Risk Concept Switzerland Hazard Analysis, Risk Evaluation and Protection Measures

Tobler Daniel and Bernhard Krummenacher

Abstract

The results of the hazard mapping system in Switzerland are visualized by three colours (red, blue and yellow) which indicate the general degree of danger PLANAT (Sicherheit vor Naturgefahren – Vision und Strategie der PLANAT. Nationale Plattform Naturgefahren, 2003). The narrative description of the three colours considers the degree by which people and assets of considerable material value are endangered. The hazard map is a primary management tool for land-use planning and regulation for settlement developments. For all other infrastructures (roads, lifelines) the risk map is the appropriate instrument to illustrate damage potential. The risk map is the basis for chronological and financial prioritisation of protection measures. It is the most appropriate tool for decision making about structural and non-structural measures. Based on the calculated risks, the cost effectiveness of protection measures can be evaluated. Switzerland developed the online-tool "EconoMe" to calculate the natural risks and cost-effectiveness of different protection measures BAFU (EconoMe – Wirtschaftlichkeit von Schutzmassnahmen gegen Naturgefahren, 2008). Today it is essential to invest funds with the most possible cost efficiency. Risk based decisions are therefore required.

Keywords

Swiss risk concept • Hazard assessment • Hazard analysis • Riske valuation • Cost-effectiveness

Introduction

Risks from natural hazards play an increasingly important role in our society (Lateltin et al. 2005; Latelin 2009). Major disasters in the past decades provide a wake-up call for authorities, insurance companies and the public at large. A review of the risk and disaster management system became evident (BUWAL 1998; Wilhelm 1999). The assessment of the prevailing hazards, vulnerabilities and risks was recognized as an important task. Therefore, hazard maps and related instruments have been developed at a federal level (PLANAT 2005a, b, 2011). The primary goal of all these instruments is to find answers to the following questions (see also Fig. 1):

– What can happen and where will it happen?
– How often and how intense will it be, and how large is the expected damage?
– What are the most efficient ways to protect people and assets?

Therefore the common denominator of these approaches is the understanding of natural hazard management as a threefold task (A) risk assessment, (B) risk evaluation, and

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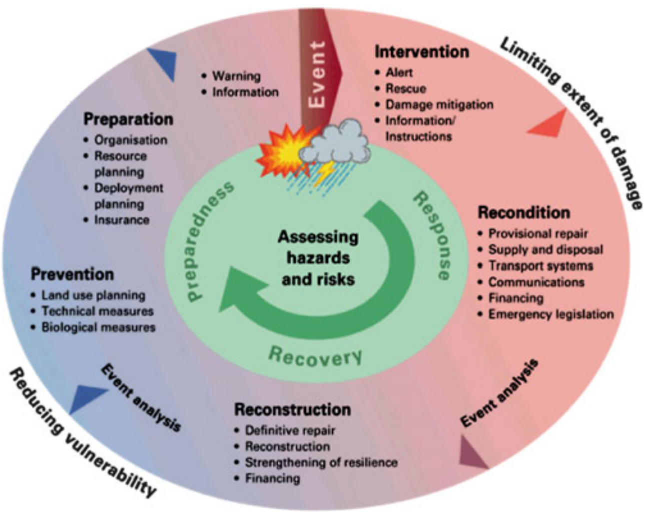

Fig. 1 Integrative risk management is understood as the systematic approach adopted within a cycle of preparedness, response and recovery (PLANAT 2011)

(C) planning of measures, applying an integrated approach (Frey and Krummenacher 2001; Bründl et al. 2009b).

The Swiss concept of risk aims at an optimised allocation of financial resources by reducing risk with a given relation of risk reduction cost, also called the marginal-cost criterion (Kienholz et al. 2004; Bründl et al. 2006; Fuchs et al. 2007). New political conditions for the subsidy of mitigation measures and limited public budgets have led to the development of a new software tool called EconoMe (Bründl et al. 2009a, b). The different tasks defined as major steps in the software are illustrated in Fig. 2. A detailed description of the different steps in the risk concept and the software EconoMe can be found in Bründl et al. (2009a).

This paper focuses on the risk analysis – especially the hazard assessment – as well on a few aspects in risk evaluation. The discussion of cost effective protection measures will be shown with a case study.

Risk Assessment

Risk assessment is the basis of decision-making for every type of involvement in disaster risk management (or disaster reduction). For this purpose several tools and instruments exist, some developed in Switzerland. They are currently being applied in a number of cases abroad (PLANAT 2005a).

Risk Analysis

The risk analysis is the heart of the risk concept. It consists of three major tasks, the hazard analysis, the exposure analysis and the consequence analysis.

Hazard Analysis

The key element of each risk analysis is the hazard analysis. The basic information about the different hazardous processes can be taken from field investigations, different kind of maps (e.g. geology, hydrogeology, topographic), event inventories and aerial photographs.

For further steps in the risk concept intensity maps are needed. They provide the spatial extent and the corresponding intensities of a natural event having a specific return period or probability (PLANAT 2005a). The intensities are normally classified into three classes (low, moderate, high). The physical impacts of the hazard can be enhanced by e.g. modelling or conclusions by analogies.

An important result of the hazard analysis is visualized in the hazard map by the three colors (red, blue and yellow), which indicate the degree of danger (Fig. 3).

The word "danger" (inappropriately used in the Swiss recommendations for hazards, due to the lack of an equivalent German term) or hazard thereby denotes the degree of exposure of persons, buildings and/or infrastructure to a potential hazard of a specified level. This three-color system is used for all types of hazards, i.e. debris flows, landslides (deep-seated, shallow), rock fall, and snow avalanches Raetzo et al. (2002). The classes of the return periods (or probability of occurrence) are the same for all hazards. The level of danger for all types of hazards is determined in a similar way: it is a combination of the magnitude (intensity) of the process in a particular location and its probability of occurrence (return period) in that location. The narrative description of the three colours considers the degree by which people and assets of considerable material value are endangered.

Exposure Analysis

In an exposure analysis the elements at risk have to be identified. These can be persons or assets, which varies in their number, type, value and probability of exposure to a certain process. The exposure for the different types of objects can be either permanent (roads, railway lines, buildings) or transient (traffic, persons). The selection of the elements at risk can easily be done using a GIS. The determination of the different probabilities of exposure follows the Swiss guidelines (BUWAL 1999).

Consequence Analysis

In the consequence analysis the expected damage for all exposed objects according to vulnerability and probability of presence has to be calculated. The consequences are

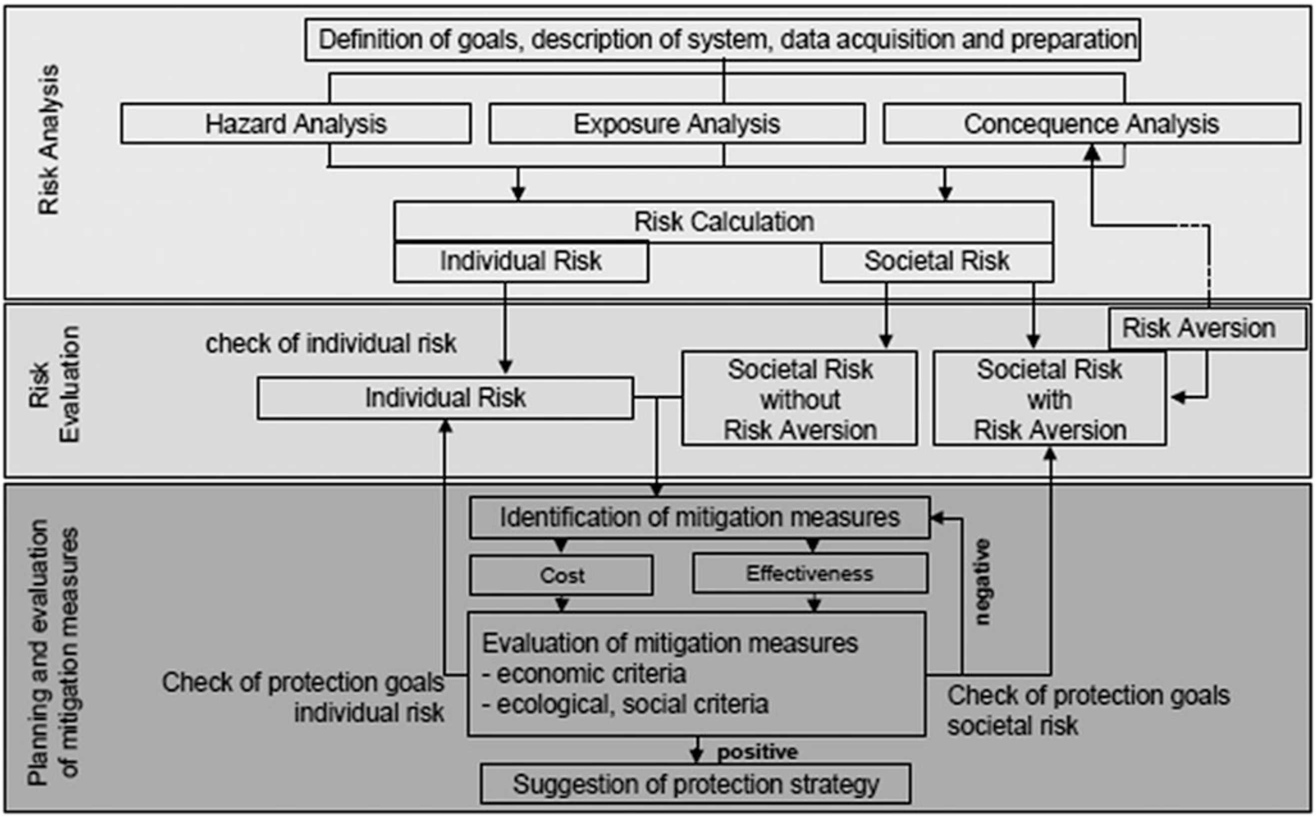

Fig. 2 Illustration of the risk concept Switzerland with the threefold task of risk analysis, risk evaluation and planning and evaluation of protection measures (Brundl et al. 2009b)

usually described in terms of different damage indicators (e.g. fatality, injury, physical loss, loss of production or income, etc.) and their vulnerability (e.g. the vulnerability of a person can be expressed as lethality).

This analysis combines the hazard and the exposure analysis yielding the expected damage or loss including all considered scenarios (Bründl et al. 2009a).

Risk Calculation

The basic definition of risk (R) can be expressed as probability (p) times consequences (C) of different outcome scenarios associated with a hazard (Bründl 2009).

$$R = p \times C \quad (1)$$

A specific person is primarily concerned with their own exposure to danger. The individual risk of a person can be defined as the probability of a specific consequence to this person. The probability of a consequence can be subdivided into the probability of the hazard scenario and the probability of the exposure to this scenario.

A hazard usually affects more than one person. The sum of the individual risks of the potentially affected people is referred to as their collective risk associated to this scenario.

Risk Evaluation

The collective as well as the individual risk are compared with predefined safety goals. The Swiss strategy of natural hazards (PLANAT 2005a) suggests safety goals for individual risks not higher than 10^{-5} for involuntarily taken risks.

To transform the different risk units into monetary risk units (e.g. fatalities/year → monetary value/year) the principle of marginal costs is applied. The marginal costs are equal to the willingness to pay for reducing the risk for one risk unit (Wegmann and Merz 2001). Persons are monetised by the value of statistical life, which expresses the amount of money a society is willing to pay for averting a fatality (Bründl et al. 2009a).

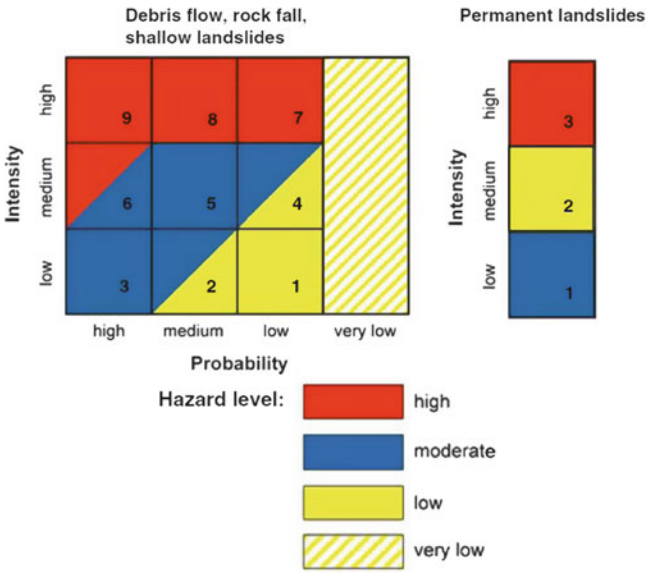

Fig. 3 Matrix for the determination of the danger level with the three colors *red*, *blue* and *yellow* (PLANAT 2005b)

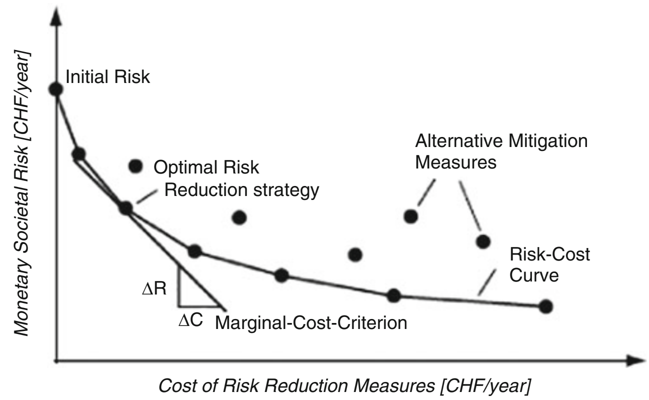

Fig. 4 Risk-cost diagram which illustrates the optimisation of mitigation measures by using the marginal-cost-criterion. Where the tangent touches the risk-cost curve the economical optimised combination of measures under the given assumptions is suggested (Bründl et al. 2009b)

Planning of Protection Measures

The risk-based planning of safety measures (risk management) is based on the risk assessment process. The following questions need to be answered: Are the risks acceptable? What options are available, and what are their associated trade-offs in terms of costs and benefit (risk reduction)? And, what is the impact of the current management decision on future options? Before it can be discussed whether a risk is acceptable or not, it is necessary to have an overview of the possible safety measures. The risk assessment gives valuable insights where to and where not to consider safety measures. The evaluation of different safety measures is basically a question of how much money can be paid to reduce the perceived risk. This question is linked to the problem of resource allocation and can be solved as an optimization task. The optimal solution minimizes the residual risk for the longest period at the cheapest price (Fig. 4).

Case Study, High Mountain Valley, Chile

Introduction

The traffic on a major motorable road in a high mountain valley in the Chilean Andes will increase due to the growth of nearby mining activities in the future. The steep slopes of solid rocks stand under a constant interaction with snow and ice and are under stress from temperature variations, producing intense jointing and generation of coarse debris with large block sizes of tens of m^3. Debris flows and rock falls from the partially altered volcanic and intrusive lithologies are present on most sites.

Hence, the risks of accidents caused by natural hazards such as rock fall, debris flows, landslides and avalanches will rise. As a first approach to reduce these risks, it is essential to carry out hazard assessments along the roads and lifelines. Second, measures to protect those locations with potential risks have to be proposed. Third, a periodization of the proposed protection measures has to be initiated on the base of the cost-effectiveness.

Hazard Analysis

The evaluation of rock fall and debris flow hazards is based on substantial on-site inspections by foot and by helicopter, on information from recorded and witnessed events, the DTM, on analysis of aerial photographs as well as the geological basics of lithology and tectonics. The existing protection measures have been taken in to consideration especially for debris flow processes.

Due to the given lithology and the strong tectonic stress of the rock, the assessed area shows strong weathering phenomena. Therefore it was challenging to define scenarios for the different processes.

The physical impacts of the hazards have been derived from a detailed process analysis, which was enhanced by physical modelling. For rock fall the model ROFMOD 3D (Tobler et al. 2009; Krummenacher and Keusen 1996; Figs. 5 and 6) and for debris flow processes the model RAMMS (Graf and McAdrell 2011; Scheuer et al. 2011; Fig. 7) have been used. Both models are well established in Switzerland.

Within the investigation area the process extensions and intensities for different scenarios have been defined. As a

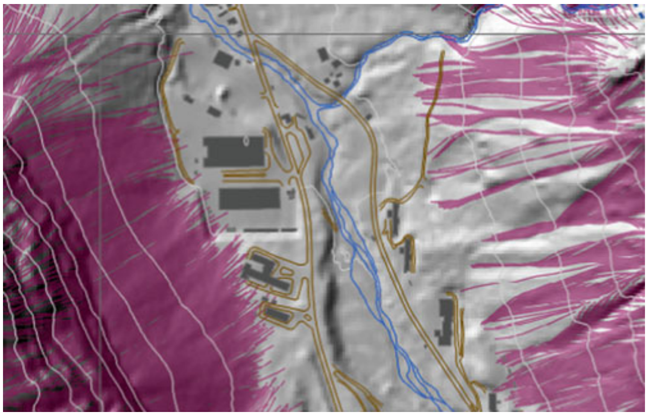

Fig. 5 Rock fall endangered area with trajectories of a 100 years scenario (block size approx. 3 m^3) derived from ROFMOD 3D

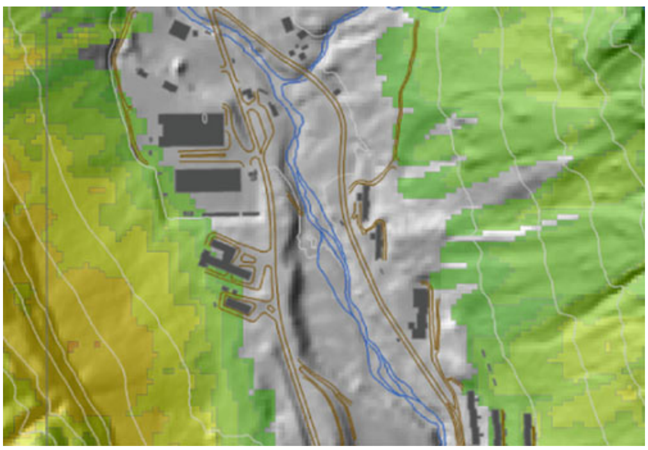

Fig. 6 Rock fall endangered area with energies of a 100 years scenario (block size approx. 3 m^3) derived from ROFMOD 3D

base for the risk calculation, intensity maps have been generated for all processes (debris flow and rock fall) and scenarios.

Exposure Analysis

In a first step the exposure analysis has been done only in a small part of the whole investigation area. Furthermore only infrastructures have been defined (Fig. 8). These operations can easily be done in a GIS. For every selected object the necessary parameters have to be specified. For a proper risk analysis it will be important to define all existing elements at risk. For this analysis the newly developed software tool EconoMe was used. All parameters were implemented in the software.

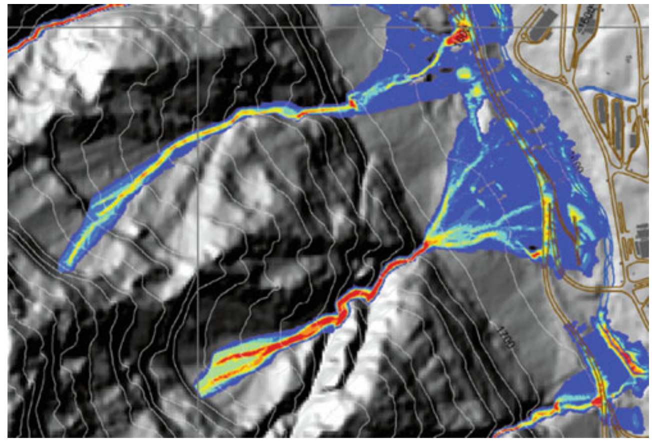

Fig. 7 Process areas with indication of flow heights of debris flows derived from the model RAMMS

Consequence Analysis and Risk Calculation

In a small test area the consequence analysis and the risk calculation have been completed. These steps are automatically done in the software tool EconoMe. The goal was to present the tool to the responsible persons and authorities. As a product the risk for every object at risk will be calculated.

Protection Measures

The measurement planning is based on the on-site findings, the model results and the long-term experience of the project team. As a first step, the measures are described only qualitatively with a rough dimensioning and cost estimation. The goal was the ranking of different types of measures in general for a basic discussion (Fig. 9).

Conclusions

The case study proved, that the proposed approach to quantify risk and rank different mitigation measures is suitable for long-term and regional planning. Based on the experience in the case-study the following qualities can be emphasized:

(a) The concept leads to an efficient and systematic assessment of risks and ranking of protection measures. It supports a long-term regional planning. All necessary data are collected and evaluated through field analysis, discussions with local experts, decision-makers, intervention and prevention specialists as well as local hazard experts.

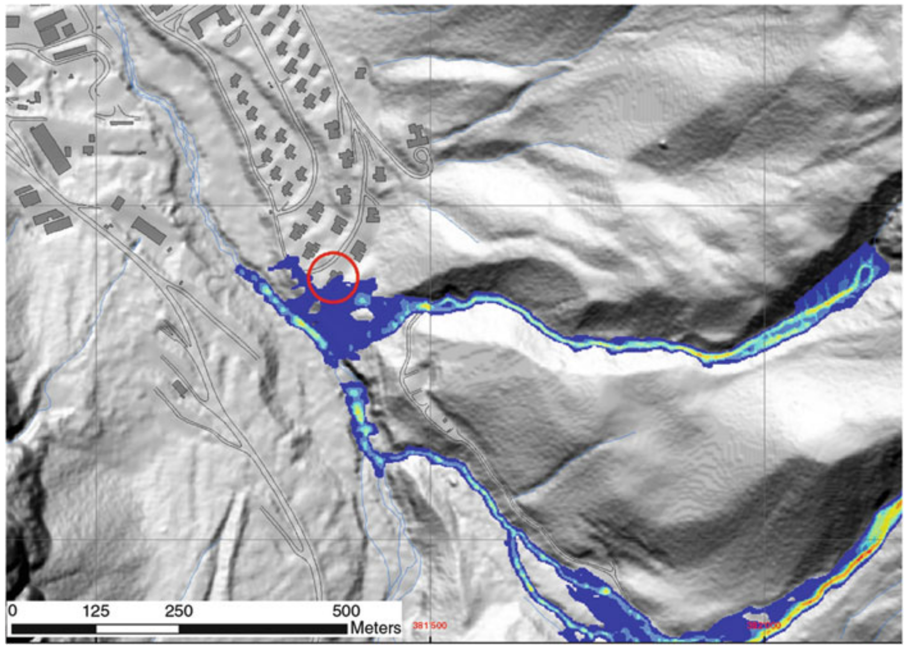

Fig. 8 Debris flow affected area with one element at risk (*red circle*). This object can be selected automatically in a GIS when cutting the element with the process layer

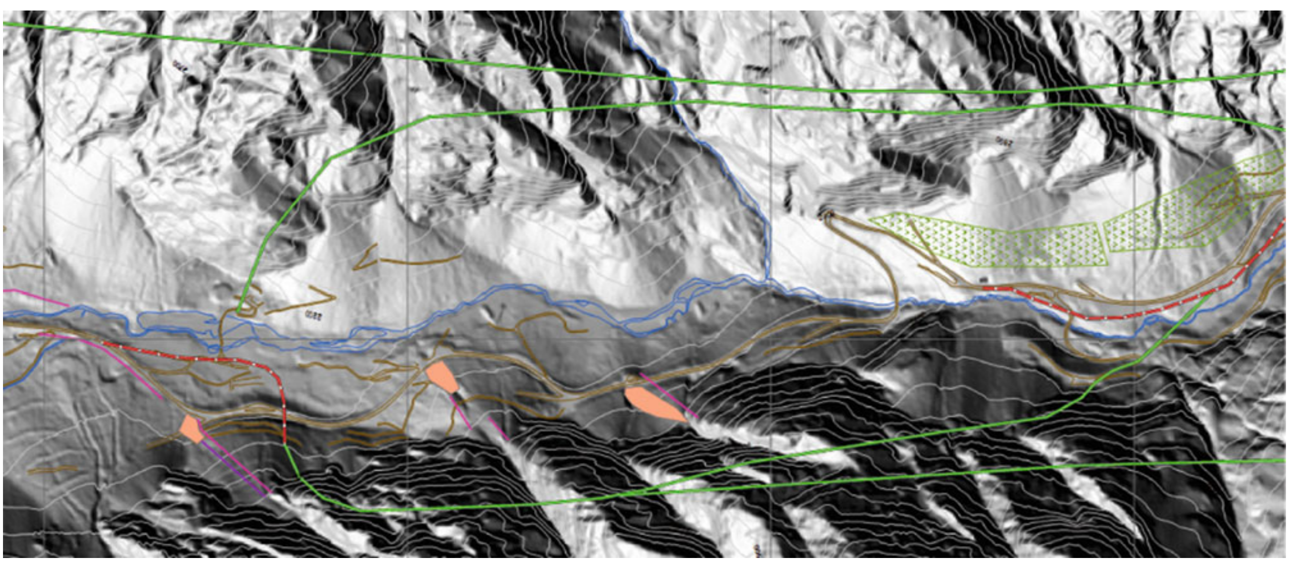

Fig. 9 Area along the analysed valley with different possible protection measures like tunnels (*green*), road relocations (*red*), retention basins for debris flows (*orange*) and deflection dams (*violet*)

(b) One of the most important parts of the whole concept is the risk analysis. The better the base dataset is, the more precise the output. A intensive field investigation is the fundamental part of every hazard analysis.

(c) A risk evaluation supports the decision-making process. The representation of risks and cost-effectiveness of protection measures allows the decision-makers to come to sound and informed decisions. The procedure is straightforward and efficient.

(d) The software EconoMe allows one to rank different protection measures with respect to their cost-effectiveness in a very efficient way. Furthermore it advocates the communication between those who are potentially affected by natural hazards and hazard experts. It supports the efforts towards a holistic, transdisciplinary and risk based safety planning. Furthermore it supports the discussion about unsolved questions, uncertainties or disagreements in a transparent and efficient manner (see also Wegmann and Merz 2001).

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