IDENTIFYING CAUSES OF ACCIDENTS AT LEVEL CROSSINGS

Michal Ballay, Eva Sventekova, Ludmila Macurova, Ladislav Imrich
University of Zilina, Slovakia
michal.ballay@uniza.sk, eva.sventekova@uniza.sk, ludmila.macurova@uzvv.uniza.sk, ladislav.imrich@gmail.com

Abstract. The article deals with the issue of safety at level crossings. The incidence of accidents at level crossings is relatively low, due to the fact, that it is the only point of direct physical contact between otherwise relatively isolated modes of transport. From a mathematical and statistical point of view, the occurrence of accidents at level crossings can be considered as rare, unevenly distributed phenomena. The occurrence of an accident must therefore be understood as the result of a complex of various types and actions, with very serious consequences - the number of dead and seriously injured. Unscheduled event has the potential to cause adverse effects. It is therefore necessary to subject these objects to a thorough analysis in terms of technical and legislative aspects, as well as to take into account the human factor issues, because the errors and mistakes of the road users cannot be ruled out. The article assesses in detail the safety at railway crossings in the Slovak Republic and in the European Union. A special part of the article is devoted to the identification of the causes of accidents at railway crossings. The authors of the article also had at their disposal an accident at the railway crossing, which will be analyzed in terms of causes and consequences. This part of the article uses a software tool, where the interaction between the vehicle and the train is determined by means of a mathematical-graphical analysis. The moment of collision as well as the position of the means of transport after the collision are examined.

Keywords: analysis, safety, accident, railway crossing.

Introduction

The issue of traffic accidents at railway crossings is a societal problem, and therefore requires a comprehensive and rational approach. Crossings can be identified as risky places with the potential for various accidents, often with serious consequences. We can assume to the detriment of the lives and health of the participants, as well as material damage will occur, as the factors influencing the occurrence of the accident cannot be completely ruled out. Accidents can be affected by several factors (or a combination of them), such as the technical condition, human factor, climatic conditions, etc.

Incorrect driving technique, failure to pay attention to the traffic situation, as well as intentional or unintentional road traffic offenses are the most common causes of accidents at level crossings. The high number of negative consequences is mainly due to the historical development of the number of level crossings of the railway line and road with the current increase in traffic intensity. For these reasons, it is necessary to subject these objects to a thorough analysis, taking into account the technical and legislative aspects, as well as the human factor issues, which would lead to a comprehensive assessment and management of risks at level crossings.

Safety at level crossings

In the case of a widely accepted concept of safety in relation to level crossings, this is the sum of the number of accidents at level crossings and their consequences over a certain period of time. Traffic accident statistics according to individual criteria are the basic starting point for determining the areas with the highest traffic accidents, analysis of the causes and consequences of traffic accidents, proposing preventive measures to increase transport safety.

Safety can be measured at the same time by a combination of two indicators – the number of accidents per thousand crossings and one million train kilometers. Figure 1 shows these two indicators for the period 2016-2021, in each ERA (European Union Railway Agency) country. A high degree of security is marked in green, what expresses that there is a low number of accidents at level crossings in a given country and at the same time the number of train kilometers traveled between two accidents is as high as possible. Within the European Union, the Slovak Republic ranks to member states with more accidents per million train-kilometers.

Railway crossings are one of the most risky elements of railway infrastructure. According to the method of security, we divide them into active (equipped with a cross-border security device and marked with traffic signs) and passive (marked only with traffic signs). They are created according to special regulations and set criteria, which include in particular the moment of transport (product of

DOI: 10.22616/ERDev.2022.21.TF271

the number of trains and the number of road vehicles), type of the railway line and road, perspective and local conditions, etc. [1; 2].

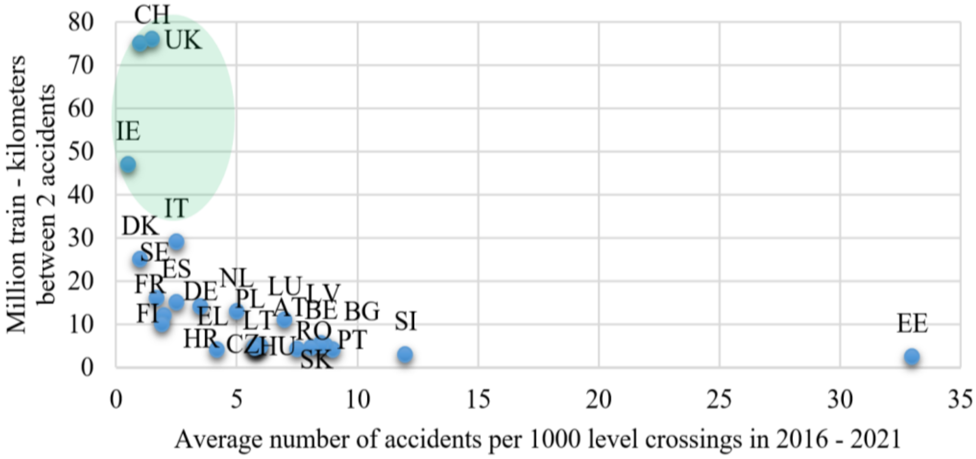

Fig. 1. **Assessment of level crossings in ERA countries [3]**

There are about 2074 crossings in the Slovak Republic, of which about half are unsecured, marked only by traffic signs, without crossing security devices. In order to increase the level of safety, the legislative requirement is to gradually replace level crossings in the form of active level crossings. Equipping only a certain part of these crossings requires significant investment costs and a clear division of responsibilities between rail and road managers [4-6].

Accidents at level crossings

Accidents at railway crossings in the Slovak Republic have recorded a stagnant number in recent years, but their consequences are much more severe in the number of participants killed and seriously injured. A more detailed overview of the number of accidents and their consequences is shown in Figure 2. The human factor has the largest share in the occurrence of various accidents at railway crossings, as traffic behavior is influenced by many external and internal factors.

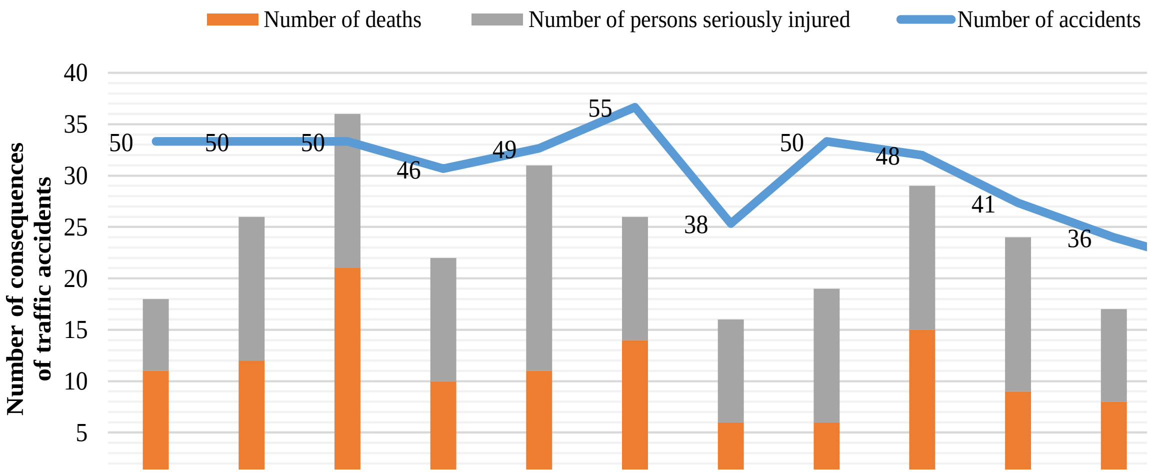

Fig. 2. **Number of traffic accidents and the number of their consequences at railway crossings [7]**

The available accident statistics show that the vast majority of accidents occurred at active level crossings (especially at level crossings of roads and railways), which were secured only by traffic lights. Active railway crossings with light and mechanical security devices can be described as the safest. A more detailed overview of the number of accidents according to the type of security at the level crossing is given in Figure 3.

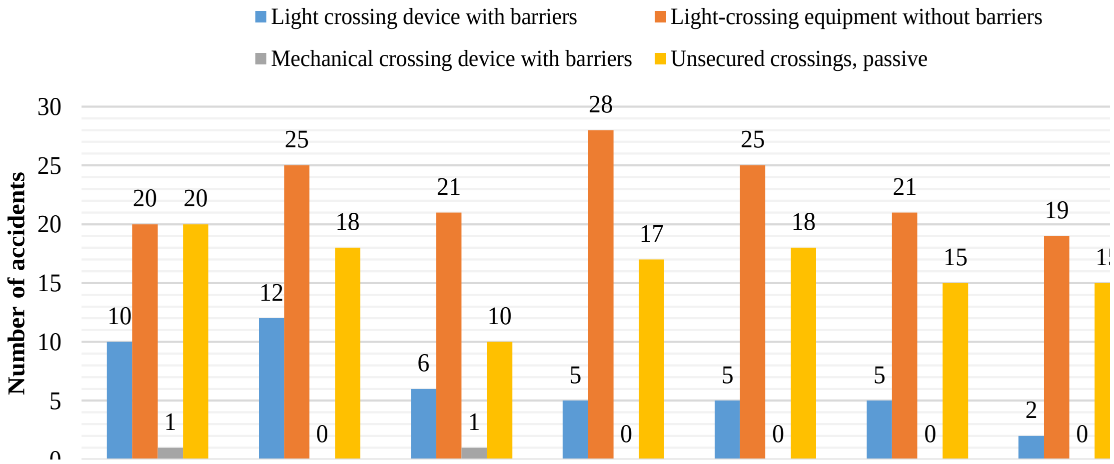

Fig. 3. **Number of accidents by type of level crossing security [7]**

According to the figure, it can be further stated that that the number of accidents at level crossings with light or mechanical barriers is much lower than the number of accidents at level crossings, without barriers. The reason may be the so-called barrier as a physical barrier for road vehicle drivers compared to traffic lights, which can be easily overlooked by drivers if they do not respect traffic rules.

Analysis of a selected accident at a level crossing

As part of the analytical evaluation and identification of possible impacts on the occurrence and course of an accident, we focused on a traffic accident at a level crossing (category A3), which occurred at an unsecured level crossing (at night) between a passenger car and a passenger train (train set – locomotive and four wagons) with a total length of 122.5 m and a weight of 268 t.

The accident in question occurred in such a way that that the driver of the road vehicle entered the railway crossing (just before the arriving train) due to incorrect driving and insufficient monitoring of the traffic situation, while the crossing signaling device for his direction of travel signaled a warning with two red alternating “Stop” lights. The driver observed the road vehicle about 30 m in front of the level crossing and immediately used the “Caution” signal repeatedly and introduced rapid train braking, but for the short distance he could no longer prevent a collision (front of the locomotive, with the right side of the vehicle). After the collision, the road vehicle was stuck in the front part of the locomotive, while the locomotive pushed this vehicle in front of it, up to a distance of about 343 m behind the crash site, as a result of which the driver of the vehicle suffered fatal injuries.

In the analysis of the accident – the collision of a passenger train with a road vehicle, it was necessary to find out the way the vehicle moved before the accident, spatio-temporal relationships with the incoming train, the technical condition of the vehicle and its possible impact on the origin and course of the accident [8-10].

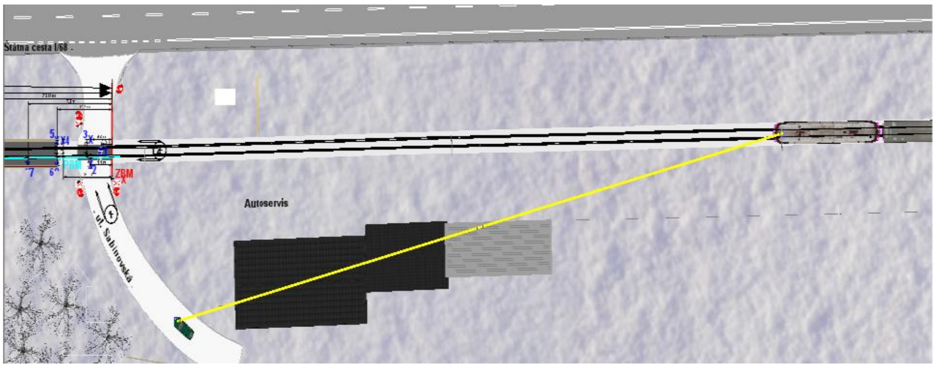

Fig. 4. **Mutual position of vehicles in time 5s before the collision – 2D view**

Subsequently, the simulation of the accident took place with the mathematical - simulation program PC-Crash 13.1. The following part of the article presents an analysis of the overall situation before the collision (mutual position of vehicles) using 2D and 3D views (in the order of 5s, 2.5s, 1.5s before the collision and at the time of the collision).

At the time of 5 seconds before the collision, the passenger train was located approximately 139 m from the railway crossing and was traveling at a speed of approximately 84 km·h^{-1}. The driver of the road vehicle was located approximately 30 m from the railway crossing (near the car service building) and moved at a speed of approximately 25 km·h^{-1}. From this point on, the driver of the vehicle did not have direct supervision of the passenger train.

Fig. 5. **Mutual position of vehicles 2.5 s before the collision – 3D view**

At the time 2.5 seconds before the collision, the driver used an audible warning (as the beginning of the reaction to the development of the traffic situation), while the passenger train was located about 58m from the crossing and moved at a speed of about 84km·h^{-1}. The driver with the vehicle was located about 10 m in front of the crossing and moved at a driving speed of about 19 km·h^{-1}.

Fig. 6. **Mutual position of vehicles 1.5 s before the collision – 3D view**

At the time of 1.5 seconds before the collision, the passenger train was located about 34 m from the railway crossing and moved at a speed of about 84 km·h^{-1}. The driver began to brake the train with rapid braking. The driver of the road vehicle was located about 3 m from the railway crossing and moved at a speed of about 17 km·h^{-1}. He did not react to the given traffic situation and continued to drive through the railway crossing, despite the warning.

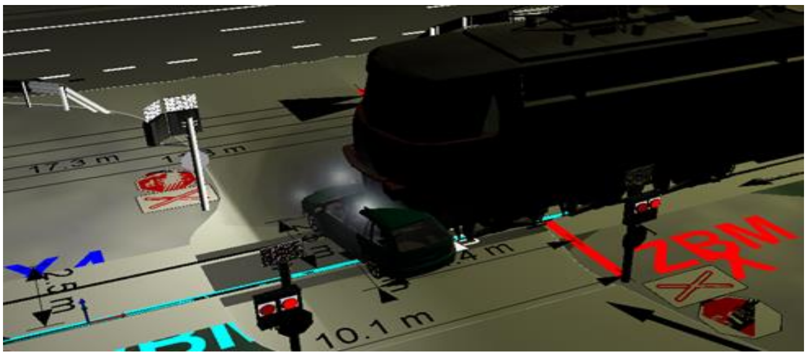

Fig. 7. **Mutual position of vehicles at the time of the collision – 3D view**

The relative position of the vehicles at the time of the collision is shown in Figure 7. From a technically acceptable calculation of the accident, it is most likely that the collision between the road vehicle and the passenger train occurred at the moment when the driver activated the rapid braking. The speed of the passenger train at the time of the collision was about 79 km·h^{-1} and the speed of the road vehicle at the time of the collision was about 13 km·h^{-1}.

Results and discussion

The assessment of the technique of entering the road vehicle at the railway crossing is shown on Fig. 8.

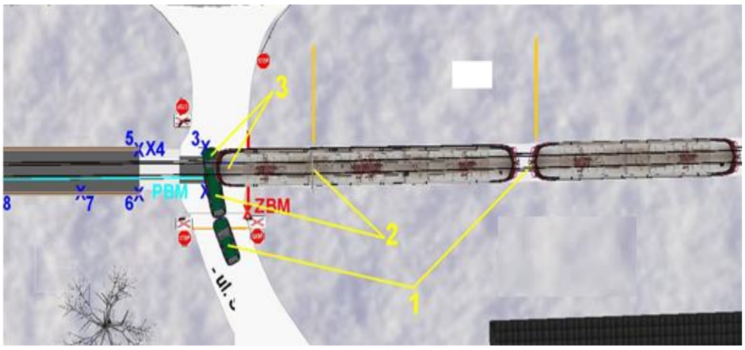

Fig. 8. **Assessment of the technique of entering the road vehicle at the railway crossing:** 1 – relative position of the vehicle and the locomotive at the moment of the beginning of the early reaction of the driver; 2 – mutual position of the vehicle and the locomotive at the moment of the onset of the braking effect of the train; 3 – mutual position of the vehicle and the locomotive at the moment of collision

By analyzing the accident, we did not find any circumstances that would prevent the driver at a sufficient distance from the crossing to see the incoming train and react correctly. Technically acceptable analyzes of the accident show that that the driver has technically created a sudden obstacle for the passenger train, because the passenger train could not be stopped in front of the collision site with the correct driving technique. We can therefore conclude that that the driver reacted to the situation in time, however, it would not be able to prevent a collision with the road vehicle even when using rapid-acting braking with maximum braking deceleration.

The technical cause of the accident in question was the incorrect driving technique of the vehicle driver (he did not pay full attention to driving the vehicle and did not sufficiently monitor the traffic situation). The result was his collision at a level crossing at a time when the crossing signaling device for its direction of travel signaled a warning with two red alternating “Stop” lights and at the same time the passenger train came to the railway crossing, thus creating a technical obstacle for the passenger train from a technical point of view. From the point of view of railway safety, it follows that that in the event of a collision between railways and roads, the railways always take precedence. A train like a multi-tone colossus cannot change the direction and its braking distance can be more than a kilometer depending on the speed and number of wagons. In the circumstances of the accident, it would clearly be appropriate that the railway crossing in question is fitted with barriers, or to reduce the maximum permitted speed of the passenger train [10; 11].

There is a lot of research in relation to mathematical-graphical analyzes of traffic accidents. For example, an article that belongs to our science and research is: The impact of critical elements on the formation and consequences of accidents at railway crossings. In this case, an analysis of the causes of the accident is again carried out of 2009 with 12 killed people as well as other serious injuries. The result from analysis is the importance of most modern security elements in no grade-separated road and rail transport.

Conclusions

The aim of the paper was, in addition to the assessment of safety at level crossings, to perform an analysis of a selected accident at a level crossing (collision of a passenger train with a road vehicle). From a technical point of view, the driver of the road vehicle created a sudden obstacle for the passenger train, which made the occurrence of an accident unavoidable. The consequences of the accident did not kill or seriously injure the railway staff and the passengers on the train. The driver of the road vehicle was killed, the road vehicle was completely destroyed, the locomotive and infrastructure were damaged, and traffic was interrupted. The total amount of damage was calculated at approximately € 14,000. It is clear from the accident in question that the human factor has failed.

The main task of unsecured level crossings is to increase safety, especially at intersections of rail and road traffic. In conclusion, we can state that systematic increase of safety at railway crossings requires not only financial resources, but also the need to take effective measures and implement comprehensive solutions (transport system, safety).

Acknowledgements

This work was supported by Grant System of University of Zilina No. 1/2021 (12803).

Author contributions:

Ľ.M and L.I. visualization, E.S. and M.B. Conceptualization, M.B. and L.I. formal analysis, M.B. writing – review and editing, E.S. and Ľ.M. writing – original draft preparation. All authors have read and agreed to the published version of the manuscript.

References

[1] Ministry of Transport and Construction of the SR. A comprehensive program to address the issue of level crossings. [online] [10.03.2022]. Available at: Komplexný program riešenia problematiky železničných priecestí (mindop.sk)

[2] Leitner B. Môcová L. Hromada M. A new approach to identification of critical elements in railway infrastructure. In: Procedia Engineering. ISSN 1877-7058. - Vol. 187 (2017), online, pp. 143-149.

[3] European Union, Agency fo Railways. 2021. Safety Overview 2021. Main figures based on CSI data. [online] https://www.era.europa.eu/sites/default/files/library/docs/annual-overview-safety-2021_en.pdf

[4] Supreme Audit Office of the Slovak Republic. "Report on the outcome of the 2021 inspection - increasing safety at level crossings". [online] [12.03.2022]. Available at: 96768-0-110.pdf (gov.sk)

[5] Leinter. B. A general model for railway systems risk assessment with the use of railway accident scenarios analysis. In: Procedia Engineering. - ISSN 1877-7058. - Vol. 187 (2017), online, pp. 150-159.

[6] Dvořák Z., Leitner B., Novák L. Software support for railway traffic simulation under restricted conditions of the rail section. In: Procedia Engineering. - ISSN 1877-7058. - Vol. 134 (2016), online, 2016, pp. 245-255.

[7] Railways of Slovak Republic. 2021. Level crossing. [online] https://www.zsr.sk/files/sluzby-verejnosti/vsetko-zeleznicnych-priecestiach/medzinarodny-den-bezpecnosti-ilcad/ilcad-2016/zeleznicne_priecestia.pdf

[8] Kasanický G., Kohút P., Lukášik M. Impact dynamics theory for the analysis and simulation of collisions. Žilina: EDIS – University of Žilina. 2004, 350 p. ISBN 80-8070-312-4

[9] Kasanický G. Kohút P. Analysis of single - track vehicle accidents. Publisher: University of Zilina, 2000. ISBN80-7100-598-3

[10] Ballay M. Sventekova E., Kubjatko T., Macurová Ľ. The impact of critical elements on the formation and consequences of accident at railway crossings. Transport Means. Proceedings of the International Conference. 23thInternational Scientific Conference on Transport Means Kaunas, 2019, pp. 963-969

[11] Ondruš J., Vrábel J., Kolla E. The influence of the vehicle weight on the selected vehicle braking characteristics. Proceedings of International Conference „Transport Means", October 3-5, 2018. pp. 384-390. ISSN 2351-7034.