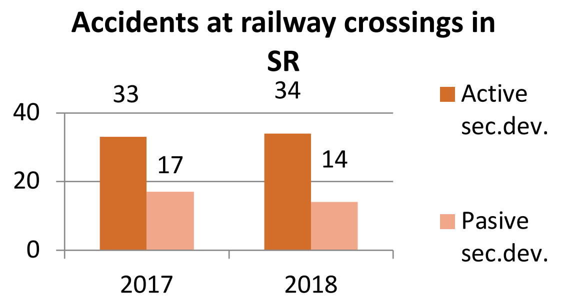

Figure 1 Number of accidents on secured and unsecured crossings in Slovakia
Source:[7]

The year-on-year comparison of accident rate data from the database of Police Force of the Slovak Republic shows rearrangements within individual categories of traffic accidents, but the long-term trend of accidents on crossings and its severe consequences in Slovakia is decreasing. This phenomenon is caused by the society-wide emphasis on increasing road traffic safety, modernization of railway crossings interlocking equipment or off-road solutions at modernized and exposed infrastructure sites. It is also vital to educate on security and to raise drivers' awareness of the principles of the safe crossing of railway tracks.

Solution for interlocking security plants of railway crossings in the Slovak Republic

From a safety point of view, it is necessary to pay increased attention to the intersection of road and rail communications and to apply adequate measures to prevent accidents at these locations and to minimize their impacts, depending on local specificities.

Tools for increasing safety at rail crossings can be either direct, with effect at the point where they are applied, or indirect, having legal, educational but also a technical or operational character with local or areal coverage.

- Direct tools: building and upgrading railway crossings using a higher level of security, extending / upgrading road signs, road surface improvement in front of and behind rail crossings, etc.
- Indirect tools: legislation on the construction and modernization of railways (rail crossings), rules on road marking, sanctions for non-respect of signaling and traffic signs, training of road users, compulsory training of professional drivers and train drivers, setting of maximum speed when the train passes the crossing, modernizing railway vehicles, etc.

As an EU Member State, the Slovak Republic has declared its participation in the construction (upgrading) of the significant communications magistrates defined in the Transeuropean Network - Transport (TEN - T), which outlines the main transport network within the common internal market through 9 corridors across Europe. TEN - T is divided into a Comprehensive Network and a Core Network, which is a subset of the comprehensive network and is made up of the most important transport routes. EU members are obliged to modernize their core network by 2030 and a comprehensive network by 2050. 3 TEN-T corridors are passing through the SR, namely: Baltic - Adriatic, Orient / East - Med, and Rhine – Danube.[15]

To modernize and construct road communications, the EU has identified funding in the Structural Funds and other instruments (e.g., CEF - Connecting Europe Facility), which can be used by individual states through operational programs and transport infrastructure modernization projects included therein.

The aim of the TEN - T network is not only to define the most critical communications across the EU but also to ensure the interoperability of individual transport systems (especially in rail transport), which are different for individual nations because of different historical background.

For this reason, the European Railway Agency has developed so-called Technical specifications for interoperability (TSIs) issued by the European Commission and published in the Official Journal of the European Union. The individual TSIs apply to specific subsystems or sub-subsystems with the primary objective of meeting the essential requirements and technical parameters for transport infrastructure and thus ensuring the coherence and interoperability of the internal transport network. The TSIs also specify the technical parameters and minimum safety requirements that the upgraded infrastructure must meet.

In the Slovak Republic, in the area of modernization of railway infrastructure, legislation at the national level is stricter than the TSIs and is defined by Act no. 513/2009 Coll. on Railroads, that: "The crossing of new main railway lines with roads is being established as a fly-over one. When upgrading or significantly restoring existing main railway lines or intersecting roadways, the builder will rebuild the existing level crossing or cancel it. "

All modernized main lines are, therefore, by national legislation, equipped with an fly-over crossings of road and rail infrastructure, which results in the complete elimination of traffic accidents that could arise in connection with the crossing of roads. The safety-related problem at rail crossings is thus automatically eliminated for a set of upgraded TEN-T lines. Through the construction of fly-over separated crossroads, socio-economic benefits are also generated in the form of prevention of traffic accidents and environmental disasters, loss of life and damage to property. Time-saving for passengers and road users is also a quantifiable benefit (an accident would result in a lockout on rail and road for reasons of elimination of road accident).

As national and European funds are limited, their allocation must be subject to some priority. This means in practice that the infrastructure modernization plan and its actual implementation take place in specific logical steps, taking into account the significant defined modernization projects and the building of integrated sections, where the synergic effects of modernization occur, possibly on the most exposed parts of the transport infrastructure.

The process of modernization of railway lines (rail crossings) therefore takes into account the volume of available funds, the importance of railway lines and intersected roads, EU requirements for interoperability and building of TEN-T network, strategic documents in the development of the transport system of the SR and also the technical readiness of individual projects.

For some lines (regional, with minor traffic importance, outside the TEN-T network), the conversion of intersections to fly-over ones is questionable. Besides, the allocation of funds for the modernization of railway lines of minor or local importance is about the state budget and EU funds problematic. Exploiting significant funds required by interlocking security plants is in some cases not even aligned with the value-for-money principle. If upgrading to such lines occurs, there is a high probability that the crossing will either be canceled or left as one at a level crossing. Thus, the security-related problem will continue. One of the ways how to solve the situation is to equip the level crossing with a higher level of interlocking equipment, but such activity may not bring the expected results when comparing the investment costs and socio-economic benefits. As shown in Figure 1, the number of road accidents on active crossings is higher than on passive crossings, with a relatively equal number of secured and unsecured rail crossings in SR (see Table 2). However, in this context, it is also necessary to take into account the extent of rail and road traffic passing through the collision points, their localization and local circumstances, as well as the psychological factor of warning traffic light device, respectively traffic signs.

For the reasons mentioned above, it is necessary to consider the assessment of the need for and the expediency of the solution of the railway crossing equipment individually. Traffic performance has a generally increasing trend, and the question of safety at rail and road intersections will become more timely as time goes by.

The solution for implementing a strategic approach to infrastructure upgrading could be to develop a document at the national level that would define the need for modernization and propose its technical parameters (including level/interchange crossing). The list of projects created should take into account the priorities of the state transport policy, the infrastructure manager, the carriers, the available funds from the state budget and the EU, the development of transport and demography and the economic situation in the regions.

A practical example of the potential impact of a change in rail crossing security

To illustrate the impact of increasing the level of rail crossing security, the following model example of changing the interlocking security plants of level crossing for road and rail communications is presented.

On the unsecured railway crossing (equipped only with traffic signs) near the village of Polomka in the Slovak Republic, a passenger train and a bus collided in 2009. This tragic accident was an impulse for the Ministry of Transport, Post and Telecommunications of the Slovak Republic (currently the Ministry of Transport and Construction of the Slovak Republic) and the railway infrastructure manager of ŽSR to increase safety in this section of the line and led to the modernization (rebuilding) of passive railway crossing to active - equipped with light signaling.

According to the Slovak Police Force's Traffic Accident Statistics, 12 people were killed in this rail crossing for the years 2006-2009 (up to the time of modernization of the interlocking safety equipment) due to road and rail collision, 6 people were seriously injured and 19 easily injured. After the application of the warning traffic light device, the number of injuries for the period 2009 - 2017 was 0 (see Table 4).

Table 4. Traffic accident statistics on the selected level crossing

Injuries	2006-2009	2010-2017
Fatal	12	0
Serious	6	0
Light	19	0

Source: [9]

Of course, it is not possible to state only by comparing traffic accident statistics on a particular rail crossing at selected time series, that changing a security device in the past would prevent any traffic accident from occurring on that crossing or eliminate its occurrence in the future.

Transport is to some extent a stochastic phenomenon, and whether a road accident occurs and the extent of its consequences (damage to property, light, severe or fatal injuries) cannot be predicted only by changing the level of road safety. However, it is clear from the data presented that since the 2009 event there have been no road accidents involving loss of life or injury to accident participants.

Other factors can also influence the emergence, course, and extent of the consequences of road accidents on rail crossings, such as road quality and road condition, weather (air temperature, road temperature), visibility, vision conditions, and other site-specific conditions of the rail crossing.

ŽSR, in cooperation with the Ministry of Transport, Post and Telecommunications of the Slovak Republic, during the modernization of the railway crossing (in 2009), spent EUR 265,550 [10] according to the medialized information on the use of light signaling equipment at the place of the traffic accident.

From investment in transport infrastructure, the socio-economic benefits of applying such a measure would be reduced social costs of accidents, time savings for passengers and road users in the case of no traffic accident and costs of property damage and environmental damage to be put back to the current state.

A detailed economic analysis of the model case in Polomka would require the availability of an extensive database and detailed non-available accident information so that only cost comparisons and social cost savings from accidents are taken into account in the calculation.

The source for a unit cost of savings for fatal, severe and light injuries is the Methodological Guide to Cost-Benefit Analysis Creation, presented in Table 5.

Table 5.Unit social costs related to accidents

Injuries	Unit value [€]
Fatal	1 593 000
Serious	219 700
Light	15 700

Source: [11]

The values given in Table 5 are related to the 2010 price level, i.e., approximately the time when a roadside interlocking device was deployed at the site of the traffic accident, so the data are comparable without the need for further correction.

The calculation of the societal benefits of the measure is shown in Table 6.

Table 6.Economic analysis of model example

	amount	Unit value [€]	Total [€]
Fatal	12	1 593 000	19 116 000
Serious	6	219 700	1 318 200
Light	19	15 700	298 300
Cost saving [€]		20 732 500	
Investment costs [€]		265 550	
Social benefits [€]		**20 466 950**	

In the case that a traffic light interlocking device would be applied at the beginning of the reporting period in 2006, and provided that an increased level of intersection security would prevent traffic accidents at that location, such a measure would generate a comparison of investment costs and economic benefits in the form of cost savings on accidental injuries from society-wide benefits of € 20,466,950.

In this context, it is also necessary to consider increased operating costs for the maintenance of railway infrastructure, which were created by the deployment of the lighting signaling equipment for ŽSR and are not taken into account in the calculation.

However, such a hypothesis is considerably simplified and based on assumptions that are difficult to prove in the stochastic conditions of transport processes. On the one hand, statistical data show that, with a comparable number of passive and active interlocking equipment, the number of accidents is higher on rail crossings equipped with active equipment. Moreover, the occurrence of one major road accident with fatal consequences can distort traffic accident statistics, so it is irrelevant in the context of the railway crossing to provide such a simplified comparison of raw data. An important factor is also the accidental occurrence of traffic accidents and the extent of their consequences and the psychological factors of signaling and traffic signs and local conditions (visibility, vision conditions) on the behavior of road users.

The price for reconstruction (modernization) of the railway crossing can be different due to local conditions, technical specifics and scope of the project. The following examples of public procurement for the modernization of railway crossings in the Slovak Republic are presented to get an idea of what costs such activity can be realized.

Construction of interlocking crossing plant (PZZ) on the track section Kraľovany - Párnica in the range: low voltage connection for PZZ, road reconstructions, traffic signs and technological security of the crossing. The total value of the procurement was EUR 268 641,29 excluding VAT[12].

Construction of an interlocking crossing plant (PZZ) on the Šahy - Čata line section in the range: low voltage connection, traffic signs, PZZ technological adjustment and PZZ itself. The total value of the procurement was EUR 396 060 excluding VAT[13].

Reconstruction of the crossing on the Komárno - Dunajská Streda railway section in the range: low voltage connection, modification of the railway substructure, superstructure, traffic signs, interlocking security plant equipment. The total value of the procurement was EUR 514 824.52 excluding VAT [14].

In general, however, if the average cost of raising the level of the signaling equipment is in the amount of hundreds of thousands of euros (building only the interlocking safety plant equipment), such a measure is profitable in the case of the modernization of the railway crossing prevention of a traffic accident resulting in 1-2 serious injuries or approximately 15 minor injuries. Fatal injuries would be cost wise several times higher than investment costs in terms of the unit social cost of accidents.

Conclusion

Currently, there is an increase in traffic performance and passenger and goods mobility globally throughout the EU. The Community supports the development and modernization of transport infrastructure to build a quality and sufficient capacity network through various financial instruments. With increased mobility, there is also a security issue that is adequately addressed by the authorities and institutions involved, as evidenced by the practical application of various road safety tools, as well as by accident statistics, which stagnate or even slowly decrease when road intensities increase.

A model example based on information and circumstances about a real traffic accident and statistics on accidents confirms that the application of suitable interlocking equipment on rail crossings can prevent traffic accidents or to positively influence the health and property impacts of passengers and road and rail users in the future. However, this statement is not generally applicable to any rail crossing, due to the impact of the stochastic phenomenon in transport and the specificities that localization and local communications crossings come with.

Therefore, all aspects of the application of such measures need to be considered comprehensively when deciding on the appropriateness of a change in the level crossing security. The main factor is the limited amount of funds available for the modernization of transport infrastructure, which in turn has to assess the allocation for individual projects in the context of the societal value and costs incurred.

The basis of the state's investment activity in the field of transport policy should be the plan for the construction and modernization of transport infrastructure and the resulting prioritization of individual projects. An important determinant is also the specific conditions in the critical site, which is the subject of research and prospective status in terms of the extent of road and rail transport, the economic development of the region and the expected demography in the particular location.

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