Risk management of gravitational driven processes in Switzerland

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ABSTRACT

Over the past 30 years, dealing with natural hazards in Switzerland has changed from being hazard-oriented to using a risk-oriented approach. After a series of catastrophic events, the National Strategy Natural Hazards was published in 2004 and updated in 2018. Following this strategy, various methods and tools were developed. We present some of these developments and give an example of risk-oriented planning for structural avalanche protection measures using the tool EconoMe. The results of the quantitative risk assessment and the benefit-cost-analysis indicate that the planned measures can be recommended for subsidisation.

1. INTRODUCTION

Over the past 30 years, several catastrophic natural hazard events and the expected increase in number and frequency of such events due to climate change have changed the natural hazard policy in Switzerland. With the floods in 1987, causing damage of 1.5 billion CHF (inflation-adjusted to 2018) in several regions of the Swiss Alps (BWG and LHG, 1991), it became apparent to authorities and politicians that investment in protection measures against natural hazards had to be adjusted according to the meaning and the value of the objects at risk. Equally, it became clear that structural measures alone where not enough. Only in combination with other types of mitigation measures, including land use planning, biological (e.g. protection forest) and organisational measures, could the impact of damaging events be reduced to an acceptable level. Since the early 1990s, dealing with natural hazards in Switzerland has developed from a strategy of hazard defence into a risk-oriented approach.

Here, we provide an overview of recent developments due to this strategy change. We concentrate on achievements in Switzerland, but the general trend of setting the focus on risk reduction instead of hazard defence can be observed throughout several Alpine countries.

2. NATIONAL STRATEGY NATURAL HAZARDS AND FOLLOW-UP PROJECTS

The aftermath of the avalanche winter of January/February 1999, the flood in May 1999 and the winter storm Lothar/Martin in December 1999 confirmed the necessity of a paradigm shift of natural hazard policy. As a consequence of these events and in response to an initiative in Swiss parliament, the National Platform for Natural Hazards PLANAT elaborated the Strategy Natural Hazards Switzerland (PLANAT 2005) and proposed the risk concept as a guiding model for dealing with natural hazards in Switzerland. The strategy aims to achieve a comparable security level for all natural hazards throughout Switzerland by measures that are economically viable, environmentally friendly and socially responsible. Following this strategy, two action plans with several projects were started implemented between 2005 and 2011 to close gaps in natural hazard risk management. In 2018, the PLANAT strategy was updated and supplemented with the concept of resilience (PLANAT, 2018). In the following, some key results are presented.

A guideline entitled "Risk Concept for Natural Hazards" (RIKO) is one result of the PLANAT action plans. The guideline's first part explains the general risk concept for natural hazards while in the second part, examples show how risk-based planning of protection measures against snow avalanches, debris flows, floods, rock fall, landslides but also non-gravitational processes such as hail, storms and earthquakes can work in practice (Bründl, 2009).

The guideline "Effectiveness of Protection Measures" (PROTECT) proposes criteria to determine whether protection measures may be taken into account for hazard mapping as well as a step-by-step procedure of how to do so. This guideline is organised in the same manner as the guideline RIKO: a general description in the first part and practical examples for different processes in the second (Romang, 2008). Three steps are suggested by which mitigation measures have to be assessed: (1) A general assessment indicates whether a mitigation measure may be relevant for a hazard assessment; (2) the reliability of a mitigation measures is assessed according to its structural safety, serviceability and durability; (3) the effectiveness of a mitigation measure is assessed according to its reliability. These steps enable practitioners to then give a recommendation on whether the evaluated measure may be considered for the reduction of hazard zones. A practical example of an assessment using PROTECT is given by Margreth (2018) and treats the hazard zones of the Vallascia avalanche in Ticino, Switzerland.

One of the main objectives of the PLANAT strategy is to achieve a comparable security level throughout Switzerland. The report "Security Levels for Natural Hazards" (PLANAT, 2014; 2015) provides a uniform definition of the objectives and suggests security levels for objects at risk (Fig. 1).

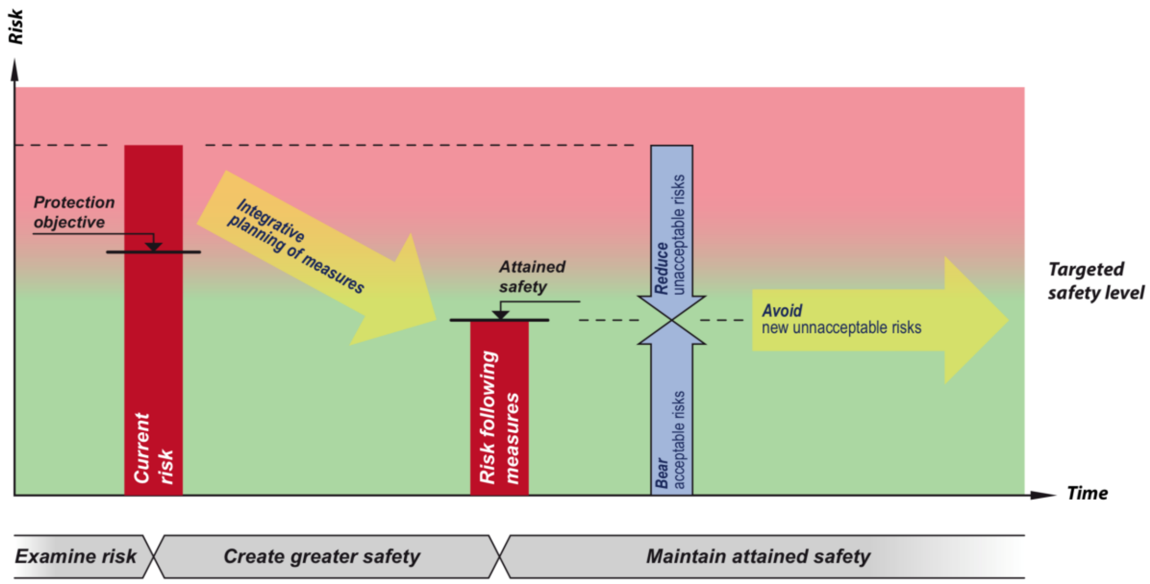

Fig. 1 Procedure to achieve the desired level of security (PLANAT, 2014).

Three categories of objects have to be protected: people, major material assets and the environment. The protection of people has the highest priority. The suggested security level for people states that the general risk of death to an individual should not be significantly increased by natural hazards. Thus, the individual risk of a person to die due to a natural hazard event should be lower than the lowest average probability of death for any age group of Swiss society. Major material assets such as buildings have to be resistant and must provide a high level of protection to the people within and their belongings. The residual risk should be acceptable by risk carriers such as insurances. The risk to infrastructure, to objects of considerable economic importance and to essential natural resources should be so low that the existence of present and future generations is not endangered. Cultural goods must be protected to permanently conserve their cultural value. Meanwhile, no explicit security level is defined for the environment.

3. EVALUATION OF THE EFFECTIVENESS AND THE ECONOMIC EFFICIENCY OF PROTECTION MEASURES

Increasing challenges to maintain and even improve the security level under the constraints of limited financial resources have prompted the Federal Office for the Environment in Switzerland to define criteria for prioritising mitigation projects. Based on the risk concept for natural hazards RIKO, the tool EconoMe was developed and introduced in 2008 to assist authorities and practitioners in the evaluation of the effectiveness and efficiency of mitigation projects (Bründl et al., 2009; 2016). Since 2008, EconoMe has been continuously developed. Operational users of EconoMe include cantonal authorities and private engineering companies. EconoMe guides the user step-by-step through a quantitative risk assessment to calculate the individual risk of a person as well as the collective risks to people, buildings, infrastructure, agricultural areas, forests and parks. The risk reduction induced by mitigation measures is then put into relation with the cost of said measures. Working steps are (1) gathering all documents and describing the area under investigation, (2) hazard assessment, (3) definition of measures, (4) assessment of the damage potential, (5) analysis of consequences (calculation of damage and risk), (6) display of risks and costs and (7) documentation of the assessment (Bründl et al., 2016). The order of the working steps is interchangeable for a user during assessment editing. Business interruption and indirect costs according to definitions provided by Meyer et al. (2013) are not taken into account.

For a first, rough assessment of the potential benefits of a mitigation measure, EconoMe-Light was developed and introduced in 2015 as an online and offline tool. EconoMe-Light allows for a simplified risk assessment and evaluation of the economic efficiency of potential mitigation measures. Practitioners and authorities use EconoMe-Light to evaluate whether the planning process of the mitigation measure should be continued. However, an EconoMe-Light assessment is insufficient grounds with which to request a subsidy from the Federal Government. This requires a full assessment with EconoMe.

In EconoMe, risk to people is calculated as individual risk, expressed as probability of death per year for an individual, and as collective risk, denoted as the number of fatalities per year. To calculate a total collective risk, the number of fatalities per year and the damage to material assets, given in Swiss Francs, must be in the same unit. EconoMe uses the value of statistical life (VSL) to monetise a prevented death with 5 million CHF (4.4 million Euro as of January 2018; Rheinberger, 2011).

Protection projects, for which an application for a subsidy is submitted to the Federal Office for the Environment FOEN, are examined according to several criteria. First, they are assessed with EconoMe concerning their effectiveness (risk reduction) and economic viability. Projects with objects in which the individual risk of death is greater than 1×10^{-5} per year have the highest priority. A project's economic efficiency, calculated as a benefit-cost-ratio in EconoMe, should be larger than one to be considered for a subsidy; for highest priority, a ratio larger than two is required. This means that the quantified risk reduction by mitigation measures must be twice as high as the cost of the measures. A further subsidy criterion is the provision for ecological aspects. Projects can also earn credit points if they are planned in a participatory process (FOEN, 2018).

4. EXAMPLE FOR A RISK-BASED ASSESSMENT OF MITIGATION MEASURES

We show a typical evaluation of the effectiveness and the economic efficiency of an avalanche defence structure using EconoMe. The example is a real case example but data were slightly adapted and location names are not provided due to data protection reasons.

4.1 Situation

The area under investigation is a community in the Swiss Alps endangered by avalanches. Several events in the past hit buildings and infrastructure and caused damage and fatalities. In response to these events, avalanche defence structures were put in place. However, due to protection deficits, additional measures were recently planned. Their effectiveness and economic efficiency were assessed in order to apply for a subsidy from the Federal Government. We present the main steps of the evaluation using EconoMe.

4.2 Hazard Assessment

The risk assessment is based on a 30-, a 100- and a 300-yearly scenario. For each of these scenarios, intensity maps for the situation without (Fig. 2) and with additional measures are calculated by a numerical avalanche model and cross-checked by the expert in charge.

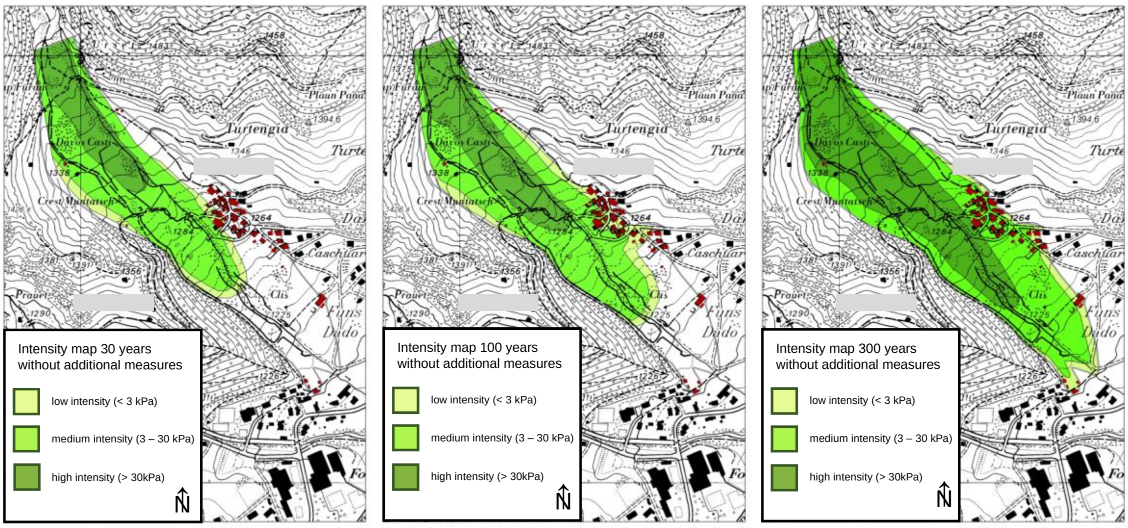

Fig. 2 30-, 100- and 300-yearly scenarios without additional measures.

4.3 Damage Potential

In EconoMe, risk can be calculated either using user-adapted values, which must be documented, or using default values, e.g. for the monetary value of objects (restoration costs) and the average number of people in buildings (2.24 people/apartment or single-family house). Risk to people is monetised by a VSL of 5 million CHF. In this example, various types of objects are endangered. In total, a damage potential of 19 million CHF is exposed (Table 1).

Table 1 Damage potential within the area of investigation.

Objects at risk	**Damage potential**
Number of people	69.77
People monetised (VSL 5 million CHF/averted fatality)	348,850,000 CHF
Buildings	14,930,800 CHF
Cantonal and communal roads	2,154,600 CHF
Telecommunication infrastructure	7,500 CHF
Agriculture and forests	1,999,200 CHF
Sum	19,092,100 CHF

4.4 Mitigation Measures at the Planning Stage

Avalanche defence structures already exist in the release zones. To further reduce the prevailing risk, permanent (steel) and temporary (wood) defence structures are planned in combination with afforestation. With an investment sum of 1,600,000 CHF, annual costs for maintenance of 16,000 CHF, a life span of 80 years and an interest rate of 2%, the annual costs result in 52,000 CHF per year.

4.5 Collective and Individual Risks

Both individual and collective risks are calculated. The risk assessment revealed that for several people, the threshold for individual risk of 10^{-5} per year is exceeded. This means that there is a protection deficit and cost-efficient measures must be put in place to reduce risk. Fig. 3 shows the calculated individual risk without and with additional measures.

The collective risk without and with additional measures for all objects at risk is shown in Table 2. The numbers suggest that all risk is eliminated for the 30-yearly scenario, while risks in the 100- and 300-yearly scenarios are greatly reduced. In total, 97% of the risks are reduced (Table 2).

4.6 Benefit-Cost-Ratio

The benefit-cost-ratio is calculated as the ratio of risk reduction and cost of measures. With a risk reduction of 58,420 CHF per year (Table 2) and measure costs of 52,000 CHF per year (section 4.4), this results in a benefit-cost-ratio of 1.1, which means that the project is economical viable by a narrow margin. Since the mitigation measures reduce individual risks to an acceptable level, the project is recommendable for subsidisation.

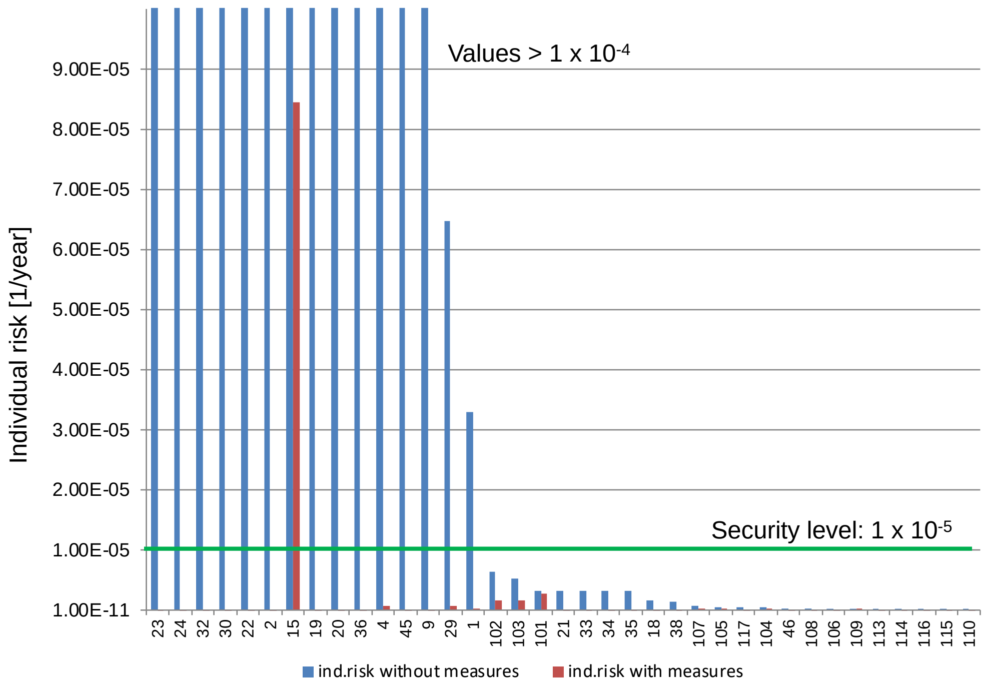

Figure 3: The individual risk of people in objects at risk for the situation without additional measures (blue columns) and with additional measures (red columns). The planned measures reduce the individual risk to an acceptable level except in the case of one building.

Table 2 Collective risks per object categories without/with measures in CHF per year. Risk reduction achieved by measures amounts to 58,414 CHF per year. Risk to people is monetised with 5 million CHF per prevented fatality.

	People	**Buildings**	**Roads**	**Agriculture and forests**	**Collective risk**
Scenario 30	21 / 0	23 / 0	328 / 0	212 / 0	584 / 0
Scenario 100	827 / 7	1,320 / 0	695 / 45	644 / 11	3,486 / 62
Scenario 300	43,423 / 481	11,434 / 772	857 / 468	720 / 306	56,440 / 2,027
Sum	44,271 / 488	12,777 / 772	1,879 / 513	1,576 / 317	60,504 / 2,090
Total risk reduction					58,420

5. CONCLUSIONS

Over the past decades, the natural hazards coping strategy in Switzerland has changed from a hazard-oriented to risk-oriented approach. Mitigation strategies should combine all available types of measures, such land use planning (hazard maps, relocation) as well as structural, biological (e.g. protection forest) and organizational measures (e.g. artificial release, road closure and evacuation). Especially organizational measures have become more important in recent years due to technical developments, such as sophisticated alarm and warning systems. In Switzerland, planning mitigation measures is based on a risk-oriented approach which aims to sink the individual risk to people below a defined threshold and to reduce collective risks with cost-efficient measures. Additional criteria for obtaining a subsidy from the Federal Government are making provisions for the environment and planning measures in a participatory approach (social acceptance). Although there is no explicit corresponding study, authorities argue that equal amount of protection is achieved with less money using a risk-oriented approach compared to the results of a hazard-oriented approach.

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