3D Simulation and Analysis of the Course of a Bus/Train Accident at a Railway Crossing

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Abstract. Rail crossings are very important elements in the field of land transport infrastructure, as they allow the combination of two different transport systems, whose mode of operation and management is subject to different regulations, transport performance and design solutions. Traffic accidents at railway crossings have become a relatively common negative phenomenon (meeting of road users with rail vehicles) with fatal consequences and extensive material damage. For this reason, level crossings are high-risk locations, with a high potential for an accident. The aim of the article is to present the results of the simulation and subsequent analysis of the accident of category A3 - collision of a train with a bus at a railway crossing and selected results from the realized computer simulation of the course of the pre-accident event and the predicted impacts of the modeled accident.

Keywords: Railway crossing · Safety · Traffic accident · Simulation

1 Introduction

Crossings are unique in the world of transport, as they represent the only possibility of a collision between two different infrastructures, the management system of which is subject to different regulations and, last but not least, vehicles with dramatically different performance and design. As a result, level crossings are high-risk locations where the potential for an accident is high, due to the fact that that the railways control only half of the level crossing environment. Unfortunately, traffic accidents have happened in recent decades a recurring phenomenon resulting in human deaths and major economic losses. Although there are legal norms, traffic regulations, standards in the design of roads, ultimately the movements of participants, they are not organized and monitored by one specific entity, as are railway movements.

Statistics show that road accidents account for more than a quarter of all rail accidents in the EU (Fig. 1) [1].

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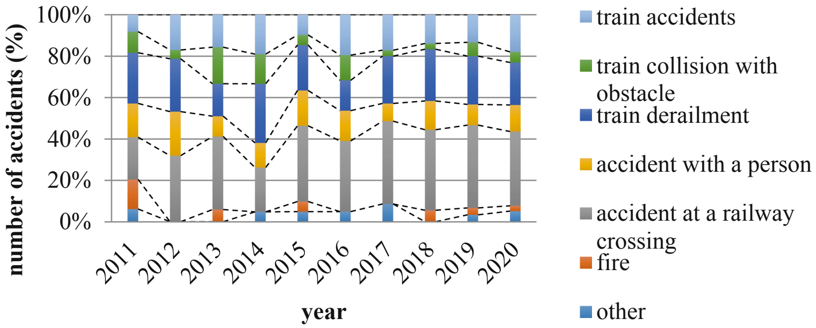

Fig. 1. Accident in rail transport in the EU [1].

In addition to statistical indicators of accidents at level crossings, the authors of the post had after the expiry of the statutory period. Details of the 2009 tragic accident, where 12 people were killed, 6 suffered severe injuries and 19 minor injuries. Based on a computer simulation of an accident [2–4], an analysis of the causes and course of an accident, it has been shown that the use of state-of-the-art safety features is necessary at level crossings where level crossing of road and railway infrastructure is not possible (overpass over the railway).

2 Analysis of Real Accident Event in Railway Crossing

To perform an accident analysis to identify the possible impacts the emergence and course of an accident in this article, we will deal with an accident of category A3 - a train collision with a bus on a rail crossing. From the point of view of accident events within the Slovak Republic it's the most tragic accident which killed 12 people, 6 suffered severe injuries and 19 were slightly injured. Accident event became an unsecured railway crossing in the Heľpa - Polomka intersection section. The overall situation of the traffic accident site is shown in Fig. 2. The traffic situation and conditions are listed in Table 1 [1, 5].

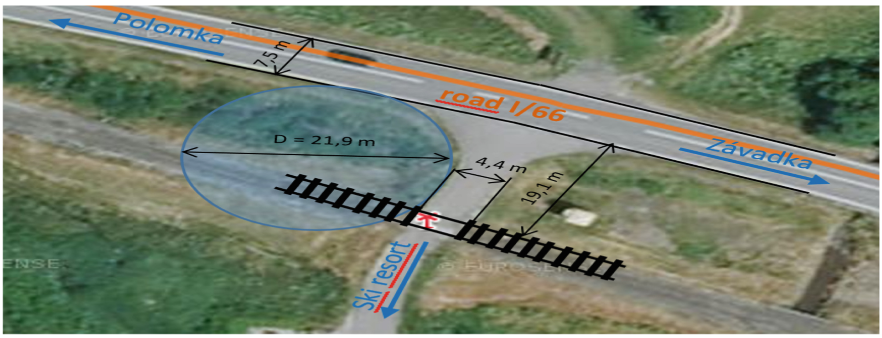

Fig. 2. Situation of a city accident [2].

Table 1. Traffic situation, road surface condition and weather conditions.

Directional conditions:	Straight section
Road surface:	Resin
Surface quality:	Good
Surface condition:	Dry surface, not dirty
Edge condition:	Curb is missing
Road fault:	No fault
Road division:	Two-lane
Special objects:	Railway crossing not secured by barriers or light warning devices
Speed limit:	60 km/h
Weather:	Unimproved weather conditions
Visibility:	During the day, visibility not reduced due to weather conditions
Viewing conditions:	Good

The course of the accident was known on the basis of the testimony of witnesses to the accident and the subsequent analysis of the accident. The accident happened so that the bus turned right off the main road and without stopping he entered the railroad crossing which is located about 19 m from the right edge of the main road. On the rail crossing, the bus entered when crossing the railway crossing from a bus driver's perspective, a train approached composed of a motor car and a wagon. The bus was thus pushed 26 m until the train stops. Figure 3 shows a 3-dimensional impact calculation [1, 6].

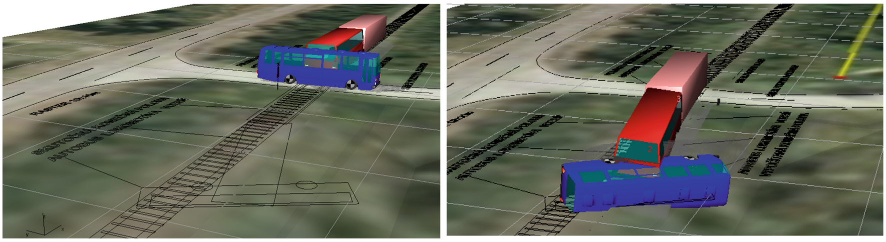

Fig. 3. Three-dimensional representation of the shock calculation [2].

When analysing an accident event - a train collision with a bus, it is necessary to find out how did the bus move before the accident what was the time-spatial relationship with the incoming train, what was the technical condition of the vehicle and its possible impact on emergence and the course of a traffic accident [8]. These questions can be answered mathematical-graphical analysis of vehicle movement using computer simulation and detailed diagnosis of the brake system, steering, transmission system and chassis parts. Impact analysis was performed using the PC CRASH computer program. The actual situation at the scene of the accident with the technical parameters was modelled in the program [7–9].

The analysis of the view conditions at the accident site was processed into a precise plan, which was processed using 3-dimensional graphics. Technical parameters for modelling include: specific vehicles, bus operating weight, number of passengers, average weight with luggage, total weight (luggage + persons), total weight of the vehicle, weight of the locomotive, weight of the wagon. With the aid of the above graphics,

Figure 4 and Fig. 5 shows exactly the viewing conditions at the accident site [2, 6, 10].

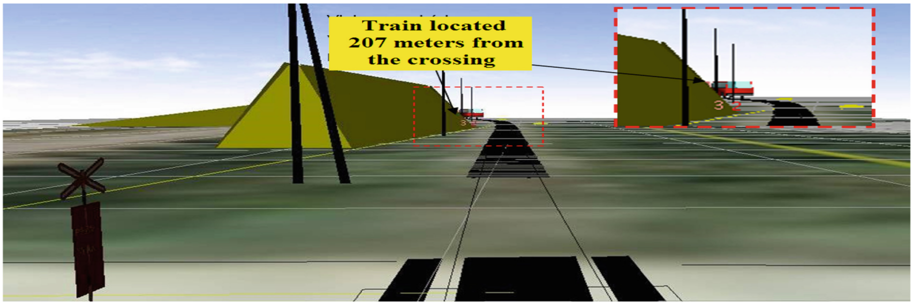

Fig. 4. Viewing distance in the PC CRASH 8.3. [2].

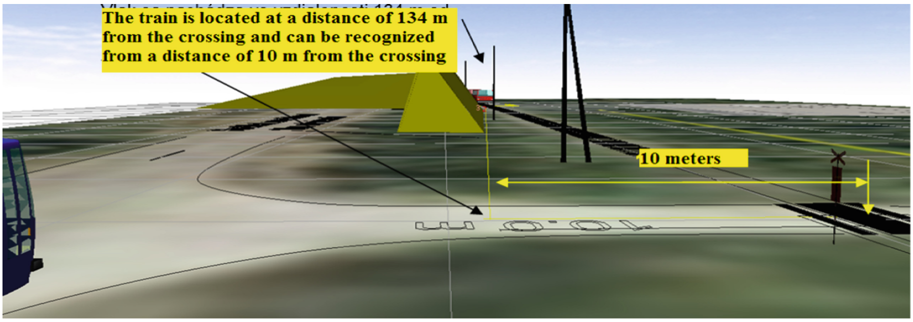

Fig. 5. Three-dimensional representation of viewing conditions for the distance of 10 m from the crossing [2].

The impact calculation showed that the train had a speed at the moment of impact corresponding to the data according to the results of the investigation at the level of 54 km.h^{-1}. According to the calculation of the impact, at the moment of impact, the bus was moving at a speed of 8 km.h^{-1}. The calculated speed data needs to be corrected due to the fact that it was not possible to model the guiding properties of the railway wheels and rails with sufficient accuracy during the calculation. The profile of the wheels puts resistance in the lateral direction to a greater extent than could be modeled using the PC CRASH 8.2 software. Therefore, it can be admitted that the speed of the bus was slightly higher than calculated at the moment of impact. Based on the above, it can be argued that the speed of the bus at the moment of impact was about 10 $km.h^{-1}$ [1, 3, 4, 6].

When analyzing the mutual movement of the bus with train before impact it is important to note. It was found in the impact calculation that the train had a speed of 54 $km.h^{-1}$ at the moment of impact and the bus was moving at between 8 and 10 $km.h^{-1}$. In the following sections article is an analysis of the overall situation before the collision [2, 6].

- **Time 11.0 s before collision** - Train is about 200 m from the crossing, bus starts turning off the main road. The bus driver is not yet in direct sight of the train because the train is located in the obstructed space for the bus driver. The train is already recognizable from the crossing. Plan view of train and bus position 11 s before impact is presented in Fig. 6 [2, 6].

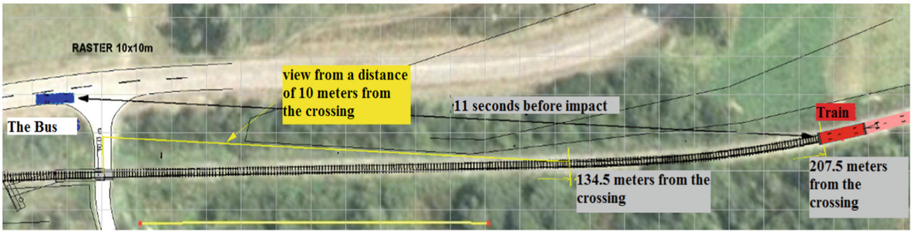

Fig. 6. 3 – dimensional view of the train and bus position 11 s before the impact [1].

- **Time 7.2 s before impact** (Fig. 6) – Train is located 132 m from the crossing. The train is already recognizable 10 m away from crossing, but the bus driver hasn't seen the train yet because the bus was more than 10 m away [2, 6].

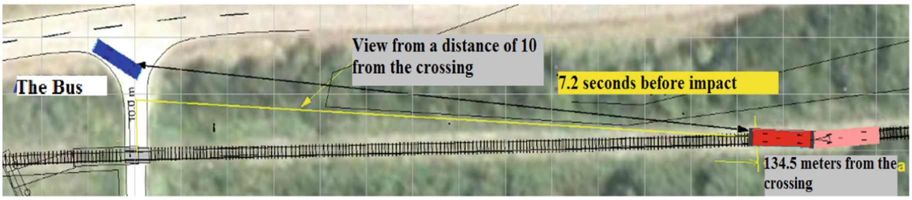

Fig. 7. 3 – dimensional view of the train and bus position 7.2 s before the impact [2].

- **4.8 s before impact** (Fig. 7) - The train is about 85 m from the crash site. The bus is located 6.8 m from the rail axis. The bus is just a short distance away should the driver start to react to the speed of 10 $km.h^{-1}$ he could stop with the bus at a safe distance from the track that is, 4.0 m from the track axis. The track required to stop the vehicle calculation is done as follows:

$$S_Z = \frac{v^2}{2.a_s} + v.t_r, \quad (1)$$

where a_s is medium vehicle deceleration (m.s^{-2}), v is vehicle speed (m.s^{-1}), t_r is driver reaction time: t_r = 0.7 s, S_z is track required to stop the vehicle 2.74 m.

Distance from rail for the latest reaction 4 m + 2.74 m = 6.74 m. With a bus speed of 10 km.h^{-1}, the driver had 1.0 s to recognize the train to be able to react and stop the bus at a safe distance from the track after recognition [2, 5, 6, 10].

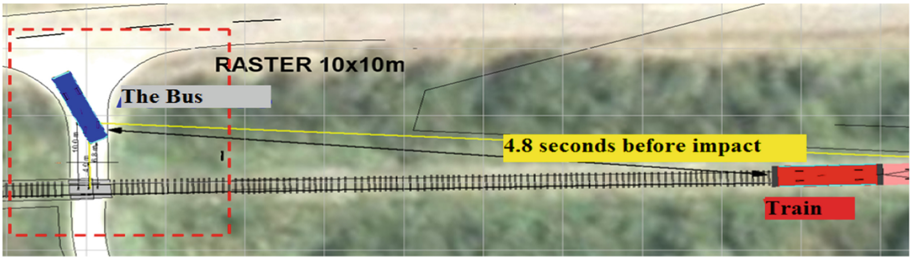

Fig. 8. Bus movement 4.8 s before impact [2].

- **Time of 2.0 s before impact** (Fig. 8) - At this point, a quick-acting brake starts to operate. The train has no way to stop. Despite the use of a high-speed brake the train will slow down from 70 km/h to a crash speed of 54 km/h [2, 6] (Fig. 9).

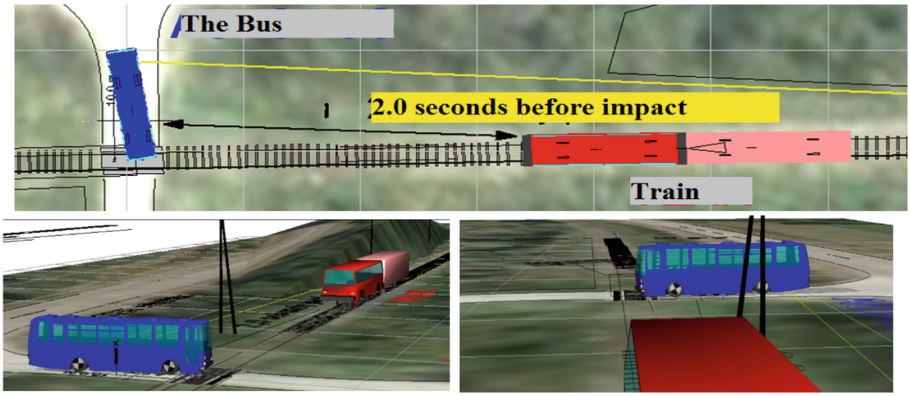

Fig. 9. Bus movement 2 s before impact [2].

It follows, that the bus driver at 10 km.h^{-1} was able to observe the incoming train at least 1.0 s to 3.2 m long stretch in front of where he should start responding at the latest and then brake, to stop at a safe distance from the railway. We consider the time and section as sufficient, while nothing prevents the bus driver from driving slower thereby making the necessary time to detect the incoming train. According to the detected bus movement the bus driver did not respond to the incoming train at all [2, 6].

Analysis found that the driver reacted when he had the opportunity to first recognize that bus approaching can't stop to the track at a safe distance from the track (Fig. 10). According to the analysis, the driver reacted in time as soon as the risk of collision could be recognized with the approaching bus [2, 6].

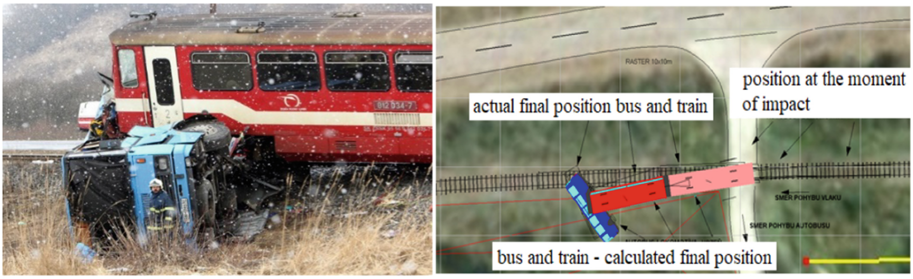

Fig. 10. Dimensional representation of the shock calculation [2].

We didn't find any circumstances by analyzing the accident that would keep the driver away to see an incoming train from the crossing and respond properly. The train driver responded in time when he had the opportunity to first recognize that the bus approaching the rail crossing will not stop. After the reaction, the driver of the train exploited in a maximum way technical possibilities to stop the train to avert and mitigate the effects of the impact the train to the bus. In the present case traffic accident participants only bus driver options to prevent a traffic accident. In the overall accident analysis and the technical condition of the bus, we found no circumstances to the driver before entering the crossing in time recognize an incoming train respond properly to the situation and stop the bus at a safe distance from the level crossing. However, in the present case several conflicting circumstances have been identified, namely:

- The level of railway crossing (as well as the condition of the road ahead of the rail crossing) he was like that that it contained inequalities and the allegations that made it logical that drivers are increasingly paying attention to directional guidance in front of the crossing, as well as driving through the railroad crossing (in order to drive the vehicle away from bulges and bumps). As a result of this factor, there was a phenomenon that drivers have less attention to drivers the situation in terms of incoming train.
- For car drivers coming in the direction of driving the bus arose on the left side of the covered view area as a result of a bush stand next to the track. For such conditions (with reduced viewing ratios) there is a phenomenon where time goes down available to the driver for proper evaluation whether the train is approaching the railway crossing.
- For drivers of longer vehicles (including buses) is for crossing the railroad crossing (under conditions of reduced vision - as happened in the present case). You need to drive through the rail crossing faster. However, this factor is contrary to the state of

rail crossing as a result of which drivers tend to move at a slower speed. However, the bus speed increases via the railroad crossing thereby reducing the driver's time to evaluate the situation in the presence of any incoming train, since the driver's view of the direction from where he came from is revealed train just before entering the railway crossing.

These factors combined with reality that bus passengers (including driver) after a relatively long journey, they were just before their destination (and that was the ski slope - to which they have seen the outlook just before the accident occurred, when the driver's attention to some extent this phenomenon ultimately led to that the bus driver responded late on an incoming train. It was clearly appropriate in the circumstances the railway crossing in question was fitted with gates with light signalling device possibly reduced maximum permitted train speed [2, 5, 6, 8, 10].

3 Conclusions

The railway crossing is a place of crossing the road with the railway network. In the event of various accidents at level crossings, road users are most at risk. From the point of view of the analysis of a traffic accident at a railway crossing, which is analysed in the article in question is clear that that the only cause of the accident from a procedural point of view was the misconduct of the bus driver. Due to the accident in question, which was analysed in the article, there was a long discussion from forensic experts and various experts. It lasted about 3 years. Alpha and omega in this accident were the conclusions drawn by the Institute of Forensic Engineering in Žilina. The bus driver was not convinced before crossing, whether it is possible to cross the level crossing safely and entered the crossing in time, when it was already possible to observe the incoming train set. In this case, there was a failure of the human factor, however, the conditions around the railway line also contributed to it, in particular the high growth around the line and the directional conditions of the line before crossing. The advantage of using computer modelling and traffic accident simulations and analysis of the conditions of any accident is in particular the possibility of experimenting with the model, changes in conditions before and during the accident, determining the dependence between the monitored quantities, etc.

One of the possibilities is the use of modelling of accident events, creating scenarios of the occurrence, the course of the accident, its expected consequences, but also the adequate response of intervening rescue services and their preparedness for common but specific traffic accidents.

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