

ACCIDENT RATE OF REGIONAL RAILWAY VEHICLES AT RAILWAY CROSSINGS FOR THE YEARS 2014 TO 2018

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ABSTRACT. From a societal point of view, there are growing demands to increase traffic safety and reduce the risk of accidents of rail and road vehicles. The research to increase the safety of railway vehicles, which is carried out at the Faculty of Mechanical Engineering of the Czech Technical University in Prague, aims to increase the active and passive safety of railway vehicles. Components and systems of active safety are designed to reduce the risk of an accident. Components and systems of passive safety are designed to minimize the consequences of accidents. One of the parts of the active safety of railway vehicles is the condition and safety of the railway lines on which the railway vehicle is operated. The first part of the article focuses on the evaluation of accident statistics of railway vehicles with other road users at railway crossings for the years 2014 to 2018 with regard to the cause of the accident and the level of security of railway crossings. The conclusion of the article is devoted to proposals for solutions that could lead to a reduction in accidents at railway crossings.

KEYWORDS: Accident, active safety, ETCS, railway crossing, railway vehicle, road vehicle.

1. INTRODUCTION

Modern rail transport provides acceptable transport speed, low energy consumption, high transport comfort and big transport capacity. For these reasons, rail transport is one of the basic pillars of international, regional and urban transport [1].

Regional rail transport enables the quick transport of passengers between cities or the transport of passengers from smaller cities to the centres of larger cities. With the increasing number of inhabitants living in agglomerations around large cities, the need for the development of regional railways is growing. The lines of the regional railways run separately from the roads. Railway crossings enable the crossing of a railway line with roads for road vehicles. There are less than 8 000 railway crossings in the Czech Republic. Each of these crossings increases the risk of a train accident with another road user – Figure 1 [2].

Each accident of a train with another road user causes a disruption of the flow of passenger transport and causes local paralysis of the railway network, as the train involved in the accident must not leave the scene until the accident is recorded by staff of Správa železnic. Throughout the removal and recording of the accident, the section of the railway line is impassable and the train operator is forced to introduce alternative transport for passengers [1].

From a societal point of view, there are growing demands to increase road safety and reduce the risk of accidents. Vehicle safety is divided into two basic groups: active and passive safety. Components and systems of active safety are designed to reduce the risk of an accident, while components and systems of passive safety are designed to minimize the conse-



FIGURE 1. Train accident with a road motor vehicle [zpravy.akutalne.cz].

quences of accidents to passengers and vehicles. One of the elements of active safety is the state and level of security of railway crossings (hereinafter only RC) – Figure 2 [1].

This article deals with the evaluation of the causes of the occurrence and influence of the RC safety on the number of accidents involving rail and road vehicles and the proposal of an adjustment that could lead to a reduction in the risk of accidents on the RC.

2. ACCIDENTAL STATISTICS FOR REGIONAL RAILWAY VEHICLES

Správa železnic (hereinafter only SŽ) provided, for the production of accident statistics, data on extraordinary events (accidents) of regional railway vehicles for



FIGURE 2. Railway crossing for pedestrian, Prague 5 – Jinonice.

the years 2014 to 2018. A total of 853 extraordinary events were recorded during the period under review. 422 accidents of the total number, i. e. 49.4%, of extraordinary events were with another participant in road traffic on RC – Table 1. The remaining, i. e. 431, extraordinary events were accidents of a regional train with game, different train, fallen tree or pedestrian in a section of track outside the RC [1].

Years	2014	2015	2016	2017	2018
Accidents	91	81	78	87	85
Total	422				

TABLE 1. Total number of accidents.

SŽ provided for individual accidents the following information: type of collision vehicle, place of the accident, type of security of the RC, culprit of the accident, cause of the accident and consequences for the health of the accidents participants [1].

Three evaluation criteria were established for evaluation of accident statistics. Individual accidents were divided into groups according to these criteria [1]:

- type of collision vehicle,
- cause of the accident,
- type of security or RC.

All three criteria were chosen so that it was possible to design a best solution to reduce the risk of accidents of trains on the RC with other road users [1].

2.1. TYPE OF COLLISION VEHICLE

The criterion the type of collision vehicle was chosen in order to determine the most common type of collision vehicle in train accidents on the RC. The individual accidents were divided according to the following types of collision vehicles [1]:

- bus,

- pedestrian,
- bicycle,
- motorcycle,
- passenger motor vehicle (here in after PMV),
- lorry,
- tractor.

2.2. CAUSE OF ACCIDENT

The criterion of the cause of the accident was chosen in order to determine whether the drivers of collision vehicle or, for example, failures of the security equipment at the RC may be more likely to cause accidents. The finding of the most common perpetrator of an accident determines whether the behaviour of drivers or the failure of safety devices has a greater influence on the frequency of accidents [1].

The individual accidents were divided according to the following types of causes:

- not giving priority to driving by another road user,
- suicide attempt,
- environmental failure,
- another cause.

Determining the most common cause of an accident will allow a more appropriate proposal for solutions to reduce accident in the RC.

2.3. TYPE OF SECURITY OF RAILWAY CROSSINGS

The criterion of the type of security of RC was chosen in order to determine whether a higher level of RC security reduces the risk of an accident. Individual accidents were divided into the following groups according to the type of RC safety [1]:

- RC secured by warning crosses,
- RC secured by a light device without mechanical barriers (RC with LD),
- RC secured by a light device with mechanical barriers (RC with MB).

2.3.1. RAILWAY CROSSINGS SECURED BY WARNING CROSSES

This is the most common type of RC used in the Czech Republic, there are a total of 3 658. It is a so-called "unsecured RC", which is secured only by vertical traffic signs according to the road laws – Figure 3.

The RC is not equipped with any warning indicating the arrival of the train at the current time. This type of RC protection is used only on railway lines with a speed of $V \leq 60$ km/h. Railway vehicles usually use an audible warning signal in the form of a horn when passing through there RCs [1].



FIGURE 3. RC secured by warning crosses [idnes.cz].

2.3.2. RAILWAY CROSSINGS SECURED BY A LIGHT DEVICE WITHOUT MECHANICAL BARRIERS (RC WITH LD)

The RC with LD belongs to the so-called "secure crossings" – Figure 4. There are a total of 2 388 RC with LD in the Czech Republic. RC with LD is equipped with light and sound signals, which alert the drivers of road vehicles to the arrival of a railway vehicle. The arrival of the railway vehicle is signalled by an intermittent red light supplemented by the sound of a bell. The RC with LD can be supplemented by a white signal indicating safe crossing of the RC [1].



FIGURE 4. RC secured by a light device without mechanical barriers [ct24.ceskatelevize.cz].

2.3.3. RAILWAY CROSSINGS SECURED BY A LIGHT DEVICE WITH MECHANICAL BARRIERS (RC WITH MB)

RC with MB are the best secured RC in the Czech Republic – Figure 5. There are a total of 1 475 RC with MB in the Czech Republic. In contrast to others types of RC are RC with MB also equipped with mechanical barriers, which prevent road vehicles from passing RC when the train passes. Drivers of road vehicles are first alerted to the arrival of rail vehicles by light and sound signals and then by lowering the barriers over the road [1].



FIGURE 5. RC secured by a light device with mechanical barriers [zdopravy.cz].

3. EVALUATION OF ACCIDENT STATISTICS

The results of the accident statistics according to all three selected criteria are shown in Table 2 and Table 3.

Collision vehicle	Cause of accident	
	Not giving priority to drive	Suicide attempt
Bus	2	0
Pedestrian	15	14
Bicycle	11	0
Motorcycle	6	0
Lorry	40	0
PMV	323	0
Tractor	11	0
TOTAL	408	14

TABLE 2. Evaluation of accident statistics, collision vehicle vs. cause of the accident.

Collision vehicle	Type of security or RC		
	Warning crosses	With LD	With MB
Bus	0	1	0
Pedestrian	7	14	8
Bicycle	3	7	1
Motorcycle	3	3	0
Lorry	27	10	3
PMV	211	109	5
Tractor	9	1	0
TOTAL		145	17

TABLE 3. Evaluation of accident statistics, collision vehicle vs. type of CR security.

The results shown in Table 2 show that the most common cause of all accidents in the RC is not giving priority to drive by another road user and violation of §28 and §29 of law 361/2000 on Traffic on Roads. Most of RC accidents could be prevented if road vehicle drivers respected the laws of the road.

Many educational campaigns have already been targeted at road vehicle drivers, informing them about the consequences of accidents with rail vehicles. Therefore, it cannot be expected that the new educational campaign will change the behaviour of drivers on the environment and it is necessary to propose another solution to reduce accidents on the RC.

The second most common cause of accidents of pedestrian is suicide attempt. Unfortunately, accidents of this type cannot simply be prevented by improving the active safety of the RC, as the pedestrian acts in such a way that an accident with a rail vehicle occurs.

From the results given in Table 3 is evident that only at the best secured RC with MB is a significant decrease in accidents involving railway vehicles with other road users. There were 71 accidents per 1 000 RC secured by warning crosses. There were 61 accidents per 1 000 RC secured with LD. There were 11,5 accidents per 1 000 RC secured with MB. A similar number of accidents occurred on less secured crossings during the period under review. The effect of the increase security with light device does not have such an effect on the reduction of accidents, compared to the security by warning crosses.

For a more accurate evaluation, it would be appropriate to consider the influence of the traffic flow (how many cars pass through the RC per hour). This effect was not evaluated due to lack of information.

4. PROPOSAL FOR REDUCING ACCIDENTS ON THE RAILWAY CROSSINGS

According to the results of accident statistics, the reduction of accidents in the RC could be achieved by equipping all RC with light devices and mechanical barriers. Another possibility seems to be the addition of security for lower secured RC with retractable barriers – Figure 6, which are used on some crossings in the Russian Federation. However, the reconstruction of all RC would be very costly, time-consuming and the operation of rail and road vehicles would be limited during the RC reconstruction [3].

For these reasons, it is appropriate to reduce the risk of accidents in the RC through less invasive RC modifications. The interconnection of communication between rail and road vehicles appears to be a possible solution that could lead to a reduction in accidents on the RC. For first step, it would be appropriate to start intensive cooperation between the manufacturers of the European hybrid train protection system ETCS



FIGURE 6. Railway crossings in Russia Federation [4].

with the manufacturers of navigation and control system for road vehicles. Transmitting train position information to the car navigation and displaying this information to the driver and storing this information in the recording equipment would increase the criminal liability of car drivers for their behaviour at railway crossings and could lead to reduction of tragic accident at railway crossings [3].

After the accident of two trains on July 7, 2020 near Pernink in the Karlovy Vary region – Figure 7, the debate on the low security of railway traffic in the Czech Republic and the need to increase traffic safety has revived [5].



FIGURE 7. Train accident near Pernink [ČTK].

The Ministry of Transport plans to increase the security of the Czech railways through the introduction of the ETCS (European Train Protection System). ETCS is gradually replacing the various European national train protection and control systems. The extension of ETCS to all rail systems in the EU will allow the abolition of costly multiple on-board signalling equipment for individual states and the inefficient exchange of locomotives at national borders [?].

The main task of the ETCS is to ensure the safety of rail transport and to actively intervene in the train control in the event of a driver failure or error. One

of the pioneers of the ETCS is the Trainguard system from Siemens s.r.o. [6].

The Trainguard system has different levels of security, depending on the equipment installed on the railway lines and railway vehicles [6]:

- Level 0,
- Level 1,
- Level 2,
- Level 3.

At security levels 2 and 3 – Figure 8, railway vehicles are equipped with radio equipment to receiving and sending information about track position, train speed, etc. [6]

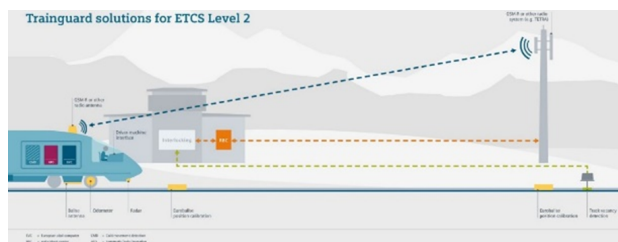


FIGURE 8. Function of ETCS at level 2 [mobility.siemens.com].

Trains equipped with ETCS level 2 and 3 could send a signal to around moving road vehicles that they are arriving to the RC and road vehicles are not allowed to ride through the RC. This information would be received by road vehicles via radio signals antennas, which are standard equipment of currently sold vehicles. The signal would then be evaluated by the on-board computer in the road vehicle. If the driver did not heed the RC's warning about the arrival of the railway vehicle, the on-board computer would prevent the road vehicle from driving through the RC and prevent a potential accident.

5. CONCLUSIONS

The results of the accident statistics shown in Table 2 show that all accidents on the RC during the period under review were caused by drivers of road vehicles and pedestrians by violation of §28 and §29 of law 361/2000. Many educational campaigns informing about the consequences of accidents on the RC have already been targeted at road vehicles drivers. Therefore the new campaign cannot be expected to lead to a reduction in RC accidents.

The results shown in Table 3 show that a similar number of accidents occur on the RC secured by warning crosses and light device. The effect of better RC security is not apparent here. The reduction of accidents occurs only at the best secured crossings, which are equipped with light and sound devices supplemented by mechanical barriers. However, the extension of this type of security to all RC cannot be expected due to the high financial and time demands.

As a possible solution, that could lead to a reduction of accidents in the RC, is introduction of communication between railway and road vehicles. Railway vehicles equipped with ETCS Trainguard Level 2 and 3 from Siemens s.r.o. would be able to send a signal of arrival to the RC. The on-board computer of road vehicles would evaluate this signal and not allow the driver to enter the RC in front of the arriving rail vehicle.

The proposed solution for reducing RC accidents described in this report must be subjected to more detailed research that would verify the possibility of use in practice.

LIST OF SYMBOLS

SŽ	Správa Železnic
RC	Railway crossing
PMV	Passenger motor vehicle
LD	Light device
MB	Mechanical barriers
ETCS	European Train Protection System
EU	European Union

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