CONHAZ
Costs of Natural Hazards

# CONHAZ Report on
# *Costs of Alpine Hazards*

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## Disclaimer

## The ConHaz EU project

Cost assessments of damage, prevention and response measures to natural hazards provide crucial information for decision support and policy development in the fields of natural hazard and risk management as well as of planning for adaptation to climate change. There is a considerable diversity of methodological approaches and terminologies being used in cost assessments of different natural hazards. This hampers the development of comprehensive, robust and reliable costs figures as well as the comparison of costs across hazard types and impacted sectors.

This report is part of the EU project ConHaz – Costs of Natural Hazards. The first objective of ConHaz is to compile state-of-the-art methods and terminologies as used in European case studies. This compilation will consider droughts, floods, storms, and alpine hazards as well as various impacted sectors, such as housing, industry and transport, and non-economic sectors such as health and nature. It will consider direct, indirect and intangible costs. ConHaz further examines the costs and benefits of risk reduction and emergency response policies. This is reflected in the work package structure of the project ConHaz (see Fig. 0.1).

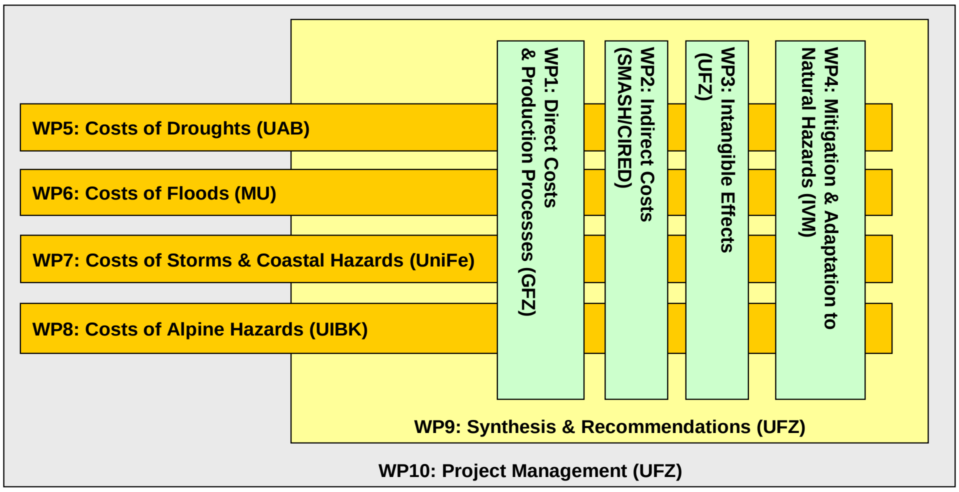

**Figure 0.1:** Work package structure of the ConHaz-Project.

The second objective of ConHaz is to evaluate the compiled methods by considering theoretical assumptions underlying cost assessment methods and issues appearing in the application of the methods, such as availability and quality of data. ConHaz will also assess the reliability of the end results by considering the accuracy of cost predictions and best-practice methods of validation. Finally relevant gaps in assessment methods will be identified. The third objective of ConHaz is to compare available assessment methods with end-user needs and practices in order to better identify best practices and knowledge gaps in relation to policy-making. Finally ConHaz will give recommendations about best practices and identify resulting research needs.

This report is part of WP8 on alpine hazards. It is primarily based on an intense literature review and on the outcomes of an excursion and a workshop with scientists and stakeholders held on 19 and 20 May 2011 in Innsbruck, Austria.

The final version of this report will be sent to all participants of the workshop, the ConHaz consortium as well as all persons stated in the ConHaz-stakeholder database dealing with natural hazard management for Alpine risks. Finally the report will be disseminated via the project homepage (http://conhaz.org).

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## Abstract

Cost assessments of damage, prevention and response measures to natural hazards and associated risks supply crucial information to policy development and decision making in the fields of natural hazard and risk management. In times of tightened public funds, economic efficiency and prioritization of measures that reduce risks due to natural hazards is of prime importance. Given that a multiplicity of analyses and case studies exist for assessing costs of alpine hazards, mitigation and adaptation measures as well as their benefits (in terms of avoided costs), the identification, compilation and assessment of such methods is essential as a basis for comprehensive recommendations to end-users. Moreover, a reliable costing approach for the complex hazard situations in alpine regions is desirable and should be part of a comprehensive risk management and adaptation strategy dealing with natural hazards. The report compiles current methods of cost assessments in countries within the European Alps, starting with a general description of Alpine hazards and specific vulnerabilities. Methods for estimating direct, indirect and intangible costs of alpine hazards as well as methods for the cost assessment of mitigation and adaptation are introduced, illustrated by case studies and assessed.

Moreover, different methods for decision support, e.g. cost-benefit-analysis approaches in different countries, are described and evaluated. The last section identifies research gaps and gives some recommendations for cost assessments of natural hazards based on the former analyses.

The report is primarily based on an intense literature review and the outcomes of a workshop with scientists and stakeholders in May 2011. It reveals that assessment techniques vary strongly over countries in the Alpine arc and a multiplicity of analyses exists for mountain hazards, but generally accepted, comprehensive and European-wide methods for Alpine risks are still missing. In addition, nearly all known methods are static, i.e. they neglect the effects of dynamic systems like human and environment interactions and global change. In the field of Alpine risks, intangibles, indirect effects or decline in regional welfare is poorly investigated, whilst direct effects are well analysed. In addition, the annual costs for public safety, like mitigation measures, emergency planning or warning, can only partly be analysed and are difficult to quantify due to the involvement of diverse administrative bodies on all levels which leads to scattered information and data sources.

## Structure

# 1 Introduction to Alpine hazards and their cost assessment

In mountain areas, extreme weather events regularly trigger hazardous and torrential processes like different kinds of flooding, landslides or avalanches. In fact, due to the high relief energy and the coincidence of multiple hazards in Alpine lateral valleys, risk-free, permanent settlement areas are very limited. Hence, the impossibility of re-locating affected structures to risk-free areas and a limited accessibility of Alpine lateral valleys in emergency situations make Alpine areas and other mountainous regions especially vulnerable to natural hazards. In addition, a mismanaged land-use development in the last decades, especially the construction of infrastructure and buildings nearby water bodies and inside floodplains, has resulted in increasing economic losses due to extreme weather events (Pfurtscheller & Schwarze 2010). The vulnerability of the alpine arc – and of mountain areas in general – to natural hazards is expected to increase, also as a result of recent climate change that is likely to intensify natural processes in some regions (Haeberli & Maisch 2007; Allamano et al. 2009). This combination of complex processes and high (increasing) exposure of human and natural environments to natural hazards make Alpine regions a special object of risk research.

Still, the empirical basis for reliably estimating costs and economic effects caused by Alpine hazards is weak. According to the CRED EM-DAT database, about 150 catastrophic events caused approximately US$ 51 billion of direct losses in Austria, France, Germany, Italy, Slovenia, and Switzerland in the last 60 years. However, only a part of these losses, which cannot be separated reliably, were triggered by Alpine hazards. More profound data and methods are however needed for a sustainable management of hazards and risks in mountain regions.

In order to i) compile state-of-the-art methods for cost assessments in Europe, ii) to analyse and assess these methods in order to identify best practice methods as well as theoretical and practical knowledge gaps, and iii) to synthesise the resulting knowledge into recommendations for the assessment of costs of natural hazards and identify further research needs, the European Coordination activity ConHaz – Costs of Natural Hazards was launched in 2010. This report will show the main project outcomes with regard to costs of Alpine hazards, i.e. data and assessment methodologies for different cost types. The analysis is based on a literature review, interviews and questionnaires as well as an exchange among practitioners, researchers and stakeholders during an inter- and transdisciplinary workshop in May 2011.

The specific objectives of the paper are:

- Compilation, analysis and assessment of methods and case studies for the cost assessment of Alpine hazards,
- Identification and compilation of methods and case studies for costs triggered by Alpine risks, especially multiple hazards and their monetary assessment,
- Determination of research gaps for the costs assessment of Alpine risks considering multi-risk approaches and emergency costs,
- Definition of best practices and recommendations for estimating costs triggered by Alpine hazards.

The case studies will mainly focus on the European Alps which will be briefly introduced in the next section.

## 1.1 The European Alps – natural and societal facts

The Alps are a mountain region in the centre of Europe which covers about 200 000 km². Apart from the boundaries of Alpine states, the exact classification of Alpine (mountain) areas is not an easy task, because of the fragmented geologic and geomorphic forms, but also due to the changing altitudes. Currently, two classifications are used that were put in place by the Alpine Convention and the EU named “Alpine Space”, respectively (see Fig. 1.1). According to this definition, beginning in the south west edge of the Alpine Arc, Monaco, France, Switzerland, Italy, Liechtenstein, Germany, Austria and Slovenia have Alpine regions.

**Figure 1.1:** Overview about countries within the borders of Alpine Convention (yellow) and Alpine Space (red).

The absolute figures derived by the Alpine Convention are given in Table 1.1. It demonstrates that huge areas in Austria, Italy, France and Switzerland are characterised as mountain regions and might potentially be affected by Alpine hazards.

**Table 1.1**: The Alps - natural and societal facts of Alpine countries in alphabetical order II; Source: Permanent Secretary of the Alpine Convention (2010a).

| Country | total area in km$^2$ | Alpine convention Area in km$^2$ | share of Alpine convention area | share of Alpine area per country |
|---|---|---|---|---|
| **Austria** | 83 871 | 54 600 | 28.7 % | 65.1 % |
| **Germany** | 357 104 | 11 160 | 5.8 % | 3.1 % |
| **France** | 543 965 | 40 801 | 21.4 % | 7.5 % |
| **Italy** | 301 336 | 51 995 | 27.2 % | 17.3 % |
| **Liechtenstein** | 160 | 160 | 0.1 % | 100 % |
| **Monaco** | 2 | 2 | 0.001 % | 100 % |
| **Slovenia** | 20 253 | 6 871 | 3.6 % | 33.9 % |
| **Switzerland** | 41 285 | 25 211 | 13.2 % | 61.1 % |
| **Total** | **1 347 976** | **190 959** | **100 %** | **n.a.** |

The Alps are not a homogenous area with regard to geographical and economical characteristics. They are in fact a fragmented space with highly variable social, economic and natural conditions. This is illustrated by Table 1.2 that gives an overview of the main societal, economic and administrative facts of the countries with Alpine areas. Especially the population density varies significantly. Densely populated areas (e.g. Monaco and the Rhine valley) alternate with depopulated or economic shrivelling regions (e.g. the Friuli region in northern Italy). In total, approximately 14 million inhabitants settle in the area classified by the Alpine Convention (Permanent Secretary of the Alpine Convention 2010a, see also Table 1.1). Because of the high share of their total population in Alpine areas (as defined by the Alpine Convention) more than 50% of the alpine residents live in Austria and Italy (Table 1.2).

Similarly, the economic performance in terms of GDP per capita varies strongly, whereby Switzerland, Liechtenstein and Monaco have the highest rates because of the strong financial sector concentrated in these countries. The other countries feature a more or less homogenous moderate GDP, except for Slovenia. From an administrative and governance perspective, different administrative and political systems are implemented in these countries, with federal states and republics prevailing as the dominant governance structures. As given in Table 1.2, e.g. public bodies dealing with natural hazard management in Switzerland, Austria or Germany are located at up to four administrative levels (i.e. state, federal states, districts and municipalities).

**Table 1.2:** The Alps - natural and societal facts of Alpine countries in alphabetical order I; Sources: Kobert et al. (2009) & Permanent Secretary of the Alpine Convention (2010a).

| country | population /population density per km2 | Share of total population in Alpine areas | GDP per capita in US$ (2006) | political and administrative structure |
|---|---|---|---|---|
| **Austria** | 8 337 000 / 99 | 23.6 % | 45 900 | federal state: state, nine federal states, districts and municipalities |
| **Germany** | 82 110 000 / 230 | 10.6 % | 42 410 | federal state: state, 16 federal states, districts, municipalities |
| **France** | 62 277 000 / 115 | 17.5 % | 42 000 | presidential parliamentary: 22 regions, 96 départements, municipalities |
| **Italy** | 59 832 000 / 199 | 30.5 % | 35 460 | republic: 20 regions, special status for five regions, districts, municipalities |
| **Liechtenstein** | 36 000 / 225 | 0.3 % | 97 990 | constitutional monarchy |
| **Monaco** | 33 000 / 16.337 | 0.2 % | n.a. | constitutional monarchy (princedom) with limited sovereignty |
| **Slovenia** | 2 021 000 / 100 | 4.2 % | 24 230 | republic: 193 municipalities |
| **Switzerland** | 7 648 000 / 185 | 13.1 % | 55 510 | parliamentary state: 23 cantons, districts, municipalities |
| **total / median** | **222 294 000/ 192** | **100 %** | **- / 42 410** | **-** |

→ The Alps represent a very inhomogeneous space with regard to their social, economic, political and natural conditions. Since also the impacts of natural hazards vary strongly in time and space – as will be shown below –, different risk management systems and assessments have evolved in the Alpine countries. Consequently, different administrative bodies on all levels deal with natural hazard and risk management.

## 1.2 Hazards in Alpine regions – a typology

The European Alps as a mountain region are under special threat of different natural hazards. Still, the term “alpine hazards” needs some explanation. In general, the term *Alpine* can be used to describe an attribute or phenomenon that is specific to the (European) Alps or to describe the ecologic altitudinal belt (biotic zone) above the treeline (Veit 2002). In this report *Alpine* mainly refers to the European Alps. However, due to similar characteristics of mountain regions, the notion *Alpine hazard* can also be used as a synonym to describe hazard events in other mountain regions all over the world.

One widespread classification (modified after Munich Re 2009) separates different natural hazard processes into volcanism and earthquakes (also subsidence and possible earthquake induced tsunamis), gravitative mass movements (landslides, rock fall, avalanches), floods (including flash floods, debris flows), windstorms (tropical vs. extra-tropical storms, storm surges, etc.), lightning strokes, heavy rainfall events (e.g. hail, snowfall), temperature extremes (frost, heat waves, droughts), vermines, wildlife fires, and erosion / desertification. In alpine regions, the triggering and resulting hazardous processes are typically mixed (e.g. heavy rainfall resulting in flash and low land floods, heavy snowfall resulting in avalanches, ice floods etc.).

A clearer distinction that accounts for the underlying process chains is the classification into hydro-meteorological and geological hazards (neglecting vermines). Both types of hazards can be single, sequential or combined in their origin and effects (CEDIM 2005), in which geodynamic (geological) hazards imply internal and external earth processes (tectonic origin or processes on the surface).

Hazards in Alpine or mountain regions are mainly dependent on surface processes (except for earthquakes). Generally, mountain environments cover about one quarter of the Earth’s surface and are characterised by their relative difference of altitudes compared to surrounding areas and between valleys, summits and plateaus with more or less steep slopes, the existence of full moulds, and a distinctive border between these forms (Leser et al. 2001). Another key element of mountain environments are the forces which form the surface, e.g. plate tectonics and coherent massif raising, as well as abrasion which accumulates sediments and - in the long run - flattens out mountainous areas, and the resulting rugged surface (Blyth et al. 2002). Relief energy can be seen as the key driver of hazardous processes and consecutive losses. Hence, apart from tectonic hazards, mountain hazards are defined in the present report as “the occurrence of potentially damaging processes resulting from movement of water, snow, ice, debris and rocks on the surface of the earth, which includes snow avalanches, floods, debris flows and landslides” (UNDRO 1991, quoted in Hübl et al. 2002).

### Hazards considered in ConHaz

According to UNDRO 1991 (as quoted in Hübl et al. 2002) floods and accompanying processes, different geological mass movements as well as avalanches are seen as characteristic for mountainous regions and occur with a specific magnitude and frequency in a given region. Therefore, this report will mainly focus on these three hazard types that will be briefly described below. Due to the high diversity of the selected processes, subcategories of the hazards were identified (see Table 1.3).

**Table 1.3:** Overview about the applied types of mountain hazards in the ConHaz project; based on Cruden & Varnes (1996), Hübl et al. (2002), Hübl et al. (2006).

| Hazards / processes | Subcategory | |
|---|---|---|
| **Floods and hydro-meteorological processes** | heavy rain (as mostly the trigger of hydrological Alpine hazards)<br>flash floods (pluvial or torrential floods)<br>river floods (fluvial floods) | |
| | debris and mud flows (flows) | |
| **Geologic mass movements** | *Falls*<br>• rock fall (“Steinschlag”) - <50cm diameter<br>• boulder fall (“Blockschlag”, “Blocksturz”) cubature approx. <100m$^3$<br>• block fall, cliff fall (“Felssturz”) - cubature approx. > 100 - 1 mio. m$^3$<br>• rock collapse, rock avalanche (“Bergsturz”), cubature approx. > 1 mio. m$^3$ | *slides / landslide sensu strictu*<br>• rock slide<br>• debris slide<br>• earth slide |
| **(Snow-) Avalanches** | Snow slab avalanche<br>Loose snow avalanche | |
| **complex processes / intermixtures** | | |

These processes often cannot be separated clearly. In most instances hazard events in alpine regions are not single-typed as suggested in Table 1.3, but are characterised by intermixtures. For example, heavy rainfall can trigger rock fall, but also debris, mud or water flows. Hence, an approach is needed that helps to identify the main damage causing process as well as to construct cause and effects relationships. Furthermore, there is a smooth transition between the different types of mountain hazards. For example, the difference between a debris flow and a debris flood or even a landslide varies only with regard to the relation of water to debris, rocks, etc. (see e.g. PLANALP 2006).

→ Mountain hazards comprise all possible destructive forces, which are triggered by the transport of frozen (snow, ice) or non-frozen water, debris and rocks or possible intermixtures. Relief energy is the key driver of mountain hazards and consequent losses. In the ConHaz-project different types of flooding, geological mass movements and avalanches will be considered as mountain or alpine hazards.

## Floods

Floods are a result of a process chain starting with (heavy) precipitation as trigger and resulting in a temporary inundation of land. The storage capacity of the affected catchment area further influences the severity of a flood. In addition, anthropogenic influences, like river regulations, construction of dams and soil sealing, affect runoff processes. According to de Bruijn et al. (2009), different types of floods can be distinguished on the basis of:

**(a) Origin of water (source)**

Coastal floods (water from the sea)
Fluvial floods (water from rivers)
Pluvial floods (water from above)
Groundwater floods (water from below)

**(b) Geography of the receiving area**

Coastal and estuarine flood (when the sea invades the land)

Fluvial flooding (when rivers overflow or breach their banks)

Areal flooding of catchments, urban areas or polders (when drainage capacity is insufficient to carry water away)

**(c) Cause**

Rainfall (inland)

Storms (coastal)

Earthquakes (tsunami)

Floods resulting from dam breaks (man-induced) or outbursts of glacier lakes

**(d) Speed of onset**

Flash floods (high flood water velocity)

Slow flooding types (flood water accumulate slowly)

Figure 1.2 shows a compilation of the most important flood types with their key factors and occurrence areas.

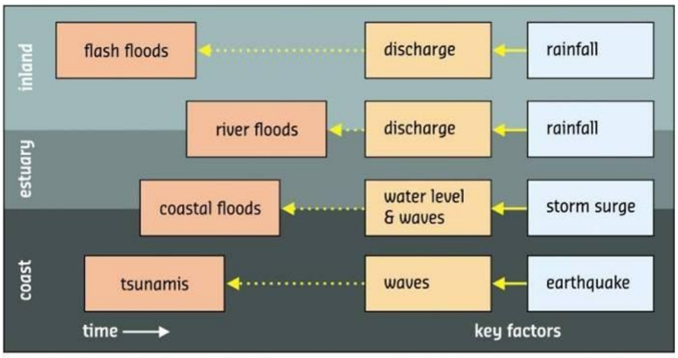


**Figure 1.2:** Overview about different types of floods, Source: de Bruijn et al. (2009, p. 16).

Relevant flood types in the Alps are pluvial and fluvial floods, which are briefly described below (after Patt 2001 and de Bruijn et al. 2009).

**1. Pluvial floods / Flash floods (Heavy rain events)**

In small catchment areas local downpour events (convective precipitation) induce flash floods. In steep catchment areas the flood wave is formed suddenly with a high energy level. They are also referred to as dynamic floods or - in the Alps - torrential floods. These floods occur locally. They are difficult to forecast, as they relate to local convective thunder storms. Flash floods never appear in the statistics of great disasters, but are responsible for considerable numbers of fatalities and cause great local damage owing to their high flow velocities and debris load. In flat areas, for example in urban areas and polders, heavy rain events can also induce pluvial or urban floods.

**2. Fluvial flood (River flooding)**

River floods develop after a long period of heavy precipitation (sometimes combined with snowmelt) within a large catchment area in connection with reduced percolation rates caused by saturation or frozen soil. They can be foreseen days ahead and are characterised by slow rise and are hence referred to as static floods. Fluvial floods bring about huge damage and may affect many people, but generally cause few fatalities in Europe. In the ConHaz-project, this type of flood is mainly dealt within WP6 “Floods” (see Green et al. 2011).

## Debris and mud flows

According to Hungr et al. (2001, p. 231) a debris flow is “a very rapid to extremely rapid flow of saturated non-plastic debris in a steep channel”. They are characterised by highly unsteady, surging flow behaviour. The key characteristic of a debris flow is the presence of an established channel or regular confined path that controls the direction of the flow and in which the debris flow is a recurrent process. A kind of longitudinal sorting of the material occurs during the process, which leads to a typical boulder front, a more homogenous suspension as body and to a turbulent or hyper concentrated flow as tail of the debris flow (see Figure 1.3). Typical diagnostic features from debris flows are U-shaped channel cross section, marginal levees of coarse boulders and steep-fronted lobate deposits (Hübl et al. 2002).

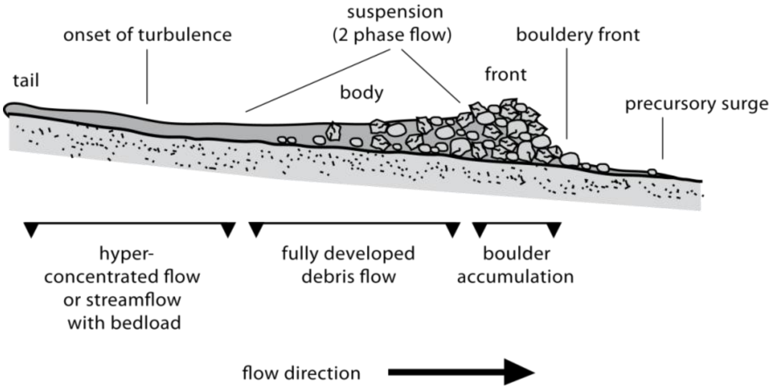


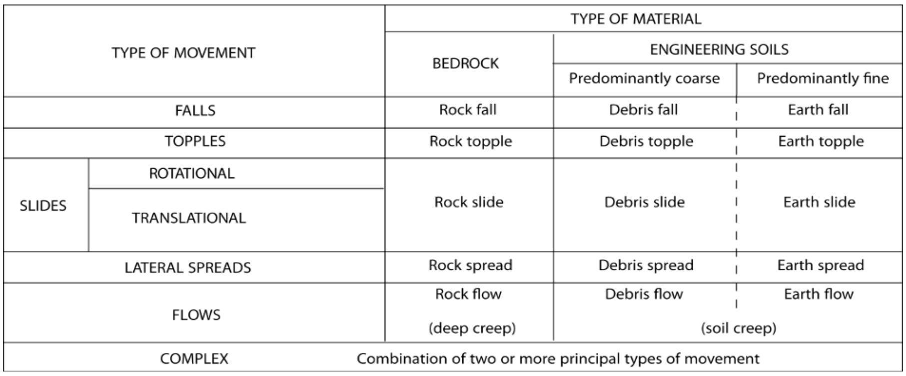
**Figure 1.3**: Schematic figure of debris flow surge; Source: Hübl et al. (2002, p. 24).

Debris and mud flows can cause great losses, because especially in alpine valleys large alluvial fans are densely populated and therefore a high damage potential is given.

## Landslides/Geological mass movements

The categorisation of landslides is difficult due to different approaches that can be found in the literature and the delimitations of scale and dimension. In general, landslides are downward movements of soil or rock masses on a sliding surface. Mainly they include fall processes (rock-, boulder-, bloc- and cliff-fall as well as rock collapse), slides and sometimes also debris flows. They can appear rapid and sudden (falls), or slow and continuous (slides), but also spontaneous and permanent. Concerning development, process and mode of action landslides exhibit considerable variety. Due to their sudden occurrence, landslides can endanger the lives of people and destroy buildings, cultivated land and forest. However, damage and destruction can also be caused in a slow and continuous way (Lateltin 1997).

**Table 1.4:** Classification of landslides after type of movement and type of material; source: USGS (2004); see also Fig. 1.4.



| TYPE OF MOVEMENT | | TYPE OF MATERIAL | | |
|---|---|---|---|---|
| | | BEDROCK | ENGINEERING SOILS | |
| | | | Predominantly coarse | Predominantly fine |
| FALLS | | Rock fall | Debris fall | Earth fall |
| TOPPLES | | Rock topple | Debris topple | Earth topple |
| SLIDES | ROTATIONAL | Rock slide | Debris slide | Earth slide |
| | TRANSLATIONAL | | | |
| LATERAL SPREADS | | Rock spread | Debris spread | Earth spread |
| FLOWS | | Rock flow<br>(deep creep) | Debris flow<br>(soil creep) | Earth flow |
| COMPLEX | | Combination of two or more principal types of movement | | |

### Classification and kinematic of landslides

A variety of landslide classifications can be found in the literature. Landslides are classified according to geomorphologic criteria, type of movement (kinematic) or activity (velocity). Different interpretations in dealing with landslides unfortunately mean that identical terms both for geomorphologic and kinematic classification of landslides are used. A typical example for inconsistent terminology of landslide processes is the German term “Sackung”. On the one hand, a “Sackung” as a kinematic term can define a continuous decreasing slow “downward creeping” of rock, whereby a discrete basal movement zone is formed (Poisel 1998). On the other hand, the term can describe geomorphologic observations, which are formed by distinctive vertical movement components, without receiving any information on the formation of movement zones (Weidner 2000). In this form, the delimitation to slides is gradual. Also the multiple used term “Talzuschub” describes geomorphologic and less kinematic phenomena. In connection with mass movements, the term “creep” is mainly used for very slow landslides with continuous decrease of displacements in the depth (Haefeli 1967). “Creep” in a rheological sense is, however, described as a continuous movement of material at constant tension conditions (e.g. Hudson & Harrison 1997). Owing to this complexity and ambiguity of classifications of mass movements, this report uses the process oriented classification developed by Cruden & Varnes (1996).

International harmonisation efforts were initiated by the working group “UNESCO Working Party on World Landslides Inventory” (WP/WLI 1993), consisting of the “International Association of Engineering Geology” (IAEG), the “Technical Committee on Landslides of the International Society for Soil Mechanics and Foundation Engineering” (ISSMFE) and the “International Society for Rock Mechanics” (ISRM). This working group adopted the simple and clear definition for the term “Landslide” by Cruden (1991, p. 27): “A landslide is a movement of a mass of rock, earth or debris down a slope.” In this definition ground subsidence and collapse are excluded, snow avalanches and ice falls are not discussed, but debris flows are included. According to WP/WLI (1993), landslides are classified by their kinematics, composition of material, activity, water content and the rate of movement (velocity). Basically, landslides can be divided into five basic kinematic types (WP/WLI 1993): fall, topple, slide, spread and flow (see Table 1.4 and Figure 1.4). Mixed types of movements appear frequently and a sharp demarcation between the different moving mechanisms is difficult. Therefore, it is very important for complex and composite types to describe the geometry (thickness and volume), the moving mechanism and the activity (velocity) in detail.

According to Cruden & Varnes (1996), all landslide processes can be structured into seven classes of velocity, which are reaching from extremely slow to extremely rapid. These two limits span ten orders of magnitude (from $10^{-7}$ to $10^3$ mm/s). With the exception of falls, all kinematic processes can reach each velocity class. The potential for destruction is closely related to the rate of movement (see Figure 1.5). An important threshold is located between “very rapid” and “extremely rapid”, because this value represents the ability of people to flee (running approximately 18 km/h) (Zangerl et al. 2008). Therefore, in many cases very rapid, but small processes (e.g. cliff falls with volume less than 100 $m^3$) are causing greater losses than bigger and very slow movements (volume up to 1 km³). For very slow to slow movements the degree of destruction depends on the internal deformation and the resulting differential movements (Zangerl et al. 2008).

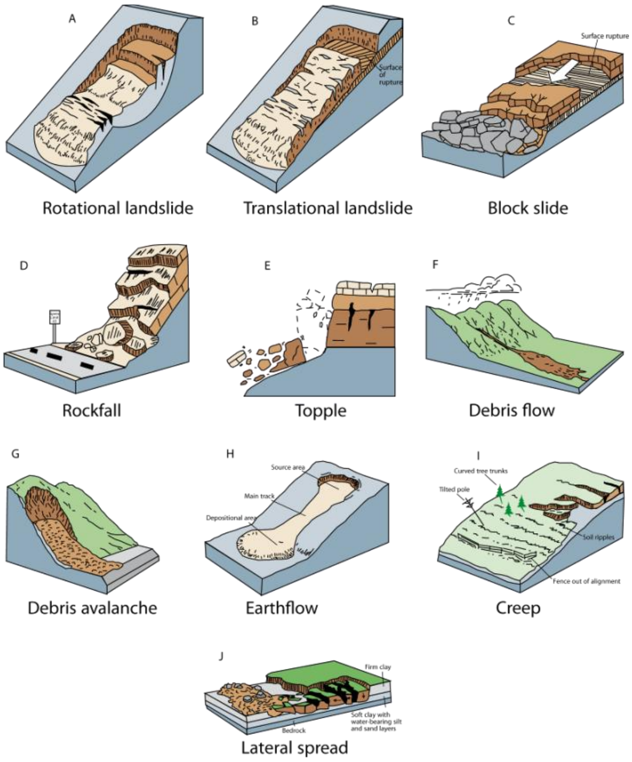
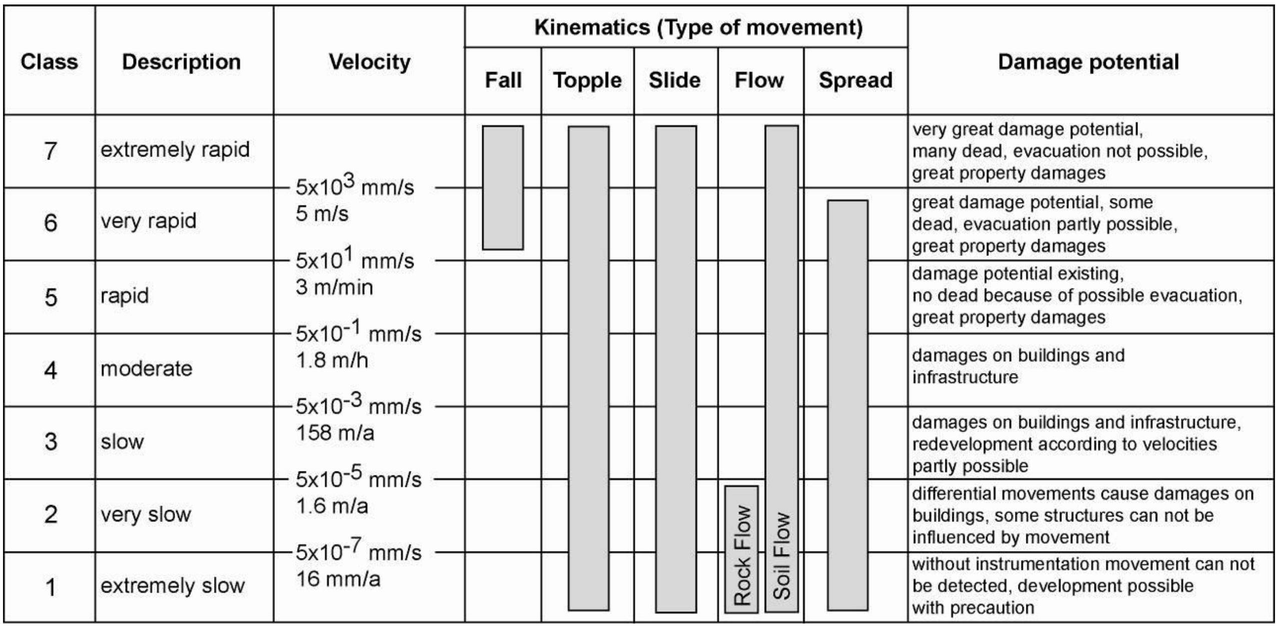


**Figure 1.4:** Major types of landslide movements; Source: USGS (2004)



| Class | Description | Velocity | Kinematics (Type of movement) | | | | | Damage potential |
|---|---|---|---|---|---|---|---|---|
| | | | Fall | Topple | Slide | Flow | Spread | |
| 7 | extremely rapid | | ▨ | ▨ | ▨ | ▨ | | very great damage potential,<br>many dead, evacuation not possible,<br>great property damages |
| 6 | very rapid | $5x10^3$ mm/s<br>5 m/s | ▨ | ▨ | ▨ | ▨ | ▨ | great damage potential, some dead, evacuation partly possible,<br>great property damages |
| 5 | rapid | $5x10^1$ mm/s<br>3 m/min | | ▨ | ▨ | ▨ | ▨ | damage potential existing,<br>no dead because of possible evacuation,<br>great property damages |
| 4 | moderate | $5x10^{-1}$ mm/s<br>1.8 m/h | | ▨ | ▨ | ▨ | ▨ | damages on buildings and infrastructure |
| 3 | slow | $5x10^{-3}$ mm/s<br>158 m/a | | ▨ | ▨ | ▨ | ▨ | damages on buildings and infrastructure,<br>redevelopment according to velocities partly possible |
| 2 | very slow | $5x10^{-5}$ mm/s<br>1.6 m/a | | ▨ | ▨ | Rock Flow ▨<br>Soil Flow ▨ | ▨ | differential movements cause damages on buildings, some structures can not be influenced by movement |
| 1 | extremely slow | $5x10^{-7}$ mm/s<br>16 mm/a | | ▨ | ▨ | Rock Flow ▨<br>Soil Flow ▨ | ▨ | without instrumentation movement can not be detected, development possible with precaution |

**Figure 1.5:** Classification of mass movements in velocity classes (modified after Zangerl et al. 2008).

## Avalanches

According to Ancey (2001, p. 2) avalanches are “rapid gravity-driven masses of snow moving down mountain slopes”. Because of their kinetic energy in combination with high pressures and accumulation avalanches can be a severe threat to human life and property. Most catastrophic avalanches follow the same basic principle: fresh snow accumulates on the slope of a mountain until the gravitational force at the top of the slope exceeds the binding force that holds the snow together. A solid slap of the surface layer can then push its way across the underlying layer, resulting in an avalanche. Typically, most avalanches travel hundreds of meters at a rather low velocity, but some can move up to 15 km and achieve velocities as high as 100 m/s. Only if the slope gets flatter (20° to 10°) for a longer distance, the movement decreases and the snow accumulates.

The term avalanche describes the whole movement from the crack area over the trajectory to the accumulation area (Hanausek 2000). For the development of avalanches, the following parameters are very important (c.f. Ancey 2001):

- terrain (mean slope, roughness, shape and curvature of starting zone, orientation to the sun),
- weather conditions (temperature, new snow, wind, rain and liquid water content) and
- snowpack structure (layers, fracture systems).

Successive snowfalls during the winter and spring accumulate to form snow cover. Depending on the weather conditions, significant changes in snow (types of crystal) occur as a result of various mechanical (creep, settlement) and thermodynamic processes (mass transfer) (Schweizer et al. 2003).

Figure 1.6 illustrates different types of avalanches. According to Hanausek (2000) avalanches can release either as slab (or powder) avalanches or as loose-snow avalanches. Slab avalanches are released by an increase in tension, a decrease in strength (stability) and an interference in snow stability. Loose-snow avalanches start at a point and grow in size as they descend. For loose-snow avalanches snow with low cohesion is prerequisite. This type of avalanche mostly develops on steep slopes (approx. 40° to 60°) and especially starts on rocky slopes.

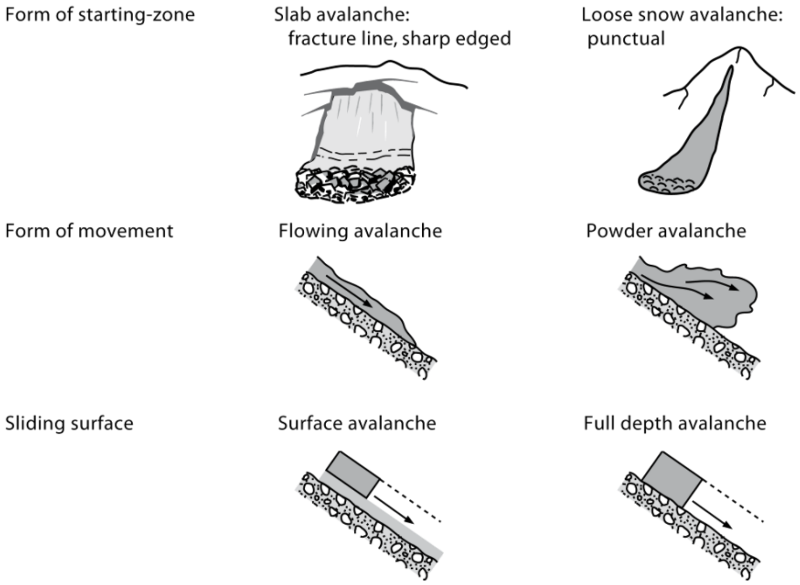


**Figure 1.6**: Characteristics of slab and loose snow avalanches / international avalanche classification; Source: Hübl et al. (2002, p. 32).

### Intermixtures and scale of impacts

As an exact classification of processes is often impossible, a classification by medium and type of transport as shown in Table 1.5 could serve as an alternative to hitherto used approaches. In this case, the available amount of water and solids define the main loss triggering process and hence the scale of impacts. Moreover, the processes depend mainly on the disposition, like exposition, slope or high potential energy.

**Table 1.5:** Distinction of mountain hazards after the corresponding medium (snow, water, solids and intermixtures), the type of dislocation and the process (adapted from Hübl et al. 2006, de Bruijn et al. 2009).

| Medium | Type of dislocation | Process | Dominant impact scale |
|---|---|---|---|
| **Snow** | Scattering | loose snow avalanche | local |
| | Floating | snow slab avalanche | local |
| **Water** | Fluvial | static/dynamic floods, fluvial sediment transport | local to regional to national |
| | fluvial with solids | debris flood | local to regional |
| | | debris flow | local to regional |
| **Solids** | Sliding | debris slide / flow slide / mudflow | local |
| | | landslide sensu strictu | local to regional |
| | fall / collapse | single rock fall | local |
| | | block fall | local to regional |
| | | rock collapse | regional to national |
| **Intermixtures** | | | depending on the scale and combination of processes |

## 1.3 Special vulnerabilities in Alpine regions

Alpine hazards can cause losses at different receptors or elements at risk, e.g. people, buildings, structures, land. Following the concept of risk, the amount of damage depends not only on the type, extent and intensity of the hazardous processes, but also on the number, types and susceptibility of the exposed elements at risk (concept of vulnerability) as well as on the risk reduction and coping measures that are in place (concept of resilience).

Due to the local to regional scale of many alpine hazard processes (see Table 1.5) the total amount of loss due to alpine hazards might often be small – in comparison to large-scale events like widespread river flooding, earthquakes or hurricanes. There are, however, some features that make Alpine areas and other mountain regions especially vulnerable to natural hazards. These are:

- intermixtures of hazards and cascade effects,
- limitation of permanent settlement areas and missing possibilities to relocate lifelines and transport networks
- special situation of lateral valleys,
- monosectorality of Alpine economies and high mobility of manpower.

This section briefly introduces typical vulnerabilities of Alpine regions, while the next section looks at management and costing aspects.

## Intermixtures and multiple processes / cascade effects

As illustrated in section 1.2, there is a smooth transition between the different processes. Hence, hazard events in mountain environments are often intermixed, which means that multiple and/or consecutive hazardous events occur in an area, partly linked as so-called domino or cascade effects. Taking the flood in August 2005 in Tyrol, Austria, as an example, it was shown by Pfurtscheller & Schwarze (2010) that the coincidence of consecutive and overlapping processes (e.g. flooding, mud and debris flows and landslides) triggered high economic losses. In addition, very different loss patterns or structural damage types could be observed in the affected area. In 2005, there was a strong divergence between damage in large-scale inundation in glacial U-shaped valleys that was dominated by high water levels and the rapid onset floods combined with dislocation of sediments and debris in Alpine lateral valleys that caused severe structural damage (Figure 1.7).

**Figure 1.7:** Occurrence of multiple hazards: e.g. floods 2005 in the Federal State of Tyrol, Austria - large-scale inundation in an U-shaped valley vs. rapid onset damages in an Alpine lateral valley; Sources: Spar Austria, C. Pfurtscheller.

## Marginal permanent settlement areas in alpine environments and high concentration of assets in lateral valleys

Due to the relief of Alpine areas, which is characterised by a sequence of mountain ranges and valleys as well as plains, important infrastructure, lifelines and buildings are mainly located in the lowest sections of the valleys. The approx. 14 million inhabitants of the Alpine arc (as at 2007) had rather limited space at their disposal for settlements and economic activities (Permanent Secretariat of the Alpine Convention 2010b). Only 17 % of the total area of the European Alps fit for permanent settlement (Tappeiner et al. 2008). The high concentration of people and assets is reflected by the high population density of 400 people per square kilometre in areas of permanent settlement. Moreover, we must acknowledge that the European Alps are a “natural obstacle” for international freight transports from north to the south of Europe. About 190 million of tonnes freight crosses the Alps per year (Permanent secretary of Alpine Convention, 2010b).

Still, permanent settlement areas in valleys are at risk. The example of the municipality of Ischgl, Federal state of Tyrol, Austria, demonstrates that nearly 75% of the whole permanent settlement area is endangered by floods, debris flows and/or avalanches (Figure 1.8). These maps are based on the Austrian Risk mapping for avalanches, floods and torrent processes which are modelled based on a reference event with a return period of 150 years.

The situation has become even more severe since regions with strong growth trends in tourism have made particular demands on the spatial resources (Borsdorf 2006). Further, a mismanaged land-use development in the recent decades has contributed to high economic losses during the latest weather events. In several cases buildings, commercial areas, infrastructure and utility services have been built in valleys near water bodies and inside floodplains (see e.g. aerial photographs and flooded areas in Habersack et al. 2006), so that there is a high concentration of public and private assets in these areas leading to a high exposure to flood-related processes. Thus the marginal permanent settlement area implies a high percentage of people and assets at risk. A lack of alternative locations for settlements and business sites as well as missing possibilities for the substitution of lifelines and transport network are further consequences.

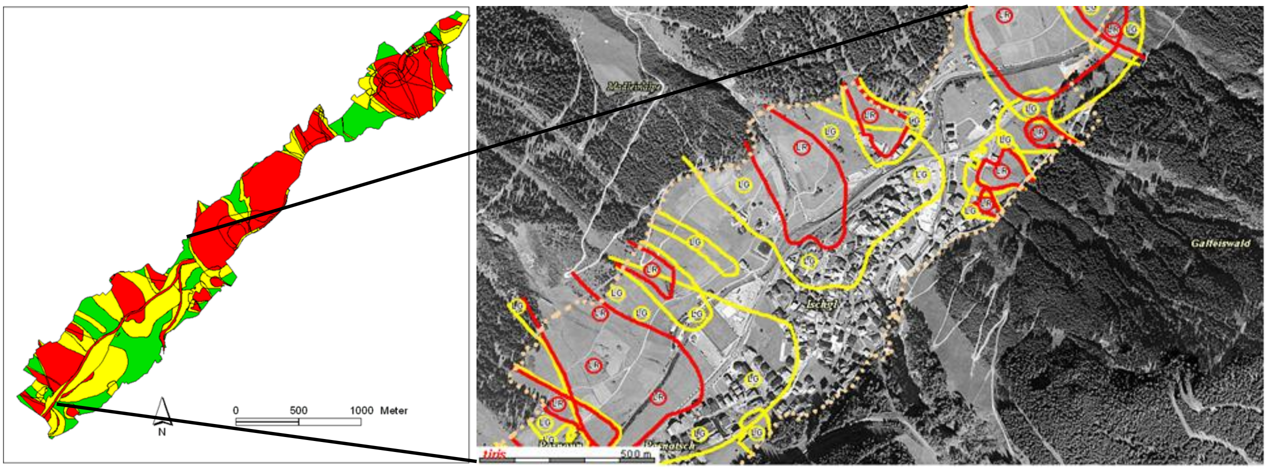


**Figure 1.8:** Permanent settlement area and endangered areas by Alpine risks (avalanches, floods and debris flows) in the municipality of Ischgl, Federal State of Tyrol, Austria (“risk-free” ares: green, medium-risk areas: yellow and high-risk areas: red). The aerial photograph on the right side shows the interference of settlements with avalanche risks (the dotted line is the border of the permanent settlement area); Source: TIRIS.

## Special situation of lateral valleys

In the case of Alpine lateral valleys, there is mostly only one lifeline by which the valley can be reached. If transport networks are interrupted due to a hazard event, this will have severe direct and indirect consequences for the valley´s wealth, but also causes difficulties for the emergency and crisis management. Consequently, the transport networks in Alpine areas are critical bottlenecks and key vulnerability to natural hazards (see Figure 1.8). Hence, enormous efforts are made to protect lifelines – also in remote areas with only few inhabitants. Figure 1.9 illustrates a road protection against avalanches that costs about 15 000 Euro per meter.

**Figure 1.9:** Road protection against avalanches in the Sellrain valley, Tyrol, Austria. Source: H. Cammerer.

### Monosectorality of Alpine economies and high mobility of manpower

Alpine areas are one of the main recreational areas in central Europe with about 120 million guests per year (Permanent secretary of Alpine Convention, 2010b). With the boom of summer resorts in the early 20th century and skiing areas in the second half of the last century, the remote regions´ income is nowadays mainly based on tourism. However, the Alpine Space is experiencing conflicting development trends with some regions on the growing and winning side while others are suffering decline and depopulation (Bätzing 2005). Therefore, there is a high mobility of working people and a high dependence of employees on commuting from valleys to centres. For example, in some municipalities about 50% of the total workforce is forced to commute every day, which emphasises the bottleneck function of transportation infrastructure for regional economies. Furthermore, the touristic infrastructures (e.g. hotels, skiing resorts) are also exposed to Alpine hazards, and a breakdown of tourism could imply substantial losses in regions, where tourism is the main source of income. Tourism also implies that there is a high seasonal variability in the number of (temporal) residents, which has to be accounted for in emergency management plans.

- → Intermixtures and multiple processes are regularly observed in Alpine hazards and trigger high economic losses due to natural hazards. The marginal permanent settlement area in mountain regions forces people to build nearby water bodies and other risky areas and, thus, increases the exposure to natural hazards. Moreover, the lacking possibilities of substitution of lifelines and transport networks in Alpine lateral valleys, the monosectorality of production, and the high mobility of manpower of Alpine economies lead to special socio-economic vulnerabilities of mountain regions. The combination of increasing exposure, due to the general growth of touristic activities, and hence, rising assets at risk will cause important future land use conflicts and triggers the need for integrated methods in assessing natural hazards losses.
- → The frequency of extreme weather events, most likely to increase due to climate change (Haeberli & Maisch 2007, Allamano et al. 2009), in combination with the lack of alternative locations for structures at risk, general growth tendencies in touristic regions (Bätzing 2005) and limited accessibility of Alpine lateral valleys in emergency situations characterise the risk setting in many parts of the Alps. This combination makes Alpine regions an object for special risk research.

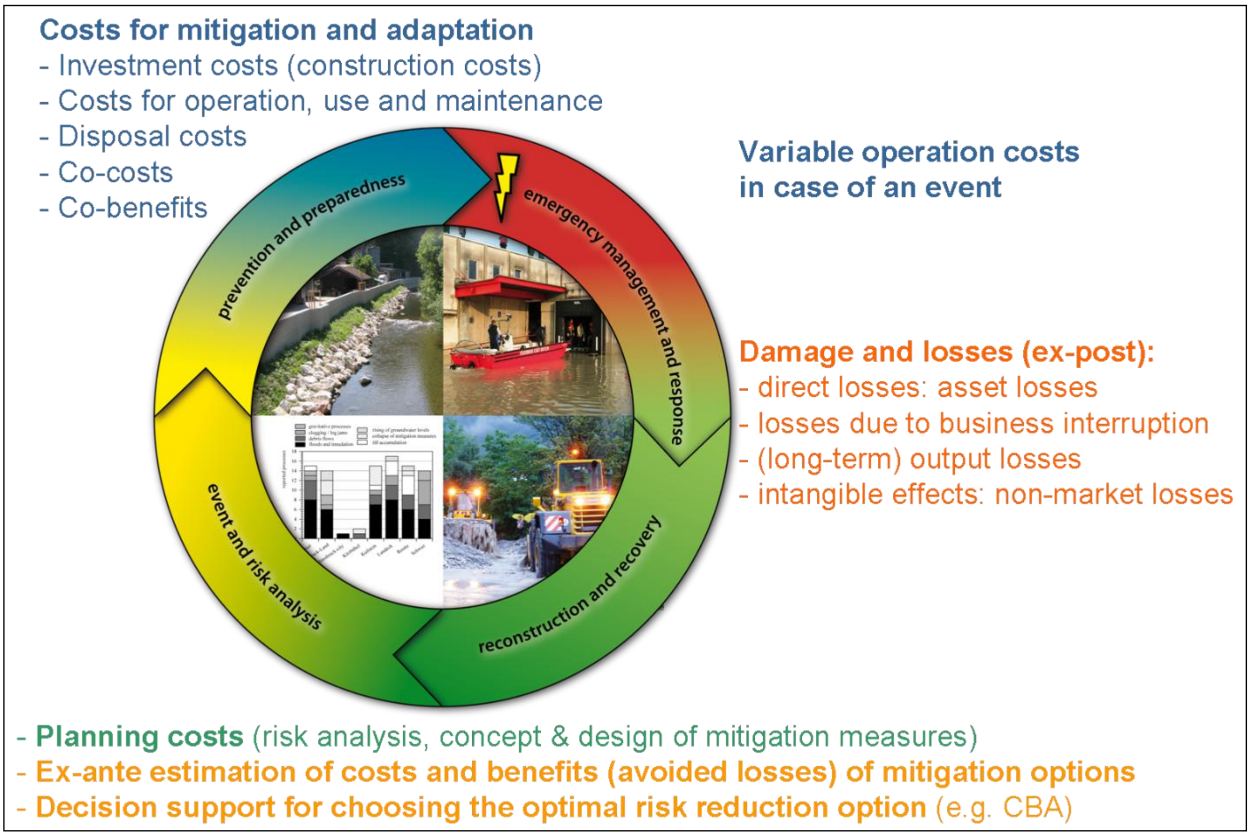
## 1.4 Alpine risks, risk management and associated cost categories

Due to their exposure to various natural hazards and due to their special vulnerabilities, alpine countries have been dealing with the management of natural hazards and risks for a long time. For instance, the Austrian Service for Torrent and Avalanche Control was already founded in 1884. This long experience and recent events with heavy impacts, e.g. the avalanche winter in 1999 or the severe floods in August 2002 and August 2005, triggered new approaches to deal with natural hazards in an integral and sustainable way.

Switzerland can be seen as the forerunner of an integrated nationwide risk management strategy. The Swiss National Platform for Natural hazards (PLANAT) was founded in 1997 and developed a cross-linked superior strategy to manage natural hazards and risks. The main foci concentrate on clear aims to improve security in mountain regions, to guarantee acceptable risk with uniform criteria, to reduce potential risks and to allocate resources in an efficient and effective way to optimise risks (PLANAT 2004). This concept bases on several pillars:

- risk analysis (What can happen? How likely is it? What are the consequences?)
- risk assessment (What may (not) happen?)
- integrative planning of measures (What safety for which price? Which measures can and should be implemented?)
- risk communication as basis for risk awareness and
- strategic controlling and monitoring of these aims.

This approach of dealing with natural hazards and risks is illustrated by the risk management cycle (Figure 1.10), which has now been widely accepted. For example, it has also been implemented in Austria and Slovenia (see e.g. Papež 2011) and serves as a basis for the work of the international Platform on Natural Hazards of the Alpine Convention (PLANALP).



**Costs for mitigation and adaptation**
- Investment costs (construction costs)
- Costs for operation, use and maintenance
- Disposal costs
- Co-costs
- Co-benefits

**Variable operation costs in case of an event**

**Damage and losses (ex-post):**
- direct losses: asset losses
- losses due to business interruption
- (long-term) output losses
- intangible effects: non-market losses

- **Planning costs** (risk analysis, concept & design of mitigation measures)
- **Ex-ante estimation of costs and benefits (avoided losses) of mitigation options**
- **Decision support for choosing the optimal risk reduction option** (e.g. CBA)

**Figure 1.10:** The risk cycle as a concept for an integral management of natural hazards and risks (based on: The Federal Office for Civil Protection FOCP, Switzerland) as well as related cost categories.

Four phases are distinguished in the risk management cycle (see e.g. Kienholz et al., 2004): 1) disaster response during a hazardous event, 2) recovery, 3) risk analysis and assessment as well as 4) disaster risk reduction which is primarily aimed at preventing and mitigating damage. A prerequisite for effective damage prevention is a thorough analysis and a subsequent assessment of risks, which includes analyses and estimations of flood impacts. Therefore, different cost types that have been used in the project ConHaz are roughly attached to the four specific phases of the risk management cycle in Figure 1.10.

Commonly, cost assessments of natural hazards can be separated into ex-ante and ex-post methodologies. The first approach tries to quantify possible losses caused by hazards before an event happens, whereas ex-post methods assess the losses which happened during and after the event (Messner et al. 2007). Amounts of actual damage and losses can thus be detected ex-post, potential losses ex-ante. Relevant data and methods will be further discussed in Chapter 2. In the project ConHaz, there is a distinction of direct, indirect and intangible losses. Direct losses (also called capital losses) occur due to the physical contact of elements at risk with water, snow or solids (debris, stones). They can often be assessed by actual repair costs. Indirect damages or output losses are induced by direct impacts, but occur – in terms of time and space – outside the hazard event or the affected area. They mainly result from an interruption of economic and social activities (Parker et al. 1987). Intangible effects mostly refer to losses that can be difficult assessed in monetary terms since they are not traded at the market, like loss of life, injuries, and ecological effects (Markantonis et al. 2011).

Losses caused by the disruption of production processes (also called business interruption) are treated as separate category of losses in the project ConHaz. The main reason for this is that business interruption can be traced back to the physical impact of the hazardous event on commercial buildings, machinery and movable goods, which then causes a decline of production. Therefore, losses due to the disruption of production processes occur in industrial, commercial or agricultural areas that are directly affected by a hazard (Bubeck & Kreibich 2011). Losses due to the interruption of production processes that occur outside of the affected area (e.g. due to supply difficulties in the production chain) are defined as indirect damage or output losses (Przyluski & Hallegatte 2011).

During the phase of risk analysis and planning of risk reduction measures the same categories of losses are quantified in order to assess the amount of loss that could be avoided by certain mitigation measures. These ex-ante loss assessments are further complemented by estimations of the (investment and operation) costs of the planned measures (see Bouwer et al. 2011). Costs and benefits are finally compared by methods for decision support in order to identify cost-effective measures and to find the best risk reduction strategy. Methods for these tasks will be further discussed in Chapter 3.

In Chapter 4, we finally look at the present expenses for mitigation and adaptation in alpine countries. Whereas mitigation combines structural and non-structural measures to minimise the adverse effects of natural hazards (ISDR 2002) on a short- and midterm perspective, adaptation refers to a long term process of adjustment to climate change (and other changes) and coherent negative effects to alpine human-environment systems.

Mitigation, which is often also called “risk reduction” or “prevention, precaution and preparedness”, can be structural (technical measures) or non-structural (e.g. spatial planning, early warning, local prevention and biological measures such as protection forests). In Austria, mitigation is divided in technical mitigation, spatial planning and temporal measures, like road blocks and limited access to certain areas (Rudolf-Miklau 2009). From a broader perspective, mitigation includes all measures, which minimise the impact of natural hazard events. Therefore, in the ConHaz-Project an expanded scheme and classification of mitigation has been used (see Table 1.6 and Bouwer et al. 2011). Whereas the categories 2 to 4 refer to the physical mitigation, the categories 1 and 5 to 9 represent non-structural measures. Risk transfer and financial incentives are often not seen as part of mitigation, but they help to facilitate private precaution and fast recovery from damaging events and are thus part of an integrated risk management.

In practise, measures of different categories might be combined for an optimal risk reduction, e.g. a water management plan might comprise retention measures, dams and several other provisions. Apart from costs for planning and investment costs for setting-up or constructing the systems, operating costs for the usage and maintenance of the systems need to be considered. In some cases, operating costs can be divided into normal (fixed) costs and variable (additional) costs that depend on the occurrence and severity of the hazardous events.

Finally, real expenses for mitigation and actual losses might improve the cost estimations that have to be performed in the framework of risk analysis and assessment. However, the assumptions for the monetary valuation (e.g. by replacement or depreciated values) might differ and depend on the task at hand (for a discussion see e.g. van der Veen & Logtmeijer 2005, Merz et al. 2010). Moreover, prices are changing in time. Hence, the reference year of costs has to be reported so that it is possible to correct data from different years by accounting for inflation (see Thieken et al. 2010).

**Table 1.6**: Mitigation categories in the case of natural hazard management, Source: Bouwer et al. (2011).

| Mitigation category | Examples |
|---|---|
| 1 Management plans, land-use planning and climate adaptation | spatial planning; adaptation strategies |
| 2 Hazard modification | artificial avalanche release, retention measures |
| 3 Construction of new infrastructure | reservoirs, dams, snow sheds, walls, snow bridges |
| 4 Mitigation measures (stricto sensu) | hazard-proof building, reforestation |
| 5 Communication (in advance of events) | education of public including hazard and risk maps as well as information about appropriate behavior in risky situations, training of experts |
| 6 Monitoring and early warning systems (just before events) | hydrological and meteorological monitoring; forecasting; extreme weather warning signals |
| 7 Emergency response and evacuation | evacuation, emergency services and aid, response and recovery operations |
| 8 Financial incentives | Financial institutions, subsidies |
| 9 Risk transfer | Insurance mechanisms, compensation by governments |

→ Catastrophic natural hazard events in the last 20 years initiated a rethinking in natural hazard management in the Alpine Space. In particular, Slovenia, Switzerland and Austria developed integrated models and methods to assess natural hazards. Generally, the integration and cooperation of public and private institutions, the establishment of national and international platforms (e.g. PLANAT - Switzerland, Intraprevent - International, PLANALP - Alpine Convention), the exchange and harmonisation issues of data, the development in direction of an integral / holistic understanding of risk, the standardisation of terms and definitions and the implementation of decision support systems based on risk concepts and cost-effective planning and action are basic pillars of recent progress in natural hazard management in alpine countries.

# 2 Costs of Alpine Hazards: Evidence from past losses

This chapter describes actual losses caused by alpine hazards and methods for event documentation and the (ex post) collection of loss data.

## 2.1 Losses caused by Alpine hazards

In order to illustrate the current amount of losses caused by floods, geologic mass movements, debris flows and avalanches in Alpine countries, this section deals with loss statistics of past events that are documented in the publicly available OFDA/CRED International Disaster Database (EM-DAT). Within EM-DAT 150 catastrophic events caused approximately US$ 51 billion direct losses (Table 2.1) and more than 4000 fatalities (Table 2.2) in the last 60 years in Austria, Germany, France, Italy, Slovenia and Switzerland. However, these figures also include non-alpine hazards in these countries.

**Table 2.1:** Overview of counted hazards and estimated direct losses in US$ from 1950 to 2009 in countries with part of surface within the Alps[1]; Source: EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be - Université Catholique de Louvain - Brussels - Belgium.

| | Number of events | | | | Estimated direct damage in Mio. US$ | | | |
|---|---|---|---|---|---|---|---|---|
| | Floods | mass m. wet[2] | mass m. dry | **sum** | floods | mass m. wet | mass m. dry | **sum** |
| **Austria** | 15 | 0 | 8 | **23** | 3 594.2 | 0 | 41.6 | **3 635.8** |
| **France** | 38 | 3 | 6 | **47** | 5 137.9 | 0 | 10.8 | **5 148.6** |
| **Germany** | 16 | 0 | 1 | **17** | 14 039.6 | 0 | 6.2 | **14 045.8** |
| **Italy** | 32 | 0 | 12 | **44** | 22 780.6 | 0 | 1 359.2 | **24 139.8** |
| **Slovenia** | 1 | 0 | 0 | **1** | 5.0 | 0 | 0 | **5.0** |
| **Switzerland** | 8 | 0 | 10 | **18** | 2 848.5 | 0 | 1 215 | **4 063.5** |
| **Sum** | **110** | **3** | **37** | **150** | **48 405.7** | **0** | **2 632.8** | **51 038.6** |

The Figures 2.1, 2.2 and 2.3 illustrate the EM-DAT data cartographically. The maps are based on the same data shown in the Tables 2.1 and 2.2, but here the disaster subtypes were used to identify floods (incl. flash floods), (snow) avalanches, and landslides. Some events were not considered due to missing spatial data. The figures illustrate that avalanches cause a high number of fatalities, whereas floods are responsible for the highest economic impacts as well as for a great number of affected people.

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[1] This table is produced on the basis of the original EM-DAT data. Because of inconsistencies and differences in data quality, figures from other databases are likely to differ.

[2] EM-DAT distinguishes two generic categories for disasters (natural and technological). The natural disaster category is further divided into five subgroups, which in turn cover 12 disaster types and more than 30 sub-types. Mass movements (dry): events originating from solid earth, mass movements (wet) as part of hydrological hazards (events caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind set-up). floods - general river flood, flash floods , mass movements (dry): rockfall, snow avalanche, debris avalanche, landslides; mass movement (wet) - rockfall, landslides, avalanches (snow, debris). For a disaster to be entered into the database at least one of the following criteria must be fulfilled: ten or more people reported killed, hundred or more people reported affected, declaration of a state of emergency, and call for international assistance. (http://www.emdat.be/explanatory-notes, 6.7.2011).

The data in Table 2.1 indicates that there are only small losses due to landslides and avalanches. However, a different picture arises when other data sources are used. For example, in the case of avalanches, national data of the Austrian Service for Torrent and Avalanche Control recorded approx. 183 events in the year 2009, in which monetary damage are mentioned, but not quantified (Federal Ministry of Agriculture, Forestry, Environment and Water Management 2009). On the contrary, single catastrophic events are often overestimated in international data bases. For example, the 1999 avalanches in Galtür and Valzur, Federal State of Tyrol, Austria, was recorded with 38 fatalities, several destroyed structures, disruption of transport networks for several days and estimated direct losses of about € 10 million by Heumader (2000), while the EM-DAT expresses this event with an estimated direct loss of USD 42 million and 50 fatalities.

**Table 2.2**: Overview of recorded hazards, number of affected people and fatalities from 1950 to 2009 in countries with part of surface within the Alps; Source: EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be - Université Catholique de Louvain - Brussels - Belgium.

| | **Total affected people**[3] | | | | **Fatalities**[4] | | | |
|---|---|---|---|---|---|---|---|---|
| | floods | mass m. wet | mass m. dry | **sum** | floods | mass m. wet | mass m. dry | **Sum** |
| **Austria** | 61.416 | 0 | 10.380 | **71.796** | 39 | 0 | 358 | **397** |
| **France** | 89.894 | 52 | 286 | **90.232** | 225 | 64 | 114 | **403** |
| **Germany** | 540.270 | 0 | 0 | **540.270** | 56 | 0 | 5 | **61** |
| **Italy** | 2.860.571 | 0 | 19.596 | **2.880.167** | 698 | 0 | 2.460 | **3.158** |
| **Slovenia** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** |
| **Switzerland** | 5.601 | 0 | 3.851 | **9.452** | 10 | 0 | 195 | **205** |
| **Sum** | **3.557.752** | **52** | **34.113** | **3.591.917** | **1.028** | **64** | **3.132** | **4.224** |

These examples illustrate that worldwide databases with defined thresholds for documentation mostly cover catastrophes with large affected areas, a high number of direct losses and a certain number of fatalities. On the contrary, they tend to neglect small scale hazards, like avalanches and torrent processes in mountain areas. The outcomes of an analysis of worldwide data are country-profiles, which display risks due to different hazards with an inherent scale bias (see footnote[1]).

In addition, also databases, which were developed for the same scale, can be inconsistent. For instance, the Munich Re database NATHAN reports losses associated with floods since 1960 with 76 billion Dollars while the EM-DAT estimates 150 billion Dollars (Gall et al. 2009).

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[3] Total affected: sum of injured, homeless, and affected. Injured: People suffering from physical injuries, trauma or an illness requiring medical treatment as a direct result of a disaster. Homeless: People needing immediate assistance for shelter. Affected: People requiring immediate assistance during a period of emergency; it can also include displaced or evacuated people. (http://www.emdat.be/explanatory-notes, 6.7.2011).

[4] Persons confirmed as dead and persons missing and presumed dead (official figures if available). (http://www.emdat.be/explanatory-notes, 6.7.2011).

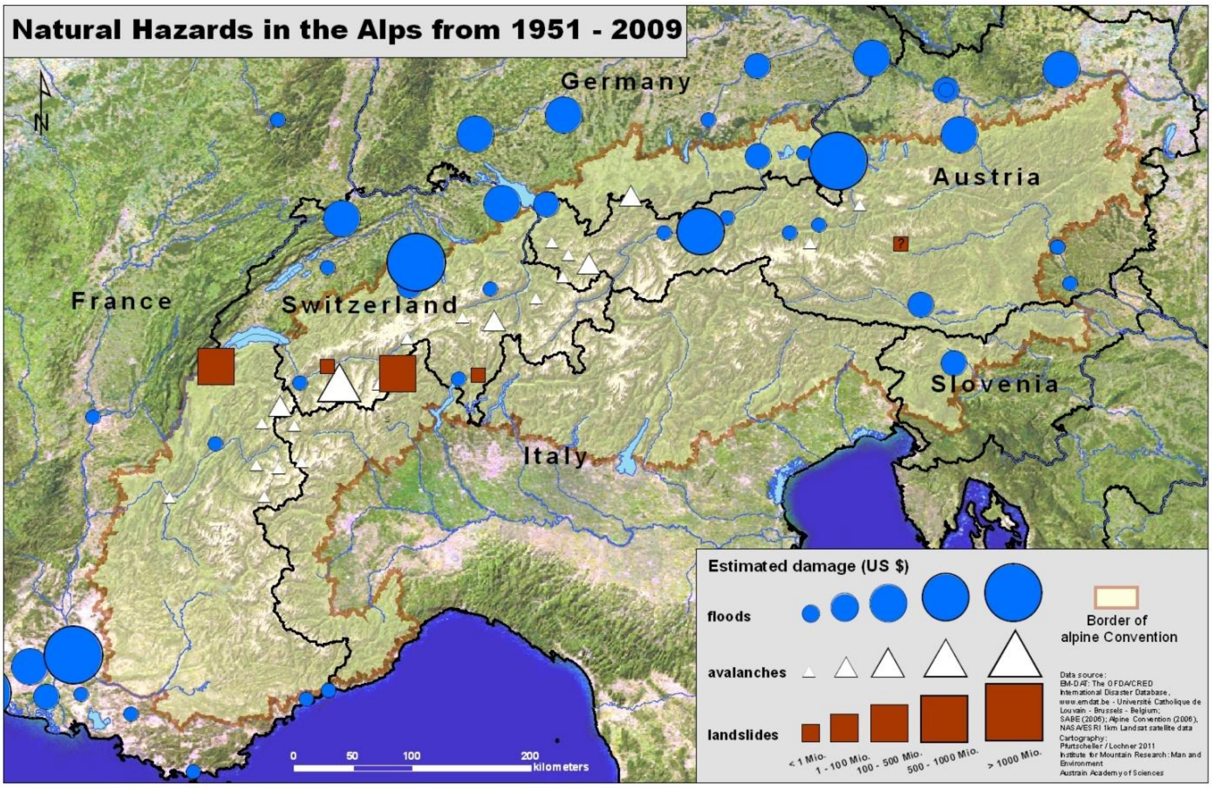

**Figure 2.1**: Cartographical overview of recorded hazard events and estimated direct losses in US$ from 1951 to 2009 in countries with part of surface within the European Alps; Source: EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be - Université Catholique de Louvain - Brussels - Belgium.

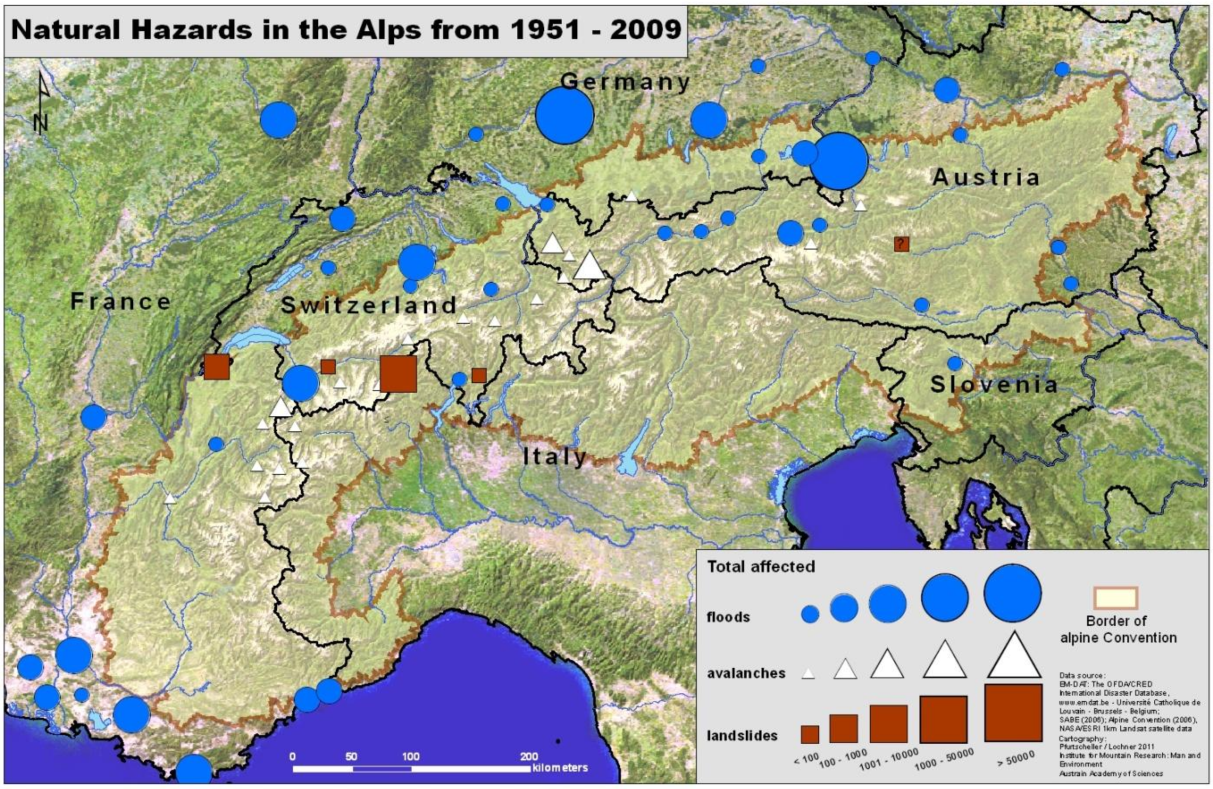

**Figure 2.2:** Cartographical overview of recorded hazard events and the number of affected people from 1951 to 2009 in countries with part of surface within the European Alps; Source: EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be - Université Catholique de Louvain - Brussels - Belgium.

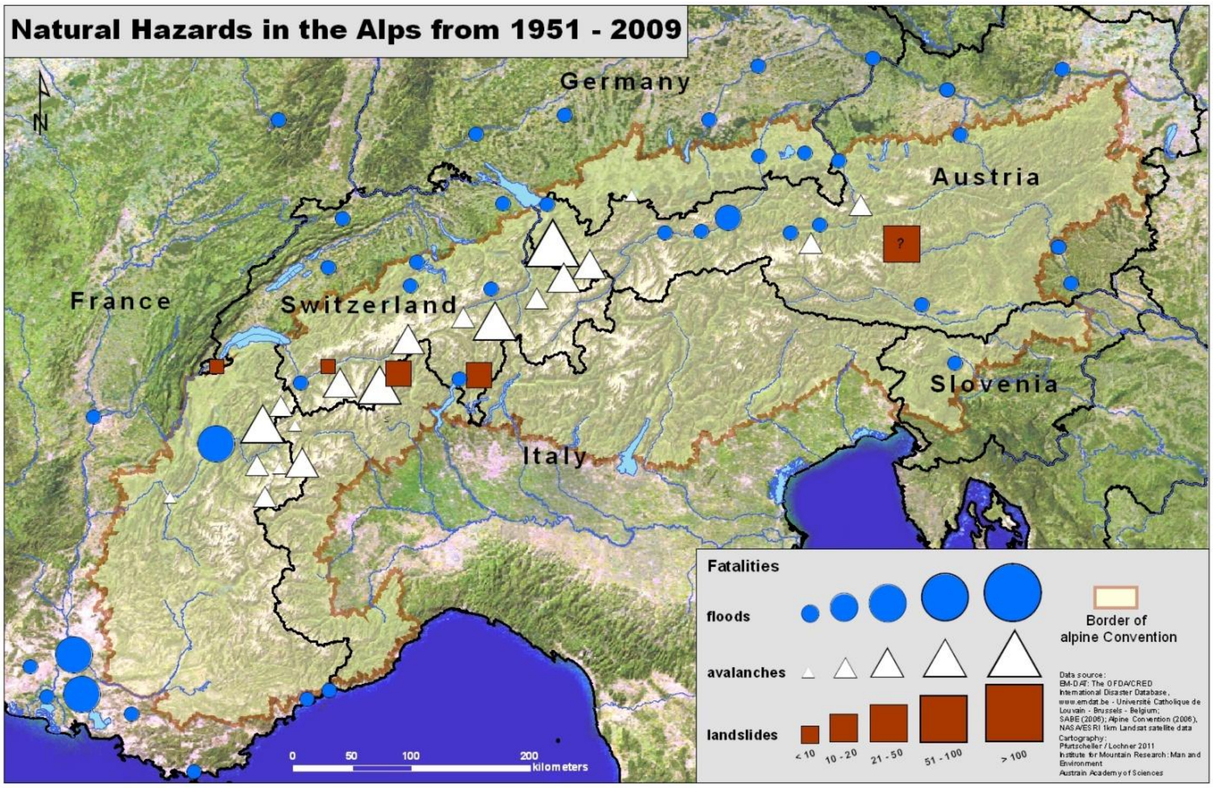

**Figure 2.3:** Cartographical overview of recorded hazard events and the number of fatalities from 1951 to 2009 in countries with part of surface within the European Alps; Source: EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be - Université Catholique de Louvain - Brussels - Belgium.

When using and interpreting disaster statistics, it should be considered that loss databases were created by multiple agencies for diverse purposes and audiences. They thus have varying levels of detail. Selection criteria might lead to over- or underrepresentation of certain types of hazards and several biases in the data as identified by Gall et al. (2009). However, end users are often unaware of these biases and use loss figures uncritically (see Gall et al. 2009 for a general discussion or Thieken et al. 2010 for a discussion on flood loss data).

The crucial point regarding data and databases of natural hazard impacts is stated by Gall et al. (2009, p. 808) as follows: “The time is now upon us to establish the much needed and long overdue National Inventory of Hazard Events and Losses (note from the authors: for the U.S.), an open access comprehensive data clearinghouse for natural hazard loss information. The policy imperative is clear: how can we reduce losses from natural hazards when we do not know how such losses are counted and when and where they occur?” Similar holds for Europe and the European Alps, although the alpine countries were among the first that agreed on a common approach for event documentation DOMODIS (Hübl et al. 2002, see below).

→ Existing macro scale loss databases are inadequate to reflect regional risks and actual losses due to Alpine hazards. In fact, small scale events are underrepresented in worldwide databases. Therefore, specific and more detailed data bases are needed for a reliable cost assessment.

## 2.2 Loss data bases for Alpine Countries

Comparable and consistent data on disaster losses are required for a number of policy issues in order:

- to assess the influences of climate, population growth, land use and policies on trends in losses (Downton et al. 2005),
- to set priorities between competing demands for national and international budget allocations (Guha-Sapir & Below 2002),
- to evaluate policy successes and failures on the basis of trends and spatial patterns of damage and to think about new policies (insurance, climate policies) (Downton & Pielke 2005) and finally
- to set priorities about what kind of research to fund as well as to evaluate contributions of science to real-world outcomes (Downton & Pielke 2005).

In most cases, damage data that are aggregated at a regional or national level (event-specific data bases) are sufficient for these purposes. However, very detailed data on specific damaging processes at affected objects are needed for understanding, planning and evaluating disaster risk reduction. Particularly, there is a growing demand for loss modelling, i.e. the estimation of potential losses. In order to derive loss models or loss functions, factors and processes that influence the type and extent of damage have to be analysed and understood. Therefore, the collection of loss data that is linked to process parameters becomes more and more important.

Different federal agencies, research projects and insurance companies have collected information and data on natural hazards and resulting losses. Table 2.3 shows a selection of important natural hazard databases with relevance for the alpine space. The heterogeneity and a lack of comparability of these data become apparent. Terminological inconsistencies between databases and between the original loss data source and the databases are also a problem. For example, the classification of debris flows either to landslides or to flood events is often inconsistent. Furthermore a major methodological problem is the varying threshold criteria that were found across different loss databases. For example, many historical events that caused monetary losses without exceeding local response capacities are not recorded in EM-DAT (see also section 2.1). The exclusion of small-scale events by global databases like EM-DAT and NATHAN is less surprising, considering the feasibility, management, and resources needed to compile and maintain such a large volume of data, but cause an inherent “catastrophe bias” (Gall et al. 2009).

Most of regional or national databases focus on the registration of events with no or incomplete information on (monetary) losses. As the assessment of indirect losses is a very difficult task – they depend on the scale of the analysis, are difficult to measure and can often only be assessed by models (see Greenberg et al., 2007 for a review) –, this information is very rare; only EM-DAT gives partly information on indirect losses. Furthermore, the linkage between hazard impacts and resulting losses is still weak.

**Table 2.3:** Overview of databases and data on Alpine hazards and their specifications.

| Data on Natural Hazards in the Alpine Space | | | | | | |
|---|---|---|---|---|---|---|
| **Country of origin** | **Austria** | | **Belgium** | **Germany** | | |
| **Basic characteristics** | | | | | | |
| **Name** | **GEORIOS** | **WLK (WLV)** | **EM-DAT** | **NATHAN** | **IAN** | **HOWAS 21** |
| **Institution/Ownership** | Geological Survey of Austria | Torrent and avalanche control (WLV) | Centre for research on the Epidemiology of Disaster, Catholic University of Louvain | Muniche Re Group | Bavarian Environment Agency (LfU) | Helmholtz-Centre Potsdam, German Geo research Centre GFZ |
| **URL** | www.geologie.ac.at | www.naturgefahren.die-wildbach.at | www.emdat.be | mrnathan.munichre.com | www.lfu.bayern.de/wasser/ian/index.htm | nadine-ws.gfz-potsdam.de:8080/howasPortal/client/start |
| **Spatial coverage** | Austria | Austria | Global | Global | Bavaria | Germany |
| **Spatial resolution** | single element at risk | single element at risk | National | National | single element at risk | single element at risk |
| **Temporal coverage** | 1850 - present | n/a | 1900 - present | 1811 - present | n/a | 2005 - present |
| **Recording tresholds** | Detailed Information to Mass Movements in Austria | Main Natural Hazards in Austria | ≥ 10 fatalities, ≥ 100 affected, declaration of state of emergency, or call for international assistance | Major Natural Catastrophes | Natural Hazards in Germany | not defined |
| **Number of records** | 22.000 | 21.000 | ≥ 16.000 | > 2.600 | n/a | 6.000 |
| **Covered types of alpine Hazard** | | | | | | |
| **Floods** | - | + | + | + | + | + |
| **Landslides** | + | + | + | + | + | - |
| **Snow avalanche** | - | + | + | - | + | - |
| **Extreme weather** | - | - | + | + | - | - |
| **Covered types of losses/damage** | | | | | | |
| **Direct losses** | +<br>(no monetary values) | +<br>(no monetary values) | +<br>(non insured) | +<br>(insured) | +<br>(no monetary values) | +<br>(partly monetary values) |
| **Indirect losses** | - | - | +<br>(partly if available) | - | - | - |
| **Intangibles** | +<br>(partly fatalities) | +<br>(partly fatalities) | +<br>(fatalities/affected) | +<br>(fatalities) | +<br>(partly fatalities) | - |
| **Data Sources and quality** | | | | | | |
| **Data sources** | Archive, scientific studies and publications, historical data, Internet, etc. | Reports from Experts in the several sections from the torrent and avalanche control austria | U.N. agencies, national governments, Red Cross, World Bank, reinsurers, Associated Foreign Press, etc. | MR NatCatSERVIVE, national insurance associations, insured, press and news agencies, national weather services, etc. | Data from Hydrology Agency (Event documentation), GEORISK data, Avalanche land register, other projects (DisALP etc.) | German speaking Geo research Organisations (GFZ, alpS, German reinsurance AG etc.) |
| **Quality check** | n/a | n/a | n/a | n/a | n/a | Advisory Board (out of special users) Assessment and illustration of data quality by different criteria |
| **Update interval** | Continuously | Continuously | Quarterly | Continuously | Continuously | Continuously |
| **Accessibility/Raw data** | | | | | | |
| **Output (map/text/tables)** | Map/Text | Map/Text/Tables | Download (Tables/csv) | Map/Text/Tables | Map/Text | Map/Text/Tables |
| **Accessibility** | Free | Login needed | Login on request, partly free | Login needed | Free | Login on request, partly free |
| **Data use** | | | | | | |
| **Main users/audience** | Scientific Experts and interested public | Scientific Experts and consulting/offices | Humanitarian aid community and many branches of research | Insurance industry | Scientific Experts, offical agencies and interested public | Scientific Experts and interested public |

**Table 2.3 continued**: Overview of databases and data on Alpine hazards and their specifications.

| Data on Natural Hazards in the Alpine Space | | | | | | |
|---|---|---|---|---|---|---|
| **Country of origin** | **France** | **Italy** | **Switzerland** | | | |
| **Basic characteristics** | | | | | | |
| **Name** | **brgm** | **IFFI** | **StorME** | **Swiss Avalanche damage database** | **Swiss flood and landslide damage database** | **Sigma** |
| **Institution/Ownership** | brgm - Geoscience for a sustainable Earth | APAT - Geological Survey of Italy | Federal Office for the Environment (BAFU) | Institute for Snow and Avalanche Research (SLF) | Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) | Swiss Reinsurance Company (SwissRe) |
| **URL** | www.mouvementsdeterrain.fr | www.sinanet.apat.it/progettoiffi | www.bafu.admin.ch/naturgefahren/01922/01926/01927/index.html | http://www.slf.ch/dienstleistungen/daten/index_DE | http://www.wsl.ch/fe/gebirgshydrologie/HEX/projekte/schadendatenbank/index_DE | http://www.swissre.com/sigma/ |
| **Spatial coverage** | France | Italy | Switzerland | Switzerland | Switzerland | Global |
| **Spatial resolution** | single element at risk | single element at risk | single element at risk | single element at risk | single element at risk | single element at risk |
| **Temporal coverage** | n/a | n/a | n/a | 1936 - present | 1972 - present | 1970 - present |
| **Recording tresholds** | not defined | Landslides over the whole Italian territory | Natural Hazards in Switzerland with: injured or dead people, consequences on traffic and settlements, damages on infrastructure > 10.000 SFr. | Every Avalanches caused damage in Switzlerand since 1936 | Floods, mass movements (falls since 2002) and debris flows caused damage in Switzerland | One of the folowing inclusion criteria: 20 deaths and/or 50 injured and/or 2000 homeless and/or >35 Mio. US$ |
| **Number of records** | n/a | > 460.000 | ca. 29.000 | ca. 13.000 | 18.000 | 7.000 |
| **Covered types of alpine Hazard** | | | | | | |
| **Floods** | - | - | + | - | + | + |
| **Landslides** | + | + | + | - | + | + |
| **Snow avalanche** | - | - | + | + | - | + |
| **Extreme weather** | - | - | - | - | - | + (no drought) |
| **Covered types of losses/damage** | | | | | | |
| **Direct losses** | +<br>(no monetary values) | +<br>(no monetary values) | +<br>(partly monetary values) | + | + | + |
| **Indirect losses** | - | - | - | - | +<br>(partly lifeline interruption included) | - |
| **Intangibles** | +<br>(partly fatalities) | +<br>(partly fatalities) | +<br>(partly fatalities) | +<br>(dead, injured and evacuated people) | +<br>(dead, injured and evacuated people) | +<br>(dead, injured, missing and homeless people) |
| **Data Sources and quality** | | | | | | |
| **Data sources** | Inventories, archives, Information from science, etc. | National Projects (AVI, SCAI,CARG), Landslide inventories, River basin plans, Emergency Declarations, etc. | Historical maps and archives, road construction and railway companies | Messages from about 3000 newspapers in Switzerland and Information from mountaineers, mountain guides and mountain rescue | Messages from about 3000 newspapers in Switzerland and for big events Information from the Cantons and Insurance companies | Information include newspapers, Lloyds, primary insurance and reinsurance periodicals, internal reports, and online databases although no primary source is suggested |
| **Quality check** | Information to reliability of each dataset | Spatial data, Attribute and Geometry check, Verification with other datasets (AVI, SCAI, CARG…) - all done by APAT | n/a | n/a | n/a | n/a |
| **Update interval** | Continuously | Continuously | Continuously | Continuously | Continuously | Continuously |
| **Accessibility/Raw data** | | | | | | |
| **Output (map/text/tables)** | Download (csv) | Map/Text/Tables | Map/Text/Tables | Map/Text/Tables (with costs!) | One report every year | Yearly publication of "raw information" |
| **Accessibility** | Free | Login needed | Login needed | no access | no access | Login needed |
| **Data use** | | | | | | |
| **Main users/audience** | Geological Experts and interested public | Geological Experts | Scientific Experts and planning engineers (for hazard mapping) | Completion of the StoreMe database with costs and fatalities | Completion of the StoreMe database with costs and fatalities | Insurance industry (the database includes natural and man-made disaster!) |

This comparison of different data bases, the data analysis shown in section 2.1 as well as other studies (e.g. Downton & Pielke 2005, Downton et al. 2005) have revealed a range of problems with loss data, such as limited accessibility, inconsistencies between different data bases, lack of details or data errors. The underlying problem is the lack of standard methods and guidelines for collecting and reporting disaster losses data by international, federal, state and local agencies. This may lead to misinterpretations of such data by planners, decision makers and other end-users.

→ In general, most of the databases concentrate on processes, not on impacts or adverse effects, and there is a missing linkage of process and loss data. Most (international) databases focus on event data, not on object-related information. Indirect losses are rarely covered by the databases. Intangible effects are commonly restricted to the number of fatalities as well as the number of evacuated and affected people. Furthermore, different data bases are inconsistent, incomplete and incompatible.

## 2.3 Methods for event documentation and collection of loss data

A guideline, which focuses on the documentation of mountain disasters DOMODIS, has already been developed (Hübl et al. 2002). In Slovenia, damage assessment is facilitated by a strong and binding legislation (Papez 2011).

Hübl et al. (2002) proposed worksheets for the documentation of mountain disasters containing a standardised map legend, two sheets for basic data (i.e. event type, date and duration of the event, coordinates, damage to people, assets, infrastructure and forestry/agriculture, hazard zone, defence schemes, documentation of further information like maps, documents, newspaper, photographs) and two sheets for event data depending on the disaster type (floods, rock-fall, mudflow, avalanche etc.). For example, for floods the following information is considered: flood type (process), meteorological situation or other circumstances that caused the flood; channel processes, inundated area, area of deposits, map. Still, the DOMODIS guideline mainly focuses on the description of the natural processes, not on the documentation of impacts and losses.

In the guideline it is further suggested including the task “event documentation and data collection” ex-ante in the general organisation of disaster response and recovery. This guarantees that trained personnel is available for data collection in the case of a disastrous event. This organisational preparation should also include the development of check lists and worksheets for data collection and documentation.

To better assess the data quality, Hübl et al. (2002) proposed that events should be classified with regard to their spatial extent (affected area: A1: local – A2: municipal – A3: regional), their frequency (from F1: several time a year to F6: never observed before) and their impact/the damage they caused (M1: without damage – M2: damage was nearly caused – M3: damage was caused). In addition, data quality can be documented by four categories (MAXO):

- M: Measured, observed
- A: Assumed, estimated
- X: unclear, to be measured

- O: not determinable

Up to now, many alpine countries have implemented DOMODIS for event documentation, but they built up distinct national data bases. The DIS-ALP project uses this guideline in order to build up a disaster database for all Alpine countries (Hübl et al. 2006). Despite the good implementation of event documentation in alpine countries, the linkage between hazard processes, consecutive impacts and resulting losses are still weak (outcome of the ConHaz workshop).

### Documentation of losses in the framework of risk transfer mechanisms

During recovery and reconstruction the actual direct costs of a disaster, i.e. costs for cleaning-up, drying, repair etc. become apparent. It depends on the severity of the event and the system of risk transfer, whether these costs are recorded, how and by whom.

For insurance companies, a balance between the interests of the insured people, i.e. quick and sufficient compensation, and the interests of the company, i.e. realistic payments for losses at low costs for loss adjustment, has to be found (Schulze-Bruckauf 2005). Therefore, small losses are often regulated only on the basis of proofed payments (receipts, vouchers etc.) without inspection of the damaged object. Moderate and high losses, especially in the commercial sector, are documented and evaluated by trained building surveyors or loss adjustors (Schulze-Bruckauf 2005). In order to save costs for loss adjustments, additional information, e.g. about the flood characteristics, is hardly recorded so that only little can be learned about damaging processes. Further, knowledge about the insurance conditions, such as deductibles or limits of indemnity, is needed in order to correctly handle loss data from insurance companies for other purposes (see Müller et al. 2010).

Loss compensation by governmental disaster assistance is aimed at helping people quickly to regain their normal live and at distributing (tax payers') money on a principle of fairness, justice and equality (Kraus 2005). Therefore, funding guidelines are published, in which damage and associated eligible costs are clearly defined. These guidelines may vary between different administrations and may be altered for different disasters.

Three principles for loss compensation by disaster funds were found by Müller et al. (2010). First, a fixed amount of money is given to each affected household without further examination of the real damage. This quick and unbureaucratic approach is often used in Germany for the distribution of immediate funds that allow people to recover quickly from low damage. In a second approach, compensation corresponds to actual or estimated repair costs. For this, affected people have to fill in detailed application forms and the administration keeps track of repair costs, i.e. first damage records contain repair costs estimated by building surveyors; the figures are updated until everything is reconstructed and paid. However, only little or no additional information about the damaging processes (impacts like water levels or buildings characteristics) is recorded.

A third approach can be found in the province Lower Austria. After severe flooding in 2002, a standardized approach for the assessment of direct (flood) damage was developed for loss compensation in the framework of the Austrian disaster fund. On the basis of formerly observed flood damage data, unit damage values, i.e. a monetary amount per square meter, were derived for affected residential buildings and contents distinguishing two water levels (Amt der NÖ Landesregierung, 2007). Likewise, unit losses were derived for different crops. The unit values are updated on an annual basis (see www.noel.gov.at or Müller et al. 2010). The approach is not used for buildings with severe structural damage, oil contamination or for commercial/industrial properties. In these cases, on-site surveys are performed.

In order to bridge the gap between hazard impacts and resulting losses by integrating data collection in loss compensation, Elmer et al. (2010) developed a standard for the documentation of (flood) losses and influencing factors in various sectors. This guideline is focused on direct losses and business interruptions. It has already been used to document damage to Austrian railway infrastructure, which starts with the definition of several distinct classes for structural damage to particular elements at risk (e.g. cross-sections, bridges, see Moran et al. 2010). In a next step, financial damage as well as impact parameters can be linked to the structural damage.

## Event analysis

Event analyses are becoming an important tool to assess the economic impacts of natural disasters and to learn from past events. Due to the occurrence of several major hazard events in the Alps in the last decades, a lot of studies exist that analysed the impacts. The following studies were carried out in Switzerland:

- WSL & FOEN 2001 & Baur et al. 2003: storm ‘Lothar’,
- WSL/SLF 2000: avalanche winter of 1999,
- FOEN 2000: floods of 1999
- Bezzola & Hegg 2007: flood event 2005.

In Austria, the floods of 2002 and 2005 were analysed in detail (Habersack & Moser 2003, Sattler et al. 2003, Kletzan et al. 2004, Habersack & Krapesch 2006, Habersack et al. 2006). Nevertheless, these studies analysed primarily direct effects, due to the mostly missing data on indirect and intangible effects. The method to analyse economic damages as part of these studies is mainly based on questionnaires and primary data collection at diverse authorities, public bodies, and private companies.

Kletzan et al. (2004) in the case of the 2002 floods in Austria, but also Baur et al. (2003) in the aftermath of the storm ‘Lothar’, analysed also macroeconomic impacts (indirect effects on a macro scale). This was done on the one hand by macroeconomic modelling and on the other hand by detailed analysing of national balances, distribution, income and prices of timber, but also tourism decline. The method used by Kletzan et al. (2004) is described in the section 3.4 ‘Indirect effects’.

Bezzola G. R. & C. Hegg (eds.) 2007: Ereignisanalyse Hochwasser 2005, Teil 1 – Prozesse, Schäden und erste Einordnung. Bundesamt für Umwelt BAFU, Eidgenössische Forschungsanstalt WSL. Umwelt-Wissen Nr. 0707.

- *Explanation*: This event analysis was carried out by public bodies in the aftermath of the 2005 flood event. Besides the analysis of the natural processes (meteorology, hydrology, precipitation and runoff, sediments, etc.), also the impacts were assessed. In the database Stor-Me (see table 2.3), triggering processes, spatial effects, direct losses as reconstruction costs of private losses (structures, inventory, vehicles) and loss to infrastructure (transport, mitigation measures, forest, railways), but also business interruption loss are documented (total sum: SFr 3 billion). Among other things, newspapers were used as source of information.
- *Cost types addressed*: Insured and non-insured losses, comparison with historic and recent events (dimension of the flood, fatalities, and monetary losses if available).
- *Objective of the approach*: to analyse disastrous natural hazard events to understand the triggers and effects, but also to adapt to possible future hazard processes
- *Impacted sectors*: direct damages on public and private assets and infrastructure, insured loss of business interruption
- *Scale*: local / municipality scale, if the process can be connected to the damage
- *Expected precision (validity)*: medium, due to the involvement of all public bodies and missing sectors
- *Parameters used for determining costs:* destroyed / insured assets
- *Results and result precision*: direct damage on regional and national scale
- *Skills required*: statistics, GIS
- *Types of data needed*: data of direct damage on assets and infrastructure
- *Data sources*: The Federal Office for the Environment - FOEN collects the data in collaboration with the Swiss insurance cooperation (Schweizerischer Versicherungsverband), cantonal insurance companies and the Swiss hail insurance company
- *Who collects the data*: see data sources
- *How is the data collected*: questionnaire and analysis of databases
- *Is data derived ex-ante or ex-post*: ex-post
- Data quality: medium, high uncertainties regarding the exact localisation of processes and the cause and effect relationship

Recently, detailed surveys have been performed among flood-affected residential and commercial properties in order to collect losses and influencing factors (e.g. Ramirez et al. 1988; Joy 1993; Gissing & Blong 2004; Thieken et al. 2005; Zhai et al. 2005; Kreibich et al. 2007; Raschky et al. 2009). In contrast to the collection of data for loss adjustment, in most of the surveys only a representative sample is investigated. Samples can be taken randomly from the whole "population", in this case all damaged items/objects. In particular cases, lumped samples are preferred, i.e. some representative municipalities are chosen for investigation, where a complete survey of all damage cases is undertaken. When regions can be clearly distinguished by a certain variable, stratified samples can also be taken (see e.g. Schnell et al. 1999). For the actual data collection different methods such as on-site expert surveys, telephone interviews, written and online-polls can be used (see Müller et al. 2010). An additional approach is the collection of synthetic damage data by experts (buildings surveyors) for different impacts e.g. water levels and building types (Penning-Rowsell et al. 2005).

Depending on the particular aim of the survey, event and object characteristics, warning variables, social factors etc. are recorded in addition to information on the flood losses. The HOWAS 21 data in Table 2.3 serve as an example for this approach.

→ Although a guideline for the documentation of mountain disasters already exists and is implemented, there is still a gap between hazard and loss information, which is both needed for risk analysis and planning issues, in different databases. Up to now, no method is implemented in practise to overcome this problem.

# 3 Methods for assessing different costs of Alpine hazards (ex-ante)

The aim of this chapter is to introduce various methods for the assessment of costs of Alpine hazards as defined in chapter 1. The different methods are illustrated by case studies. Moreover, risk reduction as a societal desire and coherent adaptation measures are increasingly evaluated by comparing the benefits of a risk reduction measure – assessed in terms of avoided damage during the lifetime of the measure – and its costs. Therefore, one section deals with methods and tools for this kind of decision support.

## 3.1 Methods for estimating direct losses

Methods for estimating direct costs of Alpine hazards are based on asset valuation techniques in combination with damage functions, which are sometimes also called vulnerability, susceptibility or fragility functions depending on the discipline. In this report, these terms are used as synonyms. In general, the loss estimation procedure comprises three steps (see Merz et al. 2010 for floods):

(1) Classification of elements at risk by pooling them into homogeneous classes.

(2) Exposure analysis and asset assessment (valuation) by describing and classifying the number and types of elements at risk and by estimating their asset value (commonly distinguished into asset values of buildings, contents/moveable objects and fixed equipment).

(3) Susceptibility or vulnerability analysis by relating the resulting (relative) damage of the elements at risk to a characteristic that describes the intensity of the process (e.g. water level in case of floods or impact pressure in case of avalanches).

This procedure implies that the damage functions are expressed as relative damage (i.e. as percentage of the damaged property, damage ratio). The absolute amount of damage is achieved by a multiplication of the relative damage with the total asset value of the structure under study, which was estimated in step 2. As an alternative, step 2 and 3 can be combined in an absolute damage function that relates the absolute monetary damage of an element at risk to the process intensity.

Various methodological variations can be introduced in each of the three steps. For example, the classification of the elements at risk can be based on economic sectors, e.g. areas/elements used for residence, commerce, industry, agriculture or transport, in a first approach. Since elements of one economic sector may be very diverse, most damage assessments introduce sub-classes (see Merz et al. 2010 for further details), e.g. different (residential) building types or different company sizes in term of the number of employees or different production types as proposed in the reference installation approach (Geldermann et al. 2008).

The classification also depends on the scale of the investigation, i.e. the size of the investigation area, the required accuracy of the results as well as on the available data. Since many alpine hazards occur on the local to regional level (see Table 1.5), analyses on the micro-scale (e.g. Fuchs & Bründl 2005, Huttenlau 2010, Riskplan www.riskplan.admin.ch) seem to be far more common for alpine hazards than for other hazards, e.g. river floods in lowlands, where meso-scale approaches are frequently used.

In the exposure analysis and asset assessment different valuation approaches play a key role. Depending on the application of the cost assessment the monetary assessment of elements is done by replacement values, insured values, depreciated or market values (see e.g. Huttenlau & Stötter 2008 or Merz et al. 2010, for a discussion when which approach can be used).

On the meso-scale, the Rhine atlas of the International Commission for the Protection of the River Rhine (ICPR 2001) serves as a good example for the cross-country harmonisation of cost assessment since it estimates people at risk and direct losses for three inundation scenarios along the whole river Rhine from its origin in Switzerland to its delta in the Netherlands by means of one common approach. The risk mapping was done on the basis of the CORINE land cover data and standard (depreciated) values per m² per land use category. The standard values were derived from economic statistics of net capital stock. The values were adapted per country by the purchasing power (for the residential sector) and by the gross national product (GNP) for the commercial and industrial sectors (ICPR 2001).

An example on the micro-scale is given by Huttenlau & Stötter (2008), who developed an asset data base on the building level for the whole State of Tyrol, Austria, on the basis of average insured values. Asset assessment and valuation is independent of the natural hazard considered. Therefore, the data base was used for the assessment of direct losses of various scenarios of different natural hazards in Tyrol including floods, wind and hail storms, earthquakes and a complex scenario of landslide and flood processes in Huttenlau (2010).

The reflection of the specific impacts of a hazardous process on an element at risk as well as the vulnerability of the affected elements and regions in the cost assessment is the key challenge in the third step. This implies that specific damage functions have been developed for different regions and different hazardous processes.

There are some review papers on damage estimation, e.g. Blong (2003a), Douglas (2007), Spichtig & Bründl (2008), Merz et al. (2010) and Papathoma-Köhle et al. (2010). One important result of the reviews is that a variety of damage functions exists for earthquakes (see Blong 2003a), floods (Merz et al. 2010) and avalanches (BUWAL 1999), while there are only a few functions for mass movements or landslides (Douglas 2007, Blong 2003a). Only recently, some approaches have been developed (e.g. Cardinali et al. 2002; Bell & Glade 2004; Papathoma-Köhle et al. 2004; Blöchl & Braun 2005).

Some reasons for the different maturity of vulnerability assessments and risk management for different hazards are seen in i) the different ability of managers to change the hazard and the exposure level for different processes, ii) characteristic time and geographical scales of the processes, iii) the complexity of the damage processes (i.e. number of important influence factors) and iv) hence the modelling effort to quantify the effects of the event on structures, v) the repairability of damaged structures, vi) the consecutive danger for human lives that is caused by damaged properties (e.g. in case of earthquakes many fatalities are due to building collapses) and the vii) availability and accessibility of model input data and viii) availability of observed damage data (Douglas 2007).

In general, different types of damage functions can be distinguished (Kaly et al. 1999 quoted in Blong 2003a):

- absolute damage functions, i.e. absolute values of the monetary loss (estimate in USD or Euro for a given reference year) are related to hazard characteristics,
- relative damage functions: percental loss estimates, i.e. cost of damage or repair as a percentage of the total asset of the affected structure, or as numerical values that range between 0 and 1 (which can be interpreted as percentage damage),
- step damage function (relative): index values on a categorical scale are linked to hazard parameters and one index value represents a range of % losses.

With regard to alpine hazards, different hazard parameters have been selected to derive damage functions (see Table 3.1). For example, flood damage functions that are commonly related to inundation depth are partly adapted to alpine conditions, e.g. by including effects of debris, wood or flow velocity (e.g. Huttenlau 2010). In the case of rock falls, it is assumed by Huttenlau et al. (2010) that the vulnerability of elements at risk is so high that economic assets will be completely destroyed, in case they are affected by rock fall.

Some examples for damage functions for debris flows and avalanches are given in the Figures 3.1 and 3.2, respectively. In Figure 3.2, also differences in the susceptibility of buildings to avalanches are considered by providing individual damage functions for five different building categories. Such an approach to account for building susceptibility has also been developed by Schwarz & Maiwald (2008) for floods. Based on data from two well-documented events in Tyrol (Austria), Barbolini et al. (2004, quoted in Papathoma-Köhle et al. 2010) produced a vulnerability curve for (relative) building damage as a function of avalanche impact pressure and flow depth.

**Table 3.1**: Hazard characteristics that are used in damage functions for alpine hazards.

| Hazard type | Intensity parameter used in damage functions | References |
|---|---|---|
| **Floods** | Water depth h [m];<br>flow velocity v [m/s];<br>debris or wood content<br>(intensity v * h [m²/s]) | e.g. Huttenlau (2010)<br>(Bründl 2009) |
| **Debris and mud flows** | Depth of deposits [m] | Fuchs et al. (2007b) |
| **Landslides** | Intensity in kilo joule [kJ];<br>Affected [yes = total damage; no = no damage] | BUWAL (1999),<br>Glade (2003) |
| **Rock fall** | Intensity in kilo joule [kJ];<br>Affected [yes = total damage; no = no damage] | BUWAL (1999),<br>Huttenlau et al. (2010) |
| **Avalanches** | Intensity in kilo Newton per square meter (kN/m²);<br>Avalanche impact pressure (kPa)<br>Avalanche impact pressure (kPa) and flow depth [m] | BUWAL (1999),<br>Wilhelm (1997),<br>Barbolini et al. (2004) |

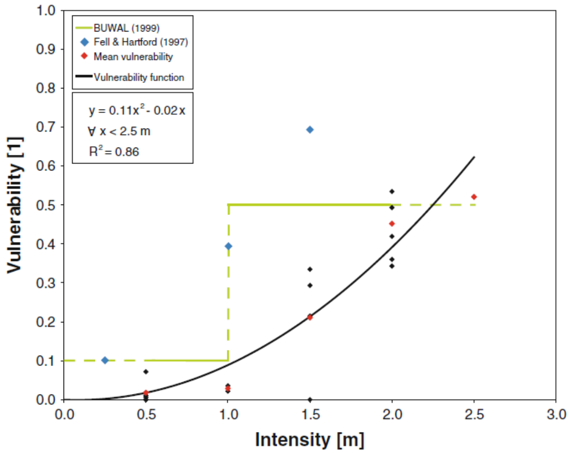

**Figure 3.1**: Generalised relation between debris flow intensity (deposition depth) and vulnerability (black curve as published by Fuchs et al. 2007b and green curve as published by BUWAL 1999); source: Papathoma-Köhle et al. (2010).

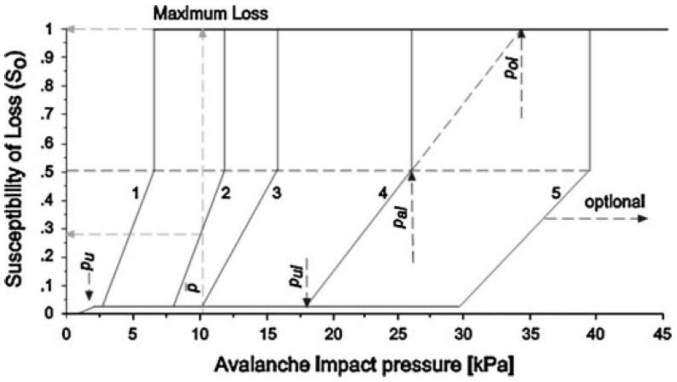

**Figure 3.2**: Relationship between avalanche impact pressure and the vulnerability of buildings for five building types: (1) lightweight construction, (2): mixed construction, (3): massive construction, (4): concrete reinforced construction, (5): reinforced construction; original source: Wilhelm (1997).

The review of Papathoma-Köhle et al. (2010) revealed that many approaches to assess vulnerability to alpine hazards are simply based on the type of processes (e.g. types of landslide) and the type of exposed element. Not all of them, however, deliver cost estimates.

In order to harmonise cost estimates, Blong (2003b) as well as Hollenstein (2005) proposed some directions for a standardized or generic risk modelling. For example, Blong (2003b) developed a damage index to estimate damage to buildings that may result from a range of natural hazards including landslides and floods. Due to the multiplicity of alpine hazards the application of such generic and standardized approaches would be valuable in mountain regions, but are – to the authors' knowledge – not widespread.

Finally, all three steps to estimate direct losses are combined in specific case studies – some examples are given in the boxes below – and in – often country-specific – software tools. Some examples with relevance for Alpine regions are the multi-hazard loss modelling tool RiskScape developed for New Zealand (King & Bell 2005), the French ARMAGEDOM (Sedan & Mirgon 2003) and RISK-NAT (Douglas 2005) as well as the Swiss RiskPlan (www.riskplan.admin.ch).

*Fuchs, S. (2004): Development of Avalanche Risk in Settlements - Comparative Studies in Davos, Grisons, Switzerland. Dissertation, University of Innsbruck.*

*Explanation*: This approach mainly deals with the application of the risk concept in natural hazard management. For the case of avalanches, the residential population at risk, the development of values of buildings from 1950 to 2000 based on different scenarios (30,100 and 300 year avalanche), the damage potential and the costs and benefits of mitigation measures against avalanches in the municipally of Davos is calculated. This is based on GIS analysis and avalanche modelling. Replacement values (and insured values) are taken into account. Moreover, a human capital approach is used to determine the possible decline of tax revenues triggered by fatalities due to avalanches.

- *Cost types addressed*: potential losses at buildings, their insured values und tax deficits triggered by avalanches
- *Objective of the approach*: To determine cost/benefit ratios of different hazard scenarios, and mitigation measures and to provide information on the change of the human sphere regarding population and buildings in the second half of the 19th century.
- *Impacted sectors*: private sector (buildings), public sector (taxes)
- *Scale*: local
- *Expected precision (validity)*: for the assessed damage categories high
- *Parameters used for determining costs*: depending on the avalanche scenario - number and values of buildings (replacement values, insurance values) and number of possible fatalities (human capital approach)
- *Results and result precision*: precision is high, due to the definite quantification of risk
- *Is the method able to deal with the dynamics of risk?* Yes, if actual numbers and values of buildings and mitigation measures are used.
- *Skills required*: GIS and avalanche modelling, basic knowledge of environmental economics and the evaluation of non-use values
- *Types of data needed*: GIS-data, avalanche modelling results, statistical information on population, insurance data of buildings
- *Data sources*: public sources (GIS-data, risk mapping), data on insured buildings
- *Who collects the data*: municipality, researcher, insurers
- *How is the data collected*: statistics, avalanche modelling
- *Is data derived ex-ante or ex-post*: ex-ante (possible future losses) and ex-post (data on the development of buildings and coherent values)
- *Data quality*: medium, due to the high variance of the benefit / cost ratios

*Blöchl, A. & B. Braun (2005): Economic assessment of landslide risks in the Swabian Alb, Germany – research framework and first results of homeowners' and experts' surveys. Natural Hazards and Earth System Sciences, 5, p. 389–396.*

*Explanation*: This preliminary study tries to improve decision making for natural hazard risk management in the case of landslides in the Swabian Alb. The major aims were to determine the extent of potential damage and economic losses caused by landslides based on GIS and risk analyses, interviews with relevant actors in politics, administration and planning, private households and land owners. Moreover, the perception and private strategies of prevention were analysed.

- *Cost types addressed*: possible direct losses triggered by landslide events (structures)
- *Objective of the approach*: to develop methods for the systematic analysis of risks and the systematic evaluation of natural risks

- *Impacted sectors*: households
- *Scale*: local with recommendations for the regional scale
- *Expected precision (validity)*: low, due to the preliminary approach
- *Parameters used for determining costs*: interviews of households and statistical data
- *Results and result precision*: precision and results low
- *Is the method able to deal with the dynamics of risk?* No, this approach is only a static one based on interviews.
- *Skills required*: statistics, basic knowledge of natural hazard management
- *Types of data needed*: GIS-data land use, former damage events and loss analysis of economic values in areas at risk, replacement values, market value of buildings based on interviews
- *Data sources*: interviews, public statistical offices
- *Who collects the data*: public statistical offices, researchers
- *How is the data collected*: interviews
- *Is data derived ex-ante or ex-post*: ex-post and ex-ante
- *Data quality*: low

*Huttenlau, M. (2010): Risk-based consequences of extreme natural hazard processes in mountain regions – Multi-risk analysis of extreme loss scenarios in Tyrol (Austria). PhD thesis. Faculty of Geo- and Atmospheric Sciences, University of Innsbruck.*

*Huttenlau, M. & J. Stötter (2008): Ermittlung des monetären Werteinventars als Basis von Analysen naturgefahreninduzierter Risiken in Tirol (Österreich). Geographica Helvetica – Swiss Journal of Geography, 63/2, 85-93.*

*Huttenlau, M. & G. Brandstötter-Ortner (2011): Risk-based analysis of possible catastrophic rockslide scenarios and linked consequences in Tyrol (Austria). Zeitschrift für Geomorphology/ Annals of Geomorphology, Vol. 55, Suppl. 3, 179-204, DOI: 10.1127/0372-8854/2011/0055S3-0058.*

*Huttenlau, M. & J. Stötter (2011, in press): The structural vulnerability in the framework of natural hazard risk analyses and the exemplarily application for storm loss modelling in Tyrol (Austria). Natural hazards, DOI 10.1007/s11069-011-9768-x.*

- *Explanation*: The analysis estimates elements at risk, corresponding damage potentials and losses induced by extreme hazard processes in the Austrian Federal Province of Tyrol. In the framework of the study extreme earthquake, flood, rockslide (including consecutive effects), wind and hail storm scenarios were considered. The methodology follows the general and commonly accepted natural-scientific technical approach including the analysis steps hazard analysis, exposure analysis and consequence analysis. Thereby, the term risk is understood as monetary losses and as a product of the general risk components hazard, elements at risk and vulnerability. The study has a property-based background and focuses mainly on building and inventory losses whereby, additionally, vehicles and humans are also considered as risk indicator. Based on a detailed geo-database of the relevant risk indicators on a single object level, exposure was analysed and losses were estimated. In order to consider the immanent uncertainties of damage models based on physical vulnerability approaches, different models were applied and ranges of potential losses were given.
- *Cost types addressed:* Solely direct property costs for buildings, inventory and vehicles were addressed, whereby replacement costs were considered for buildings and inventory and vehicle costs are based on present values.

• *Objective of the approach*: (1) Providing exposure, damage potentials and loss dimensions of extreme events for the first time in Tyrol as basis for appropriate risk management concepts concerning extreme events in general; (2) awareness building among decision makers (politics, administration and civil defence and disaster protection) on potential consequences of extreme events and provide first information for decision support; (3) providing information in order to evaluate potential effects on insurance portfolios.

• *Impacted sectors:* sectoral consideration of the built environment (buildings and inventory), additionally vehicle claims if appropriate and exposure of humans (quantification of humans at risk).

• *Scale:* Generally, regional scale approach, whereby elements at risk are considered on a single object level.

• *Effort and resources required*: High. The approach requires comprehensive geo-databases, geo-coded single insurance contract information of a market leader and comprehensive data to establish hazard scenarios and to adapt loss models.

• *Expected precision (validity):* Reasonable. While the study framework is developed for regional scale further concretisation on a more detailed scale is not feasible with the study input data and parameters. However, the study framework could be updated with more precise data in order to enable a more local significance. Further developments concerning hazard and scenario topics, but also and especially concerning the applied vulnerability concepts and damage ratio approaches are desirable. To depict more holistic consequences to society further risk indicators have to be integrated.

• *Parameters used for determining costs:* Depending on the process type corresponding process proxies like water depth, macro seismic intensity, gust wind speed, kinetic hail energy and others, object-specific values of the localised elements at risk, specific type and functionality respectively of the specific elements at risk, regional adapted loss models (damage ratios depending on the physical impacts of the process proxies).

• *Results and result precision:* Results are quantified elements at risk with corresponding monetary damage potentials and potential losses of different extreme hazard processes and scenarios.

• *Is the method able to deal with the dynamics of risk?* The general approach yes (depending on the hazard analysis procedure), the introduced case studies however are static exposure and consequence analyses of extreme hazard scenarios under the current socioeconomic situation.

• *Skills required:* Process modelling, advanced knowledge about GIS and the natural-scientific technical risk methodology.

• *Types of data needed:* Geodata (addresses, cadastre, land use planning, ortho-photos, digital terrain model, and others), GIS data of results of process or hazard analyses or data to conduct, establish hazard analyses, geocoded single insurance contracts (from an insurance company with a very high market share), different statistical data (at least on a community level) depending on the considered process type, existing loss models or empirical damage claims to develop loss models.

• *Data sources:* Public authorities, mapping services, statistic offices, weather services, geophysical services, insurers.

• *Who collects the data:* see Data sources.

• *How is the data collected:* Varies methods and partial very specific, depending on the data.

• *Is data derived ex ante or ex post*: As far as data/models concern previous, historic hazard events ex post (process and scenario analysis, damage ratios of loss models) otherwise data are independent/detached from previous or future events.

• *Data quality:* Depends on the availability and quality of existing or accessible data and corresponding rights of use and terms of data protection.

## 3.2 Methods for business interruption / interruption of production

Losses due to business interruption can occur at all kinds of businesses of an economy. In order to distinguish them from indirect effects (output losses), losses due to business interruption are regarded at the local and regional scale in areas that are directly affected by (Alpine) hazards (Bubeck & Kreibich 2011). The term “business interruption” is often related to insurance terminology and contracts, but means the same like “interruption of production”, whereas business interruption treaties can cover also indirect effects, depending on the clauses.

The ConHaz project distinguishes indirect effects (output losses) and interruption of production mainly on a temporal scale. In the short-time (about hours to weeks), the interruption of the businesses processes caused by direct damage (capital losses, e.g. destroyed machinery, structures, inventory, broken transport infrastructure) can be observed (Bubeck & Kreibich 2011). If the reduced production or revenues lasts (far) longer than the direct damage (middle- to long-term), these adverse effects are indirect losses (output losses). Hence, the temporal scales are important in assessing economic impacts, namely interruption of production/business processes and indirect losses (see Przyluski & Hallegatte 2011). However, the distinction is sometimes still ambiguous. For example, a study (Nöthiger 2003) that assesses income decline in tourism due to road blockages from a short- to long-term perspective by avalanches is described in the next section as an integrated analysis of interruption of production/business processes and indirect effects.

Further, business interruption and indirect effects have been estimated through expert judgement in case of CBA for mitigation measures in Austria (see section 3.6). The CBA carried out in Austria (Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008b) calculates business interruption losses by estimating and interviewing companies and the affected municipalities simply asking entrepreneurs´ estimates. Business interruption losses are then summed up with direct loss of the company and multiplied with a general process factor ‘p’ that depends on the type of the hazard (floods, debris flows, and avalanches) and the protection goal. This is done with all economic sectors (trade, industry and services) in the investigation area.

Although some figures for costs of business interruption exist (see Bubeck & Kreibich 2011), no advanced approaches exist for calculating losses due to business interruption caused by Alpine hazards. The main reasons for this drawback are, firstly, the unclear definition of business interruption (partial/total, delay of production, cost of excess capacity usage, temporal scales, etc.), secondly the missing approaches to deal with consecutive interruptions along the production chain/network (also outside the affected area) and thirdly, the vague distinction from other indirect effects on the local and regional scale.

## 3.3 Methods for indirect losses

Measuring indirect economic costs and other economic effects from natural hazards, especially floods in Alpine and other mountainous regions, are an important element of a comprehensive economic risk assessment. In general, there are econometric (statistical) as well as model-based approaches, e.g. input-output-models or computable general equilibrium models, to assess costs related to indirect effects of natural hazards. A description of the methods and related problems can be found in Przyluski & Hallegatte (2011).

Surpassing controversial input/output- or computable general equilibrium (CGE) model-based economic estimates, measuring indirect economic effects lead to the key task of identifying and evaluating the drivers and critical elements of indirect economic loss in the local and regional economy. Indirect losses are those where the damage does not arise due to the physical contact of objects with the damaging hazard processes, e.g. with flood water, but where it is induced by the direct impacts (including business interruption as defined above) and transmitted through the economic system. So, indirect effects comprehend all losses, which are triggered by the hazards´ consequences (Przyluski & Hallegatte 2011). For example, a production facility might be lacking an important input (electricity, raw materials, etc.) due to a flood event in its suppliers' areas, and thus be unable to operate thereby incurring financial loss. Indirect loss is necessarily attached to some form of interruption of business, but strictly different from the business interruption (disruption of production caused by the direct physical impacts on production facilities).

The distinction between indirect effects from interruption of production losses is done in ConHaz on a temporal scale (for more details see Bubeck & Kreibich 2011 and Przyluski & Hallegatte 2011). Indirect losses are those effects, which appear on the mid- and long-term perspective. Przyluski & Hallegatte (2011) suggest that indirect effects are triggered by secondary effects or that indirect losses are a consequence of a mid- to long-term business interruption (disruption of production). Moreover, the spatial scale is also relevant, where local effects might be interruption of production and effects on the national economy as consequence of a natural disaster event are evaluated as indirect effects.

As mentioned in section 3.2, the intermixture of terminology and approaches causes an inconsistent methodology in assessing economic effects of Alpine hazards. In fact, very few studies and assessments exist for the indirect effects for Alpine risks apart from macro-economic models and rough (expert) estimates. Indirect effects are, for example, quantified in cost-benefit-analysis for mitigation measures in Austria (see section 3.6).

One important study is carried out in Switzerland in the aftermath of the avalanche winter of 1999 (Nöthiger 2003). He analysed the decline of touristic income at the scale of municipalities based on statistics and questionnaire data and provided an MS Excel-tool to evaluate possible future losses triggered by avalanches also assessing the indirect effects on the local economy. Also event analyses (see also section 2.3) give important estimates of indirect effects. For example, Kletzan et al. (2004) analysed national effects of the 2002 floods in Austria using macro-economic assessment and modelling, based on input-output-analysis.

Nöthiger, C. J. 2003: Naturgefahren und Tourismus in den Alpen - Untersucht am Lawinenwinter 1999 in der Schweiz, SLF, Davos.

*Explanation*: This approach is designed to determine the decline of touristic income triggered by the avalanche winter of 1999 in Switzerland by two ways. First, an ex-post statistical approach is used to get numbers of the decline. Second, a MS Excel-tool is provided to evaluate possible future losses triggered by avalanches also assessing the indirect effects on the local economy. The tool bases on questionnaire data on overnight stays, duration of the hazard impacts, fatalities, and daily visitors in the affected municipalities. The tool calculates then the decline of income (indirect effects) in the month the hazard occurred, in the following month and in the long run in the different sectors (hotels, shops, trade, cable cars, and others). Results can be improved by further data inputs (e.g. number of days of the month the hazard occurred, share of private guesthouses, and duration of daily visitor decline).This approach showed that there was a sharp fall of income after the 1999 avalanche winter in Switzerland. Moreover, Nöthiger (2003) found out that bad weather in general, the quality of media reporting and the possible dependence on the tourism sector (monosectorality) do have strong influence on the decline of income in the tourism sector. He also pointed out that displacement and shift effects (transfer of tourists in other safer regions) play an important role. There are also significant effects in the following year after 1999 with rapid recovery of day visitors, but less rapid recovery of numbers of tourists with overnight stays.

- *Cost types addressed*: decline of income in the tourism sector (overnight stays, accommodation, retail, mountain railways and touristic services) in monetary values in the short, but also mid-term perspective
- *Objective of the approach*: evaluation and triggers of indirect economic costs of the avalanche winter of 1999, development of a tool to determine the monetary indirect effects triggered by avalanches
- *Impacted sectors*: tourism industry (hotels, private accommodations, mountain railways, restaurants, local businesses)
- *Scale*: local, regional
- *Expected precision (validity)*: The precision is relatively high for the assessed regions and for avalanche risks.
- *Parameters used for determining costs*: municipal data on overnight stays, drop of daily visitors, fatalities, daily average of tourists in the month during and after the avalanche event
- *Results and result precision*: triggers of indirect effects, monetary values of decline of overnight stays, accommodation, retail, mountain railways, restaurants and local businesses of the service sector
- *Is the method able to deal with the dynamics of risk?* Yes, the approach is designed dealing with dynamics, due to the possibility of changing monetary values and statistical data
- *Skills required*: statistics
- *Types of data needed*: general statistical data, overnight stays, bed occupancy, average expenses of tourists, number of fatalities
- *Data sources*: questionnaires and public statistical data
- *Who collects the data*: public statistical offices, municipalities, researchers
- *Is data derived ex-ante or ex-post*: both: ex- ante and ex-post
- *Data quality*: Very high

## Macro-economic assessment and modelling, input-output-analysis

Macro modelling techniques in the case of Alpine hazards are not very common. One reason for the missing usage of economic models is a very obvious one: small scale hazards like debris flows do have very little impact on macro variables, like GDP, growth or consumption. Hence, only for large scale disasters, like the 2002 floods in

Austria, it makes sense to model macro effects. Despite the fact, that this flood event is not a typical "Alpine" hazard - since it was strongly related to precipitation intensities in mountain areas - it is a possible large scale catastrophe, which had impacts on the national scale with estimated direct losses of about € 1.2 billion and estimated € 180 million of indirect losses. This is equivalent of approximately 0.1 % of Austria's GDP in 2002 (Kletzan et al. 2004). On the regional scale, these models are difficult to be implemented due to missing data of economic stocks and flows at the local or regional level. For example, in Austria a national input-output table does exist, but there is only a vague empirical basis to regionalize the flows. Hence, the assessment of economic impacts is mainly restricted to the macro-scale apart from surveys on the local level and micro scale assessments (e.g. households).

*Kletzan, D., A. Köppl, K. Kratena & A. Wegscheider (2004): Analyse der Hochwasserereignisse vom August 2002 – FloodRisk - WP Ökonomische Aspekte TP 02, StartClim.10: Ökonomische Aspekte des Hochwassers 2002: Datenanalyse, Vermögensrechnung und gesamtwirtschaftliche Effekte, Vienna.*

*Explanation*: This macro approach is based on the conceptual extension of the traditional concepts of national accounting by a welfare approach. However, the effects are evaluated by traditional macro-modelling. This macroeconomic assessment is part of event analysis of the floods 2002 in Austria (project FLOODRISK). The authors show that economic assessment of welfare effects of huge disasters impacts need further investigation and improvement of the models. So, also general points regarding economic assessment of disaster impacts are discusses, like stock vs. flow measurement and possible alternative measurements of welfare instead of GDP. There is also a micro economic perspective, which must be taken into account (households, companies, and capital stocks). The disaggregated model WIFO-MULTIMAC calculates effects on consumption, investments, imports, exports, GDP, and final demand.

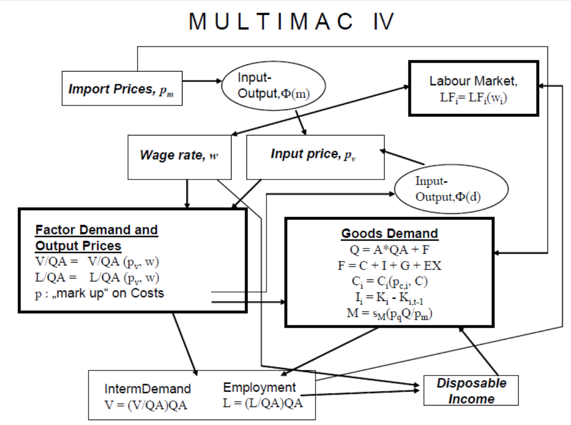

**Figure 3.3:** Structure of the MULTIMAC modell (Kletzan et. al 2004, p. 16).

The model results showed that the floods 2002 in Austria triggered about €180 million indirect losses and disruption of production. In general, the adverse impacts on the national economy were minor, but also positive effects were calculated by the model. In particular, additional investments (repairing houses, new buildings) for the construction industry and related trades were induced (approx. 1.64%, transitory shock). There were also light adverse effects on consumption due to lower household income, because of replacement investments.

- *Cost types addressed*: direct and indirect losses, macro-economic effects
- *Objective of the approach*: economic evaluation of the 2002 floods in Austria with a traditional model and conceptual development of a welfare approach to assess stocks and flows
- *Impacted sectors*: production, consumption, public sector entities and infrastructure

- *Scale*: macro / national
- *Expected precision (validity)*: high, because of the identification of general effects on consumption and investments triggered by large scale floods and the usage of object based data
- *Parameters used for determining costs*: consumption, production (see also Figure 3.3)
- *Results and result precision*: macro-economic effects on effects on consumption, investments, imports, exports, GDP, and final demand, precision medium (see also Figure 3.3)
- *Is the method able to deal with the dynamics of risk?* Yes, the model can be used with updated data (input/output table, losses, etc.)
- *Skills required*: macro-modelling techniques, statistics, economic knowledge of public accounting and welfare economics
- *Types of data needed*: quality-tested data of the private sector (investments-housing, interiors, consumption, public compensations for losses), companies (increase of depreciation rates, investments, cash flow), agriculture (business interruption, public compensations for damages), public sector (investments-structures, other investments, other public expenses, e.g. compensations), data for conventional macro-models (input/output, prices, etc.)
- *Data sources*: departments of governments of the Federal States, national statistical agency
- *Who collects the data*: departments of governments of the Federal States, national statistical agency
- *How is the data collected*: data acquisition at the departments in charge of natural hazard management (e.g. departments for water management) and private companies (railways, road administration, energy suppliers etc.), national statistical agency
- *Is data derived ex-ante or ex-post*: ex-post
- *Data quality*: medium, due to the assessment of single objects and the triggered loss and the difficulties of aggregation to national datasets (missing numbers on loss categories e.g. from some economic sectors)

## 3.4 Methods for intangibles

Intangible effects reflect losses on damage categories, which only can be evaluated in economic terms, because of missing market prices (Markantonis et al. 2011). Therefore, they are also addressed as “non-market losses”. Generally, the following intangible effects of natural hazards can be identified: environmental effects (soil and water contamination or pollution, biodiversity loss), health effects (fatalities / injuries, infectious diseases, mental illnesses e.g post-traumatic stress, depression) and damages to cultural heritage (Markantonis et al. 2011). For such goods, no market exists and hence, alternative approaches in economics have been developed to monetise these goods such as – among others – the hedonic pricing method, the contingent valuation methods, choice modelling. General descriptions of the methods are provided by Markantonis et al. (2011).

Alpine hazards can trigger intangible effects and losses, like loss of life (fatalities), injuries, ecological losses (e.g. by leakages of oil tanks in private structures) and loss of cultural heritage or memorials. However, up to now, they are only partly assessed in Alpine hazard risk management. Predominantly these approaches deal with fatalities, the possible methods to account for them and to evaluate the probability to die due to an Alpine hazard event (e.g. an avalanche). For example, Barbolini et al. (2004 quoted in Papathoma-Köhle et al. 2010) produced two vulnerability curves for the probability of loss of life for people inside buildings when an avalanche occurs and the degree of being buried by an avalanche for people outside buildings, respectively. These vulnerabilities are ex-pressed as a function of avalanche impact pressure and flow depth and were based on data from two well-documented avalanche events in Tyrol (Austria). Earlier, Jonasson et al. (1999 quoted in Papathoma-Köhle et al. 2010) related the probability of people surviving an avalanche to the avalanche velocity based on data from Iceland. Recently, a study on vulnerability for snow avalanches was presented by Cappabianca et al. (2008 quoted in Papathoma-Köhle et al. 2010) who proposed a vulnerability curve for people inside buildings affected by dense avalanches based on Wilhelm (1997).

In the case of landslides and floods in Italy, Guzzetti et al. (2005) analysed a database containing information of hazard events from the year 1279 to 2002. Events with fatalities, missing persons and injuries or homelessness were assessed. They also estimated individual risks by quantifying mortality rates for floods and landslides using the same data and a Bayesian model. Rheinberger (2009) uses contingent valuation to identify public preferences for risk reduction of mortalities on mountain roads in Switzerland. The respondents were asked the amount they would like to pay for a fictive traffic safety program. As a result, the value of statistical life (VOSL) for lethal accidents was evaluated by € 4.9 up to 5.4 million. Leiter & Pruckner (2009) also used contingent valuation to estimate the value of a statistical life in the case of avalanches in Tyrol, Austria. Respondents were asked how much they want to spend for preventing a rise in the risk of being killed. On this basis, the authors calculated the value of statistical life with approx. € 2 million.

The most impressive example for a complete risk analysis that covered various types of natural and technological hazards as well as different damage types (i.e. direct losses, fatalities, evacuated people, people that need assistance and damaged natural resources) was developed for Switzerland in 1995 (KATANOS-Study) and updated in 2003 (KATARISK-study, Bundesamt für Bevölkerungsschutz). The combination and summation of different damage types was done by marginal costs. Marginal costs were derived from the society´s willingness to pay for reducing specific risks. The KATARISK-study compiles different studies and presents costs for several categories (e.g. fatalities, injured, evacuees, relief, and vital resources). Moreover, risk curves show the frequencies and the consequences for several hazard types and scenarios resulting in a prioritization of hazards in Switzerland that is used by the civil protection.

*Guzzetti, F, C.P. Stark & P. Salvati (2005): Evaluation of Flood and Landslide risk to the Population of Italy. Environmental Management Vol. 36, No. 1, p. 15-36.*

*Explanation*: This analysis is based on data on flood and landslide events in Italy from the year 1279 und 2002. The database contains 2580 events, which triggered fatalities, missing persons, injuries or homelessness. The most fatal events happened in the Alpine regions of northern Italy and mostly fast-moving landslides and debris flows caused the high rate of intangible losses. Apart from the statistical analysis of the database, individual risk by quantifying mortality rates is calculated. Moreover, probabilities of floods and landslide events with fatalities as societal risks of floods and landslides are evaluated. This is done with a Bayesian method based on the database.

- *Cost types addressed*: number of fatalities and injuries, without monetary values

• *Objective of the approach*: Statistical analysis of intangible losses (fatalities, homelessness, etc.) which are triggered by flood and landslides in Italy and the quantification of societal risk.
• *Impacted sectors*: loss of life, missing persons, injuries and homelessness
• *Scale*: national, based on local events
• *Expected precision (validity)*: high due to the time coverage of data
• *Parameters used for determining costs*: No costs were estimated.
• *Results and result precision*: quantification of societal risk in terms of mortality due to landslides and flood events, precision is high
• *Is the method able to deal with the dynamics of risk?* Yes, if the database is constantly updated. Eventually global change phenomena can be observed through the quantification of mortality and similar intangible effects
• *Skills required*: statistics
• *Types of data needed*: long time series of data
• *Data sources*: national database on flood and landslide events in Italy
• *Who collects the data*: Italian National Research Council, L'Istituto di Ricerca per la Protezione Idrogeologica, Perugia
• *How is the data collected*: analysis of historic catalogues, continuance of internal databases
• *Is data derived ex-ante or ex-post*: ex-post
• *Data quality*: high

*Rheinberger, C.M. (2009a): Preferences for mitigating natural hazards on alpine roads: a discrete choice approach. Diss ETH, Nr 18476, doi:10.3929/ ethz-a-005922637.*
*Rheinberger, C.M. (2009b): Paying for safety: preferences for mortality risk reductions on alpine roads, FEEM working papers 2009.77, fondazione eni enricomattei, http://www.feem.it/userfiles/attach/20091118174520477-09.pdf.*
*Explanation:* This contingent valuation study shows the public preferences for risk reduction of mortalities on mountain roads in Switzerland. On the average, three fatalities per year on Swiss roads were triggered by natural hazards (landslides and avalanches). Affected persons and inhabitants of both, urban and mountain areas, were asked the amount they would like to pay for a fictive traffic safety program. So, the value of statistical life (VOSL) for fatal accidents is evaluated by € 4.9 up to 5.4 million. € 3.25 million is used by the public administration to evaluate risk to life for mitigation against natural hazards. The Willingness to Pay (WTP) for the safety program depends also on personal characteristics, like the living region (urban vs. mountain areas) or level of education.
• *Cost types addressed*: WTP for risk reduction on alpine roads, VOSL for a fatality on mountain roads
• *Objective of the approach*: to evaluate the value of statistical life in the case of natural hazards in Switzerland
• *Impacted sectors*: fatalities
• *Scale*: local / regional
• *Expected precision (validity)*: high, in the case for mountain roads in Switzerland
• *Parameters used for determining costs*: WTP for a fictive road safety program
• *Results and result precision*: VOSL, high
• *Is the method able to deal with the dynamics of risk?* Mainly the survey is based on static data, but there is the possibility to conduct a new survey which optionally will change WTP and VOSL values.
• *Skills required*: advanced econometrics
• *Types of data needed*: survey and questionnaire data
• *Data sources*: mail-questionnaire

- *Who collects the data*: researchers
- *Is data derived ex-ante or ex-post*: ex-ante
- Data quality: high

*Leiter, A. & G. Pruckner (2009): Proportionality of Willingness to Pay to Small Changes in Risk: The Impact of Attitudinal Factors in Scope Tests, Environ Resource Econ (2009) 42, p. 169–186.*

*Explanation*: This contingent valuation method (CVM) tries to estimate the WTP (willingness to pay) of about 1 000 questionnaire respondents for preventing a rise in the risk of being killed by an avalanche event. Moreover, a scope analyses is used for testing the validity of contingent valuation estimates. The explanatory variables were: risk perception, subjective avalanche risk, preferences for alternative protective measures, and the personal experience of avalanches. The WTP for the prevention of the selected avalanche risk was approx. 3.7 € up to 14.25 € per month depending on the target group. The VOSL (value of statistical life) was also estimated with about € 1.8 up to € 2.06 million.

- *Cost types addressed*: values of statistical life (VOSL), willingness to pay for preventing an increased risk of dying in an avalanche
- *Objective of the approach*:
- *Impacted sectors*: intangible loss: fatalities
- *Scale*: local / regional - due to the sample made in the Federal State of Tyrol, Austria the results are valid for this region.
- *Expected precision (validity)*: medium
- *Parameters used for determining costs*: small changing risk of dying in an avalanche
- *Results and result precision*: see addressed cost types
- *Is the method able to deal with the dynamics of risk?* Mainly the survey is based on static data, but there is the possibility to conduct a new survey which optionally will change WTP and VOSL values.
- *Skills required*: advanced econometrics
- *Types of data needed*: large random sample of face-to-face or telephone interviews, population data
- *Data sources*: interviews / questionnaires, national statistical agency
- *Who collects the data*: researchers, national statistical agency
- *Is data derived ex-ante or ex-post*: ex-ante and ex-post
- *Data quality*: high

## 3.5 Estimating costs of mitigation measures

Like losses, costs for mitigation can be assessed ex-post (see Chapter 4) and ex-ante. Ex-ante costs estimate probable future costs for different planned mitigation and prevention measures. Such assessments are important for the comparison of different mitigation variants.

Categories of mitigation measures as classified in ConHaz were already presented in Table 1.6. For some mitigation measures, fixed and variable costs can be identified (see also Figure 1.9). Some examples for fixed and variables costs are given in Table 3.2.

**Table 3.2**: Categories of fixed and variable costs triggered by Alpine hazards of different benefactors / sectors

| Fixed costs of mitigation | Variable costs of mitigation | sector |
|---|---|---|
| setting up and maintaining technical and non-technical mitigation measures, hazard modification, monitoring and early warning systems | Additional operational costs in case of an event (e.g. additional service hours, material, repair costs) | public (national, regional, local) |
| Setting-up and operating (including training) emergency services (red cross, fire departments, THW, etc.) | Additional service hours in case of a state of emergency, damage of assets of emergency services (e.g. vehicles, material), additional materials (e.g. mobile measures) | public (national, regional, local) |
| Organising and preparing additional forces in the case of huge disaster impacts: e.g. army, police, volunteers | Additional service hours in case of a state of emergency, damage of assets of additional forces (e.g. vehicles, material), additional materials (e.g. mobile measures) | public (mostly national), private sector and companies (volunteers) |

Cost assessment of mitigation measures is often done following a whole life cycle costs approach (see Bouwer et al. 2011). This includes costs for planning, investments, maintenance and operation as well as disposal costs. These direct costs can be estimated for many construction works e.g. on the basis of lists with typical (unit) costs or engineering experience. Besides direct costs, also indirect and intangibles co-costs and co-benefits might occur. However, the latter are rarely quantified and assessed (see Bouwer et al. 2011).

In order to assess costs of mitigation measures in a harmonized way, the working group on economics of climate adaptation (ECA 2009) developed a framework for the assessment of climate risks at different spatial scales as well as for the valuation and prioritization of mitigation measures, including a five-step methodology for cost assessment of mitigation and adaptation.

1. Identify potential mitigation and adaptation measures for all hazards that were included in the analysis (e.g. infrastructure, organizational measures, prevention, risk transfer etc.)
2. Determine the overall feasibility and applicability of potential measures by screening of list of step 1 with feasibility criteria such as technology, engineering, local setting and cultural constraints.
3. Calculate societal costs for each measure that passed the feasibility test by a net present value approach. This means: determine an appropriate discount rate, define the scope of the measure, i.e. determine the potential for implementation such as an expected penetration rate of incentives and other non-structural measures, calculate the costs of each measure (capital and operating expenditures as well as operating expenditures savings without taxes or other private actor costs) by a bottom-up approach to account for the specific environmental and economic settings, consider the lifetime of each measure and assume a cost trajectory growth based on inflation
4. Calculate the expected loss averted for each measure

5. Create a cost-benefit curve for all measures

This methodology has been tested in various settings (see ECA 2009).

In order to evaluate the preferences of residents, choice experiments (see box) and studies on the willingness to pay for certain measures have been performed. For example, Raschky et al. (2009) present data on the willingness to pay (WTP) for insurance against losses due to natural hazards. Data result from a survey among households in Bavaria, Germany and Tyrol, Austria that were affected by the flood in 2005. Unfortunately, only a comparatively small share of the surveyed households was willing to answer these questions, i.e. 29.3% (of 218 households) in Tyrol and 44.9% (of 305 households) in Bavaria. Among those with a positive WTP for insurance the average monthly WTP amounted to 24.76 € per month (i.e. 297 € per year) in Tyrol and to 54.05 € per month (i.e. 649 € per year) in Bavaria. These figures were reduced to 17.33 € and 47.65 € per month (or 208 € and 572 € per year) when cases with a WTP = 0 were included. The big difference between the numbers in Tyrol and Bavaria might be due to the fact that it cannot be excluded that some people in Bavaria referred their answer to a yearly WTP. Nevertheless, the WTP is approximately in the same order of magnitude of the current insurance premiums.

*Olschewski, R., P. Bebi, M. Teich & U. Wissen Hayek (2010): Avalanche protection by forests - Approaches towards an economic valuation. In: J.-P. Malet, T. Glade, N. Casagli (eds): Mountain Risks: Bringing Science to Society, Strasbourg, p. 393-399.*

*Explanation*: The approach estimates the willingness to pay (WTP) for avalanche mitigation by a choice experiment which is described by a bundle of different mitigation measures based on a 300 year avalanche scenario in the town of Andermatt, Switzerland. A Bayesian network and the contingent valuation (based on an utility function) evaluates the WTP for mitigation measure, which is about SFR 440 for a damage avoidance of 90 % (one time payment). Moreover, the WTP is higher than forestall measures of avalanche mitigation. These results were compared with on time payments of alternative technical mitigation measures and show that the WTP is significantly higher.

- *Cost types addressed*: costs of mitigation measures against avalanches, WTP of avoiding a damage scenario
- *Objective of the approach*: to determine the benefits of public avalanche mitigation compared with the WTP of private households
- *Impacted sectors*: private (structural damages) and public (costs for mitigation)
- *Scale*: local
- *Expected precision (validity)*: high at this town, due to the exactness of the model
- *Parameters used for determining costs*: WTP for avoiding losses triggered by avalanches due to a windfall and damage of the mitigation forest
- *Results and result precision*: WTP for avalanche protection, precision medium, due to the special case (Andermatt), but this approach can lead to a better understanding of WTP for mitigation measures against natural hazards in general
- *Is the method able to deal with the dynamics of risk?* No, in fact the results of the survey is a static one
- *Skills required*: econometrics, risk analysis, avalanche modelling
- *Types of data needed*: damage potential, avalanche modelling, households survey
- *Data sources*: online survey of private households, municipalities
- *Who collects the data*: municipalities, researchers

- *Is data derived ex-ante or ex-post*: both
- *Data quality*: for this case high, for avalanche risk in general medium

## Methods for the cost assessment of emergency, evacuation and clean-up

Costs of emergency are often assessed within the category of indirect effects because these costs are not triggered by the physical contact of the hazard. In the ConHaz-project emergency costs are considered part of the costs for mitigation and adaptation as variable costs. Besides ex-ante costs of natural hazards, the assessment of costs of emergency, evacuation and clean-up is still weak in the case of Alpine hazards. Local spending on emergency services is often substantial and can reach economically critical levels, especially for low-income municipalities. The cost of emergency services, evacuation, securing infrastructure and clean-up often exceeds public funds. These costs are economic ones, reflected in gross domestic and regional product, depending on the scale of assessment. In most cases the ex-post economic analysis of natural hazard events is limited to assessing direct economic costs. In the case of Austria and Germany, there is no statistical basis for estimating costs for emergency and response. The main reason for this is assumed as the split responsibility of different statutory and voluntary organizations for emergency services such as national civil protection, voluntary local fire brigades, Red Cross, etc. Costs of emergency services therefore include (Pfurtscheller & Schwarze 2010): costs of municipal and national services in searching, rescuing, and evacuating people, costs of voluntary organizations for assistance to flood victims, costs incurred by municipal and private services for flood control and clean-up, costs of avoiding water pollution from oil or chemical seep-age/leaks and costs of protecting and safe-guarding buildings against structural damage and contamination. In the case of Alpine hazards, these kinds of costs were driven also by *Alpine vulnerabilities* (see section 1.3).

*Pfurtscheller, C. & R. Schwarze 2010: Kosten des Katastrophenschutzes. In: Thieken, A., I. Seifert & B. Merz: Hochwasserschäden - Erfassung, Abschätzung und Vermeidung. Munich, p. 253-262.*

*Explanation*: This approach tries to estimate the costs of emergency triggered by Alpine flood events. In this case only the additional costs have to be considered, because they were triggered by the exogenous shock. Based on data from a survey of the voluntary public and corporate fire brigades as main resilience infrastructure in Austria, the costs for emergency management of the 2005 floods were computed with a quite simple approach - the sum of the service hours is multiplied by a monetary equivalent to obtain gross incomes of the men of the fire departments. Of course, other costs of emergency management have to be added to arrive at the total costs of emergency triggered by flood events. Moreover, this study empirically estimates the triggers of Alpine hazard losses (*Alpine vulnerabilities*).

- *Cost types addressed*: costs of local fire brigades, public losses on municipal level
- *Objective of the approach*: to assess the costs of emergency, evacuation and clean-up in the case of an Alpine flood event
- *Impacted sectors*: in the main the public sector, especially costs of municipalities and fire departments
- *Scale*: local / regional
- *Expected precision (validity)*: medium, due to the assessment of one catastrophic event

- *Parameters used for determining costs*: number of service hours of fire brigades, additional costs of the fire brigades, public losses of municipalities
- *Results and result precision*: costs of local fire brigades, high due to questionnaire data
- *Is the method able to deal with the dynamics of risk?* No, it is a static view on an already happened catastrophic event
- *Skills required*: econometrics, statistics
- *Types of data needed*: data on public losses, data of local fire brigades triggered by Alpine hazards
- *Data sources*: Federal governments, fire brigades
- *Who collects the data*: Federal governments, fire brigades
- *How is the data collected*: questionnaire, survey
- *Is data derived ex-ante or ex-post*: ex-post
- *Data quality*: medium

## 3.6 Methods and tools for decision support

Due to the increasing scarcity of public funds, methods for supporting decisions on the selection of appropriate (public and private) projects are becoming more important – also in the case of natural hazard management and mitigation measures. One of the questions in the case of natural hazard mitigation deals with the desired protection level of the society against Alpine hazards that can be achieved by appropriate measures at reasonable costs (Leiter et al. 2009).

Diverse methods have been developed to reduce risks in a cost-efficient way, because mostly mitigation against natural hazards is a national task based on legal stipulations, e.g. cost-benefit-analyses (CBA) and cost-effectiveness-analyses (CEA) have frequently been used to evaluate and select public projects for mitigation of alpine hazards ex-ante. The main aim is to achieve a cost-efficient outcome, and to identify the most appropriate project. For the selection of cost-effective measures, both sides of a measure – benefits and costs – have to be analysed. Following Ganderton (2005), all costs and benefits must be monetised, whereby the benefit side is usually assessed by the amount of losses that can be avoided when implementing a certain measure. However, not all benefits are easily to measure in monetary terms due to their public-good characteristics (e.g. non-market losses). Therefore, either valuation techniques for non-market losses are applied or multi-criteria-analyses (MCE) are used instead of CBA or CEA as proposed by Schmidtke (2011). Besides the monetary valuation of (avoided) direct losses and losses due to business interruption, potential effects of planned mitigation measures on people at risk, socio-cultural and ecological aspects are categorized as low, middle or high and are further assessed as negative or positive. In case of a negative project evaluation, a detailed outline of the reasonability of the project has to be provided (Schmidtke 2011).

The following case studies describe both, the implemented methods for evaluating mitigation measures carried out by public authorities in Austria and Switzerland, and suggestions for improving evaluation techniques for decision support. These studies were mainly used to improve cost-efficient evaluations for mitigation measures and provide a basis for future developments of costing Alpine hazards. Bründl et al. (2009) give a detailed overview about Swiss risk management in general and risk-based planning and evaluation of mitigation measures in detail. Also, the tool EconoMe is introduced.

## Cost-benefit-analyses (CBA) of mitigation measures

In Austria and Switzerland, but also in Germany CBA for (technical) mitigation measures against Alpine natural risks are carried out by public authorities. In Austria, they are more or less compulsory (dependent on the sum of investment) and should lead to rational and efficient decisions in the case of natural hazard mitigation. Despite the shared concept of CBA, the applied methods of public bodies differ with regard to the cost categories considered and to the administrative embedding of the cost analysis. Table 3.3 compares the CBA carried out in Austria, Germany, and Switzerland in the case of mountain hazards. The CBA for mitigation against river floods in Austria is also included. Whereas in the Free State of Bavaria, Germany, a simplified approach that mainly considers direct losses is implemented, CBA in Austria is theoretically well-founded and accounts for various cost types. Analysis of economic efficiency in Switzerland is based primarily on the risk and probability concept, calculating only direct losses and is done with an online tool (EconoMe 2.1, see case study). Further harmonisation is needed on the national levels, but also across the borders, since the results of evaluating economic efficiency, e.g. by CBA, are likely to depend on the type and quality of input data as well as on the considered types of adverse effects, like fatalities, direct and indirect losses etc., and the modelling approaches that are used to assess related costs.

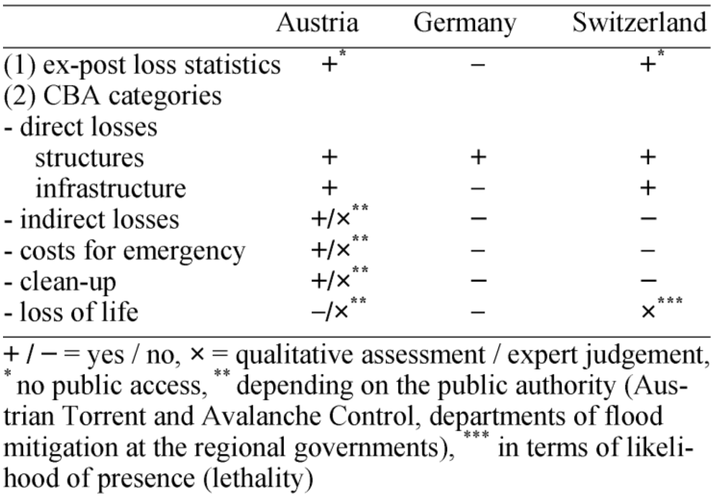

**Table 3.3:** Outline of (1) ex-post micro scale loss statistics and (2) cost categories applied in cost-benefit-analyses in Austria, Germany, and Switzerland for mitigation measures against water related mountain hazards and their quantification; Sources: Federal Office for the Environment (2010), Federal Ministry of Agriculture, Forestry, Environment and Water Management (2008a,b), Loipersberger (pers. comm.), Pfurtscheller & Thieken (2010 p. 396).

| | Austria | Germany | Switzerland |
|---|---|---|---|
| (1) ex-post loss statistics | $+^{*}$ | − | $+^{*}$ |
| (2) CBA categories | | | |
| - direct losses | | | |
| structures | + | + | + |
| infrastructure | + | − | + |
| - indirect losses | $+/\times^{**}$ | − | − |
| - costs for emergency | $+/\times^{**}$ | − | − |
| - clean-up | $+/\times^{**}$ | − | − |
| - loss of life | $-/\times^{**}$ | − | $\times^{***}$ |

+ / − = yes / no, × = qualitative assessment / expert judgement, $^{*}$ no public access, $^{**}$ depending on the public authority (Austrian Torrent and Avalanche Control, departments of flood mitigation at the regional governments), $^{***}$ in terms of likelihood of presence (lethality)

*Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008b. Richtlinien für die Wirtschaftlichkeitsuntersuchung und Priorisierung von Maßnahmen der Wildbach- und Lawinenverbauung gemäß § 3 Abs. 2 Z 3 Wasserbautenförderungsgesetz 1985. Vienna.*

*Explanation*: In Austria there is legal obligation to carry out a CBA for technical mitigation measures against torrent processes (e.g. debris flows) and avalanches above an investment sum of € 1 million. All investments below this sum and measures against rock fall and landslides, but also avalanche galleries for road protection will be assessed by a standardized utility valuation. The benefits of non-structural measures (e.g. spatial planning) are evaluated verbally. The basis to evaluate the cost-benefit-ratio and net present value of different mitigation measures is the Austrian risk mapping which identifies low (yellow) and high risk zones (red), which are modelled using a 150-year event. The CBA of the Austrian service for torrent and avalanche control (TAC) relies strongly on the application of use and non-use values (economic, social, and ecologic benefits, impacts on regional development). In general, the benefits (as prevented losses) were computed on the basis of repair costs (for buildings classified in € / $m^2$). The loss itself is computed first by determining an event factor 'E' (historic and recent events in the catchment area), process factor 'P' (based on return periods) and the loss factor 'S'. 'S' is synonymous to vulnerability function. The CBA uses Swiss values for estimating vulnerabilities, but needed an upgrade and adaptation to Austrian conditions. The CBA is supported by a standardised MS Excel template.

- *Cost types addressed*: costs of mitigation measures (project and planning costs, costs of financing the measures, reinvestment costs, and maintenance costs). Besides determination for process intensities and coherent physical vulnerabilities, following damage categories are assessed: private buildings (incl. inventory and external structures), agricultural and silvicultural structures, structures of tourism and infrastructure, public buildings, estimations on costs of clean-up, business interruption of agricultural and silvicultural businesses, costs for recultivation, damage at water bodies (clean-up and repair), clean-up and repair of infrastructure (bridges, railroads, motorways, and streets), business interruption of railways and roads, losses by the blockage of traffic network, cars, lifelines (energy, water, gas, telecom, waste water), business interruption triggered by disturbances of lifelines, indirect effects in the tourism sector (average expenses of tourists and decline of overnight stays), indirect effects (but also business interruption) in the economic sector within the risk zones (estimations by the companies), indirect effects (business interruption) of community facilities, costs for emergency (estimation). Moreover, qualitative assessment is carried out for the categories of loss of life, sustainable protection, quality of life, mitigation of mobility and other intangibles (cultural and natural heritages). The losses of intangibles are evaluated dimensionless and added as a percentage to the damage categories that were quantified in monetary terms. Due to the set-up of technical mitigation, the rise area values is possible, and hence, also evaluated by the CBA.
- *Objective of the approach*: the evaluate possible alternative mitigation projects against Alpine hazards and quantify their cost-benefit-ratio and net present value for prioritisation
- *Impacted sectors*: all sectors within the zones of Austrian risk mapping
- *Scale*: local / regional
- *Expected precision (validity)*: very high for large investment projects, effects outside the risk mapping are not considered
- *Parameters used for determining costs*: differs strongly and depends on the damage category
- *Results and result precision*: cost-benefit-ratio and net present value of technical mitigation measures, precision high
- *Is the method able to deal with the dynamics of risk?* Yes, this depends on the process inputs (update of risk mapping) and the used values and numbers for loss estimations / calculations

- *Skills required*: advanced knowledge in public natural hazards management (legal foundations), economic valuation techniques and loss estimations, vulnerability functions, and economic methods for evaluating cost-efficiency
- *Types of data needed*: GIS-data (risk mapping, spatial planning, cadastre), statistical data, economic values of different damage categories, costs of mitigation measures
- *Data sources*: public administration, municipalities, TAC, in-situ observations
- *Who collects the data*: TAC, public authorities
- *How is the data collected*: in-situ, survey, modelling (risk mapping), MS Excel analysis
- *Is data derived ex-ante or ex-post*: both, the risk mapping bases also on historical events
- *Data quality*: very high, due to the exact method to quantify cost-benefit-ratios, whereby there are some limitations on the loss estimations in general, and the distinction of indirect losses and disruption of production in special

*Bundesamt für Umwelt (BAFU) / Federal Office for the Environment (FOEN) 2010: EconoMe 2.0 - Online-Berechnungsprogramm zur Bestimmung der Wirtschaftlichkeit von Schutzmaßnahmen gegen Naturgefahren - Handbuch / Dokumentation, Bern.*

*Bründl, M., H. E. Romang, N. Bischof & C.M. Rheinberger 2009. The risk concept and its application in natural hazard risk management in Switzerland. Nat. Hazards Earth Syst. Sci., 9(3): 801-813.*

*Explanation:* This online-tool provides the answer for two questions regarding the planning of public technical mitigation measures against natural hazards: how much can the risk be reduced (effect of the measure) and how is the relationship between risk reduction and the costs of the project (economic efficiency). This is followed by a priorisation of planned measures. All necessary documents (glossary, technical manual, theoretic background) of this tool is provided at the homepage (http://www.econome.admin.ch/index.php). In general, all measures above an investment sum of SFR 1 mio. have to be evaluated by EconoMe. The concept also allows transparency and comparability of results and statistical analyses of the different projects. EconoMe bases on standardized risk analysis and calculates also Individual and collective risks. The tool can be updated with additional modules and assesses the risks of debris flows, dynamic flooding (flash floods), and inland-floods.

- *Cost types addressed*: EconoMe 2.0 assesses only direct losses. It is argued, that there are high uncertainties regarding the evaluation of indirect effects. Additionally, there are two different views of indirect losses - the economic and the company perspective and different methods to measure these effects. So, EconoMe 2.0 only evaluates costs of losses, if assets and their values were affected and the tool does not count for macro-economic effects, e.g. the substitution of a supplier, which is directly affected.

The following categories of assets are analysed: costs of setting up mitigation measures, maintenance and repair costs, private buildings, all other structures, traffic lines (roads, railways), lifelines, agricultural and silvicultural areas, and cable cars.

- *Objective of the approach*: The main aim of the tool is to gather comparability among different mitigation projects and to assess economic efficiency regarding technical mitigation measures.
- *Impacted sectors*: both, the private and public sector
- *Scale*: local
- *Expected precision (validity)*: high, due to the theoretical background of EconoMe 2.0 and the possibility to compare and analyse results
- *Parameters used for determining costs*: based on physical vulnerability functions

• *Results and result precision*: risk in SFR per year of a 30, 100, and 300 year event, damage potential, risk reduction in SFR including the measures (benefits), statistical analysis of the data (e.g. graphs), effects of the project on risk reduction, cost-benefit-ratio and ratio of costs and efficiency in terms of risk reduction

• *Is the method able to deal with the dynamics of risk?* Yes, it is possible to adapt the tool with latest values and latest model results

• *Skills required*: process modelling, knowledge in risk assessment, economic valuation techniques

• *Types of data needed*: spatial planning, intensity and process maps, damage potential, data on mitigation projects

• *Data sources*: public administration at all levels, statistical departments

• *Who collects the data*: public administration at all levels, statistical departments

• *How is the data collected*: in-situ observations, modelling, on-line calculations

• *Is data derived ex-ante or ex-post*: both

• *Data quality*: high

*Federal Office for the Environment (FOEN) & Federal Office for Civil Protection (FOCP) (2010b): RiskPlan Version 2.2 - Pragmatic Risk Management, Documentation of methodological and mathematical basis, Ittigen, Bern.*

*Explanation*: RiskPlan '*is a calculation and management tool for the practical assessment of the risks posed by hazard processes in defined areas and for ascertaining the cost-effectiveness of protective measures. The term "pragmatic" as used here expresses the idea that existing technical knowledge - be it in the form of hazard maps, hazard intensity maps, risk scenarios, hazard registers - and/or implicit knowledge and human experience are used in the assessment of risks and in the design of measures to reduce risk'* (*http://www.riskplan.admin.ch/).* Risk Plan is a cost-effectiveness-analysis which covers all types of natural hazards and technological (man-made) hazards, too. The tool is based on a risk matrix - divided in assessment areas / spatial entities (municipality, region, canton), subsequent object areas and the possible hazards risk expressed in monetary values. So, general overviews of risk are created in a certain region. Based on the results, RiskPlan enables risk communication and awarnessbuilding with various kinds of stakeholders. It is a tool for education, risk-dialog and sensitisation of people, but it is not used in an operational manner. This tool is simple, but comprehensive and based on scientific approaches.

• *Cost types addressed*: costs of mitigation by entering individual annual values and lifetime, maintenance and operating costs, number and value of fatalities, number of injuries, material damage (direct losses)

The value of a statistical life is used after a willingness-to-pay (WTP) approach, and is assumed with a value of SFR 5 million. This number is general accepted and widely used in Switzerland for the willingness-to-pay for saving a human life in natural hazard management.

• *Objective of the approach*: to determine risk reduction of a mitigation measure in monetary terms and the cost-effectiveness ratio of measures or combinations of measures

• *Impacted sectors*: all, depending on the input-data

• *Scale*: local to regional (cantonal)

• *Expected precision (validity)*: for a general overview high, for specific mitigation measures low

• *Parameters used for determining costs*: probabilities of exposure, frequency of the event, estimations of direct and intangible losses

• *Results and result precision*: total losses by a certain scenario, risk reduction of a mitigation measure in monetary terms, cost-effectiveness ratio

- *Is the method able to deal with the dynamics of risk?* Yes, if the input data and fixed values within the toll are updated
- *Skills required*: knowledge of the risk-based assessment of natural hazards, protective measures and their effect on hazard processes, vulnerability of potential hazard areas and objects and cost-benefit-analysis
- *Types of data needed*: data on direct and intangible losses, process parameters (frequency)
- *Data sources*: estimations, public administration
- *Who collects the data*: public administration, operator
- *How is the data collected*: in-situ observations
- *Is data derived ex-ante or ex-post*: both, but with a strong emphasis on possible future losses
- *Data quality*: medium

*Fuchs, S., M. Thöni, M.C. McAlpin, U. Gruber & M. Bründl (2007a): Avalanche hazard mitigation strategies assessed by cost effectiveness analysis and cost benefit analyses - evidence from Davos, Switzerland. In: Nat Hazards 41, p.113–129.*

*Explanation*: This study offers an introduction into the CBA and CEA in avalanche mitigation. This basis leads to a demonstration to apply these methods in the case of alternative avalanche protection in Davos, Switzerland. 16 avalanche risk reduction strategies were analyzed. Moreover, the findings and their uncertainties are discussed.

- *Cost types addressed*: costs, benefits and bet present values of avalanche mitigation for four scenarios (snow fences, snow fences and evacuation, snow fences and land use, snow fences, evacuation and land use)

The costs for evacuation are computed by human capital / alternative costs approach which is a combination of average hourly wage of the people to be evacuated, average time needed for evacuation, number and costs of persons conducting the evacuation, number of buildings and cost for alternative board and lodging.

- *Objective of the approach*: to assess costs, benefits and net present value of different avalanche mitigation scenarios
- *Impacted sectors*: both, the private and the public sector
- *Scale*: local
- *Expected precision (validity)*: high, due to the local scale assessment
- *Parameters used for determining costs*: average fatality rates, probabilities of damages on buildings
- *Results and result precision*: high in the case for direct losses and fatalities, low for other damage categories
- *Is the method able to deal with the dynamics of risk?* Yes, if the values and numbers, but also the model is updated
- *Skills required*: knowledge in natural hazard risk analysis, GIS, economic valuation, CBA, CEA
- *Types of data needed*: avalanche model output and release areas, statistical data, GIS-data (spatial planning, cadaster), values and numbers of people to be evacuated
- *Data sources*: public administration, researchers
- *Who collects the data*: public administration, researchers
- *Is data derived ex-ante or ex-post*: ex-ante
- *Data quality*: high

*Rheinberger, C.M., M. Bründl & J. Rhyner (2009) Dealing with the White death: Avalanche risk Management for traffic routes. In: Risk Analysis, Vol. 29, No. 1, p. 76-94.*

*Explanation*: This study is carried out to discuss possible mitigation strategies for traffic routes in the case of avalanches. Emphasis is given at organizational measures like warning systems or closure policies. The study presents a framework of avalanche risk assessment and cost-benefit comparisons for different mitigation measures, especially the impacts of closed roads on the local and region economy. The authors also developed a hybrid strategy regarding the combination of structural and organizational measures to reduce avalanche risk at traffic routes.

- *Cost types addressed:* The value of a statistical life is calculated by a normative approach. This must be monetised by assessing the benefit of a small risk reduction in terms of mortality. Consequently, quality weighted gains of discounted life expectancies of affected persons are evaluated. Also, costs of technical and organizational measures) avalanche sheds, warning service, forecasting, artificial avalanche release and road closing installation are presented (including installation, maintenance, and operation). The methods of cost assessment of traffic closures (in terms of annual average indirect costs) also contains: daily visitors, seasonal changes in guests, inhabitants, suppliers in tourism industry, forgone revenues per road closure and number of closure days.
- *Objective of the approach*: to evaluate alternative mitigation strategies on traffic routes including structural and organizational measures
- *Impacted sectors*: both, the public and the private sector - in the main the tourism sector
- *Scale*: depending on the length of the road, local / regional
- *Expected precision (validity)*: high, due to the exact methodology regarding the assessment of indirect effects and fatalities
- *Parameters used for determining costs*: life expectancy, costs for mitigation
- *Results and result precision*: benefit on avoided mortality, estimated costs of mitigation, net present values of mitigation
- *Is the method able to deal with the dynamics of risk?* Yes, if the values are updated.
- *Skills required*: advanced economic modelling, knowledge in risk and probability analysis
- *Types of data needed*: data on nearly all affected users of the road (inhabitants, tourists, private businesses), VOSL as an output of the local analysis
- *Data sources*: public institutions, researchers
- *Who collects the data*: public institutions, researchers
- *Is data derived ex-ante or ex-post*: ex-ante
- *Data quality*: high

*Wilhelm, C. 1997: Wirtschaftlichkeit im Lawinenschutz. WSL / SLF, Davos.*

*Explanation*: This comprehensive study is an early milestone in the field of assessing cost-efficiency of mitigation measures against avalanches. In particular, following points are widely discussed and can serve as a basis for a detailed introduction and future improvements in this field: calculation of damage potential and possible evaluation of future losses, risk assessment of avalanche in general, methods of economic valuations to assess the costs and benefits of avalanche protection (especially CBA and CEA) and economic efficiency of measures.

- *Cost types addressed*: all costs types are addressed, but particular attention is given to average costs of mitigation measures, marginal costs of mitigation, costs of prevented fatalities (human capital approach), overall benefits and costs of technical mitigation of avalanches, net present values, cost-benefit-ratios
- *Objective of the approach*: to assess the economic efficiency at traffic routes and settlement areas

- *Impacted sectors*: all sectors, quantitative: local effects on direct losses, fatalities
- *Scale*: all levels, quantitative: local
- *Expected precision (validity)*: medium
- *Results and result precision*: economic efficiency at traffic routes and settlement areas, general overview of methods and risk assessment in the case of avalanches
- *Is the method able to deal with the dynamics of risk?* Yes, if data is updated.
- *Skills required*: statistics, knowledge in risk analysis, probability functions, economic evaluation techniques, CBA
- *Types of data needed*: local survey data, general statistical data, data of avalanche mitigation projects
- *Data sources*: public institutions planning avalanche mitigation, municipalities
- *Who collects the data*: public institutions, municipalities, researchers
- *Is data derived ex-ante or ex-post*: both ex-ante and ex-post
- *Data quality*: high

→ CBA or CEA are used in many countries in the Alpine arc to evaluate the economic efficiency of protection measures against natural hazards. Despite the differences of assessed damage categories and legal foundations, the tools aim to identify the most suitable mitigation from a set of alternatives. In Austria, CBA are more detailed regarding the evaluated damage categories, whilst in Switzerland the emphasis is put on the risk concept and its application in natural hazard management and the pragmatic usage. Moreover, the Swiss tools are developed to improve risk communication and awareness building. Strong differences occur in assessing indirect effects and the costs for emergency. In fact, Swiss methods do not count for such kind of economic losses, whereas the Austrian CBA assesses indirect effects based on estimations without a clear theoretical concept. In contrast, MCA seems to be generally underrepresented in the Alpine countries.

## 3.7 Summary and assessment of methods

The following section focuses on the assessment of the methods described in section 3. As seen in the method descriptions, plenty of studies exist for the evaluation of costs triggered by Alpine hazards. On the one hand, there are methods and evaluation techniques for different damage categories (direct losses, business interruption, indirect losses, intangibles) as well as for the assessment of mitigation and adaptation costs, many of which are of academic interest. On the other hand, decision support by CBA and CEA are widely used in alpine hazard and risk management, i.e. scientific approaches have already been transferred into practise. Table 3.4 summarises the methods for monetary evaluation, Table 3.5 methods and tools for decision support. In the text boxes of the preceding sections, the diverse methods were described and already assessed by a set of criteria such as input data, scale, kind and precision of results etc. The use of methods for the different cost categories depends strongly on the purpose and aim of the study.

The tables also reveal possible research gaps with regard to the damage categories and their economic valuation. With respect to direct costs and damage functions, much work has already been done for single hazards, but for multi-hazards or intermixed

Alpine hazards such methods are widely missing. Also, possible future damage as part of risk analyses and costs of past events (losses) are analysed broadly, but for marginal costs and additional costs of hazards only very few case studies exist. This especially holds for emergency and clean-up costs. In general, there are only a few studies that look in detail at indirect effects of hazard events at the local or regional level. Due to the special situation of lateral valleys (see section 1.3), indirect effects are likely to have a high relevance for Alpine risk assessment.

In the case of intangible effects, mainly loss of life as well as injuries and evacuation are assessed. Other non-market effects like damage caused to the environment e.g. due to oil leakages have not been analysed at all. A systematic approach listing all intangible costs does not exist by now. The main reason for this is missing data, but also that the general public bears these kinds of costs. In times of depending scarcity of public funding, the economic analysis of public expenses is becoming more important.

From a methodical point of view, the development of a standardized cost-benefit-analysis for all types of Alpine hazard is wishful. Given the example of Austria, the officially used CBA differ significantly in concept, used data, and assessed cost categories. Pragmatic approaches like the Swiss RiskPlan could overlap the gaps between experts and the public or the potential affected population, because there is a high need for the understanding of Alpine hazard costing and risk management strategies. In general, one of the most important points is costing over the whole risk cycle. At the moment a lot of isolated applications exist, without the possibility of holistic or integral solutions to cost Alpine hazards.

**Table 3.4:** Available cost assessment methods and monetary valuation techniques for Alpine hazards.

| Methods | direct losses | disruption of production | indirect losses | intangible losses | mitigation and adaptation |
|---|---|---|---|---|---|
| Damage functions | Fuchs 2005, Huttenlau et al.2010, Wilhelm 1997 | - | - | - | - |
| market valuation techniques (incl. insurance values) | Fuchs 2004 & 2005, Blöchl & Braun 2005, Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008b, Huttenlau et al. 2010 | - | decline of touristic income: Nöthiger 2003: tax deficits: Fuchs 2004, Rheinberger et al. 2009 | Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008b | see CBA, Wegmann et al. 2007 |
| standardized values/unit values | - | - | - | Wilhelm 1997, Guzzetti et al. 2005 | - |
| replacement and repair costs | Huttenlau et al.2010, Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008b | Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008b | Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008b | - | - |
| marginal costs | - | - | costs of emergency: Pfurtscheller & Schwarze 2010, Fuchs et al. | - | - |
| input/output analysis | - | macro-economic effects: Kletzan et al. 2004 | | - | - |

| Methods | direct losses | disruption of production | indirect losses | intangible losses | mitigation and adaptation |
|---|---|---|---|---|---|
| travel costs | - | - | Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008b | - | - |
| human capital approach | - | - | cost for evacuation: Fuchs et al. 2007a | loss of life and injuries: Wilhelm 1997 | - |
| contingent valuations (CVM) and value of a statistical life (VOSL) and similar methods | - | - | - | avalanches / VOSL: Leiter & Pruckner 2009, fatalities: RiskPlan, Olschewski et al. 2010, Rheinberger et al. 2009, Rheinberger et al. 2009 | mitigation forest: Olschewski et al. 2010, Alpine road safety: Rheinberger 2009 |
| alternative costs | - | - | - | Fuchs et al. 2007a | - |

**Table 3.5:** Available methods and tools for decision support and cost categories considered.

| Methods | Direct losses | disruption of production | indirect losses | intangible losses | mitigation and adaptation |
|---|---|---|---|---|---|
| cost-benefit-Analysis (CBA) | EconoMe 2.1, Fuchs et al. 2007a, Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008a & 2008b. | Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008a & 2008b | Fuchs et al. 2007a, Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008a & 2008b | Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008a | Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008a & 2008b |
| Cost-effectiveness-Analysis (CEA) | direct losses: RiskPlan, Fuchs et al. 2007a, Wilhelm 1997 | - | Fuchs et al. 2007a | fatalities: RiskPlan | - |

# 4 Current expenses for the mitigation of and adaptation to Alpine hazards

This section outlines current expenses for structural and non-structural mitigation measures in Alpine countries and introduces climate change in mountain areas and its relevance for the costs of natural hazards.

Due to legal foundations, the protection of natural hazards in Austria is primarily a federal task, whereupon there is no legal obligation to protect each citizen. Yet it is surely a high priority and an overriding public interest to guarantee public safety and organise federal prevention measures. Primarily, these tasks are to define protection levels, planning of prevention measures and organising crisis management (Rudolf-Miklau 2009). Moreover, natural hazard management is a complex challenge, since many institutions are involved. Prevention (mitigation) of alpine hazards is carried out by different means (spatial planning, technical mitigation, risk awareness building, and risk assessments) for which different public agencies are responsible.

## 4.1 Costs for Mitigation (Public safety)

Besides statistical data on the occurrence of and losses triggered by natural hazards, annual costs for public safety measures to protect against natural hazard processes are of prime interest, if costs of natural hazards shall be systematically analysed. Due to missing data and - in most cases - multiple involved administrative bodies at diverse levels (e.g. municipal, regional, national in the case of Austria), the exact quantification of expenses for public safety is difficult and cannot easily be compared between countries. In most cases, the cost assessment of mitigation measures is done by a market-based costing approach. However, there are also public finance approaches to evaluate co-benefits of mitigation on public goods (e.g. environmental effects), like contingent valuations (CVM).

An exceptional study that quantified the total expenses for natural hazard management in Switzerland was carried out by Wegmann et al. (2007, see box). According to Wegmann et al. (2007), Switzerland spends about 0.6 % of GDP (€ 2.2 billion) in total for mitigation against natural hazards per year. This includes the private, the insurance and the public sector. The expenses for prevention – for example, risk mapping and setting up technical mitigation measures – are € 1 billion. Every year the Swiss also budget the costs for emergency response including all involved rescue institutions on approx. € 310 million (Wegmann et al. 2007).

Compared with Switzerland, the yearly expenses for public safety are significantly lower in Austria with an estimated 0.07% of GDP - without accounting costs of response and only accounting the costs of risk mitigation of floods, torrent processes and avalanches (in total € 154 million, Federal Ministry of Agriculture, Forestry, Environment and Water Management 2010). The Austrian disaster fund has an additional budget of € 340 million for risk mitigation measures and compensation for private losses (Federal Ministry of Finance 2010). Huge disaster impacts, like the 2002 and 2005 floods in Austria, show that additional technical mitigation measures are carried out and are especially funded (Figure 4.1).

These numbers must also be interpreted under the premise that very different public structures and risk transfer mechanisms regarding natural hazard management are implemented in Austria and Switzerland. For example, in Switzerland, risk transfer in the case of natural hazards is mainly done by a compulsory, state-controlled system, whereas in Austria public funding by a disaster fund and a residual private insurance-system absorb economic damages to private assets (Prettenthaler & Vetters 2005). The Swiss insurance premiums are included in the study of Wegmann et al. (2007), while they are not (completely) considered in the figures for Austria.

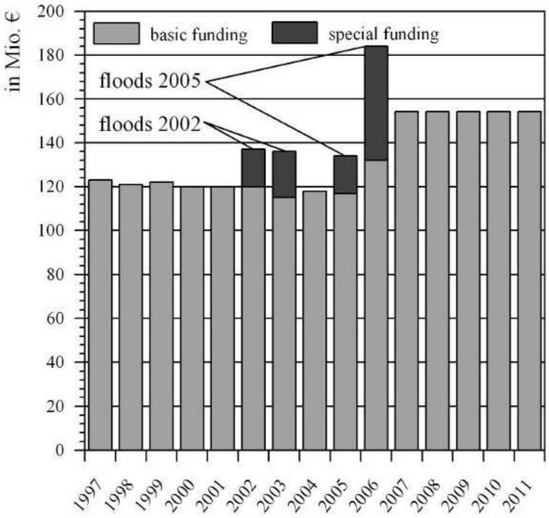

**Figure 4.1**: Costs of mitigation measures 1997 - 2011 of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management; Source: Pfurtscheller & Thieken (2010 p. 395).

*Wegmann, M., Merz, H. & K. Meierhans Steiner (2007): Jährliche Aufwendungen für den Schutz vor Naturgefahren in der Schweiz - Strategie Naturgefahren Schweiz, Umsetzung des Aktionsplans PLANAT 2005 - 2008. Bern.*

*Explanation*: This study was part of a national strategy dealing with natural hazards in Switzerland by the PLANAT-platform. The annual costs of natural hazards are the main basis for a cost-efficient assessment of natural hazards. The analysis assesses the expenses of the public sector at all administrational levels (state, cantons, and municipalities). Moreover, also the annual costs of risk transfer (insurance premiums) are analysed. The study contains the costs of floods, avalanches, geologic mass movements, earthquakes, storm, hail and extreme temperatures. In general, about SFr 400 per capita is spent each year for natural hazard mitigation in Switzerland. The study comprehends both, fixed and variable costs.

- *Cost types addressed*: All costs in the public and private sector (insurances) were assessed, which were triggered by natural hazards in Switzerland on a yearly basis. This also comprises costs of risk transfer.
- *Objective of the approach*: to get an overview about the total economic costs of natural hazards
- *Impacted sectors*: analysis of the public and the private sector
- *Scale*: from local to national
- *Expected precision (validity)*: relatively high, due to the comprehensiveness of the study
- *Results and result precision*: public and private costs of natural hazards in Switzerland
- *Is the method able to deal with the dynamics of risk?* No, this cost assessment is connected with extensive research and data collection due to the involvement of diverse public and private institutions. So, such an analysis only could be done once, if there is no systemically approach to collect he data needed.
- *Skills required*: statistics, advanced knowledge in public natural hazard management
- *Types of data needed*: alls costs triggered by natural hazards in Switzerland
- *Data sources*: all public and private institutions which deal with natural hazard management

- *How is the data collected*: survey of data at all public bodies dealing with natural hazard management at the state, cantonal, and municipal level - average values of the period 2000 to 2005
- *Is data derived ex-ante or ex-post*: ex-post
- *Data quality*: relatively high

## Comparison of risk transfer systems

The flood in 2005 offered the chance to systematically analyse the effectiveness of different risk transfer systems in Austria, Germany and Switzerland. Raschky et al. (2009) and Schwarze et al. (2011) compared: i) Bavaria (Germany) with a pure market-based insurance system and public relief in case of very severe events, ii) Grisons (Switzerland) with a compulsory insurance against natural hazards and alpine risks provided by a public (monopoly) cantonal property insurer (KGV) and iii) Tyrol (Austria) with a tax-based disaster fund that is supplemented by market insurance. In Austria and Germany insurance against losses due to natural hazards can be contracted as addition to building fire insurance. Accordingly, insurance density varies significantly: While in Grisons/Switzerland 100% of the homes are insured against natural hazards, this holds for less than 15% in Tyrol/Austria and for only 10% in Bavaria/Germany.

In addition, the costs for insurance, i.e. the premiums, differ in the three systems. People in Tyrol would pay an annual net premium of approximately 420 Euros for a fixed sum insurance assuming a house worth 335,000 Euros, i.e. approximately 1‰. Considering information of two German insurers a relative premium of more than 1‰ was calculated for Bavaria. Assuming a house with a value of 300,000 Euros and an excess of 1% of the sum insured, the yearly net premium for an insurance against damage due to fire and natural hazards would amount to 313 Euros at the first insurer (Bruderhilfe). The premium of the second insurer (Gerling) is based on an excess of 10% of damage and results in an annual net premium of 376 Euros. In contrast, the monopoly insurer in Grisons can provide insurance coverage for a house worth 500,000 CHF (about 335,000 Euros), for a yearly premium of 150 CHF (about 100 Euros). This corresponds to a relative premium of 0.3‰, i.e. less than one third of premiums in Austria or Germany.

The lower costs of public monopoly insurance was already realized within Switzerland, where in seven of 26 cantons (the so called GUSTAVO cantons), insurance is offered by private companies, which charge significantly higher premiums. Ungern-Sternberg (2002) and Fischer (2008) identified different reasons for the higher efficiency of public monopoly insurers: low advertising and other competition costs, larger reserves of the monopoly insurers and their right to participate in the processes of the Building Codes and Land Use Planning as well as the financing of the Fire Service and Cantonal Civil Defence Services. In fact, Swiss monopoly insurers invest about 15% of the premium incomes in prevention.

For comparison: In Spain, where a comprehensive legal compulsory insurance against damage caused by geo-atmospheric hazards and other ‘extraordinary events’ (terrorist attacks, political unrest) was put in place, the annual contribution amounts to 0.092‰ of the insurance sum for buildings.

## 4.2 Climate Change and its relevance for the costs of alpine hazards

Climate change is a global phenomenon, but its local impacts are heterogeneous. Mountain regions, which occupy almost between 20 to 25 % of the continental surface (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2008, p. 12), have highly diverse and rich ecosystems and show above average sensitivity to climatic changes. Although mountain regions in the world differ considerably from one region to the other they have a complex topography in common. Climatic parameters, like precipitation and temperature, show distinct altitudinal gradients (Beniston 2006), i.e. climate, in mountainous regions, changes rapidly with elevation over short horizontal distances. Indeed, mountain regions such as the European Alps react very sensitive to a (rapidly) changing climate and therefore they suit for the early detection of the signals of climate change and the related impacts on hydrology, cryosphere, ecology and finally society (Beniston 2003).

The European Alps will be confronted with various changes concerning its climate (Kohler & Maselli 2009). Driven by rising temperatures, hazards related to changes in snowfall pattern, glacier melt, permafrost are likely to aggravate. Hence, natural hazard impacts, in particular glacier lake outburst floods (GLOFs) and hillslope destabilization as a consequence of permafrost degradation, are expected to rise in the next decades. However, the increase in recent catastrophic events in the European Alps and related economic losses is also caused by the increasing settlements and assets in high risk areas, the increased vulnerability of technical and social systems and thus a higher exposure to natural hazards. Barredo (2009) initiated an analysis of normalized flood losses from 1970 to 2006 with macro scale data and showed that there is no significant trend of rising economic losses. He pointed out that growth of wealth, rising living standard and the subsequent growing exposure are the main triggers for flood losses. The climate will have a longer-term impact on economic hazard losses, but is currently obscured with climate variability and socio-economic developments. In general, combining economic losses and climate variations are currently only based on macro data and hence, are biased (see section 2.1). Moreover, the relatively short period of collected loss data does have a strong influence on the results and its significance; it is thus not predictive with regard to climate change impacts. We therefore conclude that climate change will – combined with globalization trajectories – will have a strong impact on natural hazards frequency and magnitude, as well as intensity.

Table 4.1 summarizes the results of the ClimChAlp project regarding Alpine hazards, namely floods, mass movements, torrential hazards and avalanches. Comparing the results of the ClimChAlp project (2008) and those from Jetté-Nantel & Agrawala (2007) in Table 4.2, high uncertainties of the predicted impacts triggered by climate variations remain. Mainly winter floods, debris flows in high altitudes and reactivation of mass movements could have substantial impacts on the future human sphere in the Alps. Altogether, the analysis of the OECD (Jetté-Nantel & Agrawala 2007) concluded "that many hazards which have strong linkages to climate change actually have relatively low/medium economic significance. The clearest impacts of climate change on natural hazards occur in glacial and permafrost zones which may be of limited economic significance from a national perspective, although their implications for local communities may be quite significant. On the other hand, hazards which have considerably higher economic and social significance, such as floods and windstorms, have more complex and less certain linkages with climate change."

Still, the international Platform on Natural Hazards of the Alpine Convention (PLANALP 2008) estimates that an annual budget of more than € 1 billion will be needed throughout the Alpine countries to adapt natural risk management to climate change. Actions foreseen are i) the production and updating of hazard and risk maps and ii) their integration in land-use planning, iii) the establishment of networks to share knowledge and experience at regional, national and international level (risk dialogues) including iv) monitoring systems, event documentation and analyses, v) improvement of early warning and emergency management as well as vi) an improvement and maintenance of technical measures (including testing their performance in case of overload and robust design; see PLANALP 2008).

→ Mountain ecosystems and hence human settlements as well as economic activities in these regions are very sensitive to climate variations and climate change. In general, the existing facts and estimates about climate change impacts in the European Alps show no robust and homogenous picture, but an intensification of frequencies and magnitudes of Alpine hazards is expected. It is evident, that there is an increasing risk of GLOFs and triggered floods or debris flows, an increase in permafrost degradation and coherent destabilization of precipices and a possible combination and series of reactions of these processes (multiple hazards). In the case of floods, a greater intensity and frequency of winter high waters could lead to substantial economic impacts, but the connections to climate change are not yet clear enough. These analyses are mostly based on short data periods, so results must be judged preliminary.

**Table 4.1**: Potential climate change impacts on natural hazards in the European Alps; Source: Observatoire National sur les Effets du Réchauffement Climatique (2008).

| process | climate change impact |
|---|---|
| Floods | - increased winter precipitation increases flood risk, due to reduced snow cover and higher rain limit especially for regions of about 1000 to 2500 m a.s.l.<br>- simultaneous reduction of spring flood peaks and temporal shifting of floods backwards to early spring<br>- glacial degradation triggers a short term increase of runoff |
| geologic mass movements | *deep landslides:*<br>- in general, acceleration of movement rates triggered by higher precipitation, but with respect on local preconditions<br>- re-activation of deep landslides more than activation of new processes<br>*rock fall:*<br>- increase of events which are strongly correlated to permafrost degradation, but high uncertainty<br>- increase of frequency in the permafrost area influenced by freezing - unfreezing cycles due to rising temperatures<br>- simultaneous reduction of rock fall in lower altitudes |

| process | climate change impact |
|---|---|
| torrential hazards | - no clear modelled trend, but rising debris flow intensities<br>- intensity variation could release higher volumes and stopping distances<br>- torrential hazards are highly dependent on local preconditions<br>- possible interlinkage with periglacial and glacial processes, more available material due to intensification of glacier retreat and permafrost degradation<br>- at low and medium altitudes decrease of debris flow events<br>- potential higher debris flow activity due to increased precipitation in spring and fall, but with a high uncertainty<br>- high mountain areas will be more affected by debris flow events, due to more frequent melting periods |
| avalanches | - no trends have been observed regarding the frequency and changing locations<br>- possible decreasing avalanche activity at low and middle altitudes due to reduced snow cover<br>- increased avalanche activity at high altitudes, due to increased snow cover increase triggered by intensification of precipitation<br>- potential increase in slab snow avalanches due to higher variation of melting periods and a higher snow/rain line |

**Table 4.2:** Potential climate change impacts on natural hazards in the European Alps; Source: Jetté-Nantel & Agrawala (2007, p. 70).

| Changes in natural hazards | Confidence in projected damages | Most affected regions | Economic importance |
|---|---|---|---|
| *permafrost related hazards:*<br>increase in frequency of rock fall and magnitude of debris flows | very high | high mountain range, tourism areas | low |
| *GLOFs:*<br>increasing incidence of Glacial Lake Outburst Floods (GLOFs) | very high | high mountain range, tourism areas | low |
| *other glacier related hazards:*<br>increasing frequency and magnitude | high | high mountain range, tourism areas | low |
| *winter floods:*<br>greater intensity and frequency | medium | lower mountain range, densely populated areas | very high |
| *rockfalls:*<br>increasing frequency | medium | lower to medium mountain range | medium |
| *landslides and debris flows:*<br>increasing frequency and magnitude | medium/ low | lower to medium mountain range | medium |
| *avalanches:*<br>increasing frequency and magnitude at high altitudes | low | high mountain range, tourism areas | medium |

# 5 End-user views, recommendations and knowledge gaps on costs of Alpine hazards

Various case studies that were introduced in the preceding chapters illustrate that diverse methods exist for assessing different costs related to Alpine hazards. However, a consistent evaluation of the overall costs of Alpine hazards and risks as depicted in Figure 1.10 is still missing. Nevertheless, interaction with stakeholders in the ConHaz-Project has shown that in the cost assessments in some Alpine Countries, particularly in Austria, Switzerland, but also Slovenia, are comparatively well developed and implemented. This chapter summarizes end-user views, best practices, research gaps as well as recommendations for future research. The chapter is mainly based on the literature review as well as the ConHaz-workshop "Costs of Alpine hazards" held in May 2011 in Innsbruck, Austria.

The workshop "Costs of Alpine Hazards", held on 20th May 2011 in Innsbruck, Austria, and the preceding excursion on 19th May identified strengths and shortcomings of current methods for the assessment of costs of Alpine hazards. In addition, the needs of end-users were collected with regard to the type and form of information that should be provided in case of an event as well as for risk reduction plans. Further, experiences with current methods as well as applications and impacts of broader and better information were compiled. The workshop particularly focused on methods of assessing costs and benefits due to natural hazards in mountain regions (e.g. collection and assessment of real losses, methods to assess potential direct, indirect and intangible damage, methods and guidelines for cost-benefit-analysis of mitigation measures).

The workshop had three main pillars. In the morning session six key note lectures from the different hazards communities and Alpine countries were given. The presentations showed the plurality of different methods and hazards applied in the countries of the Alpine arc. Discussion sessions in the afternoon were based on the world-café-method to encourage a maximum of interaction between the participants. Moreover, the workshop participants had the opportunity to fill out a questionnaire on the cost assessment for Alpine hazards.

In the afternoon sessions the following questions were discussed by the participants:

- What should a good approach for xxx include?
- Which approach for xxx does currently meet your requirements at best? Why?
- How can methods for xxx contribute to a better risk management or to a reduction of alpine risks?
- What do we still need to learn about xxx?
- How can we foster learning from past events and across hazard types, institutions and alpine countries?
- How can we support each other?

where "xxx" = Estimating 1. direct costs / 2. indirect costs / 3. intangible effects / 4. costs for mitigation & adaptation / 5. Collecting data about costs of alpine hazards

Five tables on the above-mentioned topics with each two moderators were established. Altogether, three discussion rounds took place so that participants had the chance to change the table/discussion topic.

At the end of the workshop the participants were asked to write a brief statement addressing two questions:

1) From what you have heard today: What was the most relevant for you?

2) What would be the most important next step?

The answers were collected and grouped to some overarching topics.

## 5.1 Assessment of direct losses

A good understanding of damage-causing processes is important for the development of reliable damage models. A good damage model should reflect the hazard specific damaging processes, such as flow-depth or avalanche pressure, but preferably also resistance parameters such as differences in building structures and especially hazard mitigation measures. Their effects on damage reduction are, however, difficult to quantify. More data on this topic should be gathered.

Requirements for a ‘good approach’ vary and depend very much on the purpose and the scale of the model application. Hence, there is no single good approach. For example, significant differences exist e.g. between small-scale and detailed project appraisals and strategic risk assessments. For example, for a quick rough estimate of losses in case of an event average losses in combination with satellite data are a good approach. This approach is, however, not suitable for project evaluations. For ex-ante loss assessments and project evaluations more detailed information is needed. It is desired that loss functions are derived from data of the region under study. If no actual loss data are available, what-if analyses should be used. Here, assumptions have to be made with regards to object properties, warning, emergency measures, prevention etc. Alternatively, hazard zone plans should be connected with common vulnerability analyses (e.g. available damage functions) for ex-ante loss assessments. After an event, vulnerability models/damage functions should be updated after a certain time slot based on detailed information on the actual losses (and event parameters). For this, special damage surveyors like in the UK, who are seen as good practice, are desirable.

Furthermore, little is known about the transferability of damage models across regions and countries. In fact, there is a demand for damage functions that better reflect regional characteristics. In comparison to other hazards, there seems to be a tendency for micro-scale approaches in damage modelling of alpine hazards, which is probably due to the diverse mountain environments and (scattered) settlements in remote areas. Nevertheless, data sharing and cross-country cooperation should be enhanced.

Most of the current damage models concentrate on building losses. In contrast, relatively few approaches exist for estimating direct losses of infrastructures, although this is an important damage category. For example, the breakdown of power supply is a key factor for the damage extent. Therefore, efforts on this topic should be increased.

There is also only little knowledge about losses due to the disruption of production processes by Alpine hazards. A lack of understanding cascading effects might be the reason for this. Many Alpine hazards are caused by the same natural processes. Heavy rain events not only cause floods, debris and mud flows, but also landslides. However, despite of the tremendous amount of work that has already been done for single hazards, approaches for multi-hazards or intermixed Alpine hazards are widely missing. There are currently no integrated models available that could provide insights into the interplay of different Alpine hazards in terms of damage.

Loss drivers in Alpine areas at all scales are difficult to identify and some Alpine hazards, such as landslides, are very difficult to predict and to model in terms of the process, the hazard characteristics and the resulting damage. Possible starting points are the studies carried out by Fuchs et al. (2007b) or Totschnig et al. (2010) for debris flows and fluvial sediment transport.

Direct cost assessments can contribute to sustainable risk mitigation strategies. Stakeholders gave examples, for instance, from analyses of damage processes in Slovenia, which led to the development of recommendations for risk mitigation measures. Also learning from past events is a prerequisite to develop better models as well as better policies in the future. Furthermore, sound cost assessment can contribute to better estimations of real risks and thus to a better risk management. Sound cost estimates are e.g. needed for Cost Benefit Analyses (CBA) that can help to allocate resources in order to efficiently to reduce existing risks from Alpine hazards. However, improved damage modelling might in practise not always be a top priority. Since there will always remain considerable uncertainty in cost estimations and since policy makers are used to take decisions under uncertainty, workshop participants argued that it should be carefully considered if and when to deploy resources to improve cost assessments. Instead, risk communication and cooperation was seen as more important.

## 5.2 Indirect damage

“Alpine economies” are mostly closed and have only few exchange relationships to the outside world. Consequently, they are much more vulnerable to indirect effects, due to the missing possibilities of substitution of lifelines, traffic networks, goods, services, and manpower. Due to the special situation of lateral valleys (see section 1.3), indirect effects are likely to have a high relevance for Alpine risk assessment at the local and regional scale. However, indirect effects are often not considered in decision making processes - even if cost-benefit-analyses were established for risk management decisions. Existing methods, like input-output-analysis, computable general equilibrium (CGE) models and impacts on gross domestic (GDP) product, were, however, developed to analyse macro-economic effects. At the regional and local scale these methods are inadequate, mainly due to missing data at this scale. More efforts are needed to close this gap.

Engineering and mathematical methods can be used to analyse network failures and provide a coherent set of methods to assess indirect effects in lifelines. However, network engineering methods are often not applied because of lacking data and high uncertainties. There is research performed on “alternative costs” (travel time, additional fuel consumption, and emissions from detours) in order to evaluate the economic effects of network failures. This network failure approach currently is the best available method and is better than the current practice to neglect indirect effects. Recently, a few studies looked at indirect effects of past events on the regional economic effects and should be used to learn more for the (ex-ante) evaluation of indirect effects.

Using GDP impacts as aggregate measures of costs was identified to be a “bad practice”, as it is influenced by a many overriding factors (e.g. relative price changes). As indirect effects are more dominant at the local and regional scale (small closed economies) aggregate measures (such as GDP) could be ill-guiding.

For a good practise approach the following aspects were regarded as important:

First, a clear definition of indirect effects is essential. In ConHaz, indirect effects are defined as follows: Indirect damages are only those damages which are induced by either direct damages or losses due to business interruption. This includes induced production losses of suppliers and customers of affected companies, the costs of traffic disruption, and the costs of emergency services. Indirect effects need to be distinguished from business interruption (disruption of production), where losses stem from the direct affection of e.g. buildings, machinery or truck fleet of a business.

Second, the (spatial) system boundaries as well as the time horizon (short-/middle-/long-term) of the assessment must be determined. Appropriate system boundaries are defined by end-user purposes. Consequently, the frame of the study and its overall purpose (e.g. macro-economic assessment vs. single business perspective) has great impact on the data, methods and results.

In general, prevented damage as benefit of mitigation should comprise a reliable number of losses and not only the relatively easy-to-manage loss categories like buildings. In this sense, pilot studies of CBA containing indirect economic effects as well as costs of emergency would be a starting point towards a holistic assessment.

As long as economic methods to assess indirect effects are lacking or questionable, non-monetary evaluation techniques, like MCA or Systems of Accounts (as in Germany) should receive more attention in research and practices to assess indirect effects. Alternatively, sensitivity analyses using different methods should be applied, but need much resources.

In the ConHaz project, the costs of emergency are also subsumed to indirect effects. These costs are a function of time, scale and the triggering natural process. In general, costs of emergency include costs of intervention, clean-up, evacuation and rescue. The warning time and contingency planning are important elements to be considered. Cost of emergency can be substantial when clean-up is considered, but are often neglected in cost-benefit approaches for risk mitigation. Current best practices are found in Slovenia where a legal framework for risk management exist including a real-time reporting of emergency services including costs, e.g. loss of material was established as well as a nested data pool from local to national level.

## 5.3 Intangible damage

The valuation of environmental goods is considered as a rather complex issue. Overall, the discussion at the workshop revealed that there is a great need for practical knowledge on the methods and the concept of intangibles. A better communication of the intangibles' best-practices including gained knowledge about effects, costs and valuation methods was requested. There is a need for participatory processes and better cooperation within the natural hazards communities in order to learn more about intangible effects and their costs. Three important points for the information on assessment of intangible effects were identified: communication, sharing knowledge, and need for interaction. For learning and mutual support, several activities were proposed: international projects should foster long-term exchange of scientific staff, strong linkages to practitioners and participation of consultancies in applied research was recommended.

There was a great reluctance for a complete monetization of all intangible effects among the participants. Transformation mistakes emerge when trying to monetize the intangible impacts. Nevertheless a need for a balanced (between quantitative and qualitative) and comprehensive approach was expressed that enables decision making along the disaster cycle for a defined purpose and system. Intangibles should be better integrated in a general (spatial) planning framework, but not necessarily as cost terms.

The usefulness of the constructed data was questioned by the participants and there is a demand for more data reliability. Further, biases-related methodological problems concerning stated preferences methods for estimating intangibles have to be acknowledged. Contingent Valuation Method (CVM) was assessed as a method with many limitations, and benefit transfer was criticised for being a weak method as the socio-economic context is never the same.

However, data collection for intangibles is very difficult except for data on injuries and fatalities. Currently, mainly loss of life as well as injuries and evacuation due to alpine hazards are assessed. Other non-market effects like health or psychological effects and damage caused to the environment e.g. due to oil leakages have not been analysed at all in the alpine region, but are needed.

Furthermore, it is important to better prioritise and classify the intangible effects. A systematic approach listing all in-tangible costs does not exist by now. The great need for a check list or guideline for practitioners was stated in order to enable them to determine the effects of importance. Such a checklist could contribute to a more systematic identification and estimation of the intangible costs. This approach should be used broadly in project planning enhancing planners to classify and evaluate the intangible effects in a qualitative way. As a starting point, a kind of “event analysis” was proposed in order to determine intangible impacts for certain scenarios. For this scenario analysis, the system and its boundaries need to be defined in terms of spatial and temporal scale. Risk mapping was considered as useful for dimensioning impacts.

Concerning risk management and risk reduction, the (ex-ante) inclusion of intangibles in each phase of the disaster cycle will contribute positively. Special emphasis has been made on the better outcome when included in the prevention phase in terms of preparedness. A two account system was proposed that presents a trade-off analysis between quantitative gains/losses on one hand, and qualitative gains/losses on other hand. In specific, traditional CBA should be combined with analysis of effects that are not monetized or where no method is available. The decision maker then could analyse the two accounts and identify trade-offs. This trade-off analysis differs from MCA as there are methodological shortcomings with MCA concerning its score system and aggregating costs in monetary terms with adverse effects on a score based system. This leads to a different decision making. The conclusion was that in reality, MCA does not work well and is also very subjective and a trade-off analysis as stated above would be preferable.

## 5.4 Costs of mitigation and adaptation

The costs of mitigation and adaptation are largely determined by the aim of prevention, i.e. the level of protection envisaged and the level of risk considered as acceptable.

There are already quite accurate estimates in terms of the initial (set-up) costs of mitigation exist, but there are often only imprecise estimates of follow-up maintenance costs. Further, there is often confusion of which measure constitutes mitigation/adaptation for the case of alpine hazards.

The workshop discussion revealed that there is a variation across countries with respect to the degree of importance given to 'preventing the loss of human life' (vs. direct monetized damages) in terms of prioritising spending. In order to better meet peopple's preferences, more data with regard to the topics of risk awareness, willingness to pay (WTP) for prevention and accepted residual risk are needed. In addition to WTP, choice experiments and other methods should be performed.

Besides economic efficiency, political decision has to include other criteria and vested interest. For example, while estimating the costs of mitigation/adaptation may be relatively straightforward (at least the direct costs), it was mentioned that it is important that the public needs to directly incur some of the costs in order to get a feeling of the magnitude of expenses. This is likely to induce more proactive behaviour. A two-step procedure was recommended: In a first step, a 'quick and dirty' approach that provides rough estimates of costs (and benefits) and allows decision makers to prioritise projects within a limited budget should be performed. This should be followed by a more elaborate exercise that includes a detailed cost-benefit analysis for the projects selected.

In recent years there has been a loss of 'risk culture'. As a result of increased mobility, individuals lose familiarity with the geographic characteristics of the areas they reside and environmental risks. Investment in mitigation infrastructure has also reduced exposure to 'mild' threats, allowing for a counter-productive sense of safety. Therefore, there is a strong need for increasing people's awareness of their exposure to risk and the level of protection. The public needs to realise that a 100% risk protection is in most cases impossible unless settlement areas are given up (retreat). Memory of past events tends to be quite short; there is a need that individuals are frequently re-minded of exposure to risk. In this context, also efforts to increase individual responsibility (proactiveness) should be increased. Financial incentives (e.g. insurance premia for properties in risk-prone areas) linked to behavioural changes and improved risk management could be one measure. This is importance to minimise 'free-riding' since individuals accept higher risks if the government or the community is entirely responsible for risk management. In fact, the combination of structural and non-structural mitigation has to be fostered. For this, more research has to focus on behavioural responses (e.g. through simulation activities) and risk communication and risk dialogue between stakeholders has to be improved.

Some measures were identified which could improve risk reduction:

- more restriction (e.g. land-use) in high-risk areas, but spatial planning seems to be a weak point, particularly in terms of implementation
- provision of funds at an early stage. Delayed funding is likely to increase exposure to alpine hazards in later time and hence result in high monetary damages in future disasters that could have been avoided at a much smaller cost)
- a safety card for buildings considering different hazard impacts

- more sophisticated warning systems need to be developed. The problem with alpine hazards is that there is often very limited time response (the risk is rather abrupt). There is also the issue of who accepts responsibility if there is a 'false' alarm/ who analyses incoming data to determine the level of threat and who co-ordinates actions.

Finally, political will is a key factor in successful risk management.

## 5.5 Cross-cutting issues

A few cross-cutting issues were identified during the ConHaz-project and the workshop. These are:

- Methods for supporting decisions on appropriate measures
- Learning from past events
- Data collection: Standards and processes
- Transboundary co-operation

Cost-efficiency methods are applied in nearly all countries, but the basis for assessing indirect effects, disruption of production (business interruption) and the costs for emergency, evacuation, clean-up, but also intangibles are weak and partly totally missing. So, it is vitally important that the perspective on estimating costs of Alpine hazards is broadened and based on a systematic model of losses and benefits triggered by Alpine risks. It is desirable that the CBA already implemented in public natural hazard management, should incorporate latest methods to assess the mentioned damage categories to reflect all adverse effects by natural hazard events. From a methodical point of view, the development of a standardized cost-benefit-analysis for all types of Alpine hazard is wishful. Given the example of Austria, the officially used CBA differ significantly in concept, used data, and assessed cost categories. Pragmatic approaches like the Swiss RiskPlan could overlap the gaps between experts and the public or the potential affected population, because there is a high need for the understanding of Alpine hazard costing and risk management strategies. In general, one of the most important points is costing over the whole risk cycle. At the moment a lot of isolated applications exist, without the possibility of holistic or integral solutions to cost Alpine hazards.

As illustrated by the examples of the assessment of indirect economic effects and costs of emergency, but also by the comparison of CBA and their specifications in Austria, Germany, and Switzerland, a European wide harmonization of cost assessments could greatly benefit from intensified knowledge transfer. Given that, research efforts in international comparative, but also in cross-border case studies should be performed, to take advantage of country-specific best practice methods and assessment of costs triggered by natural hazards. The harmonization of design levels (triggered by the EU flood directive) was identified as a first step towards an improvement of the comparability of data and approaches. It seems that there is also already much information on effective mitigation investment. However, there is a strong need in exchanging data, information and experience across different risk management centres.

A good documentation and understanding of past events was regarded as key to learn from past events. Although cooperation between institutions and countries in the Alpine arc is already very positive, learning could be fostered by further data sharing and by collaboration in common projects or activities. Currently, differences in data collection and documentation between countries hamper the comparability of results. To overcome this, it is recommended to agree on a minimum standard that should be implemented by all countries. In order to establish such a standardized system, the aim(s) of data collection must be clear and the following questions have to be answered in advance:

- Who collects data?
- Who wants to use data for what purpose?
- What data is collected (e.g. potential or actual losses)?

In order to get useable data for damage modelling, it is crucial is that the standardized system should connect data on the event impacts and on the damage/losses in ONE data base. In a second step, standardizations should be discussed, e.g. a standard classification for land uses should be used and aggregation of classifications should be possible so that data can be used on different scales. Data updates (especially losses) should be possible and the whole system should be accessible on different levels (i.e. for different users). Finally, mechanisms for data exchange and learning should be established. However, the implementation of such an “All in one database” for different users was seen to be impossible by some participants for the following reasons: Restrictions in data exchange (data privacy), different users require different data bases, and spatial and temporal coverage of different systems have to be included. It was proposed that different data bases (for diverse users) should be implemented with common data standards, so that later on a linkage is possible. The EU-initiative INSPIRE could serve as a starting point for this.

Despite the scientific development of methods to assess the different loss categories, application-oriented research has to be accelerated in order to bridge the gaps between research and practice. This needs transdisciplinary collaboration in diverse networks and strong communication of scientific results. Finally, the creation of an Alpine institution for cross-boundaries research was recommended.

## 5.6 Future directions

Table 5.1 summarises the outcomes of the workshop, complemented by some points found in the literature. The first section of the table identifies key findings and points of prime importance, which concern risk management in general, but also findings which are related to all damage categories and pointed out by all working groups of the workshop. The topics are, however, not ranked by importance or any other criteria.

The following topics were identified by the workshop participants as important next steps:

- Systematisation, coordination and exchange of terms and data (9 answers)
- Intensifying communication and cooperation – in general (7 answers)
- Methodological developments with regard to indirect costs (4 answers)
- Methodological developments with regard to intangibles (2 answers)

- Further topics (2 answers)
  - To build awareness about the fact that also non-structural measures such as awareness building, education etc. provide benefits even if it is not possible to quantify them in monetary terms
  - Improvements in assessing vulnerability

These answers can be interpreted as priorities for future research.

**Table 5.1:** Overview of key findings, research gaps, recommendations, and end-user needs in the case of Alpine hazards for direct losses / disruption of production indirect losses, intangible effects, mitigation and adaptation and collecting data about costs of Alpine hazards.

**Key findings, research gaps, recommendations, and end-user needs in the case of Alpine hazards for…**

| Direct losses and disruption of production | Indirect losses | Intangible effects | Mitigation and adaptation | Collecting data about costs of Alpine hazards |
|---|---|---|---|---|
| Definition of the scale, the impact of the hazard, system boundaries and the time horizon of the analysis | | | | |
| Promotion of research and development | | | | |
| Political will/support is a key factor in successful risk management | | | | |
| Analysis of costs according to their purposes of assessment and over the whole risk-cycle | | | | |
| Evaluation of ex-ante and ex-post costs triggered by Alpine hazards | | | | |
| Cooperation among governmental agencies, researchers and end users and between the national ministries | | | | |
| Need for cross-disciplinary and transdisciplinary approach | | | | |
| Great importance of event documentations - learning from the past | | | | |
| Improvement of communication and cooperation across countries | | | | |
| Missing risk management and cost assessment for landslides and geologic mass movements | | | | |
| Development of multi-scaled loss estimations | | | | |
| Foster risk communication to the public | | | | |
| Further data sharing between countries and hazard communities | | | | |
| Establishment of minimum standards of costing Alpine hazards | | | | |

**Key findings, research gaps, recommendations, and end-user needs in the case of Alpine hazards for…**

| Direct losses and disruption of production | Indirect losses | Intangible effects | Mitigation and adaptation | Collecting data about costs of Alpine hazards |
|---|---|---|---|---|
| No single 'good approach', requirements for a 'good approach' vary and very much depend on the purpose and the scale of the analysis | Clear definition of indirect effects is essential ( to be to be distinguished from business interruption) | Great need for practical knowledge and tools to assess intangible effects | Public needs to directly incur some of the costs in order to get a feeling of the magnitude of expenses | Attempt at present: minimum requirements loss documentation (e.g. DOMODIS) |
| Good understanding of damage-causing processes | Systems' boundaries (in terms of space), as well as the time horizon (short-, middle, ong-term) of the assessment must be determined | Valuation of environmental goods is considered as rather complex issue and in most cases missing data | Combination of structural and non-structural mitigation, but also assessment of co-benefits and costs of mitigation needed | High need for harmonization of empirical data collection and establishment of consistent databases for all scales |
| Good damage model should reflect the hazard specific damaging processes and hazard resistance parameters | Consideration of end-user purposes of the analysis of indirect effects | Biases-related methodological problems concerning stated preferences methods | Variation across countries with respect to the degree of importance given to preventing the loss of human life in terms of prioritising spending | Mechanisms for data exchange and learning necessary |

### Key findings, research gaps, recommendations, and end-user needs in the case of Alpine hazards for…

| | | | | |
|---|---|---|---|---|
| Alpine hazards, such as landslides, are very difficult to predict and to model in terms of the process, the hazard characteristics and the resulting damage | Using GDP impacts as aggregate measures of costs was identified to be “bad practice”, fostering non-monetary forms of assessment | Importance to include intangibles in structural manner but not necessarily in cost terms | The need lies more in exchanging information across different risk management centres | Hazard zone plans should be connected with common vulnerability analyses, spatial planning has to be seen as the cross-cutting issue |
| Little knowledge about losses due the disruption of production process due to Alpine hazards | Usually not considered in decision-making process | Lack of knowledge concerning the ecological, psychological and health effects | More sophisticated warning systems, risk communication | Special damage surveyors like in the UK, who are seen as good practice |
| Lack of understanding of cascading effects and currently no integrated models available | Alpine economies” are mostly closed and have only few exchange relationships to the outside world and are much more vulnerable to indirect effects | Search for a balanced (between quantitative and qualitative) and comprehensive approach that enables decision making along the disaster cycle for a defined purpose and system | Economic efficiency is an important criterion: combination of ’quick and dirty’ approach, that provides rough estimates of costs (and benefits) and allows to prioritise spending within a limited budget, followed by a more elaborate exercise | A quick rough estimate of losses in case of an event average losses in combination with satellite data are a good approach, but for ex-ante loss assessments and project evaluations more detailed information is needed |
| | Engineering and mathematical methods can be used to analyse network failures | International projects should foster long-term exchange of scientific staff | The public needs to realise that a 100%-risk protection is in most cases impossible. | Information (participation) of the public |
| | “It is better to have no numbers, instead of bad numbers“. | More linkages to practitioners, Consultancies to be included, and more applied research | Need to increase individual responsibility, impose more restriction (e.g. land-use) in high-risk areas and provide funds at an early stage | Most approaches deal with damage to buildings; in future, more data or analyses about the damage of “lifelines” is needed |
| | | | Improvements of cost-benefit-analysis and similar decision support tools by using latest scientific approaches and assessing indirect costs and the costs of emergency | More data with regard to the topics of risk awareness, willingness to pay (WTP) for prevention and accepted residual risk are needed |

# 6 List of tables

# 7 List of figures

# 8 References and literature

Allamano, P., P. Claps & F. Laio 2009. Global warming in-creases flood risk in mountainous areas. Geophysical Research Letters 36, L24404.

Ancey, C. 2001. Snow avalanches. In: N. Balmforth & A. Provenzale (Eds.): Geomorphological Fluid Mechanics, Lecture Notes in Physics 582, Berlin, p. 319–338.

BABS Bundesamt für Bevölkerungsschutz 1995. KATANOS - Katastrohen und Notlagen in der Schweiz.

BABS Bundesamt für Bevölkerungsschutz 2003. Katastrophen und Notlagen in der Schweiz - Eine Risikobeurteilung aus Sicht des Bevölkerungsschutzes

Barbolini M., F. Cappabianca, & R. Sailer R. 2004. Empirical estimate of vulnerability relations for use in snow avalanche risk assessment. In: CA Brebbia (Ed.) Risk analysis, IV. WIT Press, Southampton, p 533–542.

Barredo, J.I. 2009. Normalised flood losses in Europe: 1970–2006, Nat. Hazards Earth Syst. Sci., 9, p. 97–104.

Baur, P., K. Bernath, N. Holthausen & A. Roschewitz 2003. Lothar - Ökonomische Auswirkungen des Sturms Lothar im Schweizer Wald, Teil I. Einkommens- und Vermögenswirkungen für die Waldwirtschaft und gesamtwirtschaftliche Beurteilung des Sturms. Umwelt-Materialien Nr. 157. Bundesamt für Umwelt, Wald und Landschaft (BUWAL), Bern.

Bätzing, W. 2005. Die Alpen. Geschichte und Zukunft einer europäischen Kulturlandschaft. München.

Bell, R. & T. Glade 2004. Landslide risk analysis for Bíldudalur, NW-Iceland. Natural Hazard and Earth System Science 4(1),p. 1-15.

Beniston, M. 2003. Climatic change in mountain regions: a review of possible impacts. Climatic Change, 59(1-2), p. 5–31.

Beniston, M. 2006. Mountain weather and climate: A general overview and a focus on climatic change in the Alps. Hydrobiologia, (562), p. 3-16.

Bezzola G. R. & C. Hegg (Eds.) 2007: Ereignisanalyse Hochwasser 2005, Teil 1 – Prozesse, Schäden und erste Einordnung. Bundesamt für Umwelt BAFU, Eidgenössische Forschungsanstalt WSL. Umwelt-Wissen Nr. 0707.

Borsdorf, A. 2006. Land-Stadt Entwicklung in den Alpen: Dorf oder Metropolis? In: Psenner, R. & R. Lackner (Eds.), Die Alpen im Jahr 2020. Alpine space – man and environment 1. Innsbruck, p. 83-92.

Blöchl, A. & B. Braun 2005. Economic assessment of landslide risks in the Swabian Alb, Germany – research framework and first results of homeowners' and experts' surveys. Natural Hazards and Earth System Sciences, 5, p. 389–396.

Blong, R. 2003a. A Review of Damage Intensity Scales. Natural Hazards 29 (1), DOI: 10.1023/A:1022960414329.

Blong, R. 2003b. A New Damage Index. Natural Hazards, 30 (1), DOI: 10.1023/A:1025018822429.

Blyth, S., B. Groombridge, I. Lysenko, L. Miles & A. Newton 2002. Mountain watch - environmental change & sustainable development in mountains. UNEP World Conservation Monitoring Centre, available at http://www.unep-wcmc.org/mountains/mountain_watch/pdfs/, 24.6. 2010.

Bouwer, L.M., J. Poussin, E. Papyrakis, V.E., Daniel, C. Pfurtscheller, A.H. Thieken & J.C.J.H. Aerts2011. Methodology report on costs of mitigation. ConHaz report of WP4 “Mitigation and Adaptation”, http://conhaz.org/project/cost-assessment-work-packages/wp1-8-final-reports/CONHAZ%20REPORT%20WP04_2.pdf/at_download/file, D.4.2, Amsterdam.

Bründl M. (Ed.) 2009. Risikokonzept für Naturgefahren - Leitfaden. Nationale Plattform für Naturgefahren PLANAT, Bern.

Bründl, M., H. E. Romang, N. Bischof & C.M. Rheinberger 2009. The risk concept and its application in natural hazard risk management in Switzerland. Nat. Hazards Earth Syst. Sci., 9(3), p. 801-813.

Bubeck, P. & H. Kreibich 2011. Direct costs and losses due to the disruption of production processes. ConHaz Report of WP1, http://conhaz.org/project/cost-assessment-work-packages/wp1-8-final-reports/CONHAZ%20REPORT%20WP01_2.pdf/at_download/file, D1.2, Potsdam.

Bundesamt für Raumplanung (BRP), Bundesamt für Wasserwirtschaft (BWW) & Bundesamt für Umwelt, Wald und Landschaft (BUWAL) (eds.) 1997. Berücksichtigung der Massenbewegungsgefahren bei raumwirksamen Tätigkeiten - Empfehlungen 1997. Bern.

Bundesamt für Wasserwirtschaft (BWW), Bundesamt für Raumplanung (BRP) & Bundesamt für Umwelt, Wald und Landschaft (BUWAL) (eds.) 1997. Berücksichtigung der Hochwassergefahren bei raumwirksamen Tätigkeiten - Empfehlungen 1997, Bern.

BUWAL Bundesamt für Umwelt, Wald und Landschaft 1999. Risikoanalyse bei gravitativen Naturgefahren. Umweltmaterialien 107/I, Bern.

BUWAL Bundesamt für Umwelt, Wald und Landschaft 1999. Risikoanalysen bei gravitativen Naturgefahren - Fallbeispiele und Daten. Umweltmaterialien 107/II, Bern.

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2008. Klimawandel in den Alpen, Fakten - Folgen - Anpassung. Berlin.

Cardinali, M., P. Reichenbach, F. Guzzetti, F. Ardizzone, G. Antonini, M. Galli, M. Cacciano, M. Castellani & P. Salvati 2002. A geomorphological approach to the estimation of landslide hazards and risks in Umbria, Central Italy, Nat. Hazards Earth Syst. Sci., 2, p. 57–72.

CEDIM Center for Disaster Management and Risk Reduction Technology (Ed.) 2005. Glossary, terms and definitions of risk sciences, available at http://www.cedim.de/download/glossar-gesamt-20050624.pdf, 23.6.2010.

Cochrane, H. 2004. Economic loss: myth and measurement. Disaster Prevention and Management 13(4), p. 290 - 296.

Cruden, D. M. 1991. A simple Definition of a Landslide. Bulletin of the International Association of Engineering Geology, No 43, p. 27-29.

Cruden, D. M. & D.J. Varnes 1996. Landslide Types and Processes. In: A.K. Turner et al. (Eds.), Landslides: Investigation and Mitigation, Washington, p. 36 – 75.

de Bruijn, K., F. Klijn, A. Ölfert, E. Penning-Rowsell & J. Simm 2009. Flood risk assessment and flood risk management - An introduction and guidance based on experiences and findings of FLOODsite (an EU-funded Integrated Project). Delft.

Downton, M.W., J.Z.B. Miller & R.A. Pielke Jr. 2005. Reanalysis of U.S. National Weather Service Flood Loss Database. – Natural Hazards Review 6, p. 13-22.

Downton, M.W. & R.A. Pielke Jr. 2005. How accurate are Disaster Loss Data? The Case of U.S. Flood Damage. – Natural Hazards 35, p. 211-228.

Douglas, J. 2007. Physical vulnerability modelling in natural hazard risk assessment. NHESS 7, p. 283-288.

ECA – Economics of climate adaptation working group 2009. Shaping climate-resilient development – a framework for decision-making. 159 pp.

Elmer, F., I. Seifert, J.-O. Seifert, U. Kunert, V. Ackermann, H. Kreibich, R. Schwarze & A.H. Thieken: Vorschläge für Mindesterhebungen in verschiedenen Schadenssektoren. In: Thieken, A.H., I. Seifert & B. Merz (Eds.) 2010. Hochwasserschäden – Erfassung, Abschätzung und Vermeidung, Munich, Chapter 4, p. 81-138.

EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be - Université Catholique de Louvain, Brussels, Belgium.

Federal Office for the Environment (FOEN) (former: Bundesamt für Wasser und Geologie, BWG) (ed.), 2000. Hochwasser 1999 – Analyse der Ereignisse. Studienbericht Nr. 10.

Federal Office for the Environment (FOEN) 2010. EconoMe 2.0 - Online-Berechnungsprogramm zur Bestimmung der Wirtschaftlichkeit von Schutzmaßnahmen gegen Naturgefahren - Handbuch / Dokumentation, Bern.

Federal Office for the Environment (FOEN) & Federal Office for Civil Protection (FOCP) 2010. RiskPlan Version 2.2 - Pragmatic Risk Management, Documentation of methodological and mathematical basis. Ittigen, Bern.

Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008a. Kosten-Nutzen-Untersuchungen im Schutzwasserbau Richtlinie, KNU gemäß § 3 Abs. 2 Ziffer 3 Wasserbautenförderungsgesetz. Vienna.

Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008b. Richtlinien für die Wirtschaftlichkeitsuntersuchung und Priorisierung von Maßnahmen der Wildbach- und Lawinenverbauung gemäß § 3 Abs. 2 Z 3 Wasserbautenförderungsgesetz 1985. Vienna.

Federal Ministry of Agriculture, Forestry, Environment and Water Management 2009. Ereignisdokumentation Lawinen 2009 Bericht über die Lawinenereignisse im Februar und März 2009 in Österreich. Vienna.

Federal Ministry of Agriculture, Forestry, Environment and Water Management 2010. Budget 2009/2010. Vienna.

Federal Ministry of Finance 2010. Katastrophenfonds, online available at https://www.bmf.gv.at/Budget/Finanzbeziehungenzu_658/Katastrophenfonds/_start.htm, 7.9.2010.

Fischer M. 2008. Der lange Weg zur integralen Elementarschadenversicherung und -vorbeugung in der Schweiz. Vierteljahrshefte zur Wirtschaftsforschung 77(4),p. 98-103.

Fuchs, S. 2004. Development of Avalanche Risk in Settlements - Comparative studies in Davos, Grisons, Switzerland. Dissertation, Innsbruck.

Fuchs, S. & M. Bründl 2005. Damage Potential and Losses Resulting From Snow Avalanches in Settlements of the Canton of Grisons. Natural Hazards 34, p. 53-69.

Fuchs, S., M. Thöni, M.C. McAlpin, U. Gruber & M. Bründl 2007a. Avalanche hazard mitigation strategies assessed by cost effectiveness analysis and cost benefit analyses - evidence from Davos, Switzerland. In: Nat Hazards 41, p.113–129.

Fuchs, S., K. Heiss & J. Hübl 2007b. Towards an empirical vulnerability function for use in debris flow risk assessment. Natural Hazards and Earth System Sciences 7 (5), p. 495-506.

Gall, M., K. Borden & S.L. Cutter 2009. When do losses count? Six fallacies of loss data from natural hazards. Bulletin of the American Meteorological Society 90(6), p. 1-11.

Ganderton, P. 2005. Benefit-Cost Analysis of disaster mitigation: Application as a policy and decision-making tool. Mitigation and Adaptation Strategies for Global Change, 10, p. 445-465.

Geldermann, J., M. Merz, V. Bertsch, M. Hiete, O. Rentz, I. Seifert, A.H. Thieken, D. Borst & U. Werner 2008. The reference installation approach for the estimation of industrial assets at risk. European Journal of Industrial Engineering, 2, 1, p. 73-93.

Gissing, A. & R. Blong 2004. Accounting for Variability in Commercial Flood Damage Estimation. Australian Geographer 35(2), p. 209-222.

Glade, T. 2003. Vulnerability assessment in landslide risk analysis. Die Erde, 134, p. 123-146.

Grislain-Letrémy, C. & C. Peinturier 2010. The Insured Cost of Ground Movements in Mainland France from 1995 - 2006. In: Proceedings of the Symposium Rock Slope Stability 2010, 24 & 25 November 2010. Paris.

Greminger, P. 2003. Unwetterereignisse im Alpenraum - Analyse, Bericht der vom Ständigen Ausschuss der Alpenkonferenz eingesetzten Arbeitsgruppe Lawinen, Überschwemmungen, Muren und Erdrutsche, in Ergänzung zum Bericht Lawinenwinter 1999 der Alpenkonferenz vom 30. / 31. Oktober 2000 in Luzern. Bern.

Green, C., Ch. Viavattene & P. Thompson 2011. Guidance for assessing flood losses. CONHAZ Report WP6, D6.1, http://conhaz.org/project/cost-assessment-work-packages/wp1-8-final-reports/CONHAZ%20REPORT%20WP06_1.pdf/at_download/file, London.

Greenberg, M.R, M. Lahr & N. Mantell 2007. Understanding the Economic Costs and Benefits of Catastrophes and Their Aftermath: A Review and Suggestions for the U.S. Federal Government. Risk Analysis 27(1), p. 83-96.

Guha-Sapir, D., & R. Below  2002. The quality and accuracy of disaster data - a comparative analyses of three global data sets. Working paper for the Disaster Management Facility, The World Bank, CRED, Brussels.

Guzzetti, F, C.P. Stark & P. Salvati 2005. Evaluation of Flood and Landslide risk to the Population of Italy. Environmental Management Vol. 36, No. 1, p. 15-36.

Habersack, H & A. Moser 2003: Ereignisdokumentation Hochwasser August 2002, Vienna.

Habersack, H. & G. Krapesch 2006: Hochwasser 2005 - Ereignisdokumentation der Bundeswasserbauverwaltung, des Forsttechnischen Dienstes für Wildbach- und Lawinenverbauung und des Hydrographischen Dienstes, Vienna.

Habersack, H., G. Krapesch, O. Gstir, C. Hauer, W. Kerschbaumsteiner, G. Stimpfl, M. Widmann & B. Wagner 2006: Dokumentation der Hochwasserereignisse 2005 in Österreich im Bereich der Bundeswasserbauverwaltung, Vienna.

Haeberli, W. & M. Maisch 2007. Klimawandel im Hochgebirge. In: Endlicher, W. & F.-W. Gerstengarbe (Eds.), Der Klimawandel – Einblicke, Rückblicke und Ausblicke. Potsdam, p. 98-107.

Haefeli, R. 1967. Kriechen und progressiver Bruch im Schnee, Boden, Fels und Eis. Schweizerische Bauzeitung, 85(1), p. 1-9.

Hanausek, E. 2000. Lawinenkunde. In: Amt der Tiroler Landesregierung (Ed.): Lawinenhandbuch, Innsbruck-Vienna, p. 85-97.

Herget, J. 2007. Hochwasser, Sturzfluten und Ausbruchsflutwellen. In: Felgentreff, C. & T. Glade (Eds.): Naturrisken und Sozialkatastrophen – Grundlagen und Herausforderungen der Gefahren- und Risikoforschung. Heidelberg, p. 165-172.

Heumader, J. 2000. The catastrophic avalanche disasters of Galtür and Valzur on the 23. and 24. of February 1999 in the Paznaun valley/Tyrol. Internationales Symposion Interpraevent 2000. Villach. p. 397-409.

Hollenstein, K. 2005. Reconsidering the risk assessment concept: Standardizing the impact description as a building block for vulnerability assessment. Natural Hazards and Earth System Science 5, 3, p. 301-307.

Hudson, J.A. & J.P. Harrison 1997. Engineering rock mechanics, UK.

Hungr, O. 1995. A model for the runout analysis of rapid flow slides, debris flows and avalanches. Canadian Geotechnical Journal 32, p. 610-623.

Hungr, O., S.G. Evans, M.J. Bovis & J.N. Hutchinson 2001. A Review of the Classification of Landslides of the Flow Type. Environmental & Engineering Geoscience, Vol. VII, No. 3, p. 221-238.

Huttenlau, M. 2010. Risk-based consequences of extreme natural hazard processes in mountain regions – Multi-risk analysis of extreme loss scenarios in Tyrol (Austria). PhD thesis, University of Innsbruck.

Huttenlau, M. & G. Brandstötter-Ortner (2011). Risk-based analysis of possible catastrophic rockslide scenarios and linked consequences in Tyrol (Austria). Annals of Geomorphology, Vol. 55, Suppl. 3, p 179-204.

Huttenlau, M., A. Moran, J. Stötter & T. Steixner 2010. Comparative multi-risk analysis of extreme natural hazard events in the Austrian Province of Tyrol, In: J.-P. Malet, T. Glade, N. Casagli (Eds.): ‘Mountain Risks: Bringing Science to Society’. CERG Editions, Strasbourg, p. 363-372.

Huttenlau M. & J. Stötter 2008: Ermittlung des monetären Werteinventars als Basis von Analysen naturgefahreninduzierter Risiken in Tirol. Geographica Helvetica 63(2).

Huttenlau, M. & J. Stötter 2011. The structural vulnerability in the framework of natural hazard risk analyses and the exemplarily application for storm loss modelling in Tyrol (Austria). Natural hazards, DOI 10.1007/s11069-011-9768-x.

Hübl, J., H. Kienholz & A. Loipershberger (Eds.) 2002. DOMODIS - Documentation of Mountain Disasters, State of Discussion in the European Mountain Areas. Vienna.

Hübl, J., H. Habersack, H. Kienholz, P. Agner, E. Ganahl, M. Moser, C. Scheidl, W. Kerschbaumsteiner & F. Schmid 2006. Disaster Information System of Alpine Regions (DIS-ALP): Methodik Teil 1, IAN Report 101. Vienna.

ICPR International Commission for the Protection of the Rhine 2001. Rhine-Atlas, ICPR, Koblenz, available at: http://www.rheinatlas.de.

ISDR 2002: Living with Risk: A global review of disaster reduction initiatives, UN, Geneva.

Jetté-Nantel, S. & S. Agrawala 2007. Climate change adaptation and natural hazards management. In: S. Agrawala (Ed.): Climate Change in the European Alps - adapting winter tourism and natural hazards management. OECD, Paris, p. 61–93.

Joy, C.S. 1993. The cost of flood damage in Nyngan. Climate Change 25, p. 335-331.

Kienholz, H., B. Krummenacher, A. Kipfer & S. Perret 2004. Aspects of Integral Risk Management in Practice-Considerations with respect to Mountain Hazards in Switzerland. Österreichische Wasser- und Abfallwirtschaft 56, p. 43-50.

King, A. & R. Bell 2005. RiskScape New Zealand: A multihazard loss modelling tool, in: Proceedings of Earthquake Engineering in the 21st Century (EE-21C) conference, topic 8: Technologies and trends for disaster monitoring and reduction.

Kletzan, D., A. Köppl, K. Kratena & A. Wegscheider 2004. Analyse der Hochwasserereignisse vom August 2002 – FloodRisk - WP Ökonomische Aspekte TP 02, StartClim.10: Ökonomische Aspekte des Hochwassers 2002: Datenanalyse, Vermögensrechnung und gesamtwirtschaftliche Effekte. Vienna.

Kraus, U. 2005. Erfassung von Schäden beim Hochwasser 2002. Vortrag auf dem MEDIS-Workshop 1./2. Dezember 2005. http://www.rimax-hochwasser.de/458.html (Zugriff am 16.08.2009).

Kreibich, H., M. Müller, A.H. Thieken, T. Petrow & B. Merz 2007. Flood precaution of companies and their ability to cope with the flood in August 2002 in Saxony, Germany. Water Resour. Res. 43: W03408, doi:10.1029/2005WR004691.

Kobert, H, F. Rudloff, E. Berié, G. von der Stein & T. Steinhoff 2009. Der Fischer Weltalmanach 2010, Zahlen, Daten, Fakten. Frankfurt am Main.

Kohler T. & D. Maselli (Eds.) 2009. Mountains and Climate Change - From Understanding to Action. Geographica Bernensia with the support of the Swiss Agency for Development and Cooperation. Bern.

Lateltin, O. 1997. Berücksichtigung der Massenbewegungsgefahren bei raumwirksamen Tätigkeiten (Empfehlungen). Bern.

Leiter, A. & G. Pruckner 2009. Proportionality of Willingness to Pay to Small Changes in Risk: The Impact of Attitudinal Factors in Scope Tests. Environ Resource Econ 42, p. 169–186.

Leiter, A., M. Thöni & H. Weck-Hannemann 2009. Protective measures against natural hazards - Are they worth their costs? In: Veulliet, E., J. Stötter & H. Weck-Hannemann (Eds.): Sustainable Natural Hazard Management in Alpine Environments. Heidelberg et al., p. 200 - 227.

Leser, H., H.-D. Haas, T. Mosimann & R. Paesler 2001. Diercke Wörterbuch Allgemeine Geographie. München, Braunschweig.

Markantonis, V., V. Meyer & R. Schwarze 2011. The intangible effects of Natural Hazards. ConHaz report WP 3, D3.2, http://conhaz.org/project/cost-assessment-work-packages/wp1-8-final-reports/CONHAZ%20REPORT%20WP03_2.pdf/at_download/file, Leipzig.

Merz, B., H. Kreibich, R. Schwarze & A.H. Thieken 2010. Review article “Assessment of economic flood damage”, Nat. Hazards Earth Syst. Sci., 10, p. 1697–1724.

Messner, F., E. Penning-Rowsell, C. Green, V. Meyer, S. Tunstall, S. & A. van der Veen 2007. Evaluating flood dam-ages: guidance and recommendations on principles and methods. project FLOODsite.

Müller, M., H. Kreibich, I. Seifert, J.-O. Seifert, U. Kunert, F. Elmer & A.H. Thieken 2011. Methoden der Schadenserhebung: ein Überblick. Thieken, A.H., I. Seifert, B. Merz (Eds.) (2010): Hochwasserschäden – Erfassung, Abschätzung und Vermeidung. Oekom-Verlag, München, Chapter 3, p. 51-79.

Munich Reinsurance Company (MucRe) (Ed.) 2009. Globe of Natural Hazards - Global, regional, local - Natural hazards and climate effects at a glance. DVD, Munich.

Moran, A., A. Thieken, A. Schöbel & C. Rachoy, C. 2010: Documentation of flood damage on railway infrastructure. Data and mobility - Advances in Intelligent and Soft Computing, Volume 81/2010, 61-70, DOI: 10.1007/978-3-642-15503-1_6.

Nöthiger, C. 2003. Naturgefahren und Tourismus in den Alpen - untersucht am Lawinenwinter 1999 in der Schweiz. SLF, Davos.

ONERC Observatoire National sur les Effets du Réchauffement Climatique 2008. Climate change in the Alps: Impacts and natural hazards. Rapport Technique N°1 de l’ONERC, project ClimChAlp.

Olschewski, R., P. Bebi, M. Teich & U. Wissen Hayek 2010. Avalanche protection by forests - Approaches to-wards an economic valuation. In: J.-P. Malet, T. Glade & N. Casagli (Eds): Mountain Risks: Bringing Science to Society. Strasbourg, p. 393-399.

Papathoma-Köhle, M., B. Neuhäuser, K. Ratzinger, H. Wenzel & D. Dominey-Howes 2004. Elements at risk as a framework for assessing the vulnerability of communities to landslides. Nat. Hazards Earth Syst. Sci., 7, p. 765–779.

Papathoma-Köhle, M. ,M. Kappes, M. Keiler & T. Glade 2010. Physical vulnerability assessment for alpine hazards: state-of-the-art and future needs. - Natural Hazards, DOI: 10.1007/s11069-010-9632-4.

Papež, J. 2011: Protection against natural hazards and other disasters in Slovenia - Ministry of the Environment and Spatial Planning in cooperation with the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief and PLANALP Platform. http://www.interpraevent.at/palm-cms/upload_files/News-Veranstaltungen/Slovenia_Alpine_Convention.pdf (10.6.2011).

Parker, D., C. Green & P. Thompson 1987. Urban flood protection benefits: A project appraisal guide. Aldershot.

Patt, H. 2001. Hochwasser-Handbuch - Auswirkungen und Schutz. Berlin.

Penning-Rowsell, E., C. Johnson, S. Tunstall, S. Tapsell, J. Morris, J. Chatterton & C. Green 2005. The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques. Flood Hazard Research Centre, Middlesex University Press.

Permanent Secretariat of the Alpine Convention 2010a. Alpenkonvention - Nachschlagewerk. Alpensignale 1, Innsbruck.

Permanent Secretariat of the Alpine Convention 2010b: The Alps - People and pressures in the mountains, the facts at a glance - Vademecum. Innsbruck.

Pfurtscheller, C. & R. Schwarze 2010. Kosten des Katastrophenschutzes. In: Thieken, A., I. Seifert & B. Merz (Eds.): Hochwasserschäden - Erfassung, Abschätzung und Vermeidung. Munich, p. 253-262.

Pfurtscheller, C. & A.H. Thieken 2010. Vulnerabilities, transnational facts, and case studies as a basis for assessing costs of natural hazards in Alpine regions. - In: J.-P. Malet, T. Glade & N. Casagli (Eds): Mountain Risks: Bringing Science to Society. Strasbourg, p. 393-399.

Pfurtscheller, C. & K. Kleewein 2010. Are alpine regions especially affected by natural hazards? Meso-scale assessment of economic resilience and vulnerability based on the 2005 floods in the Austrian federal states of Tyrol and Vorarlberg. In: Borsdorf, A., G. Grabherr, K. Heinrich, B. Scott & J. Stötter (Eds.): Challenges for Mountain Regions - Tackling Complexity. Vienna, p. 94 - 101.

PLANAT 2004. Strategie Naturgefahren Schweiz - Synthesebericht in Erfüllung des Auftrages des Bundesrates vom 20. August 2003, Biel.

PLANALP Platform on Natural Hazards of the Alpine Convention (Eds.) 2006: Dokumentation von Naturereignissen – Feldanleitung. Innsbruck / Bern.

PLANALP - Platform on Natural Hazards of the Alpine Convention (Eds.) Integral Natural Hazard Risk Management – Recommendations. 25pp.

Poisel, R. 1998. Kippen, Sacken, Gleiten – Geomechanik von Felsbewegungen und Felsböschungen. Felsbau 3, p. 135-140.

Prettenthaler, F. & N. Vetters 2005. Finanzielle Bewältigung von Naturgefahren - Vorschläge zur Reform des österreischichen Modells. InTeReg Working Paper Nr. 21, Graz.

Przyluski, V. & S. Hallegatte 2011. Indirect Costs of Natural Hazards. ConHaz report WP2, D2.2, http://conhaz.org/project/cost-assessment-work-packages/wp1-8-final-reports/CONHAZ%20REPORT%20WP02_2.pdf/at_download/file, Paris.

Ramirez, J., W. L. Adamowicz, K. W. Easter & T. Graham-Tomasi 1988. Ex Post Analysis of Flood Control: Benefit-Cost Analysis and the Value of Information. Water Resources Research 24, p.1397-1405.

Raschky, P. & H. Weck-Hannemann 2008. Vor oder Nachsorge? Ökonomische Perspektiven. In: Felgentreff, C. & T. Glade (Eds.) Naturrisken und Sozialkatastrophen. Berlin, Heidelberg.

Raschky, P., R. Schwarze, M. Schwindt & H. Weck-Hannemann (2009): Alternative Finanzierungs- und Versicherungslösungen – Vergleich unterschiedlicher Risikotransfersysteme dreier vom Augusthochwasser 2005 betroffener Länder: Deutschland, Österreich und Schweiz. Report of the KGV Prevention Foundation, Berne, Switzerland.

Rheinberger, C.M. 2009a. Preferences for mitigating natural hazards on alpine roads: a discrete choice approach. Diss ETH, Nr 18476, doi:10.3929/ ethz-a-005922637.

Rheinberger, C.M. 2009b Paying for safety: preferences for mortality risk reductions on alpine roads, FEEM working papers 2009.77, fondazione eni enrico mattei, http://www.feem.

Rheinberger, C.M., M. Bründl & J. Rhyner 2009. Dealing with the White death: Avalanche risk Management for traffic routes. Risk Analysis, Vol. 29, No. 1, p. 76-94.

Rudolf-Miklau, F. 2009: Naturgefahren Management in Österreich - Vorsorge, Bewältigung, Information. Vienna.

Sattler, S., H. Wind, H. Fuchs & H. Habersack 2003: Hochwasser 2002 - Datenbasis der Schadensbilanz 2002. FloodRisk - WP Ökonomische Aspekte TP 02, StartClim.9, Vienna.

Schwarze, R., M. Schwindt, H. Weck-Hannemann, P. Raschky, F. Zahn & G.G. Wagner 2011. Natural Hazard Insurance in Europe: Tailored Responses to Climate Change are Needed. - Env. Pol. Gov. 21: 14–30.

Schmidtke, R. 2011. Projektbewertung - Kernelement im Gestaltunsprozess des integrierten Hochwasserrisikomanagements. DWA-Seminar „Hochwasserschadensanalysen und Projektbewertungen“, Bad Hennef, 3, 12pp.

Schnell, R., P. B. Hill & E. Esser 1999. Methoden der empirischen Sozialforschung.

Schulze-Bruckauf, M. 2005. Erfassung von Elementarschäden in Privathaushalten aus Sicht einer Versicherung. Vortrag auf dem MEDIS-Workshop 1./2. Dezember 2005. http://www.rimax-hochwasser.de/458.html.

Schwarz, J. & H. Maiwald 2008. Damage and loss prediction model based on the vulnerability of building types. 4th International Symposium on Flood Defence, 6-8 May 2008, Toronto, Canada. Paper 74, p. 1-9.

Schweizer, J., J.B. Jamieson & M. Schneebeli 2003. Snow avalanche formation. Reviews of Geophysics, 41(4): 1016, doi:10.1029/2002RG000123.

Sedan, O. & C. Mirgon 2003. Application ARMAGEDOM Notice utilisateur, BRGM open file BRGM/RP-52759-FR.

Spichtig, S. & M. Bründl 2008: Verletzlichkeit bei gravitativen Naturgefahren - eine Situationsanalyse. Projekt B5. Schlussbericht. http://www.planat.ch/de/infomaterial-detailansicht/datum/2010/10/22/planat-projekt-b5-verletzlichkeit-bei-gravitativen-naturgefahren/.

Tappeiner, U., A. Borsdorf & E. Tasser (Eds.) 2008. Alpenatlas – Atlas des Alpes – Atlante delle Alpie – Atlas Alp – Mapping the Alps. Society – Economy – Environment. Berlin, Heidelberg.

Thieken, A.H., M. Müller, H. Kreibich & B. Merz 2005. Flood damage and influencing factors: New insights from the August 2002 flood in Germany. Water Resources Research 41(12), W12430, DOI: 101029/2005WR004177.

Thieken, A.H., H. Kreibich, M. Müller & B. Merz 2007. Coping with floods: preparedness, response and recovery of flood-affected residents in Germany in 2002. Hydrological Sciences Journal 52(5), p. 1016-1037.

Thieken, A., R. Schwarze, V. Ackermann & U. Kunert 2010. Erfassung von Hochwasserschäden – Einführung und Begriffsdefinitionen. In: A.H. Thieken, I. Seifert & B. Merz (Eds.) 2010. Hochwasserschäden – Erfassung, Abschätzung und Vermeidung, Munich, Chapter 2, pp. 21-49.

UNDRO 1991. Mitigation Natural Disasters - Phenomena, Effects and Options. United Nations Disaster Relief, New York.

Ungern-Sternberg, T. 2002. Gebäudeversicherung in Europa. Die Grenzen des Wettbewerbs. Berne.

USGS U.S. Geological Survey 2004. Landslide Types and Processes, Fact Sheet 2004-3072.

Van der Veen, A. & C. Logtmeijer 2005. Economic hotspots: visualizing vulnerability to flooding. Natural hazards, 36, p. 65-80.

Veit, H. 2002. Die Alpen - Geoökologie und Landschaftsentwicklung. Stuttgart.

Wegmann, M., H. Merz & K. Meierhans Steiner 2007. Jährliche Aufwendungen für den Schutz vor Naturgefahren in der Schweiz - Strategie Naturgefahren Schweiz, Umsetzung des Aktionsplans PLANAT 2005 - 2008. Bern.

Weidner, S. 2000. Kinematik und Mechanismus tiefgreifender Alpiner Hangdeformationen unter besonderer Berücksichtigung der hydrogeologischen Verhältnisse. dissertation, Erlangen.

Wilhelm, C., 1997. Wirtschaftlichkeit im Lawinenschutz Methodik und Erhebungen zur Beurteilung von Schutzmassnahmen mittels quantitativer Risikoanalyse und ökonomischer Bewertung. Mitt. des Eidg. Instituts für Schnee- und Lawinenforschung, 54. Eidg. Institut für Schnee- und Lawinenforschung (WASL(SLF), Davos, 309 pp.

Wilhelm, C. 1999. Kosten-Wirksamkeit von Lawinenschutz-Maßnahmen an Verkehrsachsen 1999 - Vorgehen, Beispiele und Grundlagen der Projektevaluation. BUWAL, Bern.

WP/WLI Working Party on World Landslide Inventory 1993. Multilingual Landslide Glossary. The Canadian Geotechnical Society, Richmond.

WSL Institute for Snow and Avalanche Research SLF (Ed.) 2000. Der Lawinenwinter 1999 - Ereignisanalyse. Davos.

WSL Swiss Federal Institute for Forest, Snow and Landscape Research and FOEN Federal Office for the Environment (BUWAL) (Eds.) 2001. Lothar - Der Orkan 1999 - Ereignisanalyse. Birmensdorf, Bern.

Zangerl, Ch., Ch. Prager, R. Brandner, E. Brückl, S. Eder, W. Fellin, E. Tentschert, G. Poscher & H. Schönlaub 2008. Methodischer Leitfaden zur prozessorientierten Bearbeitung von Massenbewegungen. Geo.Alp 5, p. 1-51.

Zhai, G., T. Fukuzono & S. Ikeda. 2005. Modeling Flood Damage: Case of Tokai Flood 2000. Journal of the American Water Resources Association 41, p.77-92.

Zhai, G. & S. Ikeda 2006. Flood Risk Acceptability and Economic Value of Evacuation. Risk Analysis. Vol. 26, No. 3, p. 683 - 694.