

PAPER • OPEN ACCESS

## Risk System and Railway Safety

To cite this article: M Bulakh *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **666** 042074

View the [article online](#) for updates and enhancements.



**240th ECS Meeting** ORLANDO, FL

Orange County Convention Center Oct 10-14, 2021



Abstract submission due: April 9

**SUBMIT NOW**

# Risk System and Railway Safety

M Bulakh<sup>1</sup>, A Okorokov<sup>2</sup>, D Baranovsky<sup>3</sup>

<sup>1</sup>The Faculty of Mechanics and Technology, Rzeszow University of technology, Kwiatkowski str. 4, Stalowa Wola 37-450, Poland

<sup>2</sup>Department of Operational Management, Dniprovsky National University of Railway Transport named after Academician V. Lazaryan, Lazaryana str. 2, Dnipro 49010, Ukraine

<sup>3</sup>The Faculty of Mechanics and Technology, Rzeszow University of technology, Kwiatkowski str. 4, Stalowa Wola 37-450, Poland

E-mail: d.baranovsky@prz.edu.pl

**Abstract.** When organizing transport processes on the railway, the most important component is the safety of railway traffic. Each country has a separate approach for assessing the safety of railway traffic on domestic railways. However, railway safety and other modes of transport is associated with technical or managerial risks. Assessment of the safety condition of traffic on Ukrainian railways is carried out by absolute and specific indicators resulting from statistical data. So far as the existing methodology for assessing the level of railway traffic safety does not provide a real and adequate picture, the problem of developing a risk system is relevant. The paper presents a risk system for assessing the level of actual and predicted safety of railway traffic. The risk system includes general, local, technological and technical risks. Each risk has a quantitative characteristic and can be applied to assess the safety of the railway traffic. The developed risk system is implemented as an application program and implemented at the railway enterprises of Ukraine. The presented system of risks and their posterior and priori values allow us to characterize the real state of railway traffic safety for the study period. Based on the obtained values of posteriori and priori risks, it is possible to characterize the actual and predicted safety of the railway traffic.

## 1. Introduction

The Railway safety throughout the world is on the first place when organizing all transport processes. Each country is characterized by a separate approach to assessing traffic safety on internal railways. However, almost the whole world is of the opinion that the traffic safety on railways and other modes of transport can be interpreted through risks that can be technical, managerial and the like [1]. The risk on the railway transport of Ukraine is understood as the probability of losses and losses in the process of transportation. Risks in rail transport are characterized by complexity and diversity, therefore, their classification is carried out according to individual characteristics [1]. However, there is no risk system in Ukraine's railway transport that could be applicable to assess railway safety.

## 2. The relevance, scientific significance of the issue with a brief review of the literature

On the Ukrainian railways [1], absolute and specific indicators are used to assess the state of the railway safety. As absolute indicators, statistical data are used, such as: the number of traffic accidents



and the number of victims, fatalities or injuries, and as specific indicators, derivatives of statistical data. Since the existing methodology for assessing the level of railway safety does not provide a real and adequate picture, the problem of developing a risk system that will allow us to assess the level of actual and predicted railway safety is relevant.

On the Slovak Railway, risk assessment models are being developed with an indication of their applicability to railway safety [2]. Risk assessment models are based on accident scenarios and include an improved level of human factor modeling and the use of more sophisticated statistical analysis methods. Moreover, various dangerous events or the level of traffic safety are characterized on the basis of statistical reports with the holding of meetings and the involvement of experts on railway safety. It should be noted that a comprehensive description of traffic safety through risks has not been provided. Based on accident scenarios involving an expert, an assessment of railway safety was also performed in [3], but taking into account the human factor. However, artificial intelligence methods are used here to simulate, store and evaluate knowledge about traffic safety. At the same time, software tools are designed to facilitate the work of experts and systematize important statistics. Similar data are given in [4, 5]. According to the data of the works, it should be noted that the human factor is not taken into account when involving experts for analysis or for building intelligent systems.

On the Polish railways [6], risk management methods are associated with the processes of the maintenance system of the elements of the transport system. In this regard, the authors noted the need for further studies of the relationship between the maintenance system and risk management methods, since they will contribute to greater coherence of transport systems and increase their efficiency in implementing security policy objectives. These works do not take into account other conditions of the life cycle of vehicles. In [7], identification of risks arising in the transport system is given, and based on an analysis of the identified risks; measures are proposed for the optimal functioning of the transport system. This work does not take into account the possibility of replacing the means of the transport system chain.

The existing method of quantitative risk assessment in the Netherlands [8] for determining railway safety during transport is focused exclusively on fatal victims. The disadvantage of this technique is the inability to predict risks. Since monitoring of the railway infrastructure is a vital task for ensuring the safety of railway traffic, video surveillance is used in [9] to assess the risk of rail failure. The results obtained illustrate the practicality and effectiveness of the proposed approach, but do not take into account the influence of other means of transport and elements of railway infrastructure. The Chinese development strategy [10] applies 24 potential critical risks in the railway sector, which are divided into 6 groups. One of the methods for determining safety is a questionnaire aimed at collecting data on the likelihood of a risk and its impact; the same method was used in [11]. Another method for assessing critical risks in the railway sector, given in [10], based on a fuzzy sensitivity analysis, as criteria for their identification. The results of the application of this method confirm its effectiveness, reliability and practicality in assessing risks, since it allows you to assess risks at three different levels: risk factors, risk categories and general risk; Lexical uncertainty and uncertainty due to lack of data are included and taken into account in the assessment process. The Shanghai Railway Bureau [12] has introduced a risk management approach based on the Figure and Four Tables (AFFTM) method to assess the quality of rail design. As a result, real-time monitoring and preliminary warning of the state of risk is significantly improved, automatic generation of qualitative risk indicators, efficiency and risk management levels. However, this approach applies only to the design of railways. Risk management on the Austrian railways with a methodological management basis is given in [13], where it is shown that risk reduction in decision-making is possible at three levels. Moreover, risk assessment is carried out in terms of capital investments, which allows you to manage these risks. It is noted about the influence of the human factor in the interaction between diversified partnerships, but the latter are considered as the most important element of risk management. The disadvantage of this rating system is its bulkiness. As part of the decision-making and forecasting processes for periodic maintenance of vehicles during the operation of the UK railways [14], it is accepted that the impact on traffic safety is possible using the concept of risk management and asset management. The paper critically examines

the current risk management practices in the railway industry to identify appropriate risk management models and offers recommendations for their further improvement and inclusion in asset management. To reduce risks, a methodology for analyzing a tree of temporary errors was proposed in [15], with the help of which vehicle malfunctions and the time required to eliminate malfunctions and perform maintenance to prevent accidents can be determined. In this work, the influence of the human factor is not taken into account. In [16], the requirements for ensuring the safety of railway passenger transport were analyzed based on the theory of risk management and the PDCA cycle model. At the same time, for qualitative and quantitative risk assessments, it was proposed to create a security management group. A safety risk management system for railway passenger transport has been built; it implements risk management, performance assessment and data management functions. The disadvantage of the constructed system is that people make decisions, and this, accordingly, is the influence of the human factor. The risk management structure was proposed in [17], which serves to eliminate the causes of accidents, including hazard identification, risk analysis, assessment, processing and control. The disadvantage of this system is the length of decision making. In [18], railroad power supply systems are considered critical for the safety of the transport system and this proposal is justified using a risk analysis based on IEC 61508. The safety system is modeled on Markov circuits. By comparing the results with a simplified fault tree, the significance of accurate calculations is obtained. The disadvantage of this position is the neglect of other railway infrastructure systems. The performed risk analysis in [19] led to the solution using stochastic rather than deterministic methods in assessing traffic safety, however, based on economic indicators of losses. The paper shows the possibilities of transition to the railway system of risk analysis methods that are currently used for other transport and technological systems. But, the implementation of such a transition is not given in the work. The work [20] presents methods for assessing risks and the possibility of reducing them in the design, operation and maintenance of railway vehicles. Particular attention is paid to the design of freight cars and their impact on traffic safety. The disadvantage of this work is the neglect of other systems and means of railway infrastructure. Train safety in [21] is characterized by a quantitative assessment of human errors with the choice of a Bayesian network for studying the consequences of identified errors. The Bayesian network is used to model hazardous events, risks and quantify train safety. However, the technical condition of the railway infrastructure and its impact on the traffic safety are not taken into account.

### 3. Statement of the problem

To describe the nature and obtain a numerical characteristic of railway safety in railway transport, it is necessary to have at their disposal an evaluating risk system that will allow a comprehensive assessment of the level of the actual and forecasted state of railway safety. Therefore, the work will develop a risk system designed for a comprehensive assessment of railway safety in railway transport.

### 4. The theoretical part

For a specific point in time, the risk of transport processes on the railway is taken to be the posterior risk for certain past observation interval, and we will use priori risk to predict risks.

The posterior risk of transport processes will be characterized by statistical data on the safety of movement of a particular railway object for the study period. This indicator will characterize the risk of losses of the investigated transport system.

The priori risk of transport processes will be based on pre-processed statistical data for the entire railway or its individual facility for the most significant studied periods of monitoring traffic safety. With the help of this indicator, the magnitude of the risks of an individual object of the railway transport can be predicted.

To determine the magnitude of the risk required indicators that can be described by the following vector:

$$R = (R \downarrow (X), R(X), R \uparrow (X)), \quad (1)$$

$R \downarrow(X), R(X), R \uparrow(X)$ , posterior, real and priori risks, respectively.

To characterize the safety of railway traffic, a risk system is proposed that includes general, local, technological and technical risks.

The general posterior risk of the railway transportation facility:

$$R \downarrow = D_R \cdot R \downarrow_R; \quad D_R = \frac{N_i}{\sum_{i=1}^n N_i}, \quad (2)$$

$D_R$ , the proportion of the traffic safety violations that occurred at the transportation facility;  $R \downarrow_R$  – general posterior risk of the entire railway;  $N_i$ , the number of traffic safety violations committed by the transportation facility in the  $i$ -th period;  $n$ , the number of study periods.

Local posterior risk of the railway transportation facility:

$$R \downarrow_S = D_R \cdot R \downarrow. \quad (3)$$

Technological posterior risk of a railway transportation facility:

$$R \downarrow_{thg} = D_{thg} \cdot R \downarrow_S; \quad D_{thg} = \frac{N_{thgi}}{\sum_{i=1}^n N_{thgi}}, \quad (4)$$

$D_{thg}$ , the proportion of traffic safety violations that occurred at the transportation facility due to a violation of the transport process technology;  $N_{thgi}$ , the number of traffic safety violations that occurred at the transportation facility during a particular period due to a violation of the transport process technology.

Technical posterior risk of the transportation facility:

$$R \downarrow_{tch} = D_{tch} \cdot R \downarrow_S; \quad D_{tch} = \frac{N_{tchi}}{\sum_{i=1}^n N_{tchi}}, \quad (5)$$

$D_{tch}$ , the share of traffic safety violations that occurred at the transportation facility due to failures of technical and transport vehicles, equipment, etc.;  $N_{tchi}$ , the number of traffic safety violations that occurred at the transportation facility due to failures of technical and vehicles, equipment, etc.

To determine priori risks, the use of the following expressions is proposed:

- according to the optimistic scenario:

$$R \uparrow_O = (R + \Delta_R)P; \quad \Delta_R = \frac{\prod_{i=1}^n \Delta_i}{\sum_{i=1}^n \Delta_i}, \quad (6)$$

- an approximate real scenario:

$$R \uparrow_r = (R + \bar{\Delta})P; \quad \bar{\Delta} = \frac{\sum_{i=1}^n \Delta_i}{n}, \quad (7)$$

$\Delta_R$ , weighted average risk increase;  $\bar{\Delta}$ , average increase in effective risk;  $\Delta_i$ , risk increase in the  $i$ -th period;  $P$ , probability of uptime.

### 5. Practical relevance, suggestions and implementation results, experimental research results

The developed and described risk system makes it possible to assess railway safety at a separate railway transport facility. Each risk has a quantitative characteristic and can be applied for a practical assessment of the railway safety. The developed risk system received applied software application and was implemented at the enterprises of railway transport of Ukraine.

Experimental studies of the practical application of the developed risk system using an example of a separate railway facility made it possible to calculate posterior and priori risks. The results are shown in tables 1, 2.

**Table 1.** Posteriori risks of a railway transportation facility.

Risk system	2015, $\times 10^{-8}$	2016, $\times 10^{-8}$	2017, $\times 10^{-8}$	2018, $\times 10^{-8}$	2019, $\times 10^{-8}$
<b>General</b>	223	244	1860	584	689
<b>Local</b>	9	7	96	27	27
<b>Technological</b>	23	20	241	90	95
<b>Technical</b>	1	1	5	2	2

**Table 2.** Priori risks of the railway transportation facility.

Risk system	R, $\times 10^{-8}$	$R\uparrow_o$ , $\times 10^{-8}$	$R\uparrow_r$ , $\times 10^{-8}$
<b>General</b>	3176	3178	3933
<b>Local</b>	75	75	115
<b>Technological</b>	123	124	219
<b>Technical</b>	26	26	28

The data are shown in table 1 allow us to make an assessment of posterior values in the risk system. Based on the calculated values of posterior risks, we can conclude on the state of railway safety at the railway transportation facility for each year under consideration. The most critical year is 2017, in which the risk values are 2.5 ... 8.3 times higher compared to other years.

The priori risks of the railway transportation facility (Table 2) practically do not differ compared with the risk value of the current period R with optimistic forecasting. In the case of approximate real forecasting, in the risk system there are increased risk values 1.1...1.8 times compared with the risk value of the current period R. The approximate real scenario of forecasting the risk system is more adequate compared to optimistic forecasting, which allows us to state a more realistic description of the actual and predicted railway safety.

### 6. Conclusions

In the work, a risk system is developed and described that allows assessing the safety of traffic for a railway transport facility. The risk system includes general, local, technological and technical risks. Each risk has a quantitative characteristic and can be applied to assess the safety of the railway traffic.

The presented system of risks and their posterior and priori values allow us to characterize the real state of the railway traffic safety for the study period. Prediction of the priori risk of a railway transportation object in a separate time interval under an approximate real scenario is more adequate in comparison with optimistic forecasting. Based on the obtained values of posteriori and priori risks, it is possible to characterize the actual and predicted safety of the railway traffic.

## 7. References

- [1] Okorokov A M, Bulakh M O 2018 Proposals for improving the process of forming programs of reforming the railway transport industry Science and transport progress *Bulletin of Dnipropetrovsk National University of Railway Transport named after Academician V Lazaryan* **2(74)** pp 57-66
- [2] Bohus Leitner A 2017 General Model for Railway Systems Risk Assessment with the Use of Railway Accident Scenarios Analysis *Procedia Engineering* 187 150-159
- [3] Habib Hadj-Mabrouk 2019 Contribution of Artificial Intelligence to Risk Assessment of Railway Accidents Urban Rail Transit Vol 5 Issue 2 pp 104-122
- [4] Figueres Esteban M, Hughes P, Gulijk C 2016 Big Data for Risk Analysis: the future of safe railways XII Congreso de ingeniería del transporte 7, 8 y 9 de Junio, Valencia (España) *Editorial Universitat Politècnica de València* 347-353
- [5] Min An, Wanchang Lin, Sheng Huang 2013 An Intelligent Railway Safety Risk Assessment Support System for Railway Operation and Maintenance Analysis *The Open Transportation Journal* **7** 27-42
- [6] Piotr Smoczyński, Adam Kadziński 2016 Introduction to the risk management in the maintenance of railway tracks *Journal of mechanical and transport engineering* Vol 68 **4** 65-80
- [7] Ana Stažnik, Darko Babić, Ivona Bajor 2017 Identification and analysis of risks in transport chains *Journal of Applied Engineering Science* **15** 1 414 61-70
- [8] Ruud M Houdijk 2016 Rail Transport of Hazardous Substances from the Perspective of 'All Hazard' Risk Management *Chemical engineering transactions* Vol 48 949-954
- [9] Jamshidi A, Faghih-Roohi S, Hajzadeh S, Núñez A, Babuška R, Dollevoet R, Li Z & Schutter B D 2017 A Big Data Analysis Approach for Rail Failure Risk Assessment *Risk Analysis* Vol 37 **8** pp 1495-1507
- [10] Jelena M Andrić, Jiayuan Wang, Ruoyu Zhong 2019 Identifying the Critical Risks in Railway Projects Based on Fuzzy and Sensitivity Analysis: A Case Study of Belt and Road Projects Sustainability MDPI *Open Access Journal* Vol 11(5) pp 1-18
- [11] Patil M, Shinde R D Prof, & Hailkar S S Miss 2017 Ranking of risk in railway projects *International journal of engineering sciences & research technology* **6(6)** 472-476
- [12] LI Qing, LIU Rengkui, ZHANG Jun, SUN Quanxin 2014 Quality risk management model for railway construction projects *Procedia Engineering* **84** 195-203
- [13] Antje Otto, Patric Kellermann, Annegret H Thieken, Maria Máñez Costa, Maria Carmona, Philip Bubeck 2019 Risk reduction partnerships in railway transport infrastructure in an alpine environment *International Journal of Disaster Risk Reduction* **33** 385-397
- [14] Sasidharan Manu & Burrow M & Ghataora Gurmel & Eskandari Torbaghan Mehran 2017 A Review of Risk Management Applications for Railways 14th International Conference of Railway Engineering 2017 At Edinburgh
- [15] Peng Zhaoguang & Lu Yu & Miller Alice & Johnson Chris & Zhao Tingdi 2016 Risk Assessment of Railway Transportation Systems using Timed Fault Trees *Quality and Reliability Engineering* **32** 181-194
- [16] Wenmin Zhu, Yuanhua Jia 2018 The Research on Safety Management Information System of Railway Passenger Based on Risk Management Theory, IOP Conference Series: Earth and Environmental Science 108 042067
- [17] Berrado Abdelaziz 2011 A Framework for Risk Management in Railway Sector: Application to Road-Rail Level Crossings *The Open Transportation Journal* **5** 34-44
- [18] Oz M A, Kaymakçı O T, Koyun A 2017 A safety related perspective for the power supply systems in railway industry *Maintenance and Reliability* **19(1)** 114-120
- [19] Licciardello R, Baldassarra A, Vitali P, Tieri A, Cruciani M & Vasile A N 2013 Limits and opportunities of risk analysis application in railway systems *Transactions on The Built Environment* Vol 134 133-144
- [20] Grenčík J, Roman Poprocký, Jana Galliková and Peter Volna 2018 Use of risk assessment

methods in maintenance for more reliable rolling stock operation *MATEC Web of Conferences*  
157 04002

[21] Rekabi M M 2018 Bayesian Safety Analysis of Railway Systems with Driver Errors: NTNU