NATURAL HAZARD INVESTIGATION ALONG ALPINE RAILWAY INFRASTRUCTURES

A first super-regional and interdisciplinary approach for the safety evaluation of an entire, coherent national railway infrastructure

Christian Rachoy[1*], Anton Henle[2], Thomas Waclavicek[3], Günther Prasicek[4], Manfred Scheikl[5], Nathalie Wergles[1]

ABSTRACT

The Austrian railway system is vulnerable to numerous natural hazards at several sections within the Austrian Alps. To provide a high level of reliability a super-regional database for all segments of endangerment has to be elaborated. The reach this ambitious goal within a short time span a three step analysis was established. The three levels of investigation scale up from an overview study to a detailed process and impact analysis. It is shown that the coarse scale investigation allows a fast identification of homogeneous sections of endangerment. At the intermediate scale the relevant hazardous processes identified at the previous stage are described in detail. Based on these results organisational and structural measures at design-scale are derived. The experience form a pilot study proofs the advantage of the performed three step analysis in terms of time and data quality. Based on this study new developments to reach a higher level of protection for railway infrastructure will be designed. This implements rapid alert systems, real time monitoring and coupled numerical modelling.

Key Words: Railway infrastructure, Natural hazard, Natural hazard mapping

INTRODUCTION

Some of the most important transit routes between Northern and Southern Europe cross the Austrian Alps. The Austrian railway network covers around 6000 km of tracks. About one third is located within deeply incised alpine valleys and is taking course over several high alpine passes. As a consequence of these extreme boundary conditions the railway infrastructure is exposed to substantial danger processes: (a) single rock-fall events, (b) snow-avalanches (c) rock-avalanches (d) debris flows (e) flooding (f) rock- and soil-slides and many others. The inner alpine railway net has a considerable share on the total volume of cargo and passenger transportation. Beside this, the rail-way system becomes increasingly

1 Head of Natural Hazards Department, Austrian Federal Railways Infrastructure, Nordbahnstrasse 50, 1020 Wien, Austria (Corresponding Author; Tel.: 0043-1-93000-34418, Email: Christian.rachoy@oebb.at
2 Managing Director, Department of Hydro- and Torrent-Engineering-Services, Alp-infra Consulting + Engineering GmbH, Schillerstrasse 25/Stiege Süd/1. Stock, 5020 Salzburg, Austria.
3 Project Leader Hydrological an Avalanche Hazards, Department of Hydro- and Torrent-Engineering Services, Alp-infra Consulting + Engineering GmbH
4 Project Leader Geological and Geotechnical Hazards, Department of Geo- and Civil-Engineering-Services, Alpinfra Consulting + Engineering GmbH
5 Managing Director of Department of Geo- and Civil-Engineering-Services, Alpinfra Consulting + Engineering GmbH

important for the economy and the inhabitants of the alpine region. With respect to the increasing number of catastrophic meteorological events in context of the global climate change the reliability and availability of the railway system represents a growing challenge. Mitigation strategies against the impact of natural hazards have to be developed and adapted. Furthermore, the increasing number of private companies operating on European railroad infrastructure results in an increased liability-momentum for the provider. Therefore a coherent and superregional hazard investigation has to be performed.

METHODS

The railway net represents a linear infrastructure system, partially vulnerable to natural hazards. These vulnerable parts are interpreted as sections of endangerment specified by a track identity and a kilometre mark.
In order to identify all relevant sections of endangerment along the entire railway infrastructure within a short time span and to deal with the estimated big amount of data, a three step analysis was established. The three project levels are characterised by an increasing amount of detail in collected data and any project level is based on the results of the previous one. For an Austrian-wide investigation of natural hazards along railway infrastructure, standards had to be established, to provide a coherent and comparable data base at all scales.

Level I

In a first step an overview study was performed to define homogeneous sections of endangerment. Regarding to the large amount of investigation an evaluation scale of 1:25.000 was specified. Data at the target scale was collected and processed to provide a consistent linear dataset of the entire railway net. As a side effect sections of immanent danger were identified and immediately posted to a safety board.

Observed geomorphologic processes were assigned to defined categories to reach a high level of consistency between all data processed by different groups of investigators (Fig. 1). The hazardous potential was derived from obvious process activity and obvious usability of existing protective structures and evaluated in four classes of relevance

A) "High relevance" was defined by evidence for recent process activity (recent avalanche tracks, fresh rock faces with opened cracks, recent deposition forms without vegetation cover) and lack of sufficient protective structures.
B) "Medium relevance" was defined by existing, but at the present stage inactive processes (tree covered avalanche tracks, weathered rock faces, vegetation covered deposition forms etc.) and lack of sufficient protective structures.
C) "Minor relevance" was defined by fossil, overprinted forms or no evidence for process action. However, the possibility of hazardous processes in the future can be assumed regarding the existing topography and the morphological inventory. Furthermore the combination of recent process activity and obviously sufficient protective structures is assigned to this category.
D) "No relevance" assumes absence of any possibility of relevant process action.

In a pilot study data from regional headquarters of the Austrian railway operating company and historical data from photographs and journals was collected and stored in a database. Based on this pre-information, fieldwork (mapping and evaluation of sections of endangerment) was done. Data was stored in a geodatabase. Sections of endangerment were located along the railway tracks and a super-regional hazard map was designed.

Observed processes		Reported categories
Nival	Snow avalanche	Avalanche
	Snow slide	
Fluvial	Flood	Torrent junction
	Debris flow	
	Intermediates	
Gravitational	Rock fall	Rock fall
	Rock avalanche	
	Land/mud slide	Landslide
	Slope failure	

Fig. 1: Observed processes and relation to reported categories at Level I

Level II

In a second step sections of relevant endangerment identified by the Level I investigation are subject to more accurate and specific assessment. Investigations were and are still performed at an evaluation scale of 1:5000. At this stage the spatial resolution allows to describe each individual danger process in detail. The capability of retaining measures and the exposition of the railway infrastructure has to be analysed on site. Geospatial data obtained at this stage was collected and processed and qualitatively interpreted to provide a consistent and precise dataset of high priority areas. Homogenous sections of protection deficit as a measure of the necessity of further structural measures for hazard mitigation are the final output.

To evaluate the hazardous potential of geomorphologic processes in detail, methods differ significantly from Level I: Process categories were maintained, but in Level II linear sections of endangerment and furthermore the entire areas of the acting processes are mapped.
The process areas are split into starting zone, transport zone and deposition zone and evidence for process activity has to be described for every zone. Accordingly, the process is assigned to one of five defined classes of activity to provide coherent results (Fig. 2).
As process activity, exposition of the railway track and usability of existing protective structures are also mapped in 5 categories (Fig. 3, 4). Finally the “lack of protection” is derived by allocating the process activity, the exposition of the railway track and the usability of existing protective structures (Fig. 5).

Process activity	Examples
Moderate to high recent activity	Recent avalanche tracks, fresh rock faces (not weathered, opened cracks), recent deposition forms (without vegetation cover), big contingent of recent impact marks (on trees, buildings) etc.
Low recent activity	Mostly weathered rock faces with minor not weathered parts and without opened cracks, mostly aged deposition forms and impact marks with very small contingent of recent elements etc.
Inactive	Exclusively weathered rock faces, well confined vegetation covered deposition forms, exclusively aged impact marks etc.
Fossil	Extremely weathered rock faces, overprinted deposition forms
No process possible	

Fig. 2: classes of process activity

Usability of protective structures	Definition
No relevant protection	Protecting from less than 50% of assessable events
Low protection	Protecting from min. 50% of assessable events
Moderate protection	Protecting from min. 70% of assessable events
High protection	Protecting from min. 80% of assessable events
Full (sufficient) protection	Protecting from 98% of assessable events (2% failure possibility)

Fig. 3: classes of usability of protective structures

Exposition of the railway track	Definition
Direct exposition	Direct crossing of starting/transport zone
High exposition	Direct crossing of deposition zone
Moderate exposition	Marginal crossing of transport/deposition zone
Low exposition	No crossover with process area, but impact may be possible in context with an catastrophic event
No exposition	No impact possible

Fig. 4: classes of exposition of the railway track

Lack of protection	Consequences
Very high lack of protection	Level of protection has to be raised within one year
High lack of protection	Level of protection has to be raised within the medium term
Moderate lack of protection	Level of protection has to be raised within the long term
Low lack of protection	
No lack of protection	

Fig. 5: lack of protection

Level III

In a final step dynamic processes are quantified by a variety of tools (e.g. numerical modelling). Based on these results organisational and structural measures at design-scale are deviated.
Based on Level II investigations the railway track crossing the Semmering pass was chosen for a test site due to numerous sections characterised by a significant lack of protection. Accordingly existing dynamic processes were quantified and dimensioning of protective structures was done.

RESULTS

At present stage Level I has finalised and Level II is in progress. The Level I investigation of about 6000 km of railway tracks has been done within a few months in a fast and superficial way. The results show sections of explicit endangerment, which are subject to more accurate and specific assessment in Level II. The interpretation of the Level I investigation leads to the following results (Fig. 6). About 75 % of the entire railway infrastructure are not exposed to

danger processes or are sufficiently protected hence not relevant for further investigations. 1.9 % of the railway net are characterised by highly relevant endangerment, 13.1 % show medium and 10% minor relevance. As expected, the majority of these sections are located within deeply incised alpine valleys (e.g. Enns valley, Salzach valley, Inn valley) and at the confluence of their tributaries. Processes in order of relevance are flooding (450 km), rock fall (33 km), snow avalanches (13 km), soil slides (10 km) and torrent crossings (6.9 km). Four sections on main transition routes characterised by a high danger density were selected for a Level II pilot study.
At the present stage no statistically proofed results for the Level II pilot study are available but will be in spring 2010. An example for mapped and digitized data (process areas and sections of homogenous lack of protection) is displayed in figure. 6.

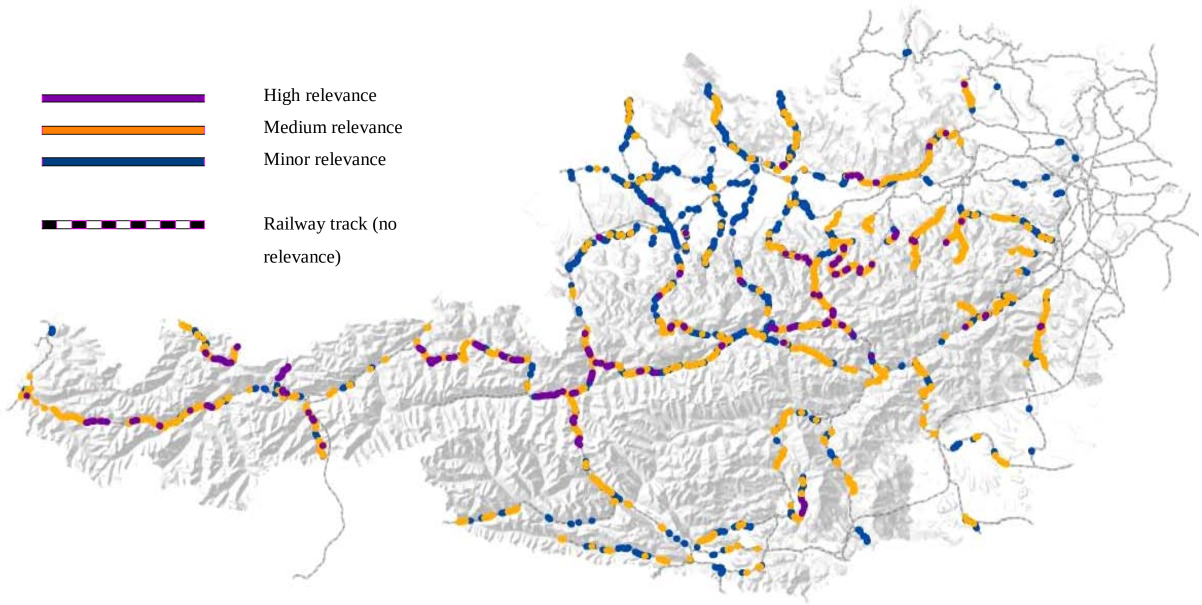

Fig. 6: Investigated railway net Level I - colour coded for relevance classes.

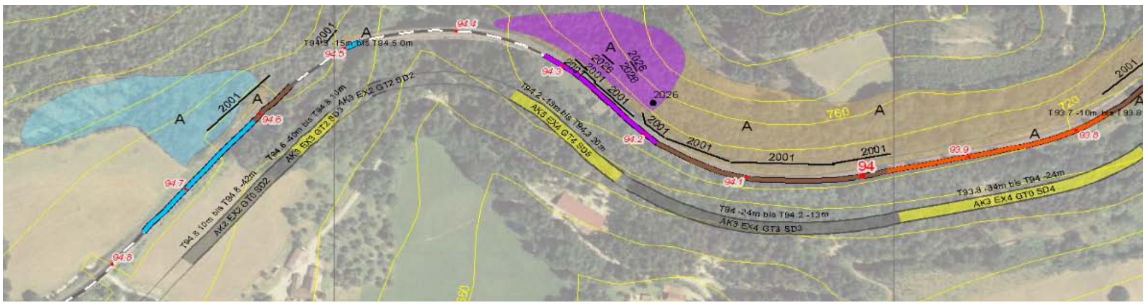

Fig. 7: Example of investigated Section at the Semmering pass - Level II

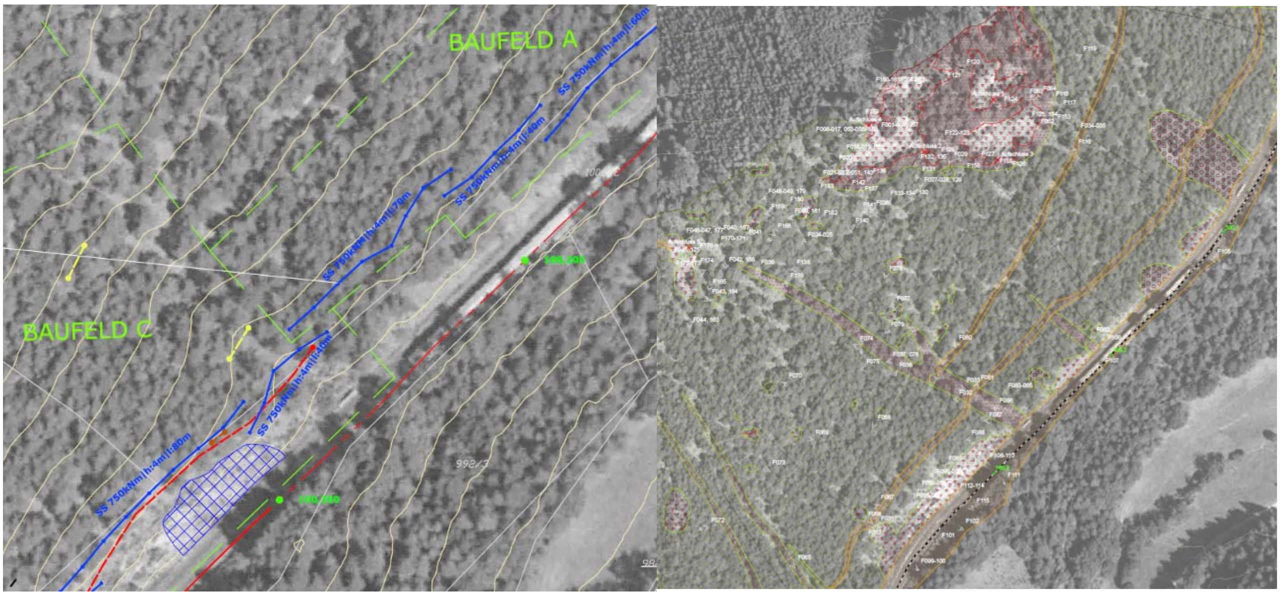

Fig. 8: Example of investigated high priority section at the Semmering pass - Level III

CONCLUSIONS

It is shown that one fourth of the total track length in Austria is vulnerable to natural hazards. The detailed assessment of these sections is progressing and any urging need for action, as a result of Level 2, is immediately implemented. The project structure consisting of a cascade of three subsequent levels of investigation proofs a fast and efficient methodology. This is shown at several high priority sections at the Level II scale (Enns valley, Inn valley etc.) and at a test site in Lower Austria (Semmering pass) at Level II scale. Start of construction of the complement protective structures in Semmering area is scheduled spring 2010.

The methodology elaborated during this study represents breaking new ground for investments in the prevention of natural hazards that are based on long-term planning instead of ad hoc measures. Furthermore, based on this study a number of new developments are planned:

- (A) A rapid alert system as a combination of natural hazards map and meteorological data
- (B) Real Time monitoring of sections of high endangerment
- (C) Integration of numerical models for the prediction of magnitude and scale of natural hazards in terms of destructive forces impacting the railway infrastructure.

REFERENCES

Aigner, H., Henle, A., (1999). Die Entwicklung einer prozessorientierten Abgrenzungskarte als Teil der Gefahrenzonenplanung. – Wildbach und Lawinenverbauung Heft 149

Kienholz, H. (1996). Gefahrenkarten: Maßgeblichen Parameter und Kriterien zur Festlegung von Intensitäten. - Int. Symp. Interpraevent Bern, Bd. 3, S.47-58, Garmisch-Partenkirchen

Mölk, M., Marschallinger, R., Stejskal, C. u. Gusenbauer, F. (2001). Teilautomatisierte digitale Bearbeitung von Geoinventar (Geologie, Geomorphologie Prozesskartierung etc.) - Anforderungskatalog und Programmtechnische Umsetzung in CAD-Umgebung. In: Vortrag zur Tagung Computerorientierte Geologie, Vorarlberger Naturschau

Rachoy C. (2004). Avalanche Protection of Alpine Traversing Railway Lines in Austria. International Research Society INTERPRAEVENT; 10th International Congress, Riva del Garda, Italy.

Rachoy C., Scheikl M., Henle A. (2004) Risk Orientated Natural Hazard Analyses along Alpine Railway Lines. 2nd International Conference on Protection of Structures against Hazards, Singapore

Rachoy C., Scheikl M. (2006). Anthropogenic Caused Mass Movements and their Impact on Railway Lines in Austria INTERPRAEVENT 639-643

Scheikl, M., Hauschild, H., Wanker, W. (2001). Instabile Hangflanken – Methodisch innovative Ansätze in den Projektphasen Grundlagenerhebung und Monitoring. Sonderband Geotechnik – Nationale Tagung für Ingenieurgeologie, Karlsruhe 2001.

Scheikl M., Angerer H., Dölzlmüller J., Poisel R. u. Poscher G. (2000). Multidiziplinary Monitoring Demonstrated in the Case Study of the Eiblschrofen Rockfall; Felsbau 18, Nr 1, Essen

Scheikl M. (2005). Felssturz Steinbruch Spitz a.d. Donau, Geotechnische Analyse, Technischer Bericht

Wergles, N. (2008). "Österreichweite Gefahrenzonenkartierung für Eisenbahninfrastruktur," *Conference Proceedings of 9. Forum Katastrophenvorsorge*, German Committee for Disaster Reduction. (in German). online under: http://www.dkkv.org/DE/events/default.asp?u=37