Proceedings of 17th International Conference. Transport Means. 2013.

Risk Reduction in Railway Tunnel

Z. Dvořák*, Z. Čekerevac, L. Novák*****

**University of Žilina, 1. Maja 32, 010 26 Zilina, Slovakia, E-mail: Zdenek.Dvorak@fsi.uniza.sk*
***UNION University of Beograd, Akademska 22, Zemun, Serbia, E-mail: Zoran_Cekerevac@hotmail.com*
****University of Žilina, 1. Maja 32, 010 26 Zilina, Slovakia, E-mail: Ladislav.Novak@fsi.uniza.sk*

Abstract

The implementation of the Common Safety Methods in railway companies in the European Union leads the individual member countries to seek ways to effectively and timely implement new procedures to railway transport. Individual subsystems rail transport should be analysed and assessed separately. The authors draw attention to the results of research in the field of risk assessment in railway tunnels. The results of the examination are published for the first time and should lead to professional public debate.
KEY WORDS: *Railway tunnel, risk reduction, risk analysis*

1. Introduction

Current applied sciences and the need for practical knowledge are leading the cooperation of academic and research teams with the experts on practise. Safety of transport and of infrastructure in rail transport leads to gradual implementation of the Common Safety Methods (CSM). However, the very first step is the applied research in the given field. As part of national and international research projects [1, 2], partial tasks have been solved which are applicable in the implementation of CSM.

The counterpart of transport safety is the hazard or threat of maintanance processes. Risk is the potential possibility of violation of the transport system safety which can be calculated by multiplying the likelihood of incident and the amount of its negative impact. Hazards, threats and risks in transport are mutually conditional. The real incindents usually happen when more threats are combined as well as when being in function. Safety and risk posses a probabilistic character. Their values lie in the range from 0 to 1 and their sum is always equal to 1.

2. Risk Assessment

Significant part of the CSM implementation in rail transport is the usage of adequate methods when assessing the risk. 2800 theoretically possible threats have been defined in the KISDIS project [1] which have been subsequently reduced to 627 threats concerning the rail transport. Theoretically as well as practically, various threat classifications are being used. One of the possibilities is dividing them in the following way:

- according to the object of threat activity, there are threats of non-military, military and combined character,
- according to the range of shielded interests, there are partial and complex threats,
- according to the location of threat source in the given system, there are internal and external threats,
- according to the threat source, there are anthropogenic threats and threats not dependent on human activity.

After the threat assessment it is crucial to follow the norms of STN (Slovak Technical Norm) concerning risk management. According to this norm, following steps must be implemented:

- definition of the connectivity and identification of risk sources, see Fig. 2,
- estimation of probability and consequences (risk calculation),
- risk evaluation – risk matrix , see Table 1.

In the scope of connectivity definition, it is crucial to set a concrete object of examination. In the risk evaluation process in rail transport, the potentially highest risk source are railway tunnels, see Fig. 1. Risk source identification of railway tunnels is focusing on examination of:

- floods,
- landslides/mass unrest,
- avalanches,
- other natural forces (e.g. ice),
- terrorist attacks,
- explosion, fire or leakage of transported material,
- suicides,
- vandalism – criminality,

- wild animals injuries,
- technical malfunction/defects (e.g. derailment of railway vehicle),
- human factor fault,
- vehicle or plane crash on the rails in front of the tunnel portal, etc. [3, 4]

Fig. 1 Railway tunnel Strečno. Photo author

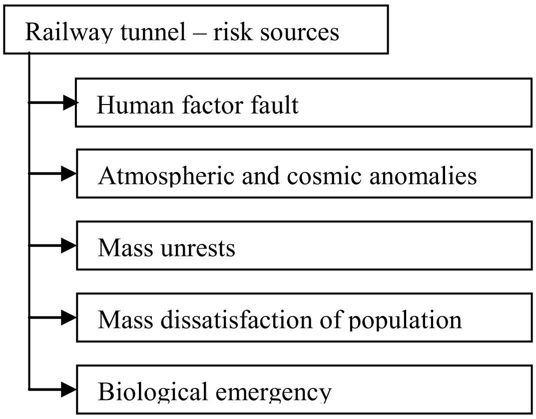

Fig. 2 Railway tunnel risk sources

The above listed threats are the cross section of possible launching events which might consequently lead to an incident. It is feasible to divide them into categories according to the impact they have on tunnels as constructions, see Fig. 1, meaning whether the threat arises from the surroundings of the tunnel or from the processes or conditions inside the tunnel tube. [8]

Table 1.

Fragment syntax of creating the name for hazard type according to the developed matrix

EVENT	RISK SOURCE ACTIVATION	LOCATION	CAUSE
Change of operational conditions due to	Bombardment of railway vehicle	Outside of railway tunnel	Atmospheric and cosmic anomalies
Change of operational conditions due to	Immobility of traction vehicle	Inside of railway tunnel	Mistake caused by human factor.

3. Risk Analysis of Incident Occurrence Inside the Tunnel

3.1. Probability of Incident Occurrence Inside the Tunnel

While solving the research tasks we have come to conclusion that the most suitable procedure for the calculation of incident formation probability inside tunnels consists of 2 parts. Firstly, it is crucial to calculate the probability that an incident is formed directly inside the tunnel. Secondly, the probability of an incident in railway transport as such.

Incident location probability (hereinafter ILP) can be calculated by dividing the total length of tunnels by the total length of railways. The result indicates probability of tunnels being the area of an incident. We also need to consider the probability of a railway incident having an impact on the incident occurrence probability inside tunnel. The actual calculation of incident occurrence probability inside tunnel emerges from the total length of tunnels in Slovakia railways (44.5 km) divided by the total length of railways (3631.4 km). [5, 6]

$$ILP = 44{,}5/3631{,}4 \quad (1)$$

$$ILP = 0{,}0122$$

This result shows that the probability of a railway incident which is formed directly in a tunnel is $1.22*10^{-2}$.

3.2. Probability of an Incident in Rail Transport.

The statistics show that average transport distance of an individual passenger is 51 km and as for cargo transport, it is 182 km. If we want to evaluate the probability of an incident in rail transport, it is essential to differentiate passenger and cargo transport. In 2011, the total number of train kilometres for passenger transport in Slovakia was 2431 mil passenger km. For further calculations, the classification of an idealistic passenger train was necessary. Total number of idealised trains was calculated as the ratio between train power (in passenger km) and average transport distance.

$$2\,431\,000\,000/51 = 47\,666\,700 \quad (2)$$

In 2011, number of 644 incidents took place excluding those at railway crossings. Incident probability of one idealised train is the ratio between number of incidents and number of idealised trains.

$644 / 47\ 666\ 700 = 1{,}35.10^{-5}$. (3)

Then the total probability of an incident happening in a tunnel is:

$PVMUT = 0{,}0122*1{,}35.10^{-5}$. (4)

$PVMUT = 1{,}6.10^{-7}$.

The value of $1{,}6.10^{-7}$ shows the probability of an incident in passenger transport in railway tunnels of Railways of the Slovak Republic (ŽSR). In 2011, total number of railway kilometres for cargo transport was 7 960 mil. ton km. For further calculations, the classification of an idealistic cargo train was necessary. Total number of idealised trains was calculated as the ratio between train power (in ton km) and the average transport distance.

$7\ 960\ 000\ 000/182 = 43\ 736\ 300$. (5)

Incidents in 2011 excluding those at railway crossings – 644. Incident probability of an idealised train is the ratio between number of incidents with number of idealised trains.

$644 / 43\ 736\ 300 = 1{,}47.10^{-5}$. (6)

Then the total probability of an incident happening in a tunnel is:

$PVMUT = 0{,}0122*1{,}47.10^{-5}$. (7)

$PVMUT = 1{,}8.10^{-7}$.

The value of $1{,}8.10^{-7}$ shows the probability of an incident in cargo transport in railway tunnels of Railways of the Slovak Republic (ŽSR).

3.3. Aftermath of an Incident Occurrence in Tunnel in Passenger Transport

Total aftermath is calculated as the sum of death and injury casualties and material damage. Since there has been no evaluation of life in the Slovak Republic, I have used the method of scientific evaluation from the Czech Republic. The life value has been determined to 700 000 EUR. Total number of death casualties is 37 excluding the ones at railway crossings. [6,[]

37*700 000 = 25 900 000 EUR

This value is divided by the number of idealised trains. $25\ 900\ 000/47\ 666\ 700 = 5{,}4.10^{-1}$.

Total number of 25 injuries excluding those at railway crossings. 25*279 676 = 6 991 920.

Idealised value of injury for the purpose of diploma thesis was calculated to be 40% of the life loss value which means 700 000 €, the exact value is

$6\ 991\ 920/47\ 666\ 700 = 1{,}4.10^{-1}$.

Damage in private transport – annual damage in private transport divided by number of idealised trains. Evaluation of all damage is formulated as the difference between total value and value concerning damage at railway crossings and further, subtracting 30% according to the comparison of passenger and cargo transport capacity. (1 630 494*0,30 = 489 148) $489\ 148/47\ 666\ 700 = 1{,}1.10^{-2}$.

3.4. Aftermath of Incident Occurrence in Tunnel for Cargo Transport

Aftermath in cargo transport has been calculated by similar means as well.

Total number of 37 death casualties excluding those at railway crossings 37*700 000 = 25 900 000 EUR.

This value is divided by the number of idealised trains. $25\ 900\ 000/43\ 736\ 300 = 5{,}9.10^{-1}$.

Total number of 25 injury casualties excluding those at railway crossings 25*279 676 = 6 991 920.

Idealised value of injury for the purpose of diploma thesis was calculated to be 40% of 699 192 EUR, which means 279 676 EUR.

$6\ 991\ 920/43\ 736\ 300 = 1{,}6.10^{-1}$.

Damage in cargo transport - evaluation of all damage is formulated as the difference between total value and the value concerning damage at railway crossings and further, subtracting 70% according to the comparison of passenger and cargo transport capacity. (1 630 494*0,70 = 1 141 346)

$1\ 141\ 346/43\ 736\ 300 = 2{,}6.10^{-2}$.

For further calculation, middle value of $1{,}85.10^{-2}$ was used.

From all the achieved results, it is feasible to calculate the risk of an incident in railway tunnels from the following:

R = probability * aftermath

$R = 1{,}70.10\text{-}7 * 1{,}85.10^{-2}$.

$R = 2.10^{-9}$.

The evaluated risk of an incident occurrence in railway tunnel being 2.10^{-9} is relevant to recommended values which are being used by German and English railways. (also in the level from 10^{-9}). [7],[9]

4. Conclusions

Implementation of the Common Safety Methods in railway companies in the European Union is one of the crucial objectives. While doing the risk research it is important to have all relevant information about the probability of occurrence and the aftermath of each risk available. Calculations presented in Chapter 3 are the contribution of authors from international discussion about the evaluation of rail transport risks. Mutual activity of several factors usually leads to the occurrence of an incident. Therefore, it is important to implement adequate safety measures into the risk management in order to decrease if not completely eliminate the risks.

One of the possibilities is to create a generally usable list of safety measures to enhance the safety of railway tunnels in the time of transport. As the research shows, the highest risk of an incident in railway tunnels is being formed especially during the transport. Needless to say, the aftermath can be catastrophic if dangerous materials are being transported. One of the solutions could be to prepare technical measures, such as using the RFID technology. Installation of a single chip enables the monitoring of a railway vehicle, its position or the condition of train switches. It can switch into an admonitory mode when a vehicle is approaching as well as transfer the data about the vehicle position.

Another possibility is the monitoring of railway tunnels with a camera system. This system consists of several video cameras depending on the length of the tunnel. It is supposed to monitor the situation outside as well as inside the tunnel. Currently, in the newly constructed tunnel Turecký vrch (1775 m long) there have been cameras installed both outside and inside the tunnel.

New classification of tunnels according to the risk also belongs to the organisational measures. Researchers are proposing 2 categories – A, B. Category A – tunnels on railways situated in corridors, category B – tunnels on side railways. Division of particular groups into subcategories in accordance with their length. Intervention could be problematic in the case of tunnels over 300 m. Proposed categories: A1 – tunnels up to 300 m, A2 – tunnels from 301 m to 500 m, A3 – tunnels from 501 to 1000 m, A4 – tunnels over 1000 m.

Another organisational measure is the update of documentation and its completisation, especially in the case of old tunnels. Amendment of the operational tunnel orders with focus on the control and maintenance (detailed reports according to the current condition) is being proposed. Tunnels in category A to be controlled quarterly, semi-annually and annually. Alternatively, special random inspections to be provided.

References

1. **Annual Report from project KISDIS - VG20122015070**/Ministry of Interior of Czech Republic – The Complex Automated Information System for Remote Management of Crisis Situations in Rail Transport with focus on Critical Infrastructure, Prague, 2012.
2. **Annual Reports from project OKID- APVV-0471-10** Critical Infrastructure Protection in Sector Transportation, Zilina, 2010, 2011, 2012.
3. **Dvorak Z., Fuchs P., Novak J., Sousek, R**. Individual and social risk during transportation of dangerous substances, Communications - Scientific letters of the University of Zilina - vol. 13, No. 2, 2011.
4. **Dvorak Z., Leitner B., SventekovA E., Sousek R.** Managing of risks in railway transport, monograph Institute J. Pernera, University of Pardubice, 2011.
5. **Dvorak Z., Sousek R. Englich J.** Preparation for solution of crisis situations in railway transport in the Czech Republic. Logistyka i Transport, Poland, 2007.
6. **Obrusnikova Z.** Risk Analysis of the Occurrence of the exceptional Incidents in the Railway Tunnel, diploma thesis, University of Zilina, 64 p.
7. **Sousek R. et al**.. Methodology of critical transport infrastructure objects identification. In: Theoretical and practical issues in transport - proceedings of the 5th international scientific conference Pardubice, University of Pardubice, 2010.
8. **Type Plan** of the Ministry of Transport. Large-Scale Disturbance of Transport System Functionality. Ministry of Transport of the Czech Republic No. 116/2010-030-CRS, 1st November 2010.
9. **Vidrikova D., Dvorak Z., Kaplan V.** The current state of protection of critical infrastructure elements of road transport in conditions of the Slovak Republic, Transport means 2011 - proceedings of the 15th international conference Kaunas University of Technology, 2011.

This paper was supported by project:
APVV 0471-10 Critical Infrastructure Protection in Sector Transportation