Acta Polytechnica CTU Proceedings **41**:15–19, 2023
https://doi.org/10.14311/APP.2023.41.0015

VISION ZERO APPLICATION ON CZECH RAILWAYS

Jan Kruntorád*, Lukáš Týfa

Czech Technical University in Prague, Faculty of Transportation Sciences, Department of Transportation Systems, Konviktská 20, 110 00 Prague, Czech Republic

* corresponding author: kruntjan@fd.cvut.cz

Abstract. The railway is perceived as a modern, safe and environmentally sustainable way of transporting people and goods. In the past, appropriate innovations in the field of infrastructure and vehicles, combined with an attractive operational concept, have gradually become the backbone of public transport in the country. Even in this system, similar to other transport systems, there are accidents (events of emergency) or potentially risky situations. The paper places the issue of railway safety in the legislative context and uncovers the points of view from which the safety of railway traffic can be viewed.

Keywords: Failure modes and effect analysis (FMEA), key player, rail sector, railway emergency, railway stakeholder, railway safety, railway security, risk analysis, risk priority number (RPN), Vision Zero (0).

1. Introduction

The paper presents selected passages of the Study of Safety and Security Issues in the Rail Sector [1], which was completed in 2022 at the Czech Technical University in Prague (CTU), Faculty of Transportation Sciences, with the participation of experts from other faculties of CTU in Prague (Faculty of Civil Engineering and Faculty of Mechanical Engineering) and the University of Defense (Faculty of Military Leadership and Faculty of Military Health Sciences) [1]. Správa železnic, státní organizace, (the infrastructure manager of railway lines owned by the Czech Republic) is the orderer (and therefore also the owner) of the study. To preserve commercial secrecy, only partial passages of the study are published in the paper. If the reader is interested in more detailed output from the study, he can contact the Správa železnic with his request.

The study focuses on safety issues from the point of view of emergencies and the implementation of the Vision Zero concept in the railway sector with a focus on the railway transport route (with a partial overlap on vehicles, traffic management, and also on transport processes). The measures to reduce risks that the study proposes should have come primarily from the area of Intelligent Transport Systems (ITS).

2. Vision Zero

2.1. Vision zero in road transport

Human errors can never be eliminated. The idea of Vision Zero was first presented in Sweden in the 1990s. In principle, it is an innovative approach to the issue of road safety. Vision Zero means that eventually no one will be killed or seriously injured within the road transport system. The basic premise of Vision Zero is the idea that mistakes must not be punished with death [2]. Therefore, it is necessary to integrate the design elements to minimize human errors and their consequences into technical standards and regulations for road design, which will increase road safety [3].

The Vision Zero concept fundamentally changes the original way of looking at responsibility for road safety. It is not only aimed at the individual road user (driver), but at all key players, or at the system as a whole. Those who design the traffic safety system and its elements bear the main responsibility for the final level of road safety. This responsibility is jointly shared by vehicle manufacturers, transporters, road managers, politicians, legislators, public sector employees, or components of the integrated rescue system. However, this in no way relieves road users of their responsibility. It is the responsibility of each individual to comply with the relevant provisions of the law. Ultimately, this is a diametrical change in the way a traffic accident is viewed, which is no longer considered the result of an individual failure of a road user, but rather a failure of the entire system.

Currently, the idea of Vision Zero in the Czech Republic is part of the Strategy of Development of Intelligent Transport Systems 2021–2027 with a View to 2050 issued by the Ministry of Transport of the Czech Republic, and its goals are implemented in the Czech Road Traffic Safety Strategy 2021–2030 [4, 5].

2.2. Vision zero application on railways

The railway is perceived as a modern, safe and environmentally sustainable way of transporting people and goods. In the past, appropriate innovations in the field of infrastructure and vehicles, combined with an attractive operational concept, have gradually become the backbone of public transport in the country. Even in this system, similar to other transport systems, there are accidents (events of emergency) or

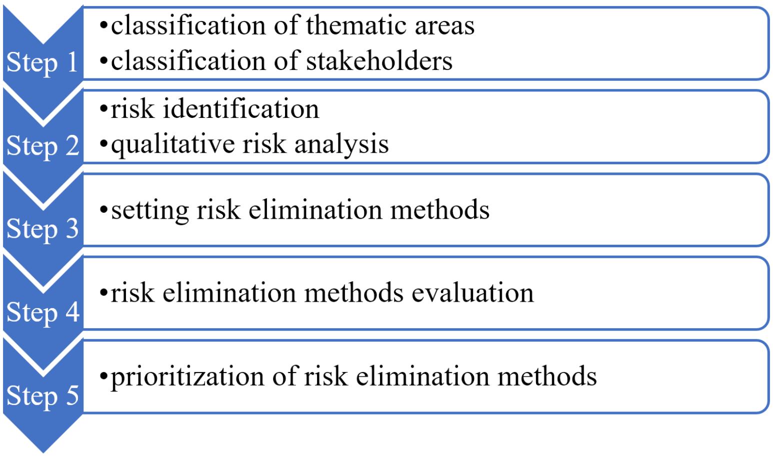

Figure 1. Study [1] procedure.

potentially risky situations. The purpose of the Study of Safety and Security Issues in the Rail Sector is to answer some questions regarding railway safety and security issues related to the achievement of Vision Zero so that the railway system strengthens its position as the backbone transport system in the Czech Republic, which will implement the most modern technological trends to increase the competitiveness of the railway compared to other modes of transport, travel comfort, and last but not least, safety and security [1].

3. Methods

An overview of the individual steps in the study is shown in Figure 1.

3.1. First step

The first step represents an initial analysis that prepares the conditions for further work. Thematic areas of rail safety and security are defined and categories of key players are identified.

3.1.1. Thematic areas

"Railway Safety and Security" is a relatively broad term, therefore, it was classified by the research team into categories as follows:

- damage to health and property due to the transport process (safety),
- resistance to illegal actions (security),
- cyber security,
- resistance to natural disasters,
- chemical and biological threats.

Due to the extensiveness of the entire study, the paper will focus mainly on the first area (safety).

3.1.2. Stakeholders' categories

To completely cover the entire railway system, the classification of railway entities was carried out as follows:

- state administration and self-government (including subordinate organizations),
- owners and operators of the railway infrastructure,
- railway carriers,
- customers of carriers and providers of specific services to carriers and railway operators,
- the human factor in rail transport,
- investors, manufacturers, suppliers and contractors of infrastructure and vehicles,
- manufacturers, suppliers and operators of IT and ITS systems,
- entities providing power electricity supplies (traction and non-traction),
- scientific research and testing institutions,
- international institutions,
- affected entities from other modes of transport.

3.2. Second step

The second step contains another analytical part of the study, specifically focusing on the identification and evaluation of risks.

3.2.1. List of risks

This creates a list of risks that identifies people who may die in connection with the transport process on the railway and the places/activities where and when they may die. Ten vulnerable people were classified, for example:

- people in a railway vehicle,
- people managing and ensuring railway traffic,
- people building or maintaining infrastructure,
- people who construct or maintain vehicles,
- other people not classified, for example, suicide.

The list contains 14 risk groups at the first hierarchical level, with a total of 79 risk factors (RF). Examples of risk groups:

Input values from the list of risks	0	1	2	3	4
Values used for the calculation of the RPN according to Equation (1)	0	1	2	4	8

TABLE 1. Conversion matrix of input values and values for RPN calculation.

- derailment of a railway vehicle while in motion,
- collision of railway vehicles,
- collision of a railway vehicle with a foreign object on a level crossing or platform,
- non-compliance with instructions when organizing rail transport,
- risky situations caused by improper cargo handling.

Examples of risk factors:

- the cause of the derailment is a technical fault on the railway track (for example, rail fracture, released rail fastening),
- the cause of the collision is a failure of railway signalling and control systems – human influence (including train driver),
- the cause of the situation is the leakage of a dangerous substance during handling (loading, unloading) – contamination of the surroundings,
- the cause of the situation is the fall of a natural object on the track (trees, rocks).

The causes of the risks themselves are evaluated by expert qualitative analysis. The qualitative evaluation uses predefined value scales 0–4; the meaning of these value scales is explained below:

Probability of cause of death:

- value 0: there is no cause-and-effect link for a specific group of vulnerable persons,
- value 1: almost zero (practically zero) probability that people will be killed,
- value 2: the low probability that people will be killed,
- value 3: the medium probability that people will be killed,
- value 4: the high probability that people will be killed.

The severity of consequences (if someone dies, typically how many people):

- value 0: there is no cause-and-effect link for a specific group of vulnerable persons,
- value 1: one person is killed,
- value 2: 2 to 9 people are killed,
- value 3: 10 to 99 people are killed,
- value 4: 100 or more people are killed.

Partial evaluation of individual experts was later converted to consensus values with the participation of the entire team. The consensus corresponded to the arithmetic mean of the ratings or their nearest integer values.

3.2.2. Risk priority number

Risks, as an eventuality (probability) of an undesirable event, can be assessed by the methods of qualitative and quantitative risk analysis in any system. Qualitative methods describe risks, fault modes and scenarios of the possible consequences of undesirable states based on the opinions of experts, and the outputs in these cases are presented on a relative scale. On the contrary, quantitative methods are used to determine the probability that an event will occur and its consequences in measurable units [6].

The chosen evaluation method is based on Failure Modes and Effect Analysis (FMEA), one of the most powerful methods used for risk assessment and maintenance management. The output evaluation criterion is a quantitive index, Risk Priority Number (RPN), which is given by the multiplication of the Occurrence (O), Severity (S) and Detection (D) of a failure. Since the security of the entire system was assessed at a theoretical level, it is not considered the Detection parameter, the relationship for RPN depends only on the Occurrence and Severity quantities [7]:

$$RPN = \sum O \cdot \sum S \tag{1}$$

- O – occurrence is the sum of probabilities that people may die,
- S – severity defines the strength of the impact of failure, expressed by an estimate of the number of dead.

A non-linear scale according to Table 1 was used to convert between a value scale and a probability or severity rating. It is a method of qualitative risk assessment to highlight significant identified relationships.

The higher value RPN according to Equation (1) is the:

- more probable cause of the risk is,
- greater number of persons may die in connection with the risk,
- more vulnerable groups are concerned with the risk.

The highest values of RPN (more than 250) were evaluated for these risky situations caused by:

- the leakage of dangerous substances and contamination of the surroundings,
- the transmission of diseases from people or animals,
- the collision of a railway vehicle with a foreign object at a crossing with insufficient visibility.

The lowest RPN values (below 50) were evaluated for risky situations caused by a sudden and unexpected change in movement of a railway vehicle, for example, due to rapid braking.

3.3. Third and fourth steps

The third step provides the first suggestions for finding methods that lead to risk reduction. The methods are expertly searched in the processing teams and presented as specific measures for specific risks. In this phase, possible opportunities for eliminating or mitigating risks are formulated, including "high-level measures", relationships with stakeholder groups, the relationship with the railway infrastructure manager and an estimate of the time required.

The fourth step presents the evaluation of the chosen risk reduction methods, which consists of consulting the chosen methods with stakeholder groups and further a mutual consensus among the expert team. The purpose is to clarify which of the methods the railway infrastructure manager is already using or at what level of development it is going to use them.

Risk catalogue sheets (fiches) are a key tool for working in these steps of the Study of Safety and Security Issues in the Rail Sector [1]. The catalogue sheet was prepared for each risk (risk factor), which had a standardized form and content. For risks of little significance (according to the RPN value), the catalogue sheet was easily filled out. A key part of each catalogue sheet (fiche) is the identification of opportunities and proposed measures to reduce the given risk. The processing of the first drafts of the catalogue sheets was divided among the members of the research team according to their specialization. Subsequently, the drafts of the catalogue sheets were revised by other members of the research team and then discussed in a workshop attended by representatives of stakeholders.

Content of the risk catalogue sheet (fiche):

- risk factor code and risk name,
- partial specification of the risk situation (description of the causes of the risk situation),
- RPN value (see above) and ranking in the evaluation of the risk significance,
- risk assessment – opportunities for change and risk mitigation (comprehensive view),
- proposal of high-level measures for change and risk mitigation from the ITS area, which is at least partially within the competence of the Správa železnic (the study orderer),
- specification of the link of high-level measures to the Správa železnic (the degree of implementation of measures by the Správa železnic; proposal of the organizational units of the Správa železnic that should address the measures),
- specification of the link of high-level measures to other stakeholders in the railway sector,
- positives (advantages, benefits) of the proposed measure (strengths and opportunities in the sense of SWOT analysis),
- negatives (limitations, difficulties) of the proposed measure (weaknesses and threats in the sense of SWOT analysis),
- the general time requirement of the implementation of the proposed measure (length of preparation and implementation of the measure, division into stages, continuity with other measures),
- recommended technical, technological and organizational means for implementing the proposed measure,
- any additional notes.

3.4. Fifth step

The fifth step represents the final design part.

3.4.1. Sorting of measures into groups

As part of the fifth step of the study work, the measures that were designed separately for individual risks in the previous steps are organized into a single system. On the one hand, similar measures are merged, and, on the other hand, the measures are sorted into groups that represent to a certain extent separate fields mainly from the ITS area, alternatively the IT area. A total of 52 proposed measures were divided into the following six groups:

- new data inputs and work with them,
- work with data already obtained,
- new technological systems,
- new educational systems,
- buildings and structures,
- amendment of legislation.

Subsequently, a catalogue of methods and measures to reduce risks was compiled. For comparison and, above all, the ranking of individual measures according to their importance, a Measure Significance Index (MSI) was defined. The MSI (2) takes into account the number of reduced risks and their importance. The MSI is based on the highest RPN value among the risk factors, which is the reduction to which the given measure contributes, and at the same time, it takes into account the amount and importance of all risk factors, which is the reduction to which the given measure contributes.

$$MSI_j = C \cdot \max_{i \in A_j}\{RPN_i\} + (1 - C) \sum_{i \in A_j} RPN_i \quad (2)$$

- MSI_j – Measure Significance Index no. j,
- j – measure order number: $j \in \{1, \dots, 52\}$,
- C – weighting coefficient of the maximum RPN value: $C = 0.8$ (the coefficient value was determined for this study),

- RPN_i – Risk Priority Number of the risk factor no. i,
- i – risk factor order number: $i \in \{1, \ldots, 79\}$,
- A_j – set of risk factors to which the reduction of which the given measure contributes, no. j.

The order of importance of the proposed measures is then compiled according to the MSI values.

3.4.2. Implementation of the scale of measures

In the final phase of the study, a schedule was proposed for the implementation of the measures, with an emphasis on the tasks of the study orderer. Risk reduction measures were timed in terms of their importance, difficulty and feasibility. The schedule for the implementation of individual measures is considered at the following three levels:

- Framework schedule for complete implementation that is implementation of a complete measure within a 25-year horizon, when the overall length of the measure and the division into rough stages are particularly important.
- A more detailed schedule of the initial short-term implementation that is a more detailed implementation of measures for risks of the highest group of significance within a maximum of five years.
- Action plan for the start of implementation that is gradual steps for the period 2022–2023.

4. Conclusions

The paper focused mainly on the fulfilment of Vision Zero, that is, reducing the number of people killed on the railway. According to the study cited, it is possible to take gradual steps in the form of ensuring the necessary measures to reduce risks, which can be solved in the short, medium, and long term. Some measures are dependent on legislation; some must be solved in coordination with the state administration, but also with carriers, railway technology suppliers, and other stakeholders so that it is possible to gradually fulfil the goals of Vision Zero.

The study should serve as a summary and supporting document to reflect on and expand other possible approaches and perspectives to reduce potential risks in the railway system. Although the study's outputs are focused on the Railway Administration, its conclusions also apply to other institutions and key players that were identified in the study.

Director of the Strategy Department of the Správa železnic, commented on the implementation of specific measures recommended in the study at the last workshop. The results of the project will need to be reflected in the internal regulations of the Správa železnic. Some conclusions of the study also lead to the initiation of changes in generally applicable legislation. At the same time, it will be necessary to separately address complex security on the high-speed railway system that is being prepared in the Czech Republic.

References

[1] T. Tichý, L. Nouzovský et al. *Study of Safety and Security Issues in the Rail Sector*. Czech Technical University in Prague, Faculty of Transportation Sciences. Praha, 2022.

[2] R. Johansson. Vision Zero – implementing a policy for traffic safety. *Safety Science* **47**(6):826–831, 2009. https://doi.org/10.1016/j.ssci.2008.10.023

[3] J. Kocourek, T. Padělek. Human (driver) errors. *Perner's Contacts* **6**(4):123–128, 2011.

[4] Ministry of Transport of the Czech Republic. Strategy of Development of Intelligent Transport Systems 2021-2027 (with a View to 2050). Praha, 2015 [2022-08-15], https://www.mdcr.cz/getattachment/Dokumenty/Strategie/ITS/Akcni-plan-rozvoje-inteligentnich-dopravnich-syste/Akcni-plan-rozvoje-ITS-prilohy.zip.aspx.

[5] Ministry of Transport of the Czech Republic. Czech Road Traffic Safety Strategy 2021-2030. Praha, 2021 [2022-08-15], https://www.ibesip.cz/Pro-odborniky/Narodni-strategie-BESIP/Aktualni-strategie.

[6] T. Javorik, L. Tyfa. Assessment of railway station modernisation combining risk analysis with multi-criteria analysis. *Communications* **17**(2):60–65, 2015. https://doi.org/10.26552/com.C.2015.2.60-65

[7] L. Ciani, G. Guidi, G. Patrizi. A critical comparison of alternative risk priority numbers in failure modes, effects, and criticality analysis. *IEEE Access* **7**:92398–92409, 2019. https://doi.org/10.1109/access.2019.2928120