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Vulnerability and Adaptation Strategies in Alpine Road and Rail Transport – Swiss Case Study

Report from the International Panel of the WEATHER project funded by the European Commission's 7th framework programme

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1 Introduction and aim

The ‘Weather’ project

There is strong evidence that climate change will have a strong impact on the weather. The consequences will be more extreme events such as hot and dry summers, heavy winter storms, storm surges, floods and landslides. The need for adaptation is recognised, but the magnitudes and consequences of these changes are not yet well understood. Therefore, the WEATHER project aims at analysing the economic costs of climate change on transport systems in Europe and explores ways for reducing them in the context of sustainable policy designs.

Aim of this paper

This paper aims to present the situation in Switzerland with regard to vulnerability and adaptation strategies of the transport infrastructure in Switzerland. A specific focus is given to the alpine area. Based on a short description of the general state of the art of vulnerability research and Swiss adaptation strategies, the specific situation of alpine transport infrastructure and infrastructure policies (prevention, damage management) is analysed. The analysis is based on own expert knowledge, literature review considering as well the ongoing discussion on the general Swiss adaptation strategy and selected interviews with responsible persons for road infrastructure management (see literature and interviewees in the Annex).

2 General situation in Switzerland

2.1 Transport infrastructure

Switzerland has a very dense transport infrastructure. This is true for road and rail since Switzerland – compared to EU average – promotes rail and public transport significantly. The road network accounts for 71’300 km, whereas 1’756 km are motorways (BFS 2009). The motorway network is still under construction and most dynamic compared to the other network parts. Based on the new legislation on task share between national and cantonal level and financial flows (Bundesgesetz über den Finanz- und Lastenausgleich, 2003), the Federal Road Administration is fully responsible for construction, maintenance and financing of the motorway network. This has also changed the responsibilities in motorway risk management, which was formerly a task of the cantons. The cantons are responsible for the cantonal part of the road network. In alpine areas the cantons of Bern, Uri, Grison (Graubünden), Ticino and Valais are most important (see Map in the Annex).

The rail network accounts for 5062 km. The national railway company (SBB Infrastruktur) is responsible for construction, maintenance and financing (linked with service level agreements and financial instruments at national level). The rail infrastructure network in alpine areas is also owned and operated by other private rail operators, such as BLS (canton Bern and transalpine axis Lötschberg) and RHB (rail network in canton Grisons).

2.2 Vulnerability

General scenarios

Switzerland has elaborated several researches on vulnerability of climate change impacts (see for example OcCC 2008, PLANAT 2009, Swiss Confederation 2010). A major focus is on natural hazards and extreme weather events. The occurrence numbers of floods, debris flows and landslides is most relevant, but did not show any significant tendency over the past decades. Flooding was the most frequent type of extreme event occurring since 1972 (60–95% of all loss events). However, despite comparable occurrence rates, damages due to extreme weather events have been growing in recent years, as Figure 1 shows. It is highly likely that climate change contributes to increased intensity and wider geographical distribution of meteorological extreme events. However, the contribution of climate change to extreme weather events is not sufficiently understood.

The most important impacts expected are the following (source Swiss confederation 2010):

- **Temperature extremes**: Temperature extremes show the most distinct trend. With a rise in mean summer temperatures, higher temperatures will also occur during hot spells. Extremely hot summers will occur more frequently if, additionally, year-to-year variability of summer temperatures increases, as various climate simulations suggest. By contrast, the frequency of cold spells and the number of frost days have already declined and will continue to decline. This effect is expected to be particularly pronounced in areas where the snow cover diminishes as a result of warming. It is expected that the size and frequency of winter and spring floods is likely to increase. In contrast, summer floods on the central plateau are expected to become smaller. To the south of the Alps, floods tend to become more severe in all seasons except for summer. Due to rising precipitation intensities, landslides are expected to become more frequent in winter and spring.
- **Drought**: In agreement with the decrease in average summer rainfall and the number of rainy days, extremely dry periods might last longer and occur more frequently.
- **Wind storms**: Scenarios for storms are very uncertain. Some models indicate that the frequency of storms is likely to decrease in central Europe. At the same time, the intensity of storms will probably increase.

Damage caused by floods, landslides and debris flows since 1972

Figure 1: Development of total annual loss (red bars, scale to the left) and aggregate loss (green line, scale to the right) of floods, landslides and debris flows in Switzerland. Over a period of 36 years (1972-2008), average annual loss is on the rise. (Source Swiss confederation 2010)

Vulnerability of infrastructures

The impact of climate change on the functioning of public utilities, in particular water supply and sewage disposal, and the vulnerability of transport infrastructures have been assessed on the basis of recent extreme events. Generally, transport infrastructures seem to profit more from milder winters than they suffer from higher maximum temperatures. However, they are vulnerable to floods, mudflows and landslides.

2.3 Adaptation policy

National level

Switzerland is still working at refining its vulnerability assessments and adaptation options. Several areas are reasonably well covered, with a good understanding of vulnerability and potential adaptive measures. A major actor is the national platform on natural hazards (PLANAT, managed by the Swiss Federal office of environment). However, some of the measures to adapt to climate change are in conflict with other objectives. For example, issues arise in the area of water management with regard to biodiversity and protection of natural landscapes. Finding the optimal solution to fulfill the interdependent requirements represents a major challenge in adaptation (Swiss confederation 2010).

For the time being, the Federal Office of Environment is elaborating an adaptation strategy. The most important principles are:

- Coordination with mitigation strategies, aiming at reaching national reduction targets of greenhouse gases,
- Improvement of assessment and planning tools, especially observation and early detection systems,
- Integrated risk management considering the three pillars ‘prevention’, ‘’handling of damages’ and ‘regeneration’,
- Sectoral approach defining measures for specific sectors (e.g. water management, biodiversity, forestry, agriculture, human health, tourism, spatial planning, energy, infrastructure, considering as well transport infrastructure).
- Collaboration with stakeholders and efficient labour share based on subsidiarity principle: Cantons, insurance companies, specific organisations with regard to climate change and natural hazards, infrastructure operators etc.

Cantonal level

Several cantons (especially in the alpine area) have elaborated their own strategy. The canton Bern for example has assessed the relevance of extreme effects (flood, slides etc.) in different sectors and regions. Based on a first assessment, transport infrastructure is seen – from the viewpoint of the cantonal administration – as a priority sector. A first cost benefit analysis has shown that there are some no-regret measures such as spatial planning, exposure avoiding and warning and early detection systems. Also the canton of Uri with its specific exposure of national transport infrastructure and flood risks (Gotthard axis) has elaborated an own strategy.

Table 1: Selected examples of weather extremes in Switzerland

OVERVIEW OF SELECTED WETHER EXTREMES IN SWITZERLAND				
Date	**Event**	**Damages**	**Impact on transport infrastructure**	**Insights**
24th – 25th August 1987 Storm disaster in the Alps	Heavy rainfall in many regions caused one of the worst storm disasters in the Alps.	Damage amounted to CHF 800 million (Uri 500 million, Valais 115 million, Ticino 120 million).	The track of Gotthard railway was washed away and the route was disconnected for 18 days. The motorway suffered a similar disconnection.	Problem perception of vulnerability of the alpine areas and transport infrastructure.
February 1999 Avalanche Winter	Intensive precipitation caused around 1'200 "catastrophic avalanches" in the northern regions of the Swiss Alps.	17 killed people and material damage over CHF 600 million.	Because of closed roads some communities remained cut off for days.	Improvement of protecting infrastructure and early detection systems.
12 May 1999 Flooding throughout Switzerland	Extremely heavy precipitation caused extensive flood damage, particularly long duration and large spatial extent.	Damage of approximately CHF 580 million.	Hindrance of transport infrastructure.	Improvements of risk analysis, protection infrastructures and early detection systems.
26th December 1999 Storm "Lothar"	The storm "Lothar" raged all over Switzerland.	The damage on buildings alone amounted CHF 500 million.	Due to fallen trees some roads and rail links were closed.	Improvements of warning systems, subsidies for less vulnerable mixed forests.
14th October 2000 Storm in Valais	Several debris flows happened, most severe in Gondo, where a protection wall was destroyed	16 people killed. One third of Gondo was destroyed. In Stalden-Neubruegg four houses were washed away.	Mudflows affected transport infrastructures.	Spatial planning as prevention measure; management systems for road closures, level of protection measures

OVERVIEW OF SELECTED WETHER EXTREMES IN SWITZERLAND				
Date	**Event**	**Damages**	**Impact on transport infrastructure**	**Insights**
May-October 2003 Heat Wave Summer 2003	In Switzerland, the temperatures recorded for the meteorological summer were 4-5.5°C higher than the long-term mean value for the period 1864-2003.	1,000 additional fatalities, heavy damages in agriculture and biosphere, large number of rockfall events due to the thawing of the permafrost soils.	The heat stressed the road surface and rail tracks	Strong arise in problem perception
21/22 August 2005 Floods in Switzerland	Torrential rain fell across wide areas on the northern slopes of the Alps. The main damage processes were flooding, erosion, overbank sedimentation, landslides and debris flows.	The flood claimed the lives of six people and caused material damage of CHF 3 billion. Approximately 900 communes were affected.	Closed roads cut off some communities for days.	The flood induced new flood protection programmes at cantonal and national level.
31 May 2006 Rock fall in Gurtnellen	A rockfall event affected the A2 Gotthard transalpine motorway and the cantonal road.	Two trucks were hit and one car, both of whose passengers were killed.	The further risk of rock fall in the location was averted by blasting. Road closure for several days.	Direct protection measures, improvement of processes between national and cantonal level
08/09 August 2007 Flooding in Switzerland	The persistent rain of 8 and 9 August 2007 gave rise to critical situations and flood damage in many cantons of northern Switzerland.	The damage on buildings alone surmounted CHF 150 million.	Closure of roads due to flooding and mudflows.	Construction of new flood protection infrastructures in some areas
10/11 October 2011 Flooding in Bernese Oberland, central Switzerland and Valais	Snowfalls followed by a temperature increase and persistent rain caused floods and mudflows	The damage sum is not yet known.	Mudflows damaged road infrastructures. At some places a closing of the road was necessary.	The analysis of the event is still in progress.

Source: PLANAT

2.4 General assessment

OcCC (2008) has elaborated the basic risk exposures and vulnerability issues for the transport sector. The following passages are directly cited from the report and are summarizing these findings: In general the transport networks (road, rail) are primarily at risk from extreme events. With preventive measures for new hazards and with adaptations in road making, disturbances and risks to road traffic will be kept largely constant.

2.4.1 Rail network

Line stability and security

Railway lines are regularly exposed to natural hazards, primarily due to extreme weather events such as long rain periods or strong snowfall. Thus, numerous railway stations were flooded in connection with the floods of August 2005. Heavy precipitation may not only result in floods but can also cause landslides and mudflows. Build up of water and waterlogging within the vicinity of the tracks, as well as bank erosion and mudflows from drainage channels, are further possible outcomes.

The threat to line stability will increase with the predicted increase in winter precipitation, which will increasingly fall as rain at lower elevations, and with the expected increase in heavy winter precipitation. In particular, the stability of embankments and slopes will be increasingly called into question. Heavy precipitation may also cause the undermining of lines. Apart from railway lines in the vicinity of slopes, the possibility that railway stretches built on artificially cut-out slopes in the midlands and the foothills of the Alps will slide away should not be underestimated. There, heavy precipitation may also lead to water logging, instability and hence to landslides. Above the snow line, larger winter precipitation amounts may result in an increase in the danger of avalanches or blocking of infrastructure (switch blocking, restricted visibility, snow piles on the lines). With regard to avalanches, the railways have a land register of the relevant avalanche tracks. Already today, critical areas are secured with protective galleries or are closely monitored during heavy snowfall. The safeguarding of further avalanche tracks could be realised relatively straightforwardly in the event that such a need arises.

The consequences of the mean temperature increase and the presumably more frequently occurring heat waves on line stability and security will primarily be of an indirect nature. The effects may result from the melting permafrost as well as possibly from the changes in thaw and frost processes. The heat-wave summer of 2003 showed the consequences of high temperatures on slope stability. In the course of that hot summer, a great number of rock falls and rock avalanches were observed in the entire alpine region, in particular at higher elevations and on north facing slopes. This extraordinary rock fall frequency can be interpreted as a sign that the destabilisation due to extreme heat occurs as an almost immediate reaction. As areas with permafrost are very often located outside of settlement and infrastructure areas, the future risk is also limited. In critical areas, risks and damages can be minimised by the expansion of protective measures (e.g. safety nets, protective walls, monitoring). At lower elevations, which will be exposed to positive temperatures more frequently due to the temperature increase, a reduction in the number of rockfalls is imaginable.

Engineering works, such as bridges, tunnels and passages, are not expected to be affected by constructional problems in connection with global warming. The magnitude of the temperature increase will normally be able to be absorbed by the works without consequence. Storms are not expected to cause structural problems either. An increase in potholes and flow problems near bridges and passages as a result of larger floodwater amounts is possible.

Contact wires and tracks

Based on the expected increase in winter storms, an increase in falling trees is to be anticipated. When trees fall on contact wires or tracks, this normally causes delays and the interruption of railway services, as well as damage to infrastructure. About one third of the 300-km route network of the SBB is forested on one or two sides. The SBB aims at a defined forest profile along all forested route sections. In the vicinity of the tracks, small bushes and scrubs are preferred, and with increasing distance more highly growing trees, so that a clear profile is generated. Thus, falling trees can rarely cause damage anymore. This procedure is beneficial with regard to availability and safety in case of storms but less favourable with regard to the shading of train embankments in the event of heat waves (microclimate of embankments).

The increase in summer temperatures affects the railway system. High temperatures lasting for days can result in lateral displacement of the tracks. This happens because expansion of the tracks due to the heat is blocked by the seamless welding. The resulting compressive forces can lead to lateral displacement of the tracks. When the tracks are laid, measures are taken in order to reduce these compressive forces and to increase the lateral resistance of the tracks. During the heat-wave summer of 2003, lateral displacements occurred about 50% more frequently than is the case during an average summer. In order to avoid the risk of derailing, trains need to reduce speed in the event of lateral displacement or, in extreme cases, are no longer able to ride the tracks concerned. Since heat waves will have become considerably more likely by the year 2050, railway companies need to prevent more frequent lateral displacements. Construction methods can be adapted with some extra costs, so that the tracks withstand higher temperatures without damage. Thus, the requirements for Ticino are already more strict today. The tracks are exposed to higher temperatures during laying in order to prevent any later deformation.

Summer heat-storms also present a potential risk to contact wires because lightning strikes can lead to operational disturbances and damage to contact wire systems. Since there have been no forecasts with regard to summer storms up to now, it is hard to es-timate whether this risk will change.

2.4.2 Road network

Fundamentally, it is expected that the extent of the effects on roads will be smaller because the road network is generally less sensitive as far as construction is concerned.

Other factors, such as a further increase in the maximum weight of lorries or a distinct increase in the number of heavy vehicles, would in all likelihood have more severe effects than the expected climate change. Furthermore, the very dense road network has the advantage of being more flexible in comparison to the railway system; when a section of road is at risk or not passable anymore, alternative routes often exist. Exceptions are transalpine axis (e.g. Gotthard, San Bernardino) and access road to alpine valleys. Road making will adapt to changed conditions where necessary in relation to materials used and the construction of roadways. The most important climatic impacts on the road network will be floods and slope instabilities. In addition, avalanches, winter storms and hail may have adverse effects on road traffic.

Heavy precipitation/Floods

Floods can affect sections of roads in a similar way to railway lines. If rivers and lakes burst their banks, excessive volumes of water may cause undercutting or, in flatter areas, floods. In mountain areas, heavy precipitation often results in landslides and mudflows. On the other hand, low-snow winters may have a positive effect on road traffic, with a decrease in accident risk and costs for road maintenance.

Slope instabilities

Just as with rail traffic, there is a risk of mudflows and rock falls for road traffic, as the case of Gurtnellen has shown. Roads at higher elevations and in exposed positions are particularly at risk. Rockfalls are not necessarily attributable to climate change but can have various causes. Trigger factors include: rock weathering, larger water masses that act as a lubricant, frost/ thaw effects that lead to the loosening of the rock formation, and the melting of permafrost due to increasing temperatures (see Line stability and security). A combination of different factors is also possible. Already today, the vulnerability of the traffic system to disturbances is great due to the large volume of traffic and people's expectation of almost unlimited mobility.

Avalanches

Just like the railway system, the road network may be affected by avalanches or avalanche risk. In conjunction with climate change, the risk will possibly increase at higher elevations, where larger precipitation amounts may fall as snow in winter.

Winter storms

Due to the expected increase in winter storms, falling trees will be more common. If these trees fall on the road, this puts drivers directly at risk and can lead to interruptions in road traffic. However, the risk is currently small and should not increase substantially in the future.

2.5 Problem perception

The problem perception in Switzerland has risen considerably in the past years. Especially the recent flooding events have led to the insight that an integrated risk assessment is crucial in order to manage future risk. It is expected that the occurrence and the damage potential will increase in the future, although a direct causal link to the effects of climate change is not always made. This is especially true for events like precipitation and flood risks and avalanches which have always been an ongoing risk in alpine regions.

In the transport sector flooding, mudflows, rock falls and avalanches are the most important risks to tackle with an integrated risk approach. Landslides and rock falls due to the rise of the permafrost level are strongly linked to the effects of climate change. The prevention strategies are based on the likelihood of events with different occurrence and damage levels (occurrence every 10, 30, 100, 300 years). The vulnerability is based on the history of incidents and statistic models. This leads to an ongoing adaption process and a so called learning curve. The number of studies to evaluate the risk exposure of transport infrastructure (so called risk maps) has increased considerably (see example in the Annex). At the same time the importance of spatial planning has increased since many damages (and especially the increase of the financial damage) is strongly connected with the fact that the exposure of the population has risen due to spatial planning decisions (especially at communal level), which have not taken the risk exposure into consideration.

The change of task share and responsibilities in the road sector (responsibility of national level for motorways) has also increased the problem perception at national level. The rock fall at Gurtnellen 2006 has however shown that early detection and event management procedures still have room for improvement, since transport management and communication procedures for important infrastructures needs coordination between several actors and levels.

3 Selected adaptation strategies

The selection focuses on road transport based on interviews with national and cantonal responsible persons.

3.1 Leagal, strategic and institutional framework

Each infrastructure owner enacts his own law, but the content is in all cases similar. The operator is obligated to ensure a save and steady operation of the infrastructure (e.g. Art 49 National Road Law). What ‘ensure a save and steady operation’ means is written down in the respective directives. Construction standards are released by professional associations as the Swiss Society of Engineers and Architects (SIA) or the Swiss Society of Road and Transport Professionals (VSS). Concerning weather extremes guidelines about natural hazards and construction standards about the water effluent are of big importance.

The guidelines about natural hazards vary with respect to standardization. The risk concept concerning natural hazards for national roads contains a full analysis of all natural hazards along the roads. Based on this analysis a uniform security level should be provided for all road segments. If the security level is not ensured protection measures are assessed at the basis of cost-benefit calculations. At the moment the analysis of the exposure to natural hazards is still in progress. The canton Berne has defined protection goals concerning human and material damage and for road infrastructures availability aims are also of big importance. The aims vary as a function of the importance of the infrastructure (Kanton Bern 2010). A similar approach is applied by the Canton Grison. An exemplary aims is the following: If cantonal main roads are due to an event which is more frequent than once in a decade disrupted for short term and the reparation can be realized within days, measures have to be assessed. If an event which is more frequent than once in 30 years has the same impact, the protection has to be enhanced. For less important roads security standards are lower (Amt für Wald und Naturgefahren Graubünden). But the standardization is not in all cantons the same. E.g. the canton Uri has no explicit risk concept for all natural hazards. Measures are planned on the basis of experience, risk maps, and local requirements. Following the flood of 2005 protection standards for floods were set and a protection programme was launched. Basically settlement areas should be protected against a 100year event, industry areas against a 300-year event (Kanton Uri 2009). In general the standardization of the risk concept is the higher the more affected the owner was in the past.

3.2 Prevention measures

The prevention strategies concentrate on damage potential detected and consider 4 stages:

analysis of risks,

1. and use regulations,
2. organisational measures and
3. construction measures.

Analysis of risks

In Switzerland the cantons are obligated to elaborate risk maps of all settlement areas. For road infrastructures outside of settlement areas risk indication maps (less detailed risk maps) exist (see example in the Annex). Risk maps show the endangered areas by type and level of risk. There are five risk zones: high, medium, low, rest risk and no risk zones. The obligation of the cantons to elaborate risk maps was a consequence of the floods in the year 1987.

Beside the risk maps an ongoing analysis of potential new dangers is necessary. The processes to discover new danger spots is not standardized but based on the observations of relevant actors (e.g. foresters). If necessary specific studies on new danger potentials and hot spots will be carried out. Because of temperature rise new risks of rock falls due to the thawing of the permafrost soils and new mudflow risks due to the decline of glacier are of major importance.

Land use regulations

Based on the risk maps in highly risk exposure areas construction bans or special construction requirements are imposed. With respect to transport infrastructures risk maps are considered when roads or railways are built. E.g. after a road in the Bernese Oberland was destroyed after the flood of the year 2005, the road was reconstructed at the other side of the valley, where the risk exposer is somewhat lower.

Organisational measures

Organisational measures aim to reduce the impact of weather extremes. Of major importance are warning and early detection systems. An insight of the flood of the year 2005 was that lot information is prevailed, but they are not tied together. Since then there are continuous efforts to bring together all relevant information about weather extremes and natural hazards. At the GIN-website (Gemeinsame Informationsplattform

Naturgefahren: www.gin-info.ch) provided by the Swiss Federation, as much information as possible about the actual danger caused by natural hazards is tied together (avalanches bulletin, perception and storm forecasts, etc.). To provide this information, a network of recording points is necessary.

As a consequence of the measuring data sometimes avalanches or rocks in movement are blasted as a prevention measure. When a road is at risk because of potential rock falls or avalanches the surveyor of highways decides, if the road should be closed and when it can be reopened.

Another organizational approach are local natural hazard consultants. In some alpine areas communities provide a local natural hazard consultant (e.g. foresters, citizen educated in natural hazard subjects). The mandate this consultant is to steadily observe the environment and adapt the prevailed information to the local situation. If a danger arises, he has to warn the respective community authorities.

Another aspect of organizational measures is the elaboration of intervention maps (see example in the Annex). They show, which areas should be protected by which measures in the case of an event. If the respective event is a flood, the intervention map shows e.g. where sandbags should be stockpiled or in which areas humans should be evacuated.

Construction measures

If land use regulations and organizational measures obtain not enough safety, construction measures as avalanche barriers, rock fall nets or water regulation systems are taken. Since some construction measures are ageing, it is important to observe the state of the constructions regularly and maintain these infrastructures.

Changes in prevention level

The level of prevention is directly linked with the level of risk potential. The expert interviews however showed a mixed picture about changes of such levels after events. In the canton Grison and Uri due to budget scarcity the protection level is increased mainly after events and at the place of the event. E.g. after a rock fall on the A2 in the canton Uri, a protecting wall was built up. After a rock fall at the railway net in the canton Grisons, the railway was reconstructed somewhat more to the valley side and a collecting pond for rocks was built between the hillside and the railway. Sometimes the protection level is also increased due to new danger spots. E.g. in Grisons a hillside in movement is observed permanently. In Bern the prevention measures have increased considerably in particular with respect to floods. Bern was three times affected by floods within ten years (1999, 2005 and 2007). Thus the willingness to pay for prevention measures has increased considerably and sometimes it was even possible to increase the prevention level at places where no event in the given magnitude had taken place.

3.3 Processes in case of damage

In general the owner is responsible for the security and reparation of transport infrastructures according to the principle of subsidiarity. There is often a close collaboration of different stakeholders at different political levels.

With regard to case management, basically five phases are to be considered.

Table 2: Phases of event management

CASE MANAGEMENT PROCESSES		
Phases	**What**	**Who**
1. During the event	Decision on information, protection, alternatives, instant measures	Infrastructure owner, fire brigade
2. Cleaning up	Rescue of people, recovering of infrastructure, instant reparation (e.g. evacuation, instant road opening)	Infrastructure owner, fire brigade, police, civil defense (military service)
3. Reparation	Repair measures, provisional/temporary and long term, realignment, rebuild. Alternative transport (such as bus transport)	Infrastructure owner, construction industry
4. Evaluation	Registration of information on damages, analysis and conclusions for future measures and risk and case management.	Infrastructure owner, together with risk experts
5. Adjustment of prevention	Evaluation of new measures according to cost benefit (case specific, general, depending on the damage level and the evaluation)	Infrastructure owner, together with risk experts and politics

Example: Destruction of a road in the Bernese Oberland

The phases are in reality interlocked. The following example shows exemplary the interaction of the phases.

In the Bernese Oberland, due to the flood 2005, an important road connection was destroyed fully over a distance of 3 km. As a consequence some communities were cut off. Thus it was important to provide access in due time. Within three to four days a provisory road was built. Since road construction in wintertime is difficult in the Alps and wintertime started three month after the event, the time for the reconstruction of the road was scarce. At the same time the risk exposure of the destroyed road was high and should be reduced. The challenge was to rebuild the road within three months and to reduce its risk exposure to floods significantly. Thanks to a strict project management with a well interaction of all stakeholders (natural hazard experts, construction professionals, canton etc.) it was possible to reopen the new road before winter time. The road was built somewhat more away from the river. The mod of the flood was used to raise the level of the road. The reconstruction of the road amounted to CHF 20 million.

Adjustment of processes

According to the interviewed experts the processes in case of damage have not changed significantly during the past years. But major changes were introduced with respect to documentation standards. In the 90thies the registry of natural hazard events was launched with the elaboration of risk maps. In the last ten years some cantons developed coherent risk management strategies (e.g. the ‘risk strategy natural hazards’ of the canton Bern or the ‘risk concept natural hazards national roads).

4 Conclusions

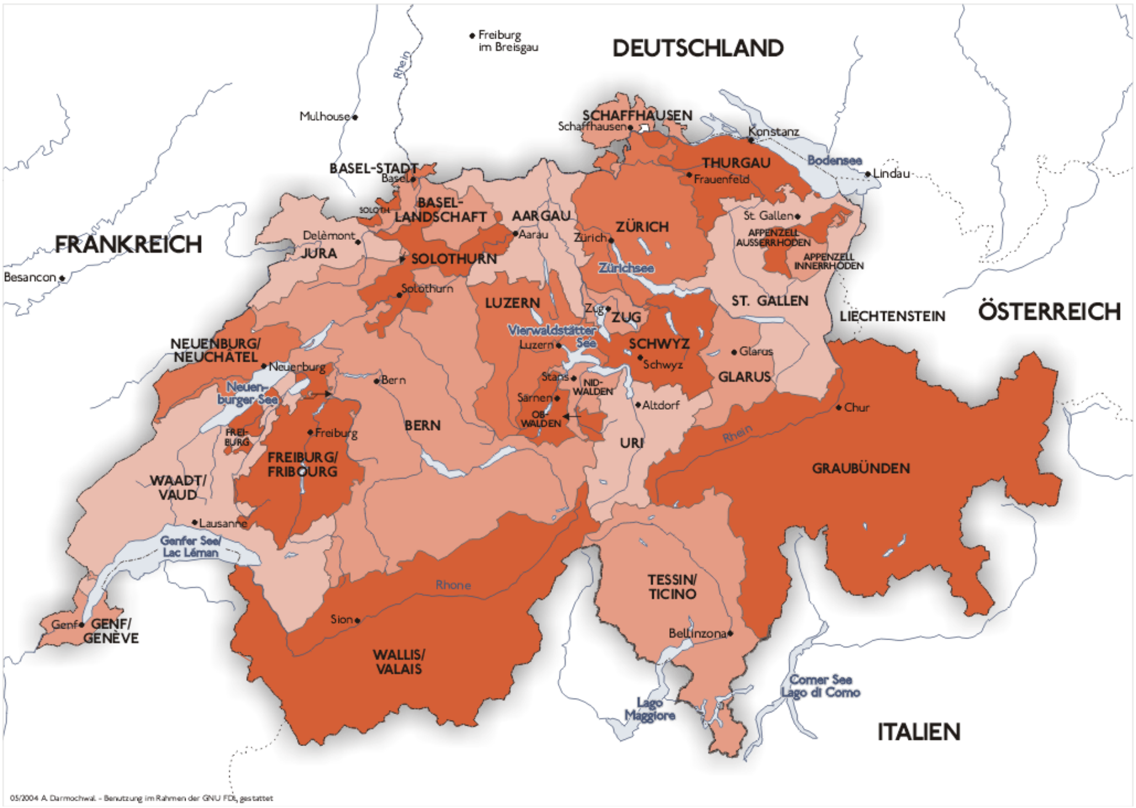
The statements on the Swiss situation and practice can be concluded as follows:

- There is an increasing problem perception of extreme weather events which also harm the transport sector, specifically floods, mudflows, rock falls and avalanches. Although the occurrence of events has remained stable, the damage potential (due to dense population and dense transport networks) has increased.
- The alpine transport network in Switzerland is getting more vulnerable especially in the summer time and during precipitation periods. The rise of the permafrost zone is strongly linked to climate change issues. Other natural hazards like flood incidents are not seen as directly causally linked to climate change.
- Independent to these risks, the standards of prevention and case management in the transport sector have always been rather high in alpine zones. There are general legal claims and technical norms for the infrastructure. Thus the institutions are not con-fronted with new type of events. The new challenge is however the implementation of integrated risk management approaches with different sectors and actors. In other words: The challenges for water management, spatial planning or the insurance sector and the financing of natural hazard related measures are considerably higher than in the transport sector. This is also true for the role of the insurance sector. Whereas the insurances have a strong role in private risk prevention (considering as well re-insurance), the transport sector is not directly involved.
- In general the vulnerability of the railways is somewhat higher than in the road sector. Nevertheless the situation for road is more complex due to the size of network and the different institutional levels. The recent change of tasks (shift of responsibilities for motorways from the cantonal to the national level) has made visible specific coordination issues. Initially there were different levels of standardisation (esp. at cantonal level). Due to institutional changes, risk management of motorways and rods in general has been improved and harmonized, based on coordinated standards. It has to be considered, that the dense road and rail network in Switzerland facilitates comodality in order to solve possible access problems during a closure of one transport mode.
- The most important adaptation measures are improved planning and early detection tools, specific risk maps and classification and detailed incident management plans in case of emergency. This risk assessment tools have a high professional standard.
- At the same time the prevention measures for transport infrastructure have been improved at selected risky spots (superstructure, protection walls etc.).

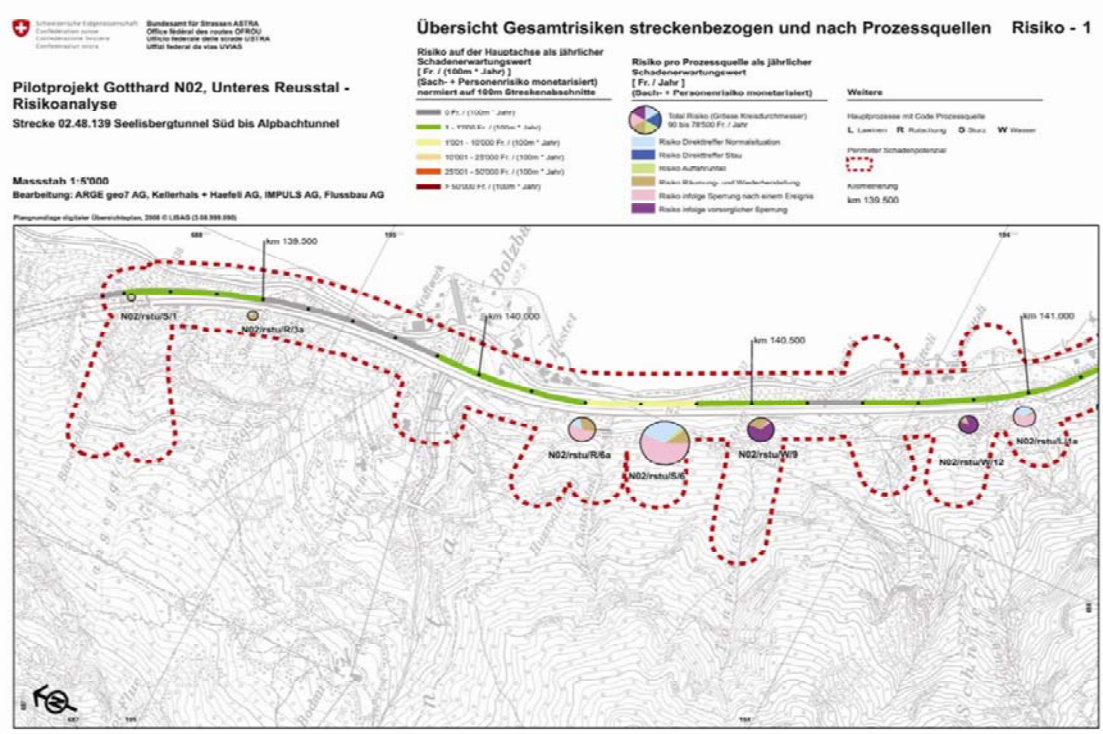
- The need for (additional) action in the transport sector is not that high than in other infrastructure sectors such as water and energy supply, since there was always high priority to secure infrastructure access. The need for coordination between different protection programmes however is high, also including improved spatial planning procedures. It has to be considered for instance that some alpine transport infrastructures are also integrated in flood risk management, for instance as temporary drainage systems.
- All in all there is still a learning process within the elaboration and implementation of the Swiss adaptation strategy with regard to climate change issues. Future incidents and re-examination processes of the risks will guide the learning path and lead to improved measures and processes.

5 Annex

Map of Swiss cantons

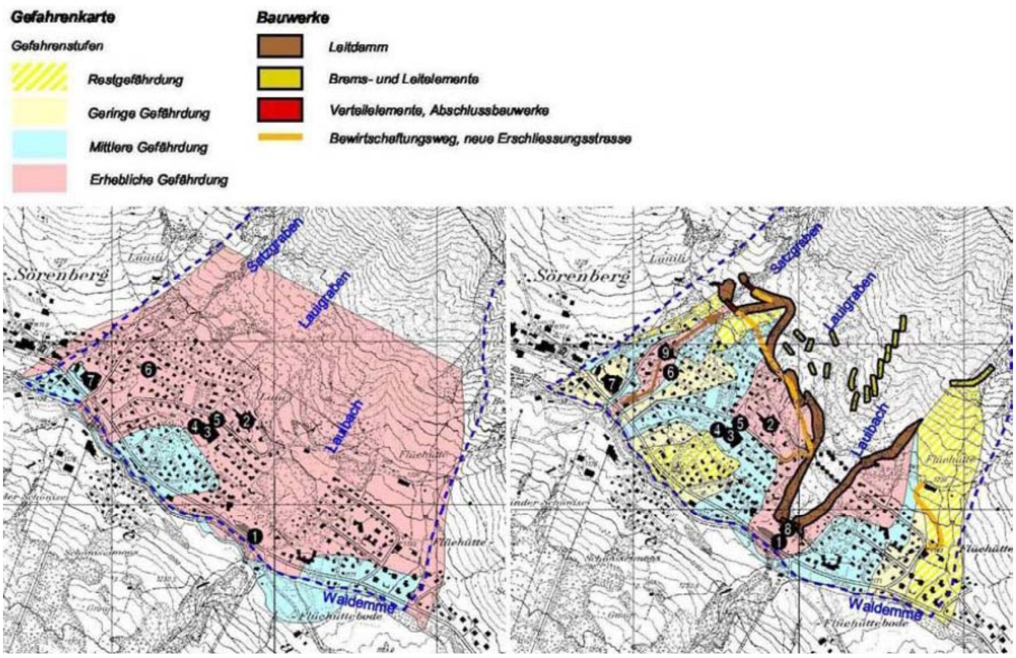


Risk map example (risk analysis national highways Gotthard corridor)



Source: Bundesamt für Straßen 2009

Risk and intervention map example



Source PLANAT 2009

Example Sörenberg (canton Bern): Risk map of natural hazards (left, without measures) and map with measures and reduced risk (right)

6 Interviewees and literature

Interviewees

Phillippe Arnold, Federal Roads Office

Markus Wyss, Public work service canton Bern

Stefan Flury, Public work service canton Uri

Christian Wilhelm, cantonal office for forest and natural hazards Grison

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http://www.clisp.eu

http://www.naturgefahren.sites.be.ch

http://www.wald-naturgefahren.gr.ch

http://www.gin-info.ch/