

## AUTOMATED RISK MAPPING FOR BUILDINGS ENDANGERED BY AVALANCHES

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**ABSTRACT:** Natural hazards have threatened humanity since time immemorial but up until recently, hazard management was conducted more as a reaction to events rather than as a precaution. Nowadays, the common approach is to plan the protection of people and assets from natural hazards before they happen; a job which requires extensive experience and expertise. The program RAMMS was developed enabling professionals to explore natural hazards by simulating snow avalanches, debris flows, hillslope debris flows and rock fall events in three-dimensional terrain. We have taken this program one step further towards managing natural hazard risks by implementing a new module called RAMMS::RISK, which calculates risk and automates risk mapping for buildings. The most attractive functionality of RAMMS::RISK is the visualization of the calculated loss and risk in combination with other building attributes. This allows users to visually explore potential risk hotspots and discover patterns in the risk information. We tested RAMMS::RISK for a case study and conclude that this tool can be a strong support for practitioners in the field of risk management of snow avalanches and other natural hazards.

**KEYWORDS:** risk management, RAMMS, natural hazard

### 1. INTRODUCTION

Natural disasters can have dire economic and social consequences, which has given rise to the mentality that it can be less costly to prevent a disaster than it is to pick up the pieces afterwards (Grossi and Kunreuther 2005). This is especially the case in more-developed countries, where a strong risk-averse culture has taken root (Smith 2013). Such management of risk requires extensive experience and expertise with the type of natural hazard and the hazard site in question: The hazard must be recognized and correctly assessed, the endangered assets need to be appraised. Finally a careful evaluation of risk hotspots is called for and appropriate mitigations measures must be decided upon, which are not only effective but also cost-efficient. These tasks can be very complex, especially when many assets are involved. Risk maps, giving an overview of the situation, help specialists reach decisions and communicate information. Indeed, visualizing and mapping risk has become an indispensable part of risk management (Van Westen 2013).

Several tools exist with the resources to map risk. The New Zealand project *Regional RiskScape* can

model regional risks originating from various natural hazards (Schmidt et al. 2011), while the US tool HAZUS builds on ArcGIS to visualize risk from earthquakes, hurricanes and floods (Schneider and Schauer 2006). The Australian natural hazards database PerilAUS can be combined with mapping tools, allowing users to explore historic incidents and their consequences in a spatial context.

Considering the already existing palette of risk mapping applications, we identified the need for a tool independent of commercial GIS products, which is not country-specific and can accommodate mountain natural hazards, such as avalanches, debris flows and rockfalls. An ideal backbone for this project was found in the program RAMMS, which was developed to aid professionals with the task of natural hazard assessment by simulating snow avalanches, debris flows, hillslope debris flows and rock fall events in three-dimensional terrain (Christen et al. 2012). We have taken this program one step further along the line of risk management by implementing a new module called RAMMS::RISK, which estimates risk quantitatively and automates risk mapping for buildings in an easy and appealing way. RAMMS::RISK resolves risk analysis down to individual buildings and can assess the following hazards: avalanche, rockfall, rock slide, deep-seated and shallow landslides, debris flow, static and dynamic floods.

In this paper we will give a brief outline of RAMMS::RISK's architecture, what functionalities

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it offers and how it performs in an avalanche case study.

## 2. METHOD

### 2.1 RAMMS::RISK

RAMMS::RISK was programmed using IDL (EXELIS 2014) and was built into the already existing framework of RAMMS (Christen et al., 2010). In this module, two main features are new to the otherwise familiar RAMMS interface: A special cursor mode was implemented to query asset attributes directly in the map, while a *Risk* tab contains the entire rest of the risk functionalities specific to this module (see Fig. 1).

The *Risk* tab is the heart of RAMMS::RISK. It envelops the *Scenario* tab, where the risk calculation results are summarized (as shown under 7 in Fig. 1), as well as the *Classification* and *Selection* tabs, which provide the means to spatially analyze the data.

*Classification* allows the user to distinguish between groups of buildings according to their attributes (see example in Fig. 2). Quantitative attributes can be split into groups using one of three classification methods: *manual* calls for a manual definition of class boundaries, *equal interval* divides the data range into a specified number of intervals of the same length and *defined interval* creates classes according to a specified interval size. Qualitative attributes are classified by selecting the attribute values which are of interest from a list. In the map the various classes are distinguished by different colors.

As the name suggests, the *Selection* tab is designed to highlight those buildings which fulfill certain selection criteria (see example in Fig. 3). Values and ranges are defined for one or more attributes. Only those buildings which satisfy all the specified conditions are finally displayed in the map.

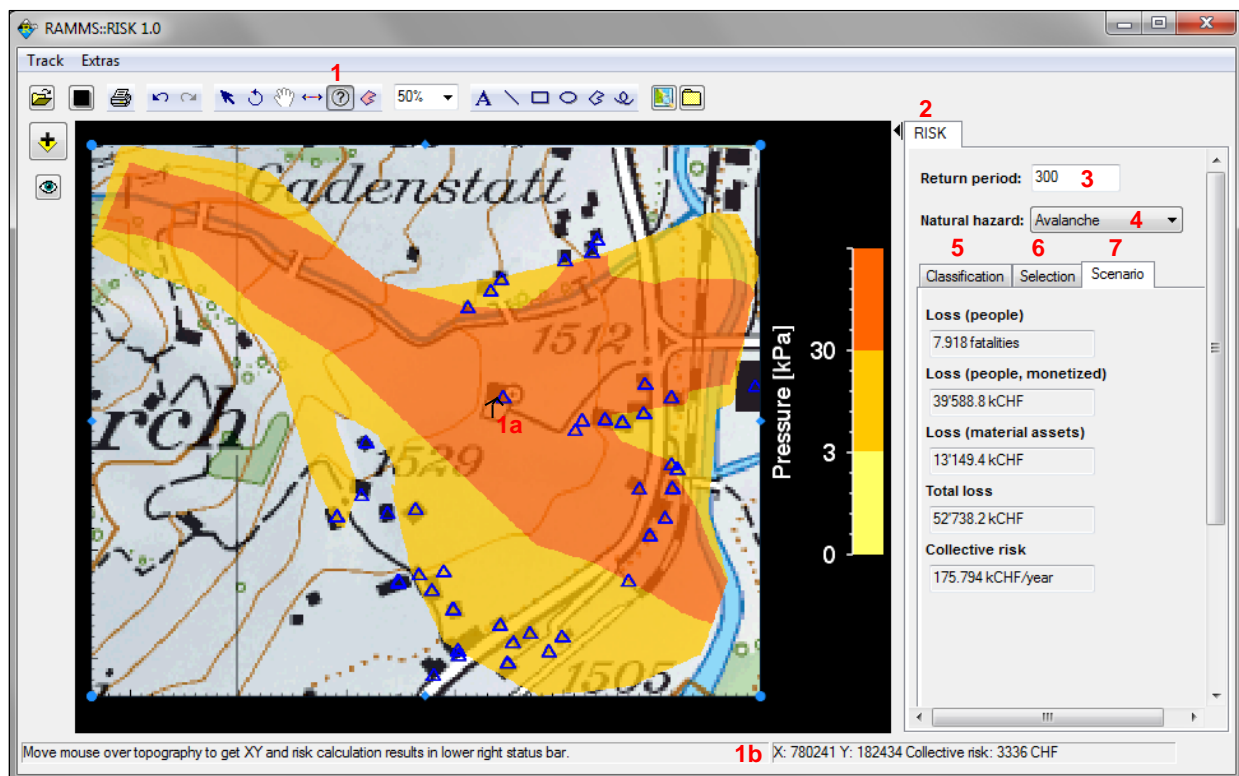


Fig. 1: The RAMMS::RISK user interface: a special cursor mode (1) to query asset attributes directly in the map (1a, 1b) and the Risk tab (2), containing information on the scenario's return period (3), the type of natural hazard (4), the risk calculation results (Scenario tab (7)), and the rest of the risk analysis functionalities (Classification (5) and Selection tabs (6)). Scenario: 300-yearly avalanche prior to mitigation measures, Davos Frauenkirch. Topographical map: pixmaps © 2014 swisstopo (57 04 000 000).

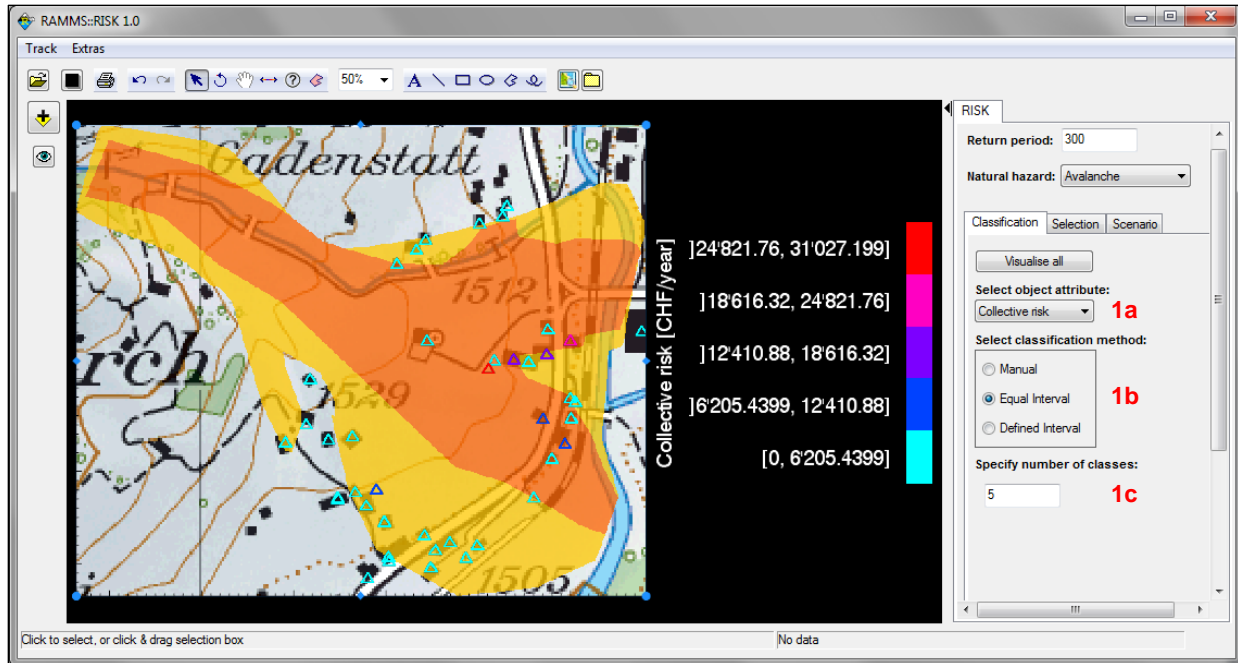


Fig. 2: Demonstration of the classification functionality: The buildings (triangles) are grouped in five classes according to their collective risk (1abc). Only seven buildings fall into the highest classes with risk values between 6'200 and 31'000 CHF/year. Scenario: 300-yearly avalanche prior to mitigation measures, Davos Frauenkirch. Topogr. map: pixmaps © 2014 swisstopo (57 04 000 000).

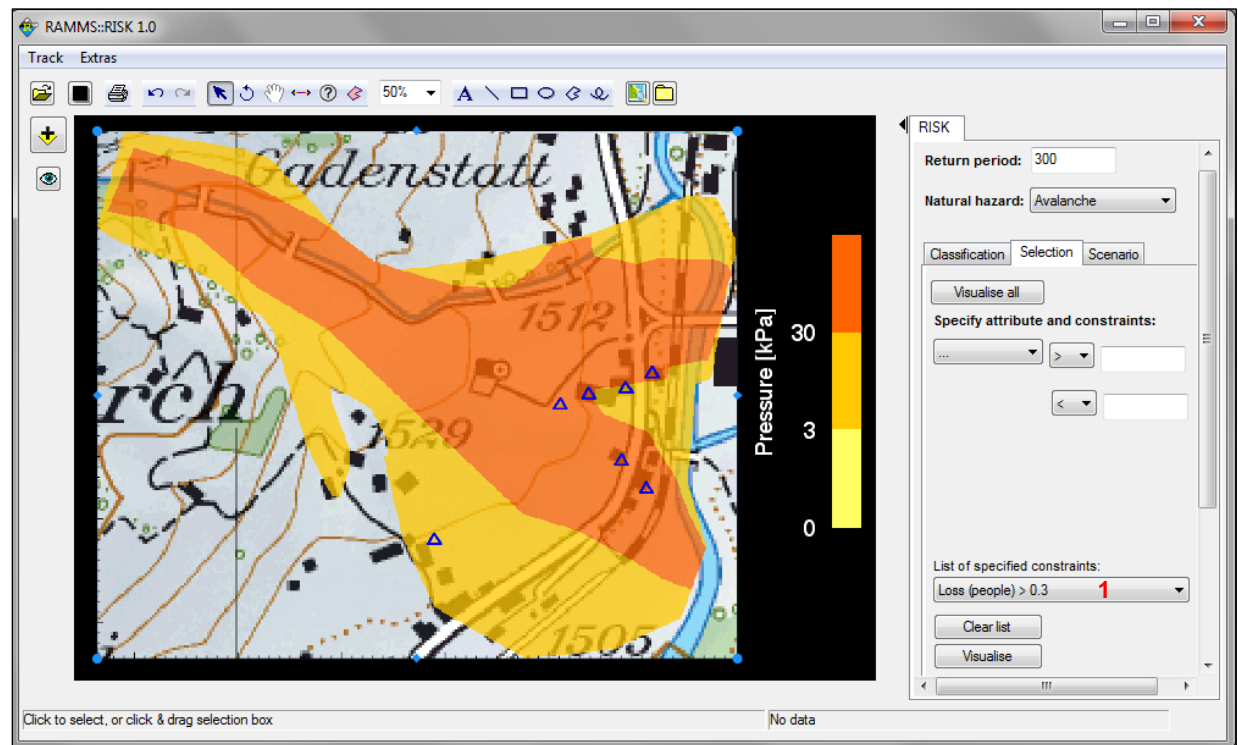


Fig. 3: Demonstration of the selection functionality: All buildings with a loss of lives greater than 0.3 deaths (1) are shown as blue triangles. Incidentally, these are the same buildings highlighted in Fig. 2 with the highest overall risk values. Scenario: 300-yearly avalanche prior to mitigation measures, Davos Frauenkirch. Topographical map: pixmaps © 2014 swisstopo (57 04 000 000).

Tbl. 1: An overview of required and optional RAMMS::RISK input files

<i>Input</i>	<i>Importance</i>	<i>Format</i>	<i>Content</i>	<i>See also...</i>
Intensity map	required	georeferenced ASCII (e.g. RAMMS simulation)	intensity information header with spatial and data-specific information  buildings to be considered in the risk analysis <i>required attributes:</i> <ul style="list-style-type: none"> <li>• type of building</li> <li>• coordinates</li> <li>• cost of building</li> </ul>	Appendix Fig. 4
Asset information	required	CSV or SHP	<i>optional but risk-relevant attributes:</i> (EconoMe default values used if absent) <ul style="list-style-type: none"> <li>• occupancy (average no. of people present in building)</li> <li>• presence factor (average portion of day which building is occupied)</li> </ul> <i>optional attributes:</i> any, e.g. building material, year of construction	Appendix Fig. 5
Topographical map, orthophoto	optional	georeferenced TIFF	image to aid spatial analysis	-

In order to calculate and display risk, RAMMS::RISK requires several input files, which are described in Tbl. 1. The tool calculates risk adhering to the methodology implemented in EconoMe, an IT tool provided by the Swiss Federal Office for the Environment to evaluate the cost-benefit ratio of natural hazard mitigation measures (FOEN 2014). The structure of EconoMe, the risk concept behind it and the formulas used to calculate risk are described in detail in Bründl et al. (2009) and Bründl (2012). RAMMS::RISK is programmed to display results in Swiss Francs but any other currency may be used.

## 2.2 Case Study

The extreme winter of 1999 in the Alps, in which avalanches claimed 17 lives in buildings and on traffic routes in Switzerland alone (Wiesinger and Adams, 2007), confirmed the value of the avalanche hazard mapping and mitigation measures that had been constructed since the disastrous winter in 1951 (Wilhelm et al. 2000). However, it also showed authorities that risk management strategies had not yet reached their full potential. In the aftermath of February 1999, the Davos district administration asked the WSL Institute for Snow and Avalanche Research SLF to develop a master plan for the integrated risk management of avalanche tracks, using the settlement of Davos Frauenkirch as a showcase project. For this expertise, intensity maps were drawn for various scenarios and the endangered assets were

accordingly identified. Based on the expertise, mitigation measures were later implemented. This detailed risk analysis of the avalanche situation in Davos Frauenkirch prior to mitigation measures has served as a source of input for our RAMMS::RISK case study<sup>1</sup>.

Since the intensity maps developed for the Frauenkirch expertise were readily available to us, we used these as the intensity input for our case study instead of reproducing them with RAMMS simulations. In these intensity files, only areas of medium and high intensity were distinguished (see also Fig. 1, Fig. 2 and Fig. 3).

The building insurance of the canton of Grisons kindly supplied a dataset of georeferenced buildings for the municipality of Davos Frauenkirch including building values. Asset information of this dataset was verified by field work. Occupancy and presence factors were estimated for all buildings according to the Frauenkirch expertise.

The Swiss national map 1:25000 no. 1197 Davos was used as a topographical map.

## 3. RESULTS AND DISCUSSION

The RAMMS::RISK calculations for the evaluated scenarios are summarized in Tbl. 2 and Tbl. 3. As

<sup>1</sup> The expertise is not available to the public. For more information on the data drawn from this expertise please contact the corresponding author.

shown in Tbl. 3, these results are of the same order of magnitude as the calculations made for the Frauenkirch expertise. Discrepancies result mainly from different risk calculation methodologies (expertise: Borter (1999), case study: Bründl et al. (2009)) and the updated asset cadaster used for this case study.

Although RAMMS::RISK clearly delivers credible results, manual validation of the calculations has shown that the tool makes some classification mistakes because RAMMS::RISK considers assets (buildings) as point objects. If this median point of the building is located outside an intensity zone, the building is not considered for risk calculations pertaining to this zone, even if the building lies partly within it. A polygon-based approach would, however, be very complex, especially with regards to the required input data.

Tbl. 2: RAMMS::RISK calculations for three avalanche scenarios (return periods) in Davos Frauenkirch prior to mitigation measures

<i>Risk and loss calculations</i>	<i>30 yrs</i>	<i>100 yrs</i>	<i>300 yrs</i>
Loss (people) [fatalities]	0.1	7.5	8
Loss (people) [kCHF]	504	37'165	39'589
Loss (assets) [kCHF]	372	12'770	13'149
Total loss [kCHF]	876	49'935	52'738
Collective risk [kCHF/year]	29	499	176

Tbl. 3: Comparison of calculations for the avalanche risk situation in Davos Frauenkirch prior to mitigation measures

<i>Method</i>	<i>Risk of death [fatalities/year]</i>	<i>Collective risk [kCHF/year]</i>
RAMMS: :RISK	0.08	704
Frauenkirch expertise	0.07	500

Two examples of possible spatial risk analyses with RAMMS::RISK are shown in Fig. 2 and Fig. 3. Fig. 2 makes apparent, that the buildings with the highest collective risk (ca. 6'200 CHF/year and higher) are not necessarily affected by high intensity (orange intensity zone). Fig. 3 shows that the high collective risk of these seven buildings is connected with their high loss of human lives. Thanks to the highly specialized nature of

RAMMS::RISK, identifying patterns such as these is made possible with little effort or software training.

#### 4. CONCLUSIONS

RAMMS::RISK, with its functionalities to analyze and understand the spatial distribution of risk, offers various possibilities to natural hazard specialists. Using the classification functionality, users of RAMMS::RISK can visually explore how loss, risk and other asset attributes are spread with relation to the intensity map. The selection functionality makes it possible to pick out and display buildings which satisfy certain conditions of interest. Both analysis tools allow the identification of risk hotspots.

The RAMMS module is independent of commercial GIS software, not country-specific and is easy to use. As shown in a case study for the avalanche endangered village of Davos Frauenkirch, RAMMS::RISK calculations are comparable to earlier assessments. The user must, however, be aware that the tool cannot reproduce or predict reality, but merely provides an estimation of the natural hazard risk. Also, the results can only ever be as good as the input; an intensity map verified by experts as well as accurate and detailed asset information are key to a sound risk analysis. Finally, interpretation of the results requires expertise and critical thinking, which cannot be provided by the mapping tool itself.

Although the module is still in its early stages of development and must be tested more rigorously before being employed for official risk planning, we believe that RAMMS::RISK can be a valuable support for practitioners in the field of natural hazard risk management everywhere.

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APPENDIX

```
ncols      444
nrows      358
xllcorner  779882.4355
yllcorner  182281.6828
cellsize   1
NODATA_value -9999
-9999 -9999 0.518 2.870 6.624 10.768
```

Fig. 4: Header and excerpt from an intensity map ASCII file (fictional). *ncols*, *nrows*: number of columns and rows, *xllcorner*, *yllcorner*: coordinates of the map’s lower left corner, given in Swiss grid coordinates (national survey 1903), *cellsize*: size of ASCII grid cells, *NODATA\_value*: value used to show that no data is available for a particular cell

```
BUICODE, LONGITUDE, LATITUDE, COST, USE, BUIMAT
87,781500.663,179619.903,1211700.00,residential,mixed
2,781506.474,179641.694,628100.00,barn,wood
4,781519.604,181822.992,50500.00,garage,brick
2,781611.071,179695.445,423800.00,barn,wood
1,781833.314,183196.948,590300.00,residential,brick
```

Fig. 5: Excerpt from a CSV file containing asset information (fictional) with the four mandatory attributes type of building (using the EconoMe buildings code), coordinates and cost of the building as well as two optional attributes (use of the building and building material). Building codes: 1=one-family house, 2=barn, 4=garage, 87=multi-family house