Challenges in defining acceptable risk levels

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ABSTRACT: Increasing demand for carrying out not only natural hazard assessments but natural risk assessments are obvious. Within risk assessments, the definition of specific risk levels is crucial, and generally dependent on either law requirements or expert judgements.

Ideally, these specific risk levels should represent the risk accepted by the threatened people. This risk is, of course, a difficult task to achieve due to the different perceptions of all involved parties. This strongly influences the decisions for adequate consequences to be established.

Within this paper social and natural scientific/technical approaches to acceptable risk levels to life are highlighted. Examples on treatments of acceptable risk levels in Iceland, Hong Kong and Switzerland are reviewed. Consequently, limitations of the technical approach as well as some general aspects to be considered when defining acceptable risk levels are adressed. How risks can vary depending on different input parameters and formulas is illustrated by presenting results mostly from a case study in Bíldudalur (NW-Iceland). As a concluding perspective, new holistic concepts integrating the strength of social and natural scientific approaches are demanded.

1 INTRODUCTION

The definition of acceptable risk levels is a very complex issue. As Smith (1992) stated "risk means different things to different people because each person holds a unique view of the environment and of environmental risk." Thus, the difficulty is to determine acceptable risk levels which individuals and society may accept.

To tackle this problem both social and natural scientists have spent enormous efforts on developing suitable approaches, resulting in the Technical approach (e.g. Starr 1969, Merz et al. 1995, Geotechnical Engineering Office 1997) including the Mathematical approach (Plattner 2005, within this book), the Psychometric approach (e.g. Slovic 1987), the Dual-process approaches (summarized by Epstein 1994) and the System theoretical approach (e.g. Luhmann 1995). All of them contribute to the question of risk perception, risk acceptance or acceptable risk levels. Unfortunately, the cooperation between social and natural scientists to merge the valuable aspects of both disciplines, to expand the current approaches and to develop new holistic concepts is still missing. Only such holistic concepts will be able to meet the challenge of natural risk management and especially the challenge of acceptable risk (levels) thoroughly. This paper focuses on risks to life rather than economic risks and aims to bring both disciplines closer together.

Mainly due to the difficulties in defining acceptable risk only some countries started a discussion about acceptable risk levels regarding natural risks. Few countries have already implemented such levels. Within technical risks acceptable risk levels are already defined in numerous countries since decades. Countries like Iceland, Hong Kong or Switzerland are following this technical approach to define acceptable risk levels for natural risks. But the question if the technical approach is suitable to encounter the challenges of acceptable risk levels for natural processes still remain. Unfortunately, the integration of social scientific approaches is commonly lacking.

Within this paper, specific aspects of acceptable risk are discussed (mainly from a social scientific perspective). For the countries Iceland, Hong Kong and Switzerland, the respective situation is briefly reviewed, followed by a discussion of topics to be considered in the definition of acceptable risk levels, demonstrating the uncertainties and limitations of the technical approach. Finally, first ideas are presented of how the complex phenomena of acceptable risks could be treated in future.

2 WHAT IS ACCEPTABLE RISK ?

From a natural scientific/technical perspective tolerable and acceptable risk are differentiated. Tolerable risk defines the level of risk society is prepared to live with as long as that risk is monitored and risk management options are taken to reduce it. In contrast, acceptable risk represents the level of risk society is prepared to accept without any specific risk management options (Glade et al. 2005, Lee and Jones 2004, Australian Geomechanics Society 2000, IUGS Working Group on Landslides - Committee on Risk Assessment 1997). However, Lee and Jones (2004) stated that the term acceptable risk is increasingly replaced by tolerable risk.

Following the technical approach specific acceptable risk levels are separately defined for individual risks and collective risks. Regarding individual risks to life acceptable risk levels are determined by comparison with other risks and/or comparison with the average mortality rate. When compared to the mortality rate risks are assumed to be acceptable if they do not rise the mortality rate significantly (for details refer to e.g. Merz et al. 1995). Acceptable collective risks to life are treated either by using so-called F-N Curves or by the concept of marginal costs. F-N Curves show the frequency-magnitude relationships of adverse consequences (referring commonly to the number of deaths and the cumulative frequency of incidents F with N or more deaths). Usually, these diagrams are divided in an unacceptable region, an acceptable region and an ‘ALARP’ region, in which the risks should be reduced As Low As Reasonable Practicable (Lee and Jones 2004). Merz et al. (1995) critically annotate that a theoretical basis for the determination of the thresholds for acceptable collective risk levels is still missing. Therefore, they prefer the concept of marginal costs as part of risk-benefit or risk-cost-benefit analysis. Assuming that risks can always be reduced by further risk reduction measures, the first question is whether the measures are cost-effective. The second question is how much money society is willing to pay to reduce the risks. Limitations of the concept are a lacking recognition of an overview on protection deficits for larger areas. Furthermore, it can only be applied if the costs and effectiveness of respective risk reduction measures are known (Hess, personal communication).

The main advantage of the technical approach is that it enables administrations and authorities to carry out risk management options based on risk analyses and the defined acceptable risk levels. However, the IUGS (1997) critically stated that “society shows a wide range of tolerance of risk, and the risk criteria are only a mathematical expression of the assessment of general opinion.” Thus, the main drawback is, that the perception and the acceptance of the threatened people is not taken into account. Furthermore, it is to question whether the acceptable risk levels defined by the technical approach really reflect the general opinion of society. These aspects are studied by social scientists. In the following the social scientific perspective on risk acceptance is briefly presented.

First of all it must be emphasized that ONE acceptable risk level does not exist. It rather depends on the questions: Who is accepting what, in which way, and when? Therefore, it is useful to differentiate between several terms of acceptance. It is suggested to distinct between five terms:

1. Individual acceptance: The acceptance of a specific person, investigated by non-aggregated quantitative or qualitative methods
2. Aggregated-individual acceptance: The mean value of multiple individual acceptances

3. System-internal acceptance: The communicated acceptance of a specific social system (e.g. stakeholders, scientists or relevant people)
4. Societal acceptance: The acceptance of a society as a whole
5. Expert acceptance: Experts define what an individual and society is willing to accept

All mentioned terms of acceptance are not time-independent, they are rather constantly in flux. That is the reason why the suggestion of Starr (1969) is not followed, who hypothesized that acceptable risk levels would be those which have been accepted in the past. In this paper acceptable risk will be understood as acceptable risk at a specific time. The following remarks will detail the five terms of acceptance and put them in a common perspective.

Social scientific acceptance research often starts with the individual, mostly in the form of quantitative surveys, which are individually able to describe individual attitudes. Within psychological research individual data are frequently aggregated. Once aggregated, it is not possible to reverse this step, i.e. to downscale findings with the aim to explain individual behaviour. As Slaby and Urban annotated this would be an *ecological inference* (Slaby and Urban 2002; refer also to Robinson 1950). Therefore, it is also not possible to deduce individual acceptance from aggregated-individual acceptance. Individual acceptance and aggregated-individual acceptance will only be the same, if the individual acceptance coincidentally suits the mean value.

In difference to the "psychological" terms of acceptance described above, system-internal acceptance and societal acceptance exists only in the communication and is consequently no longer personal. Herein systems refer to social systems. They are composed of communication and follow their own self-organised rules. Communication is in a sense independent from personal opinion, it follows primarily the logic of a social system. For instance, the societal acceptance of a specific risk is not empirically surveyed but is the perceived dominant communication pattern. Thus, societal acceptance can be determined by analysing how media report about it and how it is communicated. Hence, aggregated-individual acceptance and societal acceptance are not the same. The phenomenon of emergence must be taken into account which means that the whole is more than the sum of its components. Investigating a social system new features will appear which are not part of the individual dimension. Therefore, it is not possible to derive the social acceptance from the individual acceptance, particularly because of the wide range of individual results.

While the first four terms of acceptance above are empirically ascertainable, the last one is normatively set. Wiedemann wrote in this context about *acceptance* and *acceptability* (Wiedemann 1993). The former refers to societal attitudes to a specific technology, whereas acceptability means the expected social compatibility of a technology from the perspective of experts. This distinction easily leads to the antagonism between *lays* and *experts*, which is not effective in the context of acceptance. We follow in this paper the suggestion of Ruhrmann and Kohring (1996) to replace *lays* and *experts* by *decision-makers* and *from decision affected people*. Thus, decisions play a more important role. Acceptance and acceptability can be understood as the compliance with a decision. In this spirit the acceptance of natural risks does not exist. It is always the acceptance of a political decision, which is made (or not made) in relation to natural risks. Or as Vatn mentioned "risk is never acceptable unconditionally. It is only *actions* that are acceptable..." (Vatn 1998).

Above remarks pick out the context of risk acceptance as a central theme. But one question still remain: How can "acceptance" be comprehended? Lucke (1995) stated that efforts in defining acceptance are conditionally resolving and last in theoretical and empirical respect incapable. Thus, an expedient definition for our approach has to be given. A distinction between *active acceptance* and *passive acceptance* is suggested. Active acceptance means that affected people are able to influence the decision, whereas passive acceptance exclude the possibility to participate in decision-making. Passive acceptance is similar to the term *tolerance*, which is according to Lucke (1995) weaker than acceptance in the term of connivance. Acceptance in general means that someone (a single person, the majority of a number of people, the majority of communication in a social system or the majority of communication in a society) think about a decision as a good or at least a reasonable decision.

In natural risk research acceptable risk levels are mainly expert-defined and on this note risk researchers talk primarily about acceptability and not about acceptance. The relating problems of defining acceptable risk levels to life within the experts-system are discussed further below on the basis of different examples.

3 EXAMPLES FROM DIFFERENT COUNTRIES

3.1 *Iceland*

Following two catastrophic snow avalanche events in 1995 the hazard and risk assessment procedures were completely revised and finally, acceptable risk levels for snow avalanches and landslides were defined and implemented in national law (The Ministry of the Environment 2000).

The risk levels refer to individual risk to life per year. They were defined by comparing snow avalanche and landslide risk with other risks, e.g. the risk to die in a traffic accident. As natural risks are supposed to be involuntary risks, risk aversion factors were added, reducing the acceptable risk levels for snow avalanches and landslides. The following three risk classes were established: 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 ambitious aim of the regulation is to prevent people from living in Zone C until 2010. Consequently, if final risk maps delineate people living in Zone C, countermeasures must be taken. These are mostly either to build dams or to resettle people and their houses. A third preventive option is to use risk zones in land use planning.

Whereas detailed guidelines exist to carry out risk analyses for snow avalanches (Jónasson et al. 1999), for landslides such detailed guidelines are missing. Only an advisory guideline to integrate landslide risks is available (Jóhannesson and Ágústsson 2002, summarised in Ágústsson et al. 2003).

3.2 *Hong Kong*

In Hong Kong interim risk guidelines for landslides (from natural terrain) were proposed in 1997 by the Geotechnical Engineering Office (GEO Report No.75). Again, acceptable risk levels were defined by comparison with other risk criteria (e.g. risk resulting from major hazardous installations, railways or large dams). The proposed criteria for individual risk (per year) for new developments is <10^{-5}/ year and for existing developments <10^{-4}/ year. In addition, acceptable risk criteria for societal (or collective) risk (per year) was proposed depending on the frequency of an event and the related number of fatalities. If the frequency is low enough (~10^{-7}/ year and less), a maximum of 5000 fatalities in a single event is supposed to be tolerated – but only for certain types of developments (Geotechnical Engineering Office 1997). A detailed overview on the slope safety policy in Hong Kong is given by Malone (2005).

3.3 *Switzerland*

Currently the PLANAT (National Platform for Natural Hazards), an extra-parliamentary Swiss commission, proposed the following acceptable risk criteria. The different categories refer to the voluntary natureof risk (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: $3x10^{-5}$ – $4x10^{-6}$. These risk levels are at the stage of discussion and are not implemented yet. Beside the risk levels of individual risk a collective risk is proposed using the concept of marginal costs, referring to how much money society is willing to pay to safe the life of a single person (see Ammann 2005, within this book, for more details).

In addition to this approach, Borter (1999) published a guideline to carry out risk analyses for gravitational processes. Within this guideline risk values are calculated as individual or object risk to life per year and economic risk per year for each single object using risk matrices. Creating final risk maps risk values are standardized and refer either to individual risk to life per 100m² and year, or economic risk per 100m² and year. Using these guidelines, first applications were carried out e.g. in the cantons (states) of St. Gallen, Glarus, and Obwalden (Kienholz, Hess, Rageth, Bart personal communication).

4 WHAT TO CONSIDER WHEN DEFINING ACCEPATBLE RISKS?

Up to now only technical approaches are applied to define acceptable risk levels within various national strategies as was discussed in the previous chapter. In the following, limitations of the technical approach are shown and some general aspects are discussed which should be considered when defining acceptable risk levels. As most of the examples given below refer to a case study in Bíldudalur, NW-Iceland, some information on the study area and on the applied methodology is given first.

The study area Bíldudalur is located in the Westfjords (NW-Iceland). It is a typical Fjord landscape with a flat valley bottom and steep slopes. The lithology consists mainly of layered basaltic rocks with very gentle dips only. The village is threatened by snow avalanches, debris flows and rock falls. For details on the study area refer to Bell and Glade (2004a, 2004b). Risks are calculated as individual risks and object risks to people in buildings. Regarding individual risk to life, only a single person is considered in each house. Within object risk to life, all people living or working in a house are considered. In Hong Kong acceptable risks for societal risks were proposed. Such a societal risk can be easily derived from the object risk to life by summarising the values for a given event with a specific spatial extent. Various risks are calculated using the following formulas (based on Borter 1999; Fell 1994; Morgan, 1992):

a) Individual risk to people in buildings:

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

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:

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

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

4.1 *Risks and different process models*

Using different process models the runout-zones may vary distinctively, resulting in different hazard and consequent risk maps. In an extreme case, one model might calculate that people on the left side of a debris cone are threatened. Results applying another model delineate the other side of the cone as potentially dangerous. But even in less extreme cases risk might vary heavily (refer also to Bell et al. 2005).

4.2 *Risks and various natural processes*

Discussing acceptable risk levels for natural risks all natural processes threatening the people in the study area should be considered in risk analyses. In Bíldudalur the highest risks to people are posed by debris flows, followed by snow avalanches and finally rock falls (Bell and Glade 2004a). Considering different processes the question is whether it is sufficient to operate with just single acceptable risk criteria for all processes. The rock fall risks in Bíldudalur are only so small due to the very low probability of spatial impact. Nevertheless, one man almost died as a rock fell into his house and stopped on his bed while he was luckily staying in his kitchen. Other rocks are reported which moved down the slope all the way to the sea, illustrating that the energy is sufficient to threaten people. Looking only at the rock fall risks and comparing them to the acceptable risk classes chosen in Iceland reveals that no countermeasures must be taken. It seems that there are limitations in the method when dealing with processes of totally different characteristics, which might be countered by an adaptation of acceptable risk levels towards process specific acceptable risk levels. Implied is the question which risk formulas are best suited to analyze these risks, which will be addressed in the following.

4.3 *Risks and various risk formula*

Final risk values are highly dependent on the number of input parameters represented in the risk formula. The basic formula is: R(isk) = H(azard) x E(lements at risk/Damage potential). Previously, more detailed models are described. Table 1 clearly shows how risk may vary within specific processes if different risk formulas are applied. The question is which formula should be applied if final risk values will be compared to acceptable risk levels. Is the formula with the most parameters really the best? Or, should, for example, the probability of seasonal occurrence be dismissed, since it may decrease the final risks further by 50% (snow avalanche risk), so changing possible unacceptable risks into acceptable ones. Problems of applying the probability of spatial impact (P_s) were briefly mentioned above.

Table 1. Changing risk due to various risk formulas (object risk to life in Bíldudalur). Note: Letters in brackets refer to the official Icelandic zones for individual risk: high risk (C): >=3 x 10^{-4}/ year; medium risk (B): 1 – <3 x 10^{-4}/ year, low risk (A): 0.3 – <1 x 10^{-4}/ year. In addition, very low risk: < 0.3 x 10^{-4} / year. Although risk classes for individual risk are chosen, the calculations demonstrate how risk varies. Similar variations are expected for individual risks. Area per risk class refers to the distribution of the calculated classes within the given study area (see Figure 1).

risk formula	prob. of loss of life (R_{pe}/m² and year)		area per risk class (%)			
	min	max	very low	low (A)	medium (B)	high (C)
debris flow						
$H \times E_{pe} \times V_{pe} \times V_p$	0.000005000	0.0044940	6.19	13.40	28.87	51.55
$H \times E_{pe} \times V_{pe} \times V_p \times P_s$	0.000001500	0.0007918	23.20	44.33	28.35	4.12
$H \times E_{pe} \times V_{pe} \times V_p \times P_s \times P_t$	0.000000630	0.0003642	28.42	51.05	18.95	1.58
$H \times E_{pe} \times V_{pe} \times V_p \times P_s \times P_t \times P_{so}$	0.000000630	0.0003642	28.42	51.05	18.95	1.58
rock fall						
$H \times E_{pe} \times V_{pe} \times V_p$	0.000007500	0.0008624	15.60	46.10	34.04	4.26
$H \times E_{pe} \times V_{pe} \times V_p \times P_s$	0.000000150	0.0000130	100.00	0.00	0.00	0.00
$H \times E_{pe} \times V_{pe} \times V_p \times P_s \times P_t$	0.000000063	0.0000049	100.00	0.00	0.00	0.00
$H \times E_{pe} \times V_{pe} \times V_p \times P_s \times P_t \times P_{so}$	0.000000063	0.0000049	100.00	0.00	0.00	0.00
snow avalanche						
$H \times E_{pe} \times V_{pe} \times V_p$	0.000001000	0.0013060	44.51	13.87	23.70	17.92
$H \times E_{pe} \times V_{pe} \times V_p \times P_s$	0.000000300	0.0005190	56.07	22.54	19.65	1.73
$H \times E_{pe} \times V_{pe} \times V_p \times P_s \times P_t$	0.000000130	0.0003890	63.53	21.18	13.53	1.76
$H \times E_{pe} \times V_{pe} \times V_p \times P_s \times P_t \times P_{so}$	0.000000060	0.0001950	70.59	27.65	1.76	0.00

4.4 *Risks and different reference units*

As previous examples show, acceptable risk levels are defined in risk per year. To enable comparisons between different objects for which risk is calculated, the risk values need to be standardized, since different objects are likely to be of different sizes. Thus, risks might be calculated as e.g. risk per year and 100m² or risk per year and m². As table 2 demonstrates, there can be large differences between the final risk values depending on the reference unit chosen. The demand for standardization is supported by Borter (1999), who stated that agreement on a specific standardization of the risks is a prerequisite if decisions on acceptable risk levels are to be taken.

4.5 *Risks and different data resolution*

Input data with high resolution is essential to calculate the risk reliably, especially at local scale. However, sometimes such good data is not available and coarser data must be used.

In Bíldudalur, a raster based approach was used to model risks. Modeling was done at 1m resolution but final risk results needed to be upscaled, as not all parameters were available in such a high resolution. The question was which resolution to choose (10m, 20m,…,100m). Upscaling the results it was found that when lowering the resolution the number of pixels with high risk values decreased until at the lowest resolution of 100m all high risk pixels were lost (see also Bell et al. 2005). Therefore, when using raster based approaches within risk analysis, decisions on suitable data resolution should be made.

Table 2. Changing risk due to different reference units (individual risk to life per year (R_{ipe}) in Bíldudalur). Note: Letters in brackets refer to the official Icelandic risk zones: high risk (C): >=3 x 10^{-4}/ year; medium risk (B): 1 – <3 x 10^{-4}/ year, low risk (A): 0.3 – <1 x 10^{-4}/ year. In addition, very low risk: < 0.3 x 10^{-4} / year. Area per risk class refers to the distribution of the calculated classes within the given study area (see Figure 1).

reference unit	prob. of loss of life		area per risk class (%)			
	min	max	very low	low (A)	medium (B)	high (C)
debris flow						
R_{ipe}	0.000570000	0.0027750	0.00	0.00	0.00	100.00
R_{ipe}/m²	0.000000277	0.0000910	86.84	13.15	0.00	0.00
R_{ipe}/100m²	0.000027660	0.0091086	3.16	3.16	4.74	88.95
rock fall						
R_{ipe}	0.000010500	0.0000555	7.80	92.20	0.00	0.00
R_{ipe}/m²	0.000000059	0.0000010	100.00	0.00	0.00	0.00
R_{ipe}/100m²	0.000005898	0.0001002	39.01	59.57	1.42	0.00
snow avalanche						
R_{ipe}	0.000056531	0.0015943	0.00	33.53	26.47	40.00
R_{ipe}/m²	0.000000028	0.0000288	100.00	0.00	0.00	0.00
R_{ipe}/100m²	0.000002780	0.0028772	27.06	22.94	10.00	40.00

4.6 *Risks and single or multi hazards*

While defining acceptable risk levels, it should be decided whether these values refer to all natural hazards or only to single hazards. Using the Icelandic example, the question is whether the value of <0.3x10^{-4} is the maximum risk accepted for snow avalanches and landslides together. Or, is the maximum risk accepted for snow avalanches <0.3x10^{-4} and equally for landslides <0.3x10^{-4}. Consequently, the overall maximum risk would be twice the defined acceptable risk level. To further complicate matters, landslides could be split up into debris flows and rock falls (or even further landslide types). Then, the maximum risk level would be applicable to each of the three processes, resulting in a maximum natural risk which would be three times the defined level. And how to handle study areas in which much more natural processes (floods, earthquakes, etc.) are threatening the people and their goods?

4.7 *Individual or object risk to life?*

Especially the risk strategy in Iceland defines the acceptable risks for individual risk to life. However, calculating only individual risks, collective risks may be neglected. For example, dams are built to reduce the individual risk to life. Once the dam is built, it might be allowed to increase the population behind the dam, because the individual risk is lower after the geotechnical construction than the acceptable risk levels. Thus, the object risks and collective risks are increasing although the individual risks remain decreased. If an event larger than the design-event the dam was built for occurs, the consequences might be exponentially larger than without building such a dam. Figure 1 shows the significant differences between individual and object risk to life (see also Bell et al. 2005), which might even increase following the scenario stated above. To enable visual comparisons between individual and object risk to life the same risk classes were chosen.

4.8 *Risks, risk acceptance and spatio-temporal changes*

The implemented or proposed acceptable risk levels mentioned above are all defined at a national scale ignoring regional or local differences in the acceptance of natural risks. However, involved parties in one region might accept higher risks than in another region. Furthermore, the perception of risk and thus the acceptance of risk may change over time due to education of people, or loss of memory with elapsing time after a large event. These variations can only be determined using social scientific methods. In addition, the natural risk itself may change over time (Fuchs et al. 2004; Hufschmidt et al. 2005; Keiler et al. 2004).

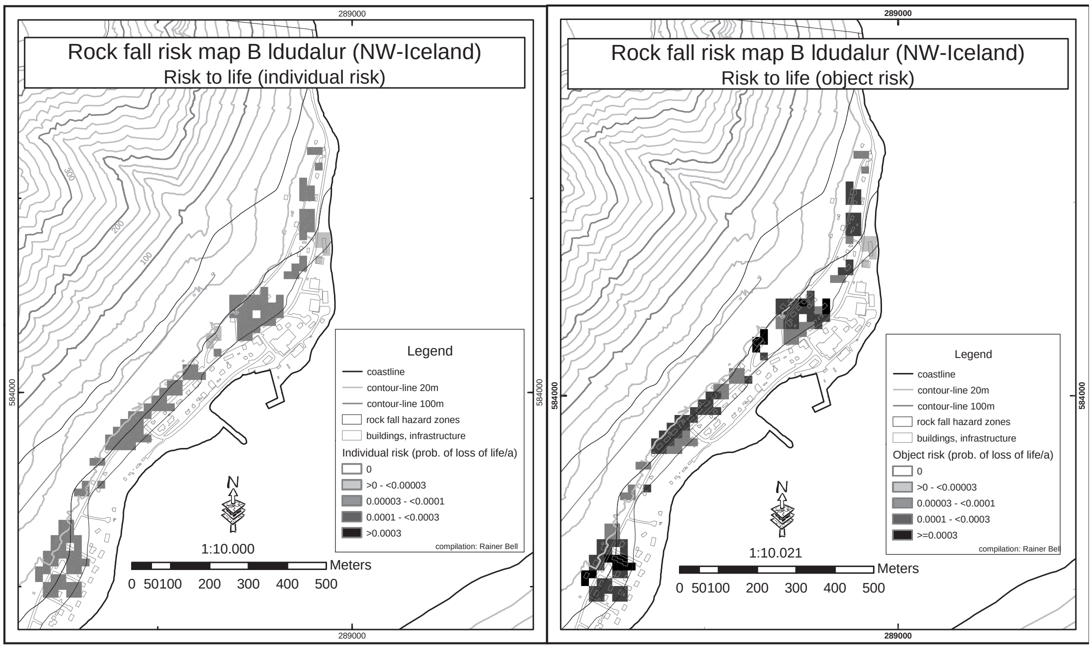

Figure 1: Differences between individual and object risk to life.

5 CONCLUSION

The aim of this paper is to highlight social and natural scientific approaches to acceptable risk, although not all aspects could be discussed in detail within the scope of this paper. Both disciplines provide considerable contributions to the subject of risk to life. The benefits of the natural scientific/technical approach are the development of suitable tools to calculate risks and to "roughly" evaluate them. Additionally, the methods of cost-benefit analysis are valuable tools if decisions for appropriate risk reduction measures are to be taken.

However, the technical approach ignores the perception and acceptance of risks of the threatened people, which are subject of the social scientific approaches. Furthermore, the system theoretical approach delivers insight into the social systems and how these systems operate within the specific social system as well as between different social systems, which is of major importance when sound risk management solutions are to be found.

Up to now only the technical approach is recognized in national strategies for natural risk management. Within this study, limitations and uncertainties within the technical approach were demonstrated. Due to the large differences between different risk analysis methods, the question arises, if specific methods (process models, risk formulas, etc.) should be implemented along with the acceptable risk levels. And, if yes, to what degree should the methods be implemented.

As discussed above, 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 whether defined acceptable risk levels are referring to single or multiple hazards. Finally, due to the variation of risks and the acceptance of risks in space and over time 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 arise. However, as is shown, defining single safety levels (separately for individual and collective risk) for the whole society may not be appropriate. There are (horizontal) differences between various social systems and (vertical) differences between the individual and the sum of individuals. Thus, new concepts might be necessary to tackle this challenge of acceptable risks thoroughly. In our perspective one potential but also ambitious approach is the integration of efforts from natural and social sciences. The discussion of differences between lays and experts is obsolete, it is more desirable to talk about 'decision-makers' and 'from decision affected people'. Attempting to integrate affected people in decisions through participation, the following sentence would become a historical character: "The real difficulty arises when risk analysts expect their conclusions to be accepted simply because they are as objective as possible whilst lay people reject such interpretations simply because they ignore individual concerns and fears" (Smith 1992). Instead of this the sentence could be: "Risk analysts provide a scientific basis for a decision process, which integrates the concerns and fears of affected people in a participating way. As a result several accepted risk levels are developed, which are well adapted for specific times and places. The gap between experts and lays is not a problem anymore but a productive precondition for cooperation."

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