Risks in defining acceptable Risk Levels

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ABSTRACT: Recently demands for performing landslide risk assessments are increasing. Applying the results of such assessments are highly dependent on the definition of risk levels, which are a consequence of acceptance in society and economy. Ideally, these specific risk levels should represent the risk accepted by the threatened people. However, defining acceptable risks is a difficult task because of the different perceptions of all involved parties. Within this study approaches to define acceptable risk levels are reviewed and examples from different countries are given. A prerequisite for the definition of acceptable risks are reliable risk analysis results. However, risks may vary heavily depending on different input parameters and models as examples mostly from a case study in Bíldudalur (NW-Iceland) show. A general conclusion and strategies for the agreement of acceptable levels of landslide risk are provided as perspectives.

1 INTRODUCTION

"Landslide risk while being challenging and interesting, is little more than an academic exercise without the … risk acceptability criteria necessary to make use of the results of the analysis" (Fell & Hartford 1997). This quote stresses the importance of defining acceptable risk levels. The ISSMGE TC32 (International Society for Soil Mechanics and Geotechnical Engineering - Technical Committee on Risk Assessment and Management) 2004 defined acceptable risks as risks which everyone impacted is prepared to accept. However, the challenge is to determine what the threatened individuals and society are willing to accept, as each person perceives and subsequently accepts risks in a different way.

Whereas regarding technical risks acceptable risks are already defined in many countries since decades, such risk acceptance levels are very rare regarding landslides. The question is if the approaches used for technological risks (mainly: comparison with other risks) are applicable for landslides as well.

In general, the definition of acceptable risk levels should be embedded in a holistic risk management framework like presented e.g. in Fell (2000), Hübl et al. (2002), Petrascheck & Kienholz (2003) and Ammann (2005).

Within this study, general approaches to define acceptable landslide risk levels are briefly reviewed, followed by a discussion how acceptable landslide risks are treated in Iceland, Hong Kong and Switzerland.

To ensure the comparability of acceptable risk levels with the calculated risk values, topics like the variation of risk due to different input parameters, process models, risk models, reference units and data resolution must be considered. Moreover, the questions if the acceptable risk levels should refer to single or multi hazards and to individual or object risk must be answered. In addition, the spatio-temporal changes of risk and risk acceptance should be adressed.

Finally, an idea is provided how the complex phenomena of accetable landslide risks could be treated in future.

2 APPROACHES TO ACCEPTABLE LANDSLIDE RISK

The acceptance of landslide risk differ between individuals and society. They both have their own acceptance levels based on respective demands and cannot be simply deduced from each other. Numerous approaches to analyse acceptable risk are available in risk research. An overview is given in Bell & Glade (2005) and summarised in the following.

The technical-normative approach introduced by Starr (1969) focuses on an universal acceptance level, based on which it should be possible to compare different risks. Within this approach risks are calculated as the product of the probability of an event and its possible consequences. This approach neglects the variations of risk acceptance over time.

Psychologists (e.g. Slovic et al. 1980) developed the psychometric approach. Using quantitative interviews societal acceptance levels are derived from present individual acceptance levels, considering that the acceptance temporally shifts.

The mathematical approach also tries to deduce societal acceptance from individual acceptance but uses mathematical formulas instead of interviews to gather information on the risks accepted by individuals (Plattner 2005).

In neuroscience the dual-process approaches were developed, focussing on the individual acceptance and the role of emotions Epstein (1994). They might be applied to natural risk research by qualitative field studies.

The system theoretical approach (Luhmann 1993) facilitates to analyse and understand how society construct acceptance levels. Within this approach risks refer to decisions and acceptance refers to people or systems which determine the level of acceptance. Thus, as the public at a whole does not take the decision about acceptable risks, a uniform safety level cannot be defined.

A basic question regarding landslide risk acceptance is who should determine such acceptable risk levels. Fell (1994) stated that the "decision will usually be made by owners, politicians or others, not by the person doing the risk analysis." This is supported by social science approaches which underline the role of social processes as decision-maker.

A very important issue within the definition of acceptable risk levels is the consideration of the variation of these levels in space and time. However, not all of the mentioned approaches have integrated such changes.

Furthermore, people have difficulties in understanding probabilistic processes (Slovic 1987). Therefore, regarding risk comparisons the same author stated that "even though such comparisons have no logically necessary implications for acceptability of risk (Fischhoff et al. 1981), one might still hope that they would help improve people's intuitions about the magnitude of risks. Risk perception research suggests, however, that these sort of comparisons may not be very satisfactory even for this purpose". These comparisons give inadequate consideration to the important differences in the nature of the risks compared.

Finally, most of the approaches focus on individuals and try to derive societal consequences. However, there are significant differences between the individual and social dimension. Statements about the social dimension cannot be easily upscaled from the individual dimension by summarising the individual results because the whole is more than the sum of its parts (emergence). This means that new features appear at the social dimension which does not exist at the individual dimension.

3 ACCEPTABLE LANDSLIDE RISK – CASE STUDIES

3.1 *Iceland*

In Iceland The Ministry of the Environment (2000) in cooperation with an official committee (including politicians, local authorities and experts) defined and implemented acceptable risk levels for landslides and snow avalanches in a national regulation.

The risk levels were defined by comparison with many other risks, e.g. the risk to die in a traffic accident, mortality rates for different age groups, acceptable risks in other areas of society such as aviation and for workers in different industries. Risk aversion factors were added since natural risks are considered to be involuntary risks. Defined risk levels refer to individual risk to life. Three risk classes were implemented: high risk (C): >=3 x 10^{-4} / year; medium risk (B): 1 – <3 x 10^{-4} / year and low risk (A): 0.3 – <1 x 10^{-4} / year. The regulation aims to prevent people living in the high risk zone until 2010. Thus, if risk analyses conclude that there are people living in this zone, countermeasures must be carried out – either by building dams or resettling people and their houses. Planning new settlements risk analyses must be carried out to ensure that no new settlements will be built in high risk zones.

While for snow avalanches detailed guidelines to carry out risk analyses exist (Jónasson et al. 1999), regarding landslides only preliminary guidelines are available (Jóhannesson & Ágústsson 2002, summarised in Ágústsson et al. 2003). *Hong Kong*

In Hong Kong the Geotechnical Engineering Office proposed interim risk guidelines for landslides (from natural terrain) in 1997. Similarly to Iceland acceptable risk levels were defined by comparison with other risk criteria (e.g. risk resulting from major hazardous installations, railways or large dams). The following risk levels were proposed to be acceptable: individual risk (per year) for new developments: max. <10^{-5}/ year; for existing developments: max. <10^{-4}/ year.

In addition acceptable risk criteria for societal risk (per year) was proposed relating the probability per year of an event causing N or more fatalities (F) to N (F-N curve). A maximum of 5000 fatalities in a single event is supposed to be tolerated if the probability (F) is low enough (~10^{-7}/ year and less) – but only for specific types of developments (Geotechnical Engineering Office 1997).

3.3 *Switzerland*

In Switzerland the PLANAT (National Platform for Natural Hazards), an extra-parliamentary commission, currently proposed the following acceptable risk criteria for individual risk to life per year and all kinds of natural hazards. Based on the degree of voluntariness four categories were defined (1= absolutely voluntary, 4 = involuntary): Category 1: 10^{-2} - 10^{-3}; category 2: 10^{-3} – $2x10^{-4}$; category 3: $2x10^{-4}$ – $3x10^{-5}$; category 4: $3x10^{-5}$ – $4x10^{-6}$. In contrast to Iceland, all categories are possible to be applied for natural risks, thus natural risks are not always seen to be involuntary. However, these risk levels are at the stage of discussion and will be tested in case studies and adapted if necessary (Ammann, pers. comm.). Beside these individual risk to life levels societal risk levels are proposed referring to how much money society is willing to pay to safe the life of a single person: Category 1: 1-2 Mio. CHF; category 2: 2-5 Mio. CHF; category 3: 5-10 Mio. CHF; category 4: 10-20 Mio. CHF. (see Ammann 2005 for more details).

In addition to these activities, Heinimann (1999) published a detailed guideline to carry out risk analyses for gravitational processes (including landslides). Within this guideline final risk values refer either to individual risk to life per 100m² and year, object risk to life per 100m² and year, or economic risk per 100m² and year. Based on these guidelines first applications were carried out in various states (cantons) of Switzerland.

4 ACCEPTABLE RISK VERSUS RELIABLE RISK

There are some risks in defining and applying acceptable landslide risks. First, as already discussed it is not trivial to define the acceptable risk levels reliably, so that these levels do refer to the risk accepted by the threatened people. Second, the risk values resulting from risk analysis must be reliable and third, the defined acceptable risk levels must be somehow comparable to the calculated landslide risk values.

However, there are large uncertainties in the analysis of landslide risks. In the following, the topics mentioned in the introduction will be addressed. Many of the examples given refer to a case study in Bíldudalur, NW-Iceland. Thus, it is necessary to give some information on the study area and on the applied methodology first.

The study area Bíldudalur is situated in NW-Iceland. It is a Fjord landscape with a typical u-shaped valley (flat valley bottom and steep slopes). The mountains are mainly built up by layered basaltic rocks with very gentle dips only. Landslide types threatening the village are debris flows and rock falls. For details on the study area refer to Bell & Glade (2004a, 2004b) and Glade & Elverfeldt (2005, this volume). Landslide risks are calculated as individual risks and object risks to people in buildings. Individual risk to life means that only a single person is considered in each house. Calculating object risk to life, all persons living or working at a house are considered. Furthermore, economic risks are determined. Various risks are calculated using a raster-based approach and the following risk formulas (based on Fell 1994; Heinimann 1999; Morgan et al. 1992):

a) Individual risk to people in buildings:

$$R_{ipe} = (H \times P_s \times P_t \times V_p \times V_{pe} \times P_{so}) \times E_{ipe} \qquad (2)$$

where R_{ipe} = individual risk to people in buildings (annual probability of loss of life to an individual); H = annual probability of the hazardous event; P_s = probability of spatial impact (i.e. of the hazardous event impacting a building); P_t = probability of temporal impact (i.e. of the building being occupied); V_p = vulnerability of the building; V_{pe} = vulnerability of the people; P_{so} = probability of seasonal occurrence (e.g. snow avalanches only in winter); E_{ipe} = individual person

b) Object risk to people in buildings:

$$R_{pe} = (H \times P_s \times P_t \times V_p \times V_{pe} \times P_{so}) \times E_{pe} \qquad (3)$$

where R_{pe} = risk to people in buildings (annual probability of loss of life); E_{pe} = number of people in each building.

c) Economic risk:

$$R_p = (H \times P_s \times V_p \times P_{so}) \times E_p \qquad (4)$$

where R_p = risk to buildings, roads, infrastructure (annual loss of economical value); E_p = economic value of the building, infrastructure

4.1 *Changing risk due to different process models*

Applying different process models may result in quite different runout-zones, leading to different hazard and consequent risk maps. Figure 1 conceptually shows that using process model A only two houses are threatened, using process model B four houses are at risk. But not only the number of threatened houses may vary, as the example shows also the location may change.

4.2 *Changing risk due to various processes*

Discussing acceptable risk levels for landslide risks all landslide types threatening the people in respective study areas should be considered in risk analyses. In Bíldudalur the highest risks to people are posed by debris flows, followed by rock falls (Bell

& Glade 2004a). Considering different processes the question is whether people really accept risks from debris flows in the same order like rock fall risks? And what is the situation like, if further landslide types or other natural risks are posing threats to people (refer also to Glade & Elverfeldt 2005). The ultimative question is: Is there a need for process specific acceptable risk levels?

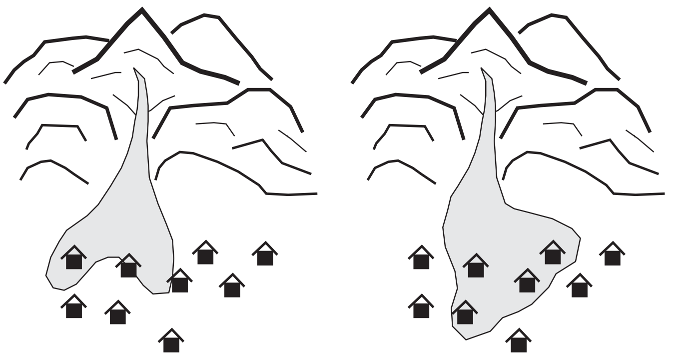

Figure 1. Changing risk due to the use of different process models

4.3 *Changing risk due to various risk models*

Final risk values are highly dependent on the number of input parameters represented in the risk model. The basic model is:

$$R_{pe} = (H \times V_p \times V_{pe}) \times E_{pe} \tag{5}$$

Further above more detailed models are described. Applying the basic model (formula (5)) to debris flow risk in the study area Bíldudalur 51.55% of the risk pixels belong to the highest risk class. Using formula (3) the proportion of the highest risk classes drops down to 1.58%. Intermediate risk models lead to intermediate proportions. Detailed results are presented in Bell & Glade (2005).

4.4 *Changing risk due to different reference units*

As was shown in chapter 3, acceptable risk levels are often defined as risk per year. But the Swiss guideline by Heinimann (1999), for example, propose to calculate the risk as risk per year and $100m^2$. There can be large differences between the final risk values depending on the reference unit chosen. Bell & Glade (2005) show that calculating rock fall risks per year using formula (3) 11.35% of the risk pixels belong the highest risk class. Using risk per year and $100m^2$ as reference unit the value drops down to 4.96%. 0% belong to the highest risk class when the risk is calculated as risk per year and $1m^2$. For details refer to Bell & Glade (2005).

4.5 *Changing risk due to different data resolution*

Calculating landslide risk reliably there is the need for good input data. Although not always applicable it can be concluded, that the higher the data resolution, the better the data is. But quite often high resolution data is missing and coarser data must be used.

As already mentioned a raster based approach was used to model landslide risks in Bíldudalur. Modeling was carried out at 1m resolution. But as not all parameters were available in such a high resolution there was the need to upscale the final risk results. The question was which resolution would meet the task of upscaling the best (10m, 20m,…,100m) without loosing information. Lowering the resolution, the number of pixels with high risk values decreased until at the lowest resolution of 100m all high risk pixels were disappeared (Figure 2). In addition, the spatial extent of the area at risk increased and the degree of detail got less. This clearly raises the question on the most appropriate data resolution for the best result aimed for a given region.

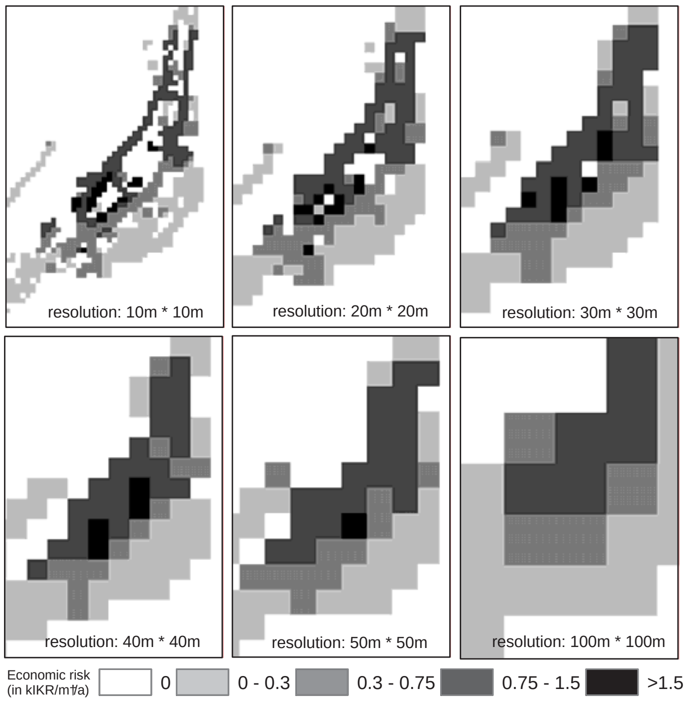

Figure 2. Changing risk due to different data resolution (Economic risk in Bíldudalur, NW-Iceland, using formula (4))

4.6 *Are acceptable risks refering to single or multi landslide hazards*

Defining acceptable risk levels one should be aware whether these levels refer to all landslide types or only to single ones. Regarding the Icelandic example, the question is if the value of $<0.3 \times 10^{-4}$ is the maximum risk accepted for debris flows and rock falls together. Or, is the maximum risk accepted for debris flows $<0.3 \times 10^{-4}$ and for rock falls $<0.3 \times 10^{-4}$ as well. The latter would mean, that the overall maximum risk would be twice the defined acceptable risk level. To further complicate matters, further landslide types or other natural hazards might threaten the people. Then, the maximum risk level might be applicable to each of the specific processes, resulting in a maximum natural risk which would exceed the defined level several times.

4.7 *Individual or object risk to life?*

Especially in Iceland and Switzerland the acceptable risk levels are defined for individual risk to life. However, it is risky to focus only on individual risks, as actual risks may be overseen. For example, dams are built to reduce the individual landslide risk to life. After the geotechnical construction is finished individual risks to life are lower than the accepted risk levels and thus, it might be allowed to increase the population behind the construction. Allowing this the object risks and societal risks will increase whereas the individual risks remain the same. If then an event larger than the design-event the dam was built for occurs, the consequences might be dramatically larger than without that dam. Table 1 shows the significant differences between individual and object risk to life.

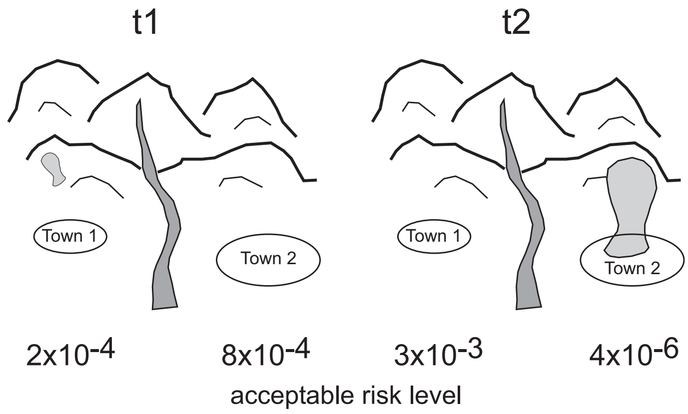

Figure 3. Spatio-temporal changes of risk and risk acceptance

5 CONCLUSION

As was presented in the previous chapter risk may vary distinctively depending on respective process models, natural processes, risk models, reference units and data resolution. In addition, risk from multi-hazards are higher than from single hazards and object risks are higher than individual risks. Finally, risks and risk acceptance are dynamic and show spatio-temporal variations. All of these topics should be considered in the definition of acceptable risk levels to reduce the risk that final risk values are not comparable with the acceptable risk levels defined and to ensure that appropriate risk management options can be taken.

Table 1. Differences between individual and object risk to life (using formula 2 and 3)

risk type	prob. of loss of life		pixel per risk class (%)			
	min ($x10^{-4}$)	max ($x10^{-2}$)	$<0.3x10^{-4}$	$0.3 – <1.0x10^{-4}$	$1.0 - <3.0x10^{-4}$	$>=3.0x10^{-4}$
debris flow						
object risk	6.30	7.77	0.0	0.0	0.0	100.0
individual risk	5.70	0.28	0.00	0.0	0.0	100.0
rock fall						
object risk	0.21	0.16	4.3	27.0	57.5	11.4
individual risk	0.11	0.01	7.8	92.2	0.0	0.0

4.8 *Spatio-temporal changes of risk and risk acceptance*

Regarding Iceland, Hong Kong and Switzerland the implemented or proposed acceptable risk levels are all defined at a national scale neglecting regional or local differences in landslide risk and the acceptance of these risks. However, threatened people and authorities in one region might accept higher risks than in another region. Moreover, as a result of risk education or loss of memory after an event risk perception and consequently risk acceptance may change over time. Finally, also the natural risk itself may change over time, as is best represented within the frequency-magnitude analysis of landslides in respective study areas. In this context, it might be risky to focus only on specific design events (e.g. a 100year event) and to ignore possible extreme events.

How risk and especially risk acceptance may change over time is conceptually shown in Figure 3. Recent studies investigate the evolution of risk over time for landslides (Hufschmidt et al. submitted) and for snow avalanches (Fuchs et al. 2004 and Keiler et al. 2004).

In Switzerland, proposed acceptable risk levels refer to risk per year, while the guideline suggests to calculate risks as risks/100m² and year. But using different reference units can result in very different risk values. Thus, in extreme a comparison of the acceptable risk levels and the calculated risks might not be possible anymore.

Following the large variations in risk when using different risk analysis methods, the question must be asked whether specific methods (process models, risk models, etc.) should be implemented along with the acceptable risk levels. And, if yes, to what extent should specific methods be implemented.

Focussing on individual risks only may lead into a larger catastrophe in future, so that also object risks and societal risks should be considered in the definition of acceptable risk levels. In addition, the discussion of acceptable risks should address the question if defined acceptable risk levels are referring to single or multi hazards.

Finally, due to the variation of risks and the acceptance of risks in space and over time rather dynamic approaches instead of static approaches to analyse risks and to define acceptable risk levels are needed.

6 PERSPECTIVES

Demands to guarantee a uniform safety level accepted by the public are increasing. But as discussed there might be differences from state to state, village to village, etc. Thus, new approaches and concepts might be necessary to find sound solutions for the challenge of acceptable risks. One possible solution might be the concept of the scale dependent definition of acceptable risk levels (figure 4). Whereas at a national scale acceptable risks might be defined by using the technical-normative approach (as applied in Iceland, Hong Kong and Switzerland) or a mathematical approach (Plattner 2005), at lower scales other approaches are needed.

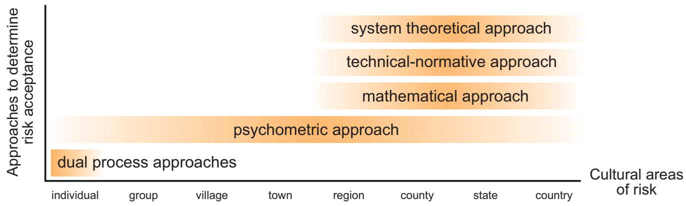

Figure 4: Scale dependent definition of acceptable risk levels and proposed approaches to use (Bell & Glade 2005)

Figure 2 shows that the psychometric approach is applicable at all scales. This only refers to how the approach is used currently. As discussed in chapter 2 it is questionable to derive societal risk acceptance levels from individual risk acceptance levels. Thus, there is still a lack of suitable approaches to define acceptable risk levels at lower scales.

The need for new concepts and new approaches is also stressed by the following statements. Decision-makers, however, need to understand how people think about and respond to risk. Otherwise well-intended policies may be ineffective (Slovic 1987). Furthermore, “without any input from the public on their views and feelings, the decision makers are seen to be making assumptions on behalf of the public without any consulatation. … a survey of landslide risk perception is a form of public consultation and should be part of any risk management system” (Finlay & Fell 1997). Finally, “risk communication and risk management efforts are destined to fail unless they are structured as a two-way process. Each side, expert and public, has something valid to contribute. Each side must respect the insights and intelligence of the other” (Slovic 1987).

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8 REFERENCES

Ágústsson, K., Jóhanneson, T., Sauermoser, S., Sigurðsson, H.ó. & Jensen, E.H. 2003. Hazard zoning for Bíldudalur, Vesturbyggð. *Report, VÍ-ÚR23-03034*. Reykjavík: Icelandic Meteorological Office. (http://www.vedur.is/snjoflod/haettumat/bi/bi_tech.pdf (02-12-2005))

Ammann, W. 2005. Natural Hazards: Risk Concept and Integral Risk Management. In CENAT (ed.) *Coping with risks due to natural Hazards in the 21st century - RISK21*, Rotterdam: Balkema.

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

Bell, R. & Glade, T. 2004b. Multi-hazard analysis in natural risk assessments. In Brebbia, C.A. (ed.) *International Conference on Computer Simulation in Risk Analysis and Hazard Mitigation (RISK ANALYSIS 2004), Rhodes, Greece*: 197-206. WIT Press.

Bell, R. & Glade, T. 2005. Challenges in defining acceptable risks. In CENAT (ed.) *Coping with risks due to natural Hazards in the 21st century - RISK21*, Rotterdam: Balkema.

Epstein, S. 1994. Integration of the Cognitive and the Psychodynamic Unconscious. *American Psychologist*, 49: 709-724.

Fell, R. 1994. Landslide risk assessment and acceptable risk. *Canadian Geotechnical Journal*, 31(2): 261-272.

Fell, R. 2000. Landslide Risk Management Concepts and Guidelines - Australian Geomechanics Society Sub-Committee On Landslide Risk Management. In International Union of Geological Sciences (ed.) *Landslides, Cardiff, UK, 25.06.2000*: 51-93. International Union of Geological Sciences.

Fell, R. & Hartford, D. 1997. Landslide risk management. In Cruden, D.M. & Fell, R. (eds.), *Landslide risk assessment - Proceedings of the Workshop on Landslide Risk Assessment*, *Honolulu, Hawaii, USA, 19-21 February 1997:* 51-109. Rotterdam: A.A. Balkema.

Finlay, P.J. & Fell, R. 1997. Landslides: Risk perception and acceptance. *Canadian Geotechnical Journal*, 34(2): 169-188.

Fischhoff, B., Lichtensetin, B.S., Slovic, P., Derby, S.L. & Kenney, R.L. 1981. *Acceptable Risk*, In Cambridge: Cambridge University Press.

Fuchs, S., Bründl, M. & Stötter, J. 2004. Development of avalanche risk between 1950 and 2000 in the Municipality of Davos, Switzerland. *Natural Hazard and Earth System Science*, 4: 263-275.

Geotechnical Engineering Office 1997. Landslides and boulder falls from natural terrain: interim risk guidelines (GEO REPORT No. 75). Hong Kong

Glade, T. & Elverfeldt, K.v. 2005. MultiRISK: An innovative Concept to model Natural Risks. In Vancouver Geotechnical Society (ed.) *Landslide risk management, Vancouver, 31.05. - 04.06.2005*.

Heinimann, H.R. 1999. *Risikoanalyse bei gravitativen Naturgefahren - Methode*, In BUWAL (Bundesamt für Umwelt Wald und Landschaft), Umwelt-Materialien, 107/I, Bern.

Hübl, J., Kienholz, H. & Loipersberger, A. (eds.) 2002. *DOMODIS - Documentation of mountain disasters*, Schriftenreihe 1: Klagenfurt.

Hufschmidt, G., Crozier, M.J. & Glade, T. submitted. Natural hazard and risk evolution - Wellington Region, NZ. *Natural Hazard and Earth System Science*.

ISSMGE TC32 (International Society for Soil Mechanics and Geotechnical Engineering - Technical Committee on Risk Assessment and Management) 2004. Glossary of Risk Assessment Terms - Version 1.

Jóhannesson, T. & Ágústsson, K. 2002. Hazard zoning for debris flows, rockfall, slushflows and torrents and slushflows mixed with soil in steep slopes (in Icelandic). *Report, TóJ/Kri-2002/01*. Reykjavík: Icelandic Meteorological Office.

Jónasson, K., Sigurdsson, S.P. & Arnalds, P. 1999. Estimation of avalanche risk. *Report, VÍ-R99001-ÚR01*. Reykjavík: Icelandic Meteorological Office.

Keiler, M., Meibl, G. & Stötter, J. 2004. Determination of the damage potential: a contribution to the analysis of avalanche risk. In Brebbia, C.A. (ed.) *International Conference on Computer Simulationin Risk Analysis and Hazard Mitigation (RISK ANALYSIS 2004), Rhodes, Greece*: 187-196. WIT Press.

Luhmann, N. 1993. *Risk: A Sociological Theory*, In Berlin, New York.

Morgan, G.C., Rawlings, G.E. & Sobkowicz, J.C. 1992. Evaluating total risk to communities from large debris flows. In *Geotechnique and Natural Hazards, 6 - 9 May 1992, Vancouver, Canada*: 225-236.

Petrascheck, A. & Kienholz, H. 2003. Hazard assessment and mapping of mountain risks in Switzerland. In Rickenmann, D. & Chen, C.-L. (eds.), *Debris-flow hazards mitigation: mechanics, prediction, and assessment, 10-12 September 2003, Davos, Switzerland*: 25-38. Millpress, Rotterdam, Netherlands.

Plattner, T. 2005. Evaluation of risks due to natural hazards. A conceptual approach. In CENAT (ed.) *Coping with risks due to natural Hazards in the 21st century - RISK21*, Rotterdam: Balkema.

Slovic, P. 1987. Perception of Risk. *Science*, 236: 280-285.

Slovic, P., Fischhoff, B. & Lichtenstein, S. 1980. Perceived Risk. In Schwing, R.C.A., W. A. (ed.) *Societal risk assessment: How safe is safe enough?*, New York.

Starr, C. 1969. Social benefit versus technological risk. *Science*, 165: 1232-1238.

The Ministry of the Environment 2000. Reglugerð nr. 505/2000 um hættumat vegna ofanflóða, flokkun og nýtingu hættusvæða og gerð bráðabirgðahættumats. [Regulation on hazard zoning for avalanches, debris flows and rockfall, the usage of hazard zones, and the making of preliminary hazard zoning]. (http://www.vedur.is/snjoflod/enska/haettumat/index.html (02-06-2005))