Occurrences in Czech Railway Infrastructure and their Relation to the Economic Efficiency of Investments

V Hromádka¹, J Korytárová¹ and E Vítková¹

¹Brno University of Technology, Faculty of Civil Engineering, Veveří 331/95, 602 00 Brno, Czech Republic
E-mail: hromadka.v@fce.vutbr.cz

Abstract. The paper focuses on the evaluation of impacts of occurrences in the Czech railway transport system on social and economic benefits and financial efficiency of investment projects in railway infrastructure. The evaluation of financial and economic efficiency of investment projects financed from the funds of the European Union is based on the Guide to Cost-Benefit Analysis of Investment Projects by European Commission from 2014. In the Czech Republic, this Guide has been complemented, for the purposes of economic and financial evaluation of projects in transport infrastructure, by the Departmental Guideline for the Evaluation of Economic Effectiveness of Transport Construction Projects by the Ministry of Transport of the Czech Republic which specifies economic evaluation of projects of roads and highways, railways and waterways important for traffic. The Departmental Guideline defines benefits which can be included into the economic evaluation, e.g. savings in the operation costs, the decrease in costs connected with accidents, the decrease in costs connected with the travel time or negative externalities usually related to impacts on the environment. However, in the case of the railway infrastructure, benefits connected to the increase in safety and fluency of the transport due to introducing security and information systems are not taken into account, even if these investments form a standard part of most railway infrastructure investment projects. The objective of the paper is to identify both the number and the structure of railway occurrences, which can influence effective functioning of railway transport for the purpose of their subsequent research in order to take into account decrease in their use in economic analysis. The methodology of the research is based on detailed analysis of individual occurrences which happened on Czech railways during past three years. The output of this paper provides a detailed statistic of occurrences including damage caused and propose recommendations for the next steps which should lead to the quantification of relevant benefits.

1. Introduction
The implementation of public transport infrastructure projects is always linked to the need of large amount of financial resources. In the Czech Republic, these funds are usually provided by the State Transport Infrastructure Fund. In order to provide these funds, the investor (e.g. the Road and Motorway Directorate, the Railway Infrastructure Administration or the Directorate of Waterways) must, among other duties, prove the effectiveness of the project which funding is being applied for. Methodologically, the processing of economic evaluation of projects in transport infrastructure is covered by the Departmental Guideline of the Ministry of Transport of the Czech Republic. This Guideline is detailed and addresses many aspects of economic analysis of transport infrastructure projects in all transport
modes, i.e. road, rail and water. However, some aspects are not dealt with in more detail. This concern, among other things, the economic evaluation of railway infrastructure projects, in particular evaluation of the benefits related to the increase in safety and reliability of the railway infrastructure. The implementation of measures leading to the increase in safety and reliability of the railway infrastructure forms an integral part of most railway transport constructions, however, the present methodological documents do not allow to adequately evaluate the benefits related to the implementation of these measures. This article can be considered as an introductory text to a broader project task which aim will be the evaluation of the benefits mentioned and their reflection in the already existing methodological materials. This paper deals with the analysis of extraordinary events (occurrences) which happened in the 2015–2017 period in the relation to the railway infrastructure in the territory of the Czech Republic which were registered and investigated by the Railway Inspectorate of the Czech Republic. The purpose of the research is to identify key types of occurrences, determine their socio-economic impacts and define the amount of damage that could be prevented by the timely implementation of measures aimed at increasing safety and reliability of the railway infrastructure. Part of the results of the research is designing the subsequent procedure within the topic which the research deal with.

2. Literature review

While the issue of assessing socio-economic benefits in the form of savings in costs related to the occurrences related to the increase in the level of security and reliability of the railway infrastructure is not currently being dealt with in detail, resent publication have activity paid significant attention to the issue of railway occurrences and their causes. “There have been numerous international studies that have identified error types using an alternative approach to the analysis of occurrence reports. These studies describe and analyse railway workers’ tasks and consequently identify and classify worker errors and factors associated with those errors” [1]. There exists „the motivation to better understand why these accidents occur, and how they can be prevented” [2]. The paper [3] focused on Application of Human Factors Analysis and Classification System (HFACS) to the rail safety of the line incidents and concludes that „Minor safety incidents on the railway cause disruption, and may be indicators of more serious safety risks” [3]. The relations between latent and active errors are the subject of the paper [4]. The authors are of the opinion that “the effectiveness and the safety of railway operations depend on many factors including rail traffic rules, equipment reliability, general and safety management, and other human factors, and latent errors pose the greatest risk to the system safety” [4]. The paper [5] concentrates on the conditions affecting safety on the railway from the point of view of train drivers’ experiences and perceptions and concludes that the most beneficial for the railway safety are rail traffic management systems which “were seen as the primary safeguards within the railway system and were considered the predominant reason for the decrease in crashes” [5] Klockner [6] looks on the railway occurrences from the socio-economic point of view and states that “the new assumption and challenge calls for the understanding that accidents are complex processes involving the entire socio-technical system” [6].

It is clear from the above-mentioned quotations that railway occurrences are analysed in detail in order to find the crucial causes and consequently the means to prevent them. It can be assumed that the reduction in the number of occurrences will lead to more efficient operation of the railway transport and that measures aiming at reducing the consequences of occurrences can be quite effective from an economic point of view. This article focuses specifically on identifying the possibilities how the effectiveness of measures aiming at reducing the number of occurrences can be determined.

In general, the Guide to Cost-Benefit Analysis of Investment Projects [7] issued by the European Commission deals with the public sector project efficiency assessment. This document provides basic CBA analysis implementation procedures for public sector projects, especially projects funded by the European Union. The specifics of CBA analysis implementation for individual public sector areas are demonstrated by several case studies. The key document for the projects implemented in the Czech Republic in the field of transport constructions is the Departmental Guideline for the Evaluation of the Economic Effectiveness of Transport Construction Projects [8] issued by the Ministry of Transport of
the Czech Republic. This document builds directly on the Guide [7] and develops CBA principles, particularly for the implementation of transport infrastructure projects including road and highway projects, railways and waterway transport projects.

3. Methodology

The paper focuses on the issue of evaluating the benefits related to the increase in safety and reliability of the railway infrastructure. The subject of the article is an initial analysis focused on assessing the socio-economic impacts of railway occurrences. The outcome of the text is the interpretation of the results obtained and formulation of recommendations for further procedure for evaluating the benefits associated with the implementation of the measures with the purpose to increase reliability and safety of the railway infrastructure. These measures can be in the form of the station security equipment, the track-side security equipment and the train security equipment. All these measures become common part of the project in the railway infrastructure, however benefits connected with these measures are not methodologically included in the economic analysis.

The basic data source was the database of final reports from the investigation of occurrences registered and investigated by the Railway Inspectorate of the Czech Republic [9]. For the purpose of the article, final reports from the 2015–2017 period were used. The authors created a database based on these final reports including the occurrence registration number, the description of the occurrence, the number of people injured or killed, the material damage caused within the occurrence and expert estimate whether the occurrence would not happen if equipment increasing safety and reliability was installed in the corresponding railway section. This expert estimate were carried out by members of the project team participating on the project cited in the Acknowledgement according to the experiences with occurrences in the Czech railway system and the description of individual occurrences taken from final reports from the investigation of occurrences. An expert estimate was made by assigning it by one of the following descriptions:

- Certainly not,
- Probably not,
- Maybe yes,
- Probably yes,
- Definitely yes.

Depending on the description of the occurrence, the investigated events were divided into five groups according to the prevailing cause of their emergence. The following groups of occurrences have been identified:

- Unauthorised train journey,
- Trains collision,
- Collision with a person,
- Technical problem,
- Derailment of the railway vehicle.

Such structured occurrences were further analysed. Firstly, a comprehensive analysis of the occurrence frequency and their impacts (injury, death, material damage) divided according to the occurrence predominant cause was made.

Secondly, only those occurrences from the database, for which the above-mentioned expert estimate was identified as "probably yes" and "certainly yes" were taken into account. The data analysis identified the frequency of these occurrences and the amount of damage to health and property that could have been prevented by installing equipment for improving safety and reliability of the railway infrastructure.

Thirdly, the evaluation of the damage to the health was carried out using the data determined in the subchapter [8] and the total amount of socio-economic damage related to the occurrence emergence,
which could have been prevented by introducing appropriate measures for increasing safety and reliability of the railway infrastructure, was identified.

4. Results and discussion

Occurrences on the Czech railways recorded and investigated by the Rail Safety Inspection which is responsible for investigating the causes and circumstances of the occurrence emergence were analysed within the case study. The analysis carried out within the case study included all the investigated occurrences from the 2015–2017 period, except for occurrences in the form of a collision of the railway vehicle with the other road users at the railway crossings. In total, 56 occurrences were included in the analysis (27 from 2017, 11 from 2016 and 18 from 2015). As a result of these occurrences, a total property damage amounted at CZK 380,846,492 was created during the 2015–2017 period, six people died and 89 people were injured. Table 1 lists the damage caused by occurrences divided by the predominant cause of the occurrence emergence.

| Predominant cause of the occurrence emergence | Number of occurrences | Number of deaths | Number of injured | Material damage (CZK) |
|---------------------------------------------|-----------------------|-----------------|------------------|----------------------|
| Unauthorised train journey                  | 17                    | 2               | 38               | 236,637,007          |
| Trains collision                            | 15                    | 1               | 42               | 74,099,216           |
| Collision with a person                      | 5                     | 3               | 2                | 5,400                |
| Technical problem                           | 4                     | 0               | 7                | 26,662,065           |
| Derailment of the railway vehicle           | 14                    | 0               | 0                | 43,461,274           |

Source: authors’ own work according to [9]

The paper focuses on the evaluation of the benefits related to the implementation of equipment increasing safety and reliability of the railway infrastructure. For this reason, in the case of the occurrences mentioned above, it was researched whether these events would not happen if the measures to improve safety and reliability of the railway infrastructure were implemented in the corresponding area. The above-mentioned occurrences were assessed by the authors as to whether or not the above-mentioned measures for increasing safety and reliability could have prevented the occurrence from happening on the scale defined in the section 3.

For further analysis, only those occurrences with results "probably yes" and "definitely yes" in the evaluation were taken into account. A summary of the information on these occurrences is given in Table 2.

| Predominant cause of the occurrence emergence | Number of occurrences | Number of deaths | Number of injured | Material damage (CZK) |
|---------------------------------------------|-----------------------|-----------------|------------------|----------------------|
| Unauthorised train journey                  | 6                     | 1               | 34               | 203,494,987          |
| Trains collision                            | 4                     | 0               | 22               | 35,752,315           |
| Collision with a person                      | 0                     | 0               | 0                | 0                    |
| Technical problem                           | 0                     | 0               | 0                | 0                    |
| Derailment of the railway vehicle           | 0                     | 0               | 0                | 0                    |

Source: authors’ own work according to [9]

Building on the materials and methodologies for cost-benefit analysis (CBA) processing [7], [8], a transformation of socio-economic impacts in the form of health damage or loss of life on cash flows
could be made. As already mentioned in the methodological section, the economic loss shown in Table 3 can be assumed in a simplified way in relation to the damage to health or life.

### Table 3. Occurrences influenceable by implementation of the measures for increasing safety and reliability.

| Damage as a result of the occurrence | Socio-economic impact (CZK) |
|-------------------------------------|----------------------------|
| Death                              | 20,790,000                 |
| Damage to health                   | 942,053                    |

Source: authors’ own work according to [7, 8]

In relation to the previous Tables 1 to 3, it is possible to determine the overall socio-economic impacts caused by occurrences in the 2015–2017 period for all investigated occurrences as well as for all occurrences which could have been prevented by the timely implementation of measures leading to increase in safety and reliability of the railway infrastructure. These impacts are shown in Table 4.

### Table 4. Overall socio-economic impacts caused by occurrences in the 2015-2017 period.

| Predominant cause of the occurrence emergence | Total socio-economic impacts (CZK) | Socio-economic impacts which could be prevented (CZK) |
|----------------------------------------------|------------------------------------|-----------------------------------------------------|
| Unauthorised train journey                   | 314,015,021                       | 256,314,789                                         |
| Trains collision                             | 134,455,442                       | 56,477,481                                          |
| Collision with a person                      | 64,259,506                        | 0                                                   |
| Technical problem                            | 33,256,436                        | 0                                                   |
| Derailment of the railway vehicle            | 43,461,274                        | 0                                                   |
| Total occurrences                            | 589,447,679                       | 312,792,270                                         |

Source: authors’ own work according to [7], [8], [9]

From the information listed in Tables 1 and 2 it can be deduced how many occurrences emerged during the researched period, what damage to health and life occurred and what damage could have been prevented if measures to increase safety and reliability had been implemented in the past. From the point of view of the number of occurrences, there was no significant reduction, previously implemented measures for increasing safety and reliability would have prevented about 18% of occurrences. In terms of the total material damage, however, the impact was more significant, in the case of implemented measures for increasing safety and reliability of the railway infrastructure, 62% of the material damage, one loss of life and 63% of injuries would not happen.

After the conversion to the socio-economic impacts given in Table 4, it can be concluded that as a result of the previous implementation of the measures for increasing safety and reliability of the railway infrastructure, a 53% reduction in the socio-economic costs related to the occurrence emergence on the railway could be expected.

The results of the analysis carried out can be taken as informative only, as the analysis itself did not cover all the occurrences that happened on the railway. The analysis included only those occurrences that were investigated by the Railways Inspectorate of the Czech Republic and thus were considered more important. However, it is clear from these results that the implementation of measures for increasing safety and reliability of the railway infrastructure can bring a large number of socio-economic benefits, which consist in particular in the savings related to damage resulting from occurrences in relation with the health and property. Evaluation of these benefits can therefore bring a very interesting input into the economic analysis to assess the effectiveness of railway projects. The evaluation of these benefits and their reflexion into economic analysis will be the aim of further research in this field. However, the research will not focus only on the information obtained from the Railway Inspectorate of
the Czech Republic, but attention will be paid also to a much more detailed database of occurrences managed by the Railway Infrastructure Administration.

5. Conclusions

The paper focuses on the socio-economic evaluation of measures dealing with the railways infrastructure which aim at increasing safety and reliability of the railway infrastructure. The article represents an initial article within a larger research task and brings partial conclusions in relation to the analysis of occurrences in relation to the railway infrastructure and identification of possible socio-economic benefits of implementing measures for increasing its safety and reliability. The data from the final reports on the investigation of the occurrences, which was carried out by the Railway Inspectorate of the Czech Republic in the 2015–2017 period, were used for the analysis. The analysis shows not only the frequency of the investigated occurrences during the period under research and the amount of damage caused by these occurrences, but also the number of occurrences and the level of socio-economic impact that could have been prevented by the possible implementation of measures for increasing safety and reliability of the railway infrastructure. This paper brings partial conclusions in the researched area and proposes further procedure for dealing with the benefits evaluation related to the implementation of measures for increasing the safety and reliability of the railway infrastructure proposed and implemented within the framework of the railway infrastructure projects. The final objective of the research is to complete the methodology for the assessment of the effectiveness of projects in the railway infrastructure.

Acknowledgement

This paper has been worked out under the project of the Technology Agency of the Czech Republic “TL02000278 Evaluation of increased safety and reliability of railway infrastructure after its modernization or reconstruction”.

References

[1] Baysari M, McIntosh A and Wilson J Understanding the human factors contribution to railway accidents and incidents in Australia. Accident Analysis and Prevention [online], Elsevier, 2008, 40 (5), 1750-1757 [cit. 2019-02-18]. DOI: 10.1016/j.aap.2008.06.013. ISSN 0001-4575

[2] Read G J M, Lenné M G and Moss S A Associations between task, training and social environmental factors and error types involved in rail incidents and accidents, Accident Analysis & Prevention, Volume 48, 2012, Pages 416-422, ISSN 00014575, DOI: 10.1016/j.aap.2012.02.014

[3] Madigan R, Golightly D and Madders R Application of Human Factors Analysis and Classification System (HFACS) to UK rail safety of the line incidents, Accident Analysis & Prevention, Volume 97, 2016, Pages 122-131, ISSN 0001-4575, DOI: 10.1016/j.aap.2016.08.023

[4] Zhou J-L and Lei Y Paths between latent and active errors: Analysis of 407 railway accidents/incidents’ causes in China, Safety Science, Volume 110, Part B, 2018, Pages 47-58, ISSN 0925-7535, DOI: 10.1016/j.ssci.2017.12.027

[5] Forsberg R Conditions affecting safety on the Swedish railway – Train drivers’ experiences and perceptions, Safety Science, Volume 85, 2016, Pages 53-59, ISSN 0925-7535, https://doi.org/10.1016/j.ssci.2015.12.015

[6] Klockner K and Toft Y Railway accidents and incidents: Complex socio-technical system accident modelling comes of age. Safety Science [online]. Elsevier, 2018, 110, 59-66 [cit. 2019-02-18]. DOI: 10.1016/j.ssci.2017.11.022. ISSN 0925-7535

[7] Sartori D Guide to Cost-benefit Analysis of Investment Projects, Economic appraisal tool for Cohesion Policy 2014-2020. European Commission, Directorate-General for Regional and Urban policy. 2014. ISBN 978-92-79-34796-2.

[8] Ministry of Transport of the Czech Republic Departmental Guideline for the Evaluation of
Economic Effectiveness of Transport Construction Projects. 2017. Retrieved from http://www.sfdi.cz/pravidla-metodiky-a-ceniky/metodiky/

[9] Rail Safety Inspection Office. Database of investigated accidents and incidents and final reports. Retrieved from http://www.dicr.cz/zaverene-zpravy-z-mimoradnych-udalosti.