SIXTH FRAMEWORK PROGRAMME

Project no. 018412

IRASMOS

Integral Risk Management of Extremely Rapid Mass Movements

Specific Targeted Research Project

Priority VI: Sustainable Development, Global Change and Ecosystems

D5.3 – Information brochures on IRM of rapid mass movements for decision-makers, the public, and relevant planning experts

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WSL Swiss Federal Institute for Snow and Avalanche Research

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

FP 6 – specific targeted research project

Integral Risk Management of Extremely Rapid Mass Movements

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IRASMOS

A Merge of Theory and Practice

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Imprint

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Snow supporting structures above Davos, Switzerland.
Photo: Nicole Bischof

IRASMOS

Rock avalanches, debris flows, and snow avalanches are landslide- and landslide-related processes, subsumed under the term **extremely rapid mass movements.** These processes pose varying degrees of risk to land use, infrastructure, and personal safety in many mountain regions.

Despite increasing efforts to quantify the risk in terms of potential damage or loss of life, most previous studies have achieved partial rather than total risk solutions.

IRASMOS addresses these shortcomings by reviewing, evaluating, comparing and augmenting methodological tools for the hazard and risk assessment of extremely rapid mass movements. Risk considerations in dealing with natural hazards have become more important during recent years and a wide variety of methods and tools have been developed in many European countries.

EU FP 6

At the Lisbon summit in March 2000, EU governments called for a better use of European research efforts through the creation of an internal market for science and technology – a "European Research Area" (ERA). The EU's Research Framework Programmes (FP) are the EU's main instrument for research funding in Europe. The FP 6 is the financial instrument to help make ERA a reality.

Overview

The risk-related characteristics of debris flows, rock avalanches, and snow avalanches encompass a broad range of causative factors, trigger mechanisms, processes and runout distances, as well as possible mitigation measures. While substantial work has been carried out to assess the hazards and risks associated with each of these processes, no comprehensive approach addressing the range of possible process combinations in both space and time has yet been developed. IRASMOS was therefore intended to steer the focus towards the holistic, i. e. Integral Risk Management of Extremely Rapid Mass Movements and away from mere process-based research. Our research was not guided by individual natural phenomena, but rather by finding effective ways to quantify and mitigate the total risk from several phenomena on the basis of current knowledge.

The key objectives of the IRASMOS project were:
1. To critically review common practice in hazard and risk assessment of debris flows, rock avalanches, and snow avalanches.
2. To evaluate the sensitivity of risk as a function of varying hazards, vulnerability, and elements at risk.
3. To discuss and quantify aspects of risk aversion.
4. To address cause-effect relationships between Extremely Rapid Mass Movements and their off-site and long-term effects in a multi-risk approach.
5. To develop methodological tools for an Integral Risk Management (IRM) paying equal attention to active and passive measures of prevention, intervention, and recovery.
6. To propose IRM strategies for detecting, monitoring, and responding to Extremely Rapid Mass Movements, given the constraints of data quality, availability, and analysis, and especially given the limited allocation of technical, logistical, and financial budgets.

Integral Risk Management (IRM)

Snow fences and fresh released slab avalanche. Near Leukerbad, Switzerland.
Photo: Peter Schwitter

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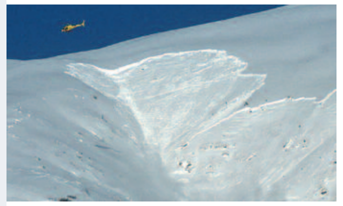
Goals

(1) to review and compile the causes (disposition), trigger mechanisms, and inherent quantitative and qualitative thresholds of motion for Extremely Rapid Mass Movements; (2) to test the applicability of triggers and thresholds for inter-regional comparison with respect to environmental boundary conditions, such as climate, terrain, vegetation cover and human interference; and (3) to put together and evaluate international state-of-the-art methods and technologies for modelling and forecasting the triggering mechanisms, runout, and damage potential of the selected rapid mass movements.



Work package 1

From cause to forecasting

Lead: University of Trento

A detailed review of international literature and data was conducted on the (a) *causes,* (b) *trigger mechanisms,* and (c) *associated thresholds of motion* for debris flows, rock avalanches, and snow avalanches, and serves as the background for summarizing the state-of-the-art in process- and prediction-based research.

The state-of-the art of methods and techniques for modelling and forecasting extremely rapid mass movements was summarized in three comprehensive reports. These summaries include an evaluation of cost-efficiency, applicability, compatibility, and rapidity of implementation of these methods and technologies in European mountain areas. Some of these modelling tools have also been improved as a result of this work package.

The regional variation of causes and triggers with respect to their applicability in up-/down-scaling and modelling was also reviewed. This study includes a discussion of the limits of prediction techniques. The three processes snow avalanches, debris flows, and rock avalanches exhibit extreme differences in:
- Frequency
- Process knowledge
- Databases
- Experts knowledge and experience
- Forecasting practice
- International harmonization
- Defined and accepted hazard scales

Of the three processes, the triggers of snow avalanches are best understood because their frequency and interference with living and leisure activities have resulted in the availability of a huge amount of data and information, which can be analysed to throw light on trigger mechanisms and forecasting. Moreover, the basic substrate for snow avalanches, as opposed to debris flow and rock avalanches, is annually re-supplied in the release zone and removed in the run-out zone, thus providing repeatedly very similar conditions for the process. Given these favourable conditions, the forecasting of snow avalanches is comparably very precise regarding the release time and extent of an event.

Considerable advances have also been made in understanding the dynamics and triggers of debris flows in recent years. However, forecasting of debris flows remains less precise than for snow avalanches due to the lack of relevant data, especially concerning the prerequisites causing an event, such as soil humidity and spatially precise precipitation forecasts. Yet, there is great potential for transferring forecast knowledge between the different processes, particularly snow avalanches and debris flows.

In contrast to snow avalanches and debris flows, the trigger mechanisms of rock avalanches are much more difficult to understand, which means it is nearly impossible to forecast rock avalanches unless the spatial area where they occur is already known, e.g. from past events and movements. However, hazards that may occur subsequent to rock avalanches, such as the formation of valley barriers or tsunamis, can be predicted and estimated in a more reliable manner.

Avalanche release with explosives. Wyoming, USA.
Photo: Benjamin Zweifel

Goals

(1) To review and compile the range of existing technical, biological, and organizational countermeasures against Extremely Rapid Mass Movements; (2) to elucidate the effectiveness of these measures and to highlight their maximum protection potential against a process or a combination of the processes considered; and (3) to propose recommendations for the future installation and implementation of countermeasures.

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Work package 2

Countermeasures

Lead: Norwegian Geotechnical Institute, Norway

One of the results of WP 2 is a comprehensive dictionary describing the countermeasures commonly used with diagrams and photos. The description includes the purpose of the measure, the design criteria, the effectiveness and the cost for each measure.

In general, there are a series of alternatives for reducing a risk:
1. Land-use planning and legislation in long-term planning
2. Relocation of the endangered goods
3. Use of non-physical measures: establishing emergency plans and procedures, forecasting hazards, and temporary evacuation and closure
4. Use of physical protection measures

Physical measures can be divided into three main categories depending on their location:
- Measures in the starting zone where the main purpose is to stabilise the sliding material and reduce the possibility of release;
- Measures in the path where the main purpose is to reduce entrainment, brake the velocity or deflect the sliding material;
- Measures in the run-out zone where the main purpose is to stop or deflect the sliding material, or to reinforce the element at risk to withstand the forces.

When discussing preferable alternatives, the optimal solution should be sought both for the people directly exposed to the hazard, and for the local community and country as a whole. The reduction of risk and the increase in safety obtained by each of the methods must be compared to the total cost of their implementation by:
- Determining cost/risk functions
- Determining benefit/risk functions
- Calculating the net benefit
- Selecting the maximum net benefit solution

All direct and indirect costs and benefits must be taken into account in cost/benefit analyses. Other factors may also need to be considered, e.g. political prioritising, social-psychological or cultural heritage aspects.

It should also be kept in mind that reducing natural hazards and risks may include conflict between experts, the political authorities and the people directly exposed to the hazard. Experts may regard the hazard differently from the local people exposed to the hazard and may therefore present solutions to reduce risk which are not acceptable to the people involved, or to the politicians. Therefore communicating risk, in order to create a shared perspective about the situation and the measures to be envisaged, plays a vital role, in the risk management process.

Non-physical measures are preferable as a temporary means of risk reduction for infrequent processes and for low-risk objects like roads. In general, temporary mitigation measures are superior to structural measures if hazards are: a) infrequent, or b) spatially fuzzy and thus difficult to predict. On the other hand, structural measures are superior if: a) the hazard is known, delimited and frequently returns, b) the stakes at risk are high and failure to mitigate the risk will have large consequences, and c) it is foreseeable that the measure will be useful for its whole lifetime.

For residential areas, non-physical measures are often used as preliminary solutions until permanent physical measures are in place or as an additional measure to reduce the residual risk.

View from Parsenn on Davos Dorf, Switzerland.
Photo: Nicole Bischof

Goals

(1) To review and evaluate state-of-the-art methods of hazard mapping of debris flows, rock avalanches, and snow avalanches; (2) to assess the sensitivity of these hazard forms to changes in environmental boundary conditions (like climate change, increased structural protection measures, and anthropogenic interference); and (3) to propose a best practice for hazard mapping of rapid mass movements as an integrated component in risk formula.

3

Work package 3

Hazard assessment and mapping of rapid mass movements

Lead: University of Pavia, Italy

Hazard mapping is a well-known and widely applied methodology in hazard assessment and management. Hazard maps are used for spatial planning in consistence with hazardous areas, for assessing risks, and for planning of mitigation measures and intervention. In this work package current knowledge and recent approaches to mapping snow and rock avalanche and debris flows as hazards have been summarized, evaluated, and rationalized. The result is a state-of-the-art report on hazard mapping of extremely rapid mass movements in Europe. A "decalogue" lists the 10 most important subjects for hazard mapping of snow avalanches, debris flows and rock avalanches. It furthermore summarizes the present state-of-the-art and "best practice" mapping methods as well as the practical implications for risk assessment.

An essential prerequisite for hazard mapping is understanding the process dynamics and their interaction with built structures. As with forecasting, more is known about the processes involved in snow avalanches as compared to debris flow and rock avalanches. There is also more data available and the resulting hazard maps are thus more accurate. The field of hazard mapping was pioneered when snow avalanches were first mapped in the 1950s. In contrast, the development of hazard maps for rock avalanches is extremely difficult, because they occur infrequently and it is difficult to quantify run-out zones.

Not only are there discrepancies between the reliability of the hazard mapping of the different processes, but there are also considerable differences between the IRASMOS partner countries. The long-term aim is to propose a European-wide standard for hazard mapping and quantifying hazard levels of extremely rapid mass movements. However, European harmonization of hazard mapping approaches and criteria will probably be very challenging. The reason is that hazard maps tend to have considerable economic impact on land-use planning because they influence land prices. The economic consequences of even a small modification of a map may be considerable.

Such harmonization initiatives and the future scope of the European-wide implementation of commonly accepted rules of "best practice" for effective disaster reduction with respect to extremely rapid mass movements were discussed at the "IRASMOS Round Table on Integral Risk Management" in Chamonix-Mont-Blanc, France, in January 2007. This meeting brought together stakeholders in the field of risk and crisis management with respect to rapid mass movements, such as scientists, practitioners, natural resource planners and decision-makers.

One of the main issues emphasized by many of the experts of rapid mass movements is short-term risk management. This includes early warning, artificial release (for snow avalanches) and intervention measures, which are intimately connected with settlement structures and therefore hazard mapping. As a consequence of several incidents with fatalities, particularly during the avalanche winter 1999, the central role of good documentation of the decisions made when an incident occurs became apparent. The experts agreed that, almost irrespective of country, clearer definitions of tasks and institutional responsibilities were needed. Long-term risk management, in contrast, seems to be heavily dependent on political decisions. For these a sound scientific basis is all the more important, although it takes time for them to feed into practice.

Powder snow avalanche. Tilicho Peak, Nepal.
Photo: Giovanni Kappenberger

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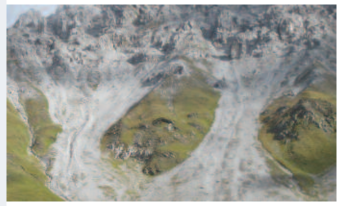
Goals

(1) To assess property damage and human losses due to debris flows, rock avalanches, and snow avalanches in selected alpine villages and regions; (2) to derive a catalogue of indicators for quantifying technical, socio-economic, and ecological vulnerability to these processes; and (3) to provide a simple means for weighting and merging these various types of vulnerability for integration into the risk equation.



Work package 4

Vulnerability

Lead: Cemagref, France

Vulnerability is a measure of the impact or the consequences of a natural hazard event on various elements at risk. These elements can be people, built structures, infrastructure or even entire communities. As such, they need to be addressed from a sociological as well as from a technical or economic perspective. The present work package focusses on technical and economic aspects in assessing vulnerability to torrent events and avalanches. The focus was on taking an economic perspective to develop an object-based vulnerability function with respect to torrent events and avalanches, and on taking a technical perspective to assess the structural resilience of values at risk. Local structural protection, such as reinforced concrete constructions, has a major influence on decreasing vulnerability.

In this work package a catalogue of vulnerable elements in mountain areas was compiled. An overview and critical assessment of existing vulnerability functions was elaborated for the processes snow avalanches, rock avalanches and debris flows. In this context, vulnerability to rock avalanches is easiest to quantify: the coincidence of a rock avalanche with values at risk results in a complete destruction of objects such as buildings or infrastructure.

Several case studies have been carried out with respect to numerical and empirical modelling of vulnerability. A series of empirical vulnerability functions describing the potential harm to both people and buildings exists. Most of these functions suffer from being based on insufficient data. It is therefore hard to generalize them as they apply to the situation for which they were elaborated. To overcome this problem, we followed an alternative approach in IRASMOS, attempting to evaluate the destructive force of a snow avalanche on a building using 3D numerical computer simulations and a structural damage index.

All of these approaches contribute a piece to a puzzle. However, there is still considerable need for future research, in particular to unify and reconcile these different approaches and to apply them in the analysis of multi-risk situations, where even less data are available. The goal should be to arrive at representative standardized scenarios, allowing for the derivation of vulnerability functions that depend on as few variables as possible.

Rockfall protection near Rothenbrunnen, Switzerland.
Photo: Yvonne Schaub

Goals

(1) To present the application of the risk concept as a basis for the development of protection strategies using European case studies, (2) to discuss uncertainties in risk analysis and their effects on decisions, (3) to propose ways of dealing with multi-risk situations, (4) to document technically the methodology for risk-based decision making, (5) to illustrate examples of best practice from the partner countries Austria, France, Italy, Norway and Switzerland, and (6) to recommend ways of dealing with natural hazards in Alpine countries.

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The main conclusions in this work package are:

- *There are considerable differences in the implementation of risk management strategies in the partner countries.*
- *Hazard analysis, including physical process modelling, is a crucial part of risk analysis. Therefore, we need to know more about the release mechnisms and process dynamics to provide reliable risk analyses.*
- *Uncertainties concerning factors in the risk equation considerably influence the result of a risk assessment and should be adequately interpreted and clearly indicated before being fed into decision making. This holds particularly for aspects of vulnerability.*
- *The effectiveness of countermeasures is the main factor in determining their benefit and should therefore be assessed carefully and comprehensively.*
- *The significance of organisational measures has increased during recent years due to improvements in early warning and will increase in the future. This has not yet been sufficiently taken into account by the risk management community.*
- *Risk communication and risk education are key factors in risk management and should be improved.*
- *The advantages of prospective, risk-based land-use planning could be stressed more on the administrative and political levels.*
- *Harmonization of risk management processes will be a future issue all over Europe. While harmonization will be relatively easy concerning countermeasures and early warning, it will be more challenging for hazard mapping and land-use planning.*

Work package 5

Integral Risk Management

Lead: WSL Institute for Snow and Avalanche Research SLF, Switzerland

Some best practice examples of integral risk management of the three processes snow avalanches, rock avalanches and debris flows have been addressed in case studies published as scientific papers. The case study on rock avalanches, for example, presents current attempts to quantify potential risk in Norwegian communities that could be impacted by a tsunami wave caused by the Åknes rockslide. It explores how risk can be quantified using two different methodologies: an explicit approach and a Bayesian networks approach. The case study on snow avalanches presents a method for optimizing avalanche mitigation for traffic routes in terms of both their risk reduction impact and their net benefit to society. The results suggest that the site-specific characteristics of avalanche paths, as well as the economic importance of a traffic route, are decisive for the choice of optimal mitigation strategies.

The technical report provides the technical basis for risk assessment and risk management, and could serve as a reference handbook for practical applications.

The best-practice handbook outlines methods for integral risk management from a practical point of view. Illustrated with three case studies, it provides recommendations for today's and tomorrow's "best-practice" in integral risk management in European countries. In national workshops experts from the risk management sector were interviewed to examine strengths, weaknesses, opportunities and threats (SWOT) within the operational risk management process. Some of the main results of the qualitative group discussion are listed here:

- Prevention is the only well-integrated part of the mitigation strategy. Thus the whole mitigation process cannot yet be considered "integral";
- Tools for risk assessment should be improved to make them more user friendly;
- Not all stakeholders are familiar with the notion of risk culture;
- More instructions and education on risk perception is needed;
- The roles and competence of stakeholders are often not clearly defined, neither on the strategic nor on the operational level.

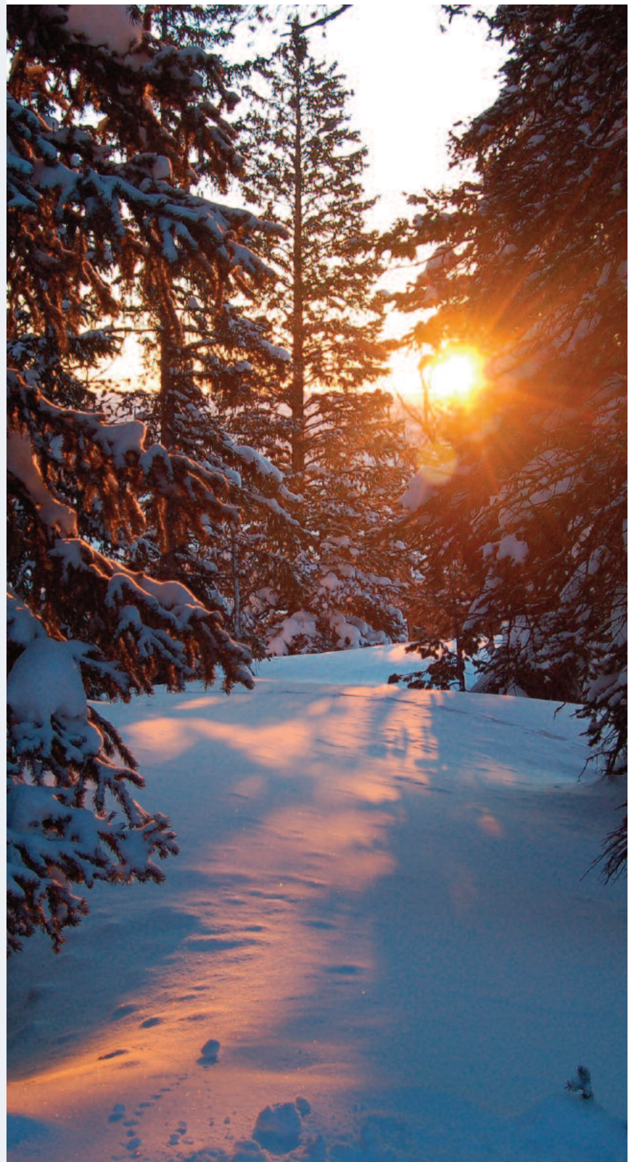
The insights in this work package were disseminated at an international conference in Davos, Switzerland in May 2008 with participants from seven European countries. The focus of this conference was on presenting and discussing the results of the project with not only scientific researchers, but also practitioners and administrators.

Different risks and benefits in mountain regions.
Bergell area, Switzerland.
Photo: Yvonne Schaub

Open Questions

The following list can be regarded as a selection of important open questions which need to be tackled and answered in the future.

- The quantification of risk includes a considerable degree of uncertainty. *How should we deal with this uncertainty in the practical realisation of protection strategies?*
- A dialogue among all stakeholders is necessary to reduce risks. *How could this dialogue be initiated and how should we communicate risks to the public?*
- For the development of mountain regions in Europe, efficient countermeasures are necessary. *How can the effectiveness of countermeasures be determined accurately?*
- Multi-risk considerations include risks from different sources, such as natural, technological or societal hazards. *How can these risks be compared and integrated in risk assessments in order to fully achieve the goal of integral risk management?*
- The future development of risks is closely connected to changes in our environment and the climate. *How can climate change considerations be included into risk assessment?*
- There has been an international harmonization of snow avalanche warning and forecasting in Europe. *How can other warning and forecasting systems for mountain regions be harmonized?*



Recommendations

Several recommendations for the practical application of integral risk management were formulated within the IRASMOS project. Some of the most important are presented in the following:

- Process understanding and forecasting procedures should become more precise spatially and temporally in future in order to improve the potential of organisational measures and to further improve the acceptance of decisions by the public.
- To support a risk-based land-use planning strategy, a future task is to further develop the current hazard maps into risk maps, with the long-term goal of producing dynamic risk maps reflecting short-term changes in the hazard and exposition during a critical incident.
- Climate change will influence the hazard scenarios. This influence and its consequences for a possible re-assessment of risk mitigation measures should be explored.
- Increases in population, land use, and tourist development will gradually lead to expansion into previously unsettled mountainous regions, and thus, a higher proximity to potentially adverse natural processes. The methods to compare natural hazard risks and potential socio-economic benefits on a quantitative basis are still unsatisfactory and should be further developed.
- Risk communication will play a central role in the future risk management process. Particular attention should be payed to an intensified dialogue between science and engineering and planning practice.

The IRASMOS project attempted to go beyond trying to provide partial risk solutions. It was designed to treat as far as possible prevention and intervention on an equal footing, keeping in mind that neither of them are adequate alone. Equal attention should also be given to recovery. In cases where both types of measures are not able to reduce the likelihood of an incident occurring sufficiently, a well-organised recovery plan might mitigate the impact of natural hazards. We hope that IRASMOS will provide a valuable contribution to developing integral risk management strategies for extremely rapid mass movements.

Avalanche protection above Ftan Engadin, Switzerland.
Photo: Yvonne Schaub

EU-Grant

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Further Information

Further information on the project and its deliverables can be found at www.slf.ch/irasmos.

Project partner

www.slf.ch

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