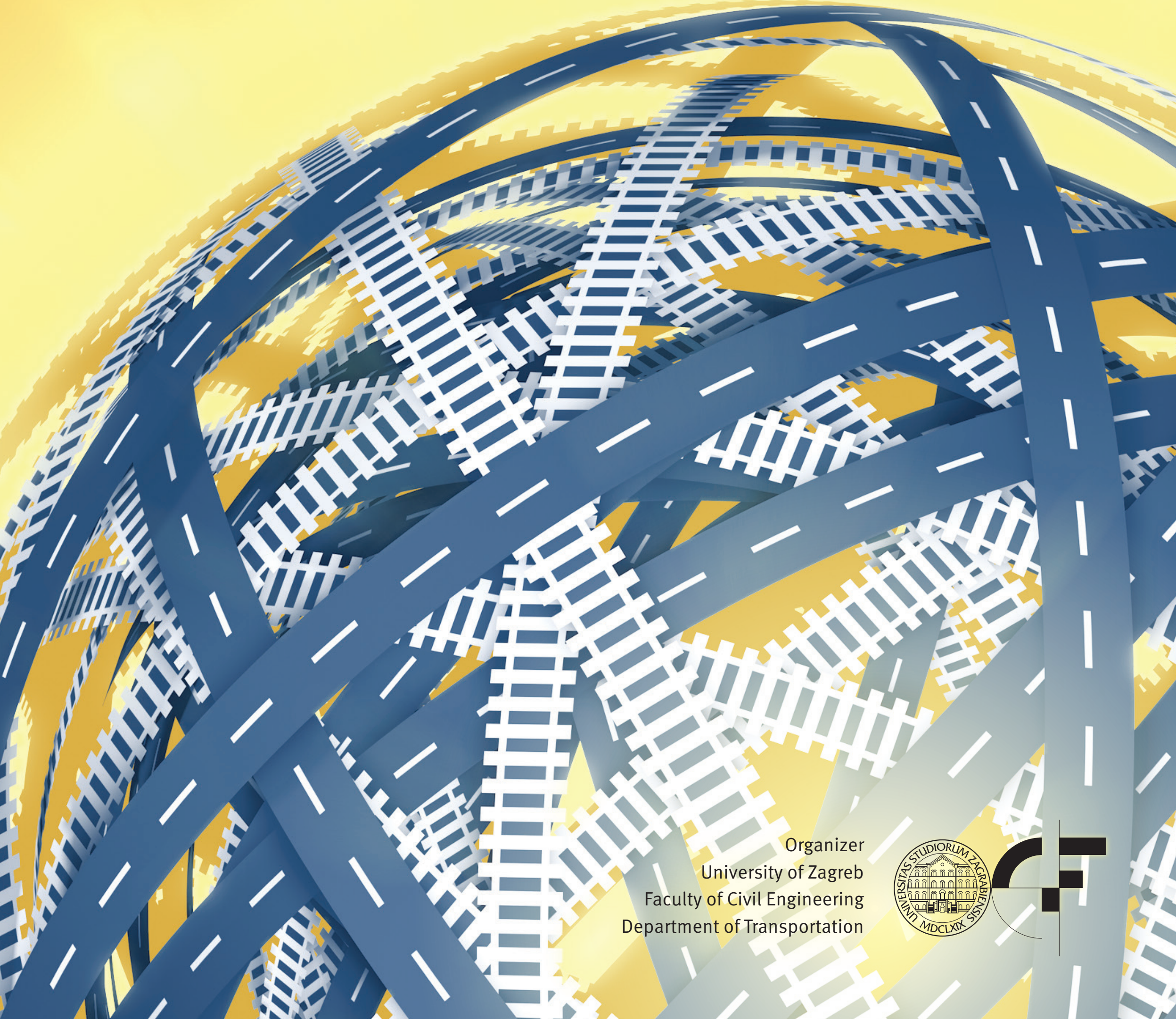
CETRA 2016

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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ENHANCING RAILWAY INFRASTRUCTURE ASSETS AGAINST NATURAL HAZARDS

Jelena Aksentijevic[1], Andreas Schöbel[1], Christine Schönberger[2]
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Abstract

The transportation system in Alpine countries plays a vital role in the European transit of passengers and freights from north to south and east to west. In addition, transportation lines are essential for the accessibility of lateral valleys and their economic welfare. In mountain areas, extreme weather events regularly trigger hazardous and torrential processes like different kinds of flooding, landslides or avalanches and their intermixtures. Their intensity will increase in the next years due to climate change. As railway infrastructure has a bottleneck function in the Alps, this case study will focus on enhancing resilience of a transportation network in a multi-hazard context and on reducing adverse effects of natural hazards in the transportation infrastructure in Austria.

Keywords: natural hazards, resilient railway infrastructure, flood damage railway model

1 Introduction

Over the years, given their central position in Europe, Alpine railways became key for freight transport and travellers with growing economic perspectives. Moreover, the Austrian railway network is also essential for the accessibility of lateral alpine valleys and is thus of crucial importance for their economic and societal welfare. If traffic networks are (temporarily) disrupted, alternative options for transportation are rarely available.

The harsh mountainous nature of the Eastern Alps, within which 65% of the national territory of Austria is situated (Permanent Secretariat of the Alpine Convention, 2010), poses a particular challenge to railway transport planning and management issues. Due to limited usable space or for reasons of economic or technical feasibility, railway lines often follow rivers in valley plains and along steep unsteady slopes, which considerably exposes them to flooding and, in particular, to alpine hazards such as debris flows, rock falls, avalanches or landslides. These can lead to disruption of railway tracks, causing large economic damages and temporary closures of line sections; since railway tracks and bridges can be washed away or can be severely damaged. Such events can cause substantial damage to railway infrastructure and pose a risk to the safety of passengers, wherefore they are a great issue of concern for the Austrian Federal Railways (ÖBB).

The Austrian Railway Infrastructure AG (ÖBB Infra), along with the civil and governmental partners are left with the difficult and costly mandate to assess risks, take preventive measures, and ensure the continuous operation of the network. Although done with dedication, the risk partnership suffers from mixed information exchange and cost-sharing divergence. Hence, risk analysis and management are important issues of railway operation in Austria, which is indicated by the fact that the ÖBB maintains an own department for natural hazard management and partnerships with various stakeholders at different administrative levels.

In this context, the ÖBB follows two main risk management strategies, namely:
- The prevention of Alpine hazards through the implementation of structural protection measures.
- The use of non-structural/organization risk reduction strategies such as a weather monitoring and warning system.

Both strategies, the MSPs collaborating in the respective risk reduction strategy and the research conducted within the ENHANCE project are depicted in Figure 1.

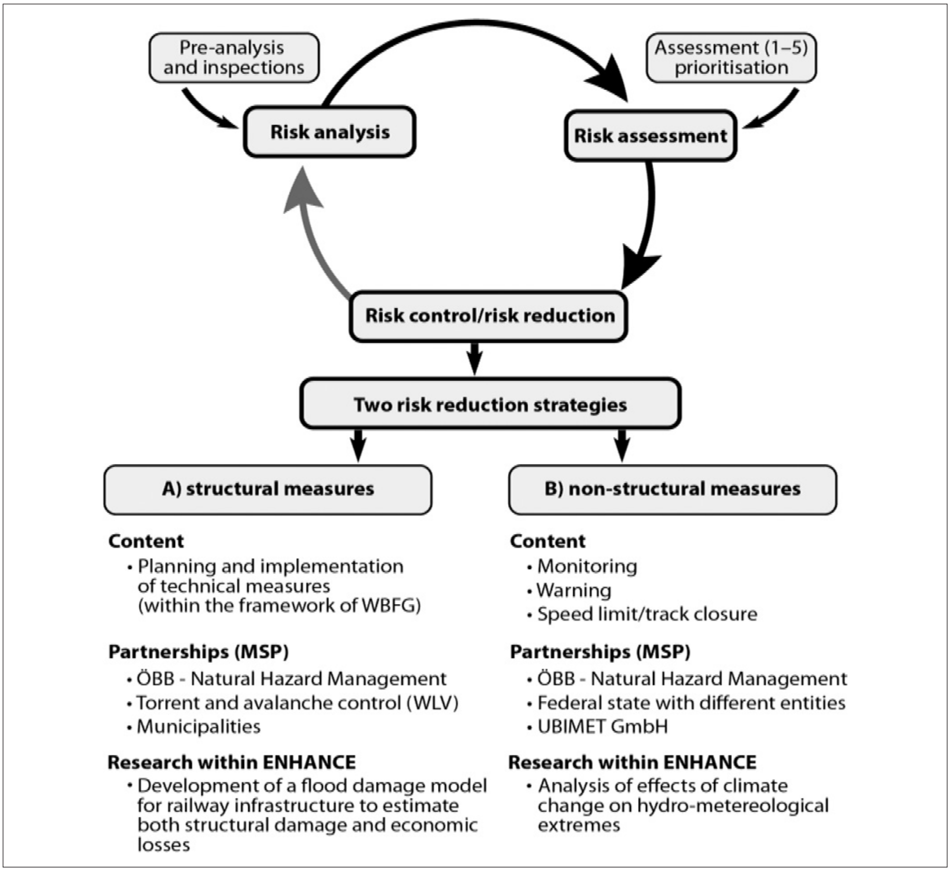

Figure 1 Two main strategies of risk reduction in railway transport and according work strands in ENHANCE. Source: own illustration. Information derived from interview/consultation 12. [WBFG = Hydraulic Engineering Assistance Act; MSP = Multi-stakeholder partnerships; ÖBB = Austrian Railway Infrastructure].

To protect their railway infrastructure from Alpine hazards, the ÖBB plans and implements structural (protection) measures on its own. If other stakeholders are affected by these protection measures, the ÖBB engages in partnerships to jointly plan and implement them. The core of these partnerships on structural measures lies in cost sharing and, in preparation for it, also in information exchange. It includes both formal, standardized processes fixed in regulations, as well as informal elements and ad-hoc negotiations. Further details on the strategies and specifications of the multi-sectoral-partnerships (MSPs) identified in this case study can be found in [7].

Since the possibility to address the risks from natural hazards in the Alpine topography by means of technical protection measures such as dikes or avalanche protection is limited, due to the sheer number of torrents and avalanche paths, the ÖBB additionally engages in non-structural/organizational risk reduction measures. This strategy focuses on risks occurring from meteorological hazards (i.e. extreme weather) and alpine hazards (e.g. avalanches, torrential processes, debris flows). The main idea of partnerships following this precautionary strategy is to gather and exchange information in order to better evaluate risk situations. Herein, a key element is the weather monitoring and early warning system called Infra:Wetter, which is jointly operated by the multi-sectoral partnership (MSP), as defined in [5], between ÖBB and the private weather service Ubimet GmbH. Also information from the national meteorological office (ZAMG) is included in this system. Besides providing individualized and route-specific warnings to approximately 1500 users, Infra:Wetter is also used to identify so-called critical meteorological conditions (CMCs) in advance: weather conditions that potentially lead to larger disruptions of train traffic and thus require coordinated action by the Natural Hazards Management Department of the ÖBB.

2 ENHANCE case study

As part of its commitments, ENHANCE brings in-depth study of the hazards through a detailed risk assessment for floods and debris flows at various locations for railway tracks. Furthermore, a comparison of the frequency of critical events with the number of floods and debris flows was done. Finally, an analysis of how improved risk information will influence the cooperation between stakeholders and decisions to close tracks, or to implement risk reducing protection measures.

2.1 Flood Damage Model: RAIL

Taking the core of partnerships on structural risk reduction measures into account, this ENHANCE case study focused on supporting strategic decision-making regarding structural protection measures via provision of valuable information on risks by means of a statistical modelling approach derived from empirical damage data, i.e. photo-documented damage on the Northern Railway in Lower Austria caused by the March river flood in 2006, and simulated flood characteristics, i.e. water levels, flow velocities and combinations thereof, as it can be seen in the Figure 2.

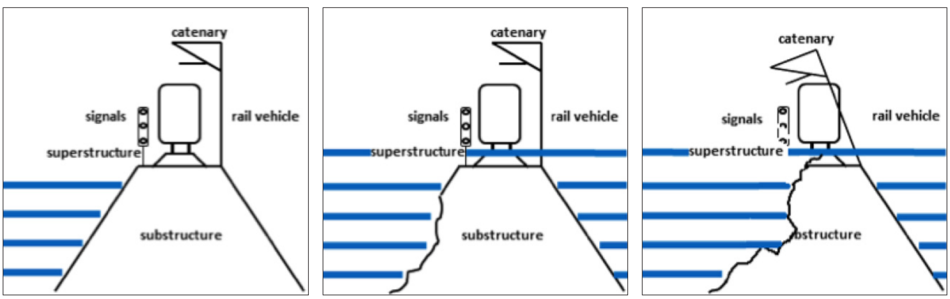

Figure 2 Damage classification scheme (adapted from [6])

A model was developed which will enable the estimation of 1) expected structural damage for the standard cross-section of railway track sections and 2) resulting repair costs. The first step in particular is usually skipped in existing flood damage models, since only (relative or absolute) monetary losses are computed. However, the localization of significant structural damage potentials at specific track section and, coupled therewith, the identification of risk hot spots creates great added value for railway constructors and operators in terms of network and risk management. Such information allows, for example, the targeted planning and implementation of (technical) risk reduction measures. In this regard, the results of the risk assessment indicate that the model performance already proves expedient as the mapped results plausibly illustrate the high damage potential of the track section located closely adjacent to the course of the river March as well as a general accordance with inundation depths. The estimates of financial losses (i.e. repair costs) amount to a plausible order and scale as the total costs increase for lower probability events and the results for the flooding in 2006 only overestimate the real expenses by approximately 2 %. The findings, furthermore, show that the development of reliable flood damage models for infrastructure is heavily constrained by the continuing lack of detailed event and damage data. More details on the structural risk assessment results are presented in [2] and [4].

2.2 Non-structural Flood Damage Model

Since knowledge and information are the main focus of the partnership on the non-structural risk reduction measure Infra:Wetter, the case study at hand delivered new insights into possible climate change impacts on frequencies of extreme events to support decision-makers in the comprehensive and sustainable natural hazard management. After Infra:Wetter was established in 2006 in the aftermath of a major flood event in 2005, the system was stress-tested for the first time in June 2013, when extreme rainfall resulted in floods and debris flow events obstructing and interrupting train transportation in large parts of Austria. The event was predicted with a sufficient warning time and operational measures such as track closures and temporary speed limits reduced the risk to passengers and staff.
The frequency analysis of CMCs in a changing climate revealed a noticeable to strong alteration of the current hazard profile in Austria. Notwithstanding, the fact that climate change impacts can also have positive effects on some sectors (e.g. winter service), the occurrence of the most relevant type of CMC analyzed, i.e. very intensive rainfall events, is likely to increase significantly in future, which overall leads to new challenges for the ÖBB natural hazards management. If no action is taken, the costs due to extreme weather events must be expected to rise in future. An application of the risk layer approach, which evaluates the suitability of mitigation measures based on disaster risk characteristics shows that Infra:Wetter in combination with a risk absorption mechanism provided by the federal government is generally an appropriate solution to address the risk from CMCs.
Currently, CMCs are defined using a threshold approach, which was defined by experts of the MSP, i.e. ÖBB and Ubimet GmbH. Given the importance of these thresholds, potentially resulting in precautionary operational measures such as track closures and/or temporary speed limits, an empirical examination of these thresholds would provide important insights into the suitability of these thresholds. Therefore, a method to assess the suitability of the current thresholds is provided and exemplified. The modification of the thresholds for the identification of CMCs revealed that frequencies of extreme weather events are quite sensitive to changes of this decisive factor. In the context of climate change, this result emphasizes the importance to carefully define and constantly adapt and validate the thresholds in order to optimize the effectiveness as well as the adaptive capacity of a weather monitoring and warning system. For a real application of this method, a more detailed longitudinal damage data base would be required, though, highlighting the importance of event and damage documentation. Event documentation including “near misses” can enable risk managers to better understand and learn from historical events and, thus, to adapt natural hazards management according to future changes. More details on the non-structural risk assessment results are presented in [3].

3 Stakeholder impact

A central idea of the research conducted throughout the project was to respond to the specific needs and requests of the main stakeholder and the existing partnership, respectively. It started with a meeting with the main stakeholder ÖBB, whose support continued throughout the project. The goals were to 1) specify the concept and objectives of the case study, and 2) get an detailed overview of the stakeholder`s perspective, strategies and existing partnerships in the framework of hazard and risk management.
The main achievement of the risk assessment conducted in the context of structural protection measures (see Fig. 1) was the provision of the flood damage model RAIL [4]. The RAIL model can be used to estimate both structural damage to railway infrastructure exposed to flooding and related repair costs. This two-stage approach allows a consideration of both structural damage types and direct economic losses. Particularly the first step provides new information on the occurrence of specific flood damage grades at exposed track sections. These can then be used for different risk management purposes, e.g. for the planning of (targeted) technical protection measures. Hence, the tool has potential to support the stakeholder ÖBB in terms of e.g. conducting cost-benefit analyses or identifying risk hot spots along the entire Austrian railway network.
RAIL has only been applied to a test section, so far. The ÖBB signaled interest to apply the RAIL model on a larger scale to gain insights into hot-spots of risks of the entire network. A large scale risk assessment could provide important insights into priorities in terms of risk reduction measures. Detailed data on potentially inundated railway infrastructure in the Mur catchment were already provided and the assessment is currently in preparation. Furthermore, the ÖBB initiated discussions on how the RAIL model could be transferred also to other natural hazards than floods. The ÖBB would be especially interested in developing a similar method for debris flow events, for which hazard maps but no damage and risk model are available.
The research conducted in the context of non-structural protection measures focused on the analysis of effects of climate change on the frequency of meteorological extremes (see Fig. 1). The new insights on potential future changes of CMC frequencies due to climate change and related implications for railway transportation in Austria gained from the ENHANCE case study research is seen by the stakeholder as a significant benefit. The results can support the development of targeted adaptation strategies for railway infrastructure and service. The stakeholder and partners agree that given the importance of such thresholds, an empirical examination of thresholds defined by expert judgment would further substantiate their adequacy, providing important insights for the MSP on weather monitoring and early warning. For such an empirical validation, a detailed and long-term damage data base would be required. However, such longitudinal data bases with a high level of detail in terms of damage due to natural hazards are currently not available for railway infrastructure in Europe. Hence, the application of the approach using currently available event and damage data for railway infrastructure would not allow drawing certain conclusions regarding the validity of the specific thresholds currently applied in Infra:Wetter.
In addition, the ÖBB was interested to gain further insights into indirect damage arising from natural hazards. Indirect damages occur if train services are disrupted or delayed because parts of the railway infrastructure are blocked or destroyed, for instance, through a debris flow event. It was initially planned to model these effects by means of an “availability analysis” of the network on the basis of the graph theory. This approach has been successfully applied for cross overs and even larger railway stations (see [10]) but, unfortunately, it does not really cover the complexity of dependent natural hazards along a railway line. Hence, due to this complexity as well as lacking data, this assessment could not be realized within the term of the case study at hand.

4 Conclusion

In conclusion, by analyzing existing processes and combining them with new risk projections, ENHANCE provided a robust handgrip to secure current and future resilience in the Alpine railway lines whilst paying attention to costs shared by the different actors. The results of this project have provided improved knowledge for decision-making with a broader approach than the commonly applied cost-benefit analysis, by applying a multi-criteria analysis. This is of great importance since the hazard situation will not be static, due to climate change. Most importantly, the ÖBB also became aware of the fact that damage documentation system does not exist on a European level and is already focused on developing one. As a result, there will be a possibility for sharing knowledge and experiences on international level and Austria will become a “good practice example” when developing innovative tools for natural hazard management strategies on European level.

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