THE COSTS OF NATURAL HAZARDS IN ALPINE ENVIRONMENTS

CURRENT PRACTICE, END-USER NEEDS AND RECOMMENDATIONS

Clemens Pfurtscheller[1] and Annegret H. Thieken[2]

ABSTRACT

Public funding for reducing risks of natural hazards is getting scarcer. For example, in Austria, the budget for technical mitigation against mountain hazards is currently stagnating at approx. € 160 million per annum. Hence, economic efficiency and prioritization of measures that reduce risks due to natural hazards are of high importance. This paper compiles the results of the work package "Alpine Hazards" of the EU-FP7 project costs of natural hazards (ConHaz). Starting with a general description of alpine hazards and specific vulnerabilities of mountain regions, an analysis of current methods of cost assessments in countries within the European Alps was done for the cost categories of direct, indirect and intangible costs. In addition, data on real losses and an analysis of different data bases are given. Moreover, different methods for decision support are described and evaluated. Finally, research gaps, end-user needs, and recommendations for cost assessments of the different damage categories are discussed.

Keywords: Mountain hazards, monetary evaluation of costs and benefits, tools for decision support, recommendations and research needs

INTRODUCTION

Cost assessments of damage caused by natural hazards as well as costs for risk prevention and mitigation measures provide crucial information for 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 of natural hazards are of high importance. There is, however, a considerable diversity of methodological approaches and terminologies being used in cost assessments of different natural hazards (Bubeck & Kreibich, 2011, Przyluski & Hallegatte, 2011, Markantonis et al., 2011). This hampers the development of comprehensive, robust and reliable costs figures as well as the comparison of costs across hazard types and impacted sectors. 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), there is a sound basis for the identification, compilation and evaluation of methods used in research and practice. Further, this serves as a basis to identify current research gaps and to give some recommendations for end-users.

This paper compiles current methods of cost assessments in countries within the European Alps, starting with a general description of alpine hazards and specific vulnerabilities. Then, 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. Moreover, different methods for decision support, e.g. cost-benefit-analysis approaches in different countries, are described and evaluated. Finally, key findings as well as recommendations are presented. This paper gives a résumé of the ConHaz-report "Costs of alpine hazards" (Pfurtscheller et al., 2011). The report is based on an intense literature review and the outcomes of a workshop with scientists and stakeholders held in Innsbruck in May 2011.

[1] Clemens Pfurtscheller. University of Innsbruck, Institute of Geography, Austria and Austrian Academy of Sciences, Institute of Mountain Research (IGF), 6020 Innsbruck, Austria (e-mail: clemens.pfurtscheller@oeaw.ac.at).
[2] Prof. Dr. Annegret Thieken. University of Potsdam, Institute of Earth and Environmental Sciences, 14476 Potsdam-Golm, Germany.

ALPINE HAZARDS AND SPECIAL VULNERABILITIES OF EUROPEAN MOUNTAIN AREAS

Relief energy can be seen as the key driver of hazardous processes and consecutive losses. Hence, mountain hazards or alpine hazards are risks triggered by the downhill movement of water, snow, ice, debris and rocks (UNDRO, 1991). These processes include avalanches, floods, debris flows, and landslides (Tab. 1). Moreover, alpine hazards are characterised by intermixtures of mediums and processes as well as cascade effects (Pfurtscheller & Schwarze, 2010). There are smooth transitions between the different types of alpine processes, so an explicit distinction is not possible. As a consequence, high economic losses due to natural hazards might occur, e.g. large-scale inundations in an U-shaped valley vs. rapid onset damages in an alpine lateral valley were observed simultaneously during the floods in 2005 in Western Austria (Fig. 1).

Tab. 1 Types of mountain hazards considered 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 flash floods (pluvial or torrential floods) river floods (fluvial floods)	
	debris and mud flows (flows)	
Geologic mass movements	falls - rock fall (“Steinschlag”), <50cm diameter - boulder fall (“Blockschlag”, “Blocksturz”), cubature approx. <100m^3 - block fall, cliff fall (“Felssturz”), cubature approx. > 100 to 1 mio. m^3 - rock collapse, rock avalanche (“Bergsturz”), cubature approx. > 1 mio. m^3	slides / landslides (sensu strictu) - rock slide - debris slide - earth slide
(Snow-) Avalanches	snow slab avalanche loose snow avalanche	
Complex processes / intermixtures		

Mountain regions in Europe are also characterised by special vulnerabilities, which result from the socio-economic settings, but also from spatial particularities. There is very limited space for settlement and economic activities in mountain regions (Permanent Secretariat of the Alpine Convention, 2010). The marginal permanent settlement area in mountain regions forces people to concentrate assets in valleys and to build nearby water bodies and other risky areas and, thus, increases the exposure to natural hazards. Further, possibilities for the substitution of lifelines and for the creation of redundant structures are missing. Especially lateral valleys are at high risk of getting isolated, e.g. as a consequence of road blockages caused by hazard events as happened during the floods 2005 in the Federal State of Tyrol. Besides these predispositions, alpine economies depend to a high share on tourism and have a high variability of (temporal) residents. Due to the general growth of touristic activities, assets at risk are expected to rise further. Current developments may result in future land use conflicts, but may also illustrate the need for integrated methods of assessing costs of natural hazards, costs and benefits of risk reductions as well as harmonized and transparent decisions on mitigation and adaptation measures.

Fig. 1 Multiple hazard occurrence during the floods of 2005 in the Federal States of Tyrol and Salzburg (Austria); sources: district government Zell am See, Austrian Armed Forces Photograph/KONRAD.

FRAMEWORK FOR COSTING OF NATURAL HAZARDS

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 as well as recent events with heavy impacts, e.g. the avalanche winter in 1999 or the severe floods in August 2002 and August 2005, launched a rethinking of how to deal with natural hazards in an integral and sustainable way.

For example, the risk management cycle (see e.g. Kienholz et al., 2004) has become a widely accepted approach. It commonly consists of four phases: 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 hazard impacts and associated costs. Different cost types are roughly attached to the four phases of the risk management cycle as compiled in Tab. 2.

Commonly, cost assessments of natural hazards are 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 an event (Messner et al., 2007). Amounts of actual damage and losses can thus be detected ex-post, potential losses ex-ante.

In ConHaz, several cost categories were distinguished. Direct losses (also called capital or asset losses) occur due to the physical contact of elements at risk with water, snow or solids (debris, stones). They can often be assessed ex-post 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 a 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 a 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. However, the methods for the assessment of these costs differ from methods for assessing direct as well as indirect costs.

Tab. 2 Cost types occurring in different stages of risk management

stage of risk cycle	emergency management and response	reconstruction and recovery	event and risk analysis	prevention and preparedness
main cost category	*variable operational costs*	*damage and losses*	*ex-ante cost estimations of costs and benefits, planning costs and decision support*	*costs for risk reduction*
Examples	costs for emergency management (e.g. operation control)	direct losses (asset losses, repair costs)	ex-ante estimation of costs of risk reduction measures	investment and construction costs of mitigation measures
	search & rescue	losses due to business interruption	ex-ante estimation of costs and benefits of risk reduction options	costs for operation, use, maintenance and disposal of mitigation measures
	health care and supply	(long-term) output losses (indirect losses)	costs for risk analyses and design of risk reduction measures	co-costs (e.g. environmental costs) of mitigation measures
	safeguarding structures	losses of non-market goods (intangible effects)	decision support for choosing the optimal risk reduction option (e.g. cost-benefit-analysis)	co-benefits (e.g. recreational areas) of mitigation measures

During the phase of risk analysis and planning of risk reduction measures the loss categories are quantified ex-ante in order to assess the losses that could be avoided by certain mitigation measures. These ex-ante loss assessments are further complemented by ex-ante estimations of the costs of the planned measures. Cost categories for a structural or non-structural risk reduction measure include: planning and design costs, investment costs, costs for operation and maintenance, disposal costs, co-costs and co-benefits. 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.

In the phase of prevention and preparedness, where risk reduction measures are implemented, real expenses for mitigation and adaptation occur. In practise, different measures 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 (e.g. emergency response measures), 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 (ex-post) and actual losses (ex-post) might improve the ex-ante 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).

EVENT DATA AND REPORTED LOSSES - SCALE AND PURPOSE DRIVEN

We analysed different data sources for the occurrences of mountain hazards in the European Alps at the supranational and national scale and associated damages. Although the DOMODIS guideline (Hübl et al., 2002) can serve as a common framework for event documentation, the data bases implemented in the different countries for different purposes differ significantly in quality and quantity of entries as well as in described loss categories (Tab. 3). Direct losses are mostly assessed, but indirect losses and intangible effects are not well covered.

Tab. 3 Databases of alpine natural hazards and loss categories based on Pfurtscheller et al. (2011).

<table>
<tr><th>Name</th><th>Country of origin</th><th>Direct losses</th><th>Indirect losses</th><th>Intangible effects</th></tr>
<tr><td>NATHAN</td><td>DE</td><td>insured loss</td><td rowspan="8">not included</td><td>fatalities</td></tr>
<tr><td>IAN</td><td>DE</td><td rowspan="7">monetary losses (partly)</td><td>fatalities (partly)</td></tr>
<tr><td>HOWAS 21</td><td>DE</td><td>not included</td></tr>
<tr><td>GEORIOS</td><td>AT</td><td rowspan="5">fatalities (partly)</td></tr>
<tr><td>WLK (WLV)</td><td>AT</td></tr>
<tr><td>StoreME</td><td>CH</td></tr>
<tr><td>IFFI</td><td>IT</td></tr>
<tr><td>BRGM</td><td>FR</td></tr>
<tr><td>EM-DAT</td><td>BE</td><td>monetary loss</td><td>partly</td><td>fatalities / affected</td></tr>
</table>

Due to different scopes and entry thresholds, data entries are inconsistent and difficult to compare. For example, national data bases are much more detailed than global data bases, which totally underestimate local and regional events with a relatively low economic loss. Fig. 2 shows the recorded hazard events and estimated direct losses in US$ from 1951 to 2009 of the EM-DAT database.

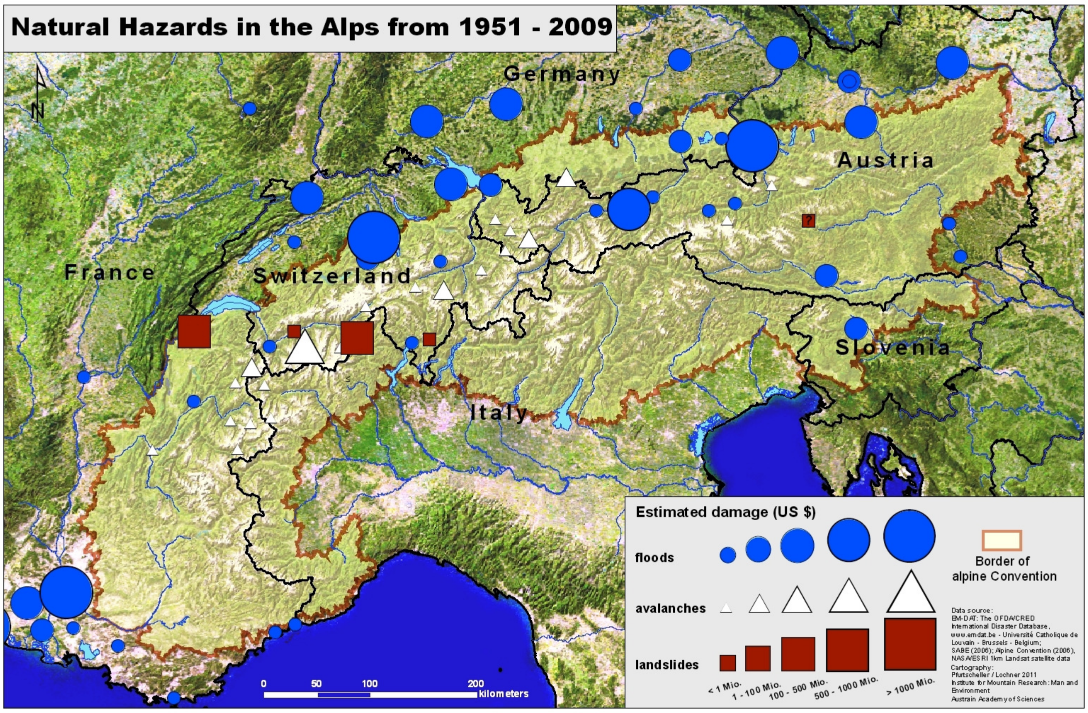

Fig. 2 Recorded hazard events and estimated direct losses in US$ from 1951 to 2009 in countries with part of surface within the European Alps; source of data: EM-DAT.

Although large events are included in global data bases, the data quality differs as is illustrated by the example of the avalanches that occurred in the Paznaun valley, Federal State of Tyrol (Austria), in 1999. Based on official data of the public administration, Heumader (2000) reports about Euro 10 million direct losses and 38 fatalities. The EM-DAT database counts for the same event 50 fatalities and about USD 42 million direct losses.
Hence, a minimum standard for data collection and storage, more international and national collaboration (data exchange) and linking event and damage data would be wishful. Based on high-quality data, data analysis might reveal dominant consequences of hazard events as well as successful mitigation strategies. Thus better data can help to improve disaster risk management strategies. There is also a huge data gap with regard to indirect and intangible losses (Tab. 3). Regarding high impact events on national scale, indirect (output) effects can be measured with standard economic methods (e.g. input-output analysis), but effects on a smaller scale cannot be measured at all, due to the absence of methods.

METHODS FOR THE EX-ANTE ESTIMATION OF DIRECT LOSSES

Methods for estimating direct costs of alpine hazards are mainly based on asset valuation techniques in combination with damage functions, which are sometimes also called vulnerability, susceptibility or fragility functions depending on the hazard community.
A lot of studies exist that evaluate direct effects for different hazards. However, there is a lack of multi-hazard approaches, despite the occurrence of overlapping processes. Further, most studies focus on direct damage of buildings, whereas very little is known about damage to infrastructure. The precision of studies and approaches vary due to the aim and scale of an analysis. When an event occurs, a first rough estimate can be obtained by a combination of average losses and satellite data. For project appraisals, detailed methods are needed - preferably with regional damage functions that include intensity as well as resistance parameters. Due to a lack of regional damage functions, an estimation of losses on the basis of regional hazard information and general damage functions is possible as a first approach. Whenever possible, the damage functions should be adapted to the region under study on the basis of experienced events and loss estimates should then be updated.

METHODS FOR THE EX-ANTE ESTIMATION OF BUSINESS INTERRUPTION

Losses due to business interruption can occur at all kinds of businesses. 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, so a company must be directly affected, e.g. by destroyed machinery, to suffer business interruption (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.
Although some figures for costs of business interruption exist (see Nöthiger, 2003, Bubeck & Kreibich, 2011), no advanced approaches exist for calculating losses due to business interruption caused by alpine hazards. These kinds of losses can only be measured by surveying lost turnover of the businesses. The analysis of such effects is hindered by the intermixture of effects, diverse terminology and missing empirical data. It is wishful to investigate indirect effects and business interruption on single events as part of a comprehensive event analysis.

METHODS FOR THE ESTIMATION OF INDIRECT LOSSES / OUTPUT LOSSES

Due to the special vulnerabilities of alpine regions and especially of lateral valleys (see above), indirect effects are likely to have a high relevance for alpine risk assessment – particular at the local and regional scale. Indirect effects occur at companies, which are not hit directly by the hazard, but lose turnover, because of interrupted economic activities of both, (forward-linked) supply and/or (backward-linked) sales.
In general, there are macro-econometric (statistical) as well as model-based approaches, e.g. input-output-models or computable general equilibrium models, to assess the costs related to indirect effects

of natural hazards (see descriptions by Przyluski & Hallegatte, 2011). These methods can be applied to estimate the decline of economic activities after large events such the floods in 2002 or in 2005. They are, however, inadequate at the regional and local scale, mainly due to missing input data at this scale. In fact, very little is known about the economic effects and interdependencies at small scales. Network failure approaches are currently the best available method for the regional scale, but these approaches often neglect the measurements of economic flows. They rather measure the decline in turnover of single companies.

Since the terminology used to assess indirect effects varies among countries and methods, a clear definition of indirect effects (and its distinction from business interruption) is essential. Moreover, the (spatial) system boundaries as well as the time horizon (short-/medium-/long-term) of the assessment must be determined to identify the effects in the affected area correctly.

Further research on possible methods for the evaluation of indirect effects and case studies in alpine valleys should be undertaken to allegorise the economy of lateral valleys, based on scenarios of interrupted economic activities and stopped private and economic traffic (commuters, in- and outgoing tourist flows, supply, etc.). The investigation of indirect effects and business interruption in the aftermath of catastrophic events should be part of event analyses.

METHODS TO ASSESS INTANGIBLES / NON-MARKET LOSSES

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, a variety of 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 (see Markantonis et al., 2011, for a description of the methods).

Alpine hazards can trigger intangible effects, like loss of life (fatalities), injuries, ecological losses (e.g. by leakages of oil tanks in private structures) or loss of cultural heritage or memorials. However, up to now, they are only partly assessed in risk analyses. Loss of life as an intangible loss is frequently quantified by counting casualties and injured people, but occasionally also by assessing e.g. the value of a statistical life. General effects on health, e.g. costs of psychological traumas or injuries are not investigated. Other intangible effects are usually not assessed although a lot of economic valuation approaches exist.

The ConHaz workshop revealed that the usefulness and reliability of economic estimates of intangible effects are questioned by stakeholders. Despite a variety of available methods, monetarisation is often not wanted. Nevertheless, intangibles should be better integrated in the assessment of risk reduction measures, e.g. by cost-benefit-analysis and trade-off analysis. Classification and prioritisation of intangible effects (e.g. with check lists) can be a first step. In general, there is a great need for knowledge transfer on available valuation methods, and participatory approaches. Cooperation between different hazard communities as well as strong links between science and practice should be strengthened in order to foster learning and mutual support, e.g. by international projects with staff exchange.

METHODS AND TOOLS FOR DECISION SUPPORT

Based on the ex-ante-methods and approaches to assess direct, indirect, and intangible effects cost-benefit-analysis (CBA) or cost-effectiveness-analysis (CEA) are used in many countries in the Alpine arc to evaluate the economic efficiency of protection measures against natural hazards by public risk and disaster management agencies. Despite the differences of assessed damage categories and legal foundations, the methods aim to identify the most suitable mitigation option 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 have been developed in order to improve risk

communication and awareness building. There are strong differences with regard to the assessment of 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 of experts without a clear theoretical concept.
Multi-criteria-analysis (MCA) seems to be generally underrepresented in the Alpine countries, but is a suitable method to account for intangible effects. Economic effectiveness methods should be implemented considering all cost types. Also, the integration of latest methods and application on all hazard types is suggested to illustrate the total effects of possible future losses. Neglecting indirect effects and business interruption, as well as intangible effects, but also costs for emergency and clean-up could result in misleading decisions of priorising and building mitigation measures.

EXPENSES FOR RISK REDUCTION: MITIGATION AND ADAPTATION

Besides statistical data on the occurrence and losses triggered by natural hazards, annual costs for public safety measures 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 be easily compared between countries.
Until now, only one study exists that systematically counts all public expenses for risk mitigation and preparedness. Wegmann et al. (2007) evaluated the average annual expenses for a fictive year from 2000 to 2005 for mitigation and preparedness for Switzerland in a comprehensive manner. National wide, Switzerland spends about 0.6 per cent of GDP (about SFR 3 billion or Euro 2.2 billion) in total for mitigation of natural hazards per year (Wegmann et al., 2007). 59 per cent of the total is paid by the private sector (in the main insurance premiums). About SFR 1.2 billion are spent by public administration (federal government, cantons, and municipalities).
In order to better compare expenses for public safety between countries and to assess successes and failures of risk reduction, guidelines and standards for data documentation and collection are needed.

CONCLUSIONS

Cost assessments of losses caused by natural hazards as well as of prevention and emergency measures provide 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.
The analysis by Pfurtscheller et al. (2011) revealed that a multiplicity of analyses exists for mountain hazards, but generally accepted, comprehensive and European-wide methods for alpine risks are still missing. Intangibles, indirect effects or decline in regional welfare are 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.
Based on the presented findings and the ConHaz workshop discussions the following recommendations can be given:

- systematise, coordinate and exchange terms and data,
- clearly define the scale, the purpose, the key impacts, the system boundaries and the time horizon of a cost analysis and choose methods that are appropriate for the given scale and purpose,
- improve methods for the cost assessments of geologic mass movements,
- improve methods for estimating losses to infrastructures,
- develop method to better assess indirect costs,
- learn more about methods to assess intangibles and apply them more often,
- establish standards and procedures for the documentation of losses as well as for expenses for risk reduction to receive comparable and reliable data,
- foster risk communication to the public, and finally

- intensify communication and cooperation between science and practise as well as between different hazard communities (intensify cross-disciplinary and transdisciplinary approaches).

ACKNOWLEDGEMENTS

This research was undertaken during the project ConHaz - Costs of Natural Hazards funded by the 7th framework programme (FP7) of the European Community (Contract 244159, http://conhaz.org) and was also supported by the Austrian Academy of Sciences (ÖAW), Institute of Mountain Research: Man and Environment (IGF).

REFERENCES

Bubeck P., Kreibich H. (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.

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

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

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 Symposium Interpraevent 2000. Villach: 397-409.

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

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

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

Markantonis V., Meyer V., Schwarze R. (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., Kreibich H., Schwarze R., Thieken A.H. (2010). Review article "Assessment of economic flood damage", Nat. Hazards Earth Syst. Sci., 10:1697–1724.

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

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

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

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

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

Pfurtscheller C., Lochner B., Thieken A.H. (2011). Costs of Alpine hazards. ConHaz-Report of WP8 http://conhaz.org/project/cost-assessment-work-packages/wp1-8-final-reports/CONHAZ%20REPORT%20WP08_1.pdf/at_download/file. Innsbruck.

Przyluski V., Hallegatte S. (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.

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

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

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

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