RISK AND AVALANCHE RESCUE

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ABSTRACT: The risk to rescuers is of serious concern for the International Commission for Alpine Rescue (ICAR). For good reason, since ICAR receives annually reports of fellow rescuers injured or killed while on missions. In avalanche rescue many call outs occur when the general danger rating is 3 or higher and where conditions are further deteriorating. This means that both the approach and the accident site can be exposed to avalanche danger. Under these circumstances the risk of rescue missions in avalanche terrain can be comparable to settings where explosions, structure collapses, hazardous materials, etc., present a risk to the rescue personnel. This work outlines a decision analysis approach to risk and benefit assessments in avalanche rescue missions. A simulation-optimization model allows for assessing the expected outcomes of rescue missions by considering key variables affecting both rescuers and the buried subject. The large number of input variables, their probability and the interaction between the input variables lead to a level of complexity which is difficult to handle without a well-structured decision making tool.

KEYWORDS: risk assessment, risk management, rescue simulation, rescuer safety, acceptable risk

1. INTRODUCTION

In the past, many avalanche rescuers worldwide have died during organized rescue missions. In some cases the accidents seem to be in the range of residual risk which is simply unavoidable and survival chances of the buried subjects were still great at the time of the accident. In other cases, fellow rescuers unfortunately died in situations where it was hard to justify the residual risk they accepted, both as an individual and as an organization when compared to the very low survival chances of the buried subjects. In some cases rescuers might not have been aware of the risk they took. In other cases the willingness to take risks seemed very unbalanced compared to the residual survival chances of the buried subjects.

The authors feel that the dictum “Risk a life to save a life” should be qualified and the desired outcomes of rescue missions better specified. Every rescue mission includes certain risks. Some risks are inherent to the environment of the accident site, and some of risks are inherent to standard means of transport in mountain rescue. Besides the inherent risks, which are hard to avoid due to lack of alternatives, there are many risks which may be reduced or avoided by alternative procedures, such as lowering uncertainty or postponing the rescue mission. In order to have the necessary awareness level, the contributing risk factors need to be quantified. This includes on the side of those subjects in need of help, survival chances at the time organized rescue is alerted and then the decrease of survival chances over time.

Balancing the collective risk of the rescue mission against the collective survival chances of the buried subjects will lead to a more transparent and objective decision base. If we, “society”, is regarded as a stakeholder, the preferred objective could be stated as an “optimization of the rescue effort, without subjecting the rescuers to an unacceptable risk”. We therefore propose to look at rescue operations using principles from decision theory.

1.1 Ethical and legal issues

Although there is a vast literature on the ethics of emergency medicine, e.g. triage, very little is written about the ethics of rescue services, such as fire fighting and search and rescue (SAR) operations. Decision theory is based on the maximum expected utility (MEU) action axiom and uses a purely utilitarian point of view. Uncertainties are quantified by using probabilities, often derived from statistics. Although this may seem to some as bordering to cynicism, the principle for action embodied by an action axiom (such as MEU) is ethically defensible in many areas of civil society today, i.e. in the health services.

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Many rescue services do state that the safety of the rescue personnel is a main concern and guidelines are often stated something like "Whatever you do, don't increase the magnitude of a disaster by becoming a victim yourself". This can be seen as a variant of the dictums "First, do no harm" (*Primum non nocere*) and "Take care of your own self" (*Cura te ipsum*) in the medical professions. In some rescue organizations, however, having an informed consent from the rescue workers is assumed to be a way for decision makers to avoid responsibility for accepting a high risk mission. Besides the fact that this is not a feasible option to reduce loss of rescue personnel in the long run, the ethical dilemmas arising are analogue to the “trolley problem”*, a classical philosophical dilemma concerning the ethics of sacrificing a life to prevent even bigger losses. It is also recognized that in recreational activities, people are typically willing to accept a much higher risk level than would acceptable in a work setting. This asymmetry means that a rescuer often cannot enter into the same risk domain as the victim, without breaching the organizational regulations.

There is also the possibility of legal action in case of an accident. In rescue situations there are examples of legal action being taken from the victim’s side in case of rescuers refusing a high risk exposure. One is the case where a relative of a B.A.S.E. jumper went to court suing the volunteer alpine rescue group for waiting too long with the rescue effort after a failed parachute jump off a cliff in Norway in 2000 (Bore, 2002). It is also conceivable that civil cases can arise against rescue organizations where rescue workers (especially professionals) are injured or killed.

Even with worker protection laws existing in most countries, we are aware of few quantifications of the acceptable risk levels. Generally, many seem to follow the ALARP principle, i.e. that any risk should be “As Low As Reasonably Practicable”. Although this can be seen as cost/benefit approach, it opens a wide field of legal interpretation.

When it comes to defining the acceptable risk levels for individual rescuers, a possible approach could be to consider the statistics of similar occupational hazards. In addition, society’s aversion for large scale accidents could be taken into account. Of course, a complicating issue is that many rescue services, and especially the voluntary ones, depend on a heroic image to get economic contributions and goodwill from the general public, since the image of professionalism does not always seem to generate the same degree of sympathy. This is however not a topic in this work.

The objectives for taking the proposed approach to quantitative risk analysis and decision making are the following:

a) To help increase the awareness of risks to rescuers using a quick quantitative risk analysis,
b) To optimize the use of the available rescue resources using a risk/benefit assessment,
c) To make the decision making process as objective and transparent as possible.

2. METHODS

A first approach was done in Norway around 2004 following discussions at the ICAR assembly in Poland the same year. Inspired by an Aviation Risk Assessment Chart developed, and kindly provided by the US Coast Guard, an adaptation was tried within the Norwegian Red Cross SAR (NRC-SAR) for avalanche rescue missions.

The chart (figure 1) uses of weighted sums of different risk components, influence of risk management actions, and subsequently, a benefit

Risk Management Calculator - Winter rescue operations
Based of Model by Krister Kristensen, NGI (2007)
Modifications by Dale Atkins, Dec 2007

Step 1	**Assess Risk**	Enter data into outlined cell	
Step 2	**Assess Benefit**	Pick benefit in outlined cell	
Step 3	**Evaluate Risk / Benefit from table**		

Step 1 Assess Risk

PERCEIVED RISK FACTORS	1 to 5, low, moderate, considerable, high, extreme	
Avalanche Danger Rating **HIGH**	16	
	1 to 5, low, moderate, considerable, high, very high	
Plan comprehensive plan based on good intelligence	3	
Environment terrain, weather, visibility, access, safe zones, familiarity	4	
Mission complexity, typicality, intelligence, control	3	
Resources competency, capability, reliability, knowledge, skills, communications	4	
	Perceived Risk Subtotal	**30**
PERCEIVED RISK REDUCTION FACTORS	**0 to 3**, no change, little, some, considerable	
Plan more intelligence, more detailed plan, external help, time exposure	-2	
Environment improved conditions, typicality, alternative access, limited time exposure	-0	
Mission improved control, better intelligence, air support, better communications	-2	
Resources alternative resources, competency, capability, reliability, knowledge, skills, communications	-0	
	Perceived Risk Subtotal	**4**
	PERCEIVED RISK - ADJUSTED - TOTAL	**26**
RESIDUAL RISK REDUCTION FACTORS	**0 to 3**, no change, little, some, considerable	
Experience for this kind of mission	-2	
Precautions personal protection gear, beacon, recco, avalung, airbag, communications, explosive mitigation	-2	
	Residual Risk Subtotal	**4**

OVERALL RISK ASSESSMENT **22**

LOW	MODERATE	CONSIDERABLE	HIGH	VERY HIGH	
=5	6 – 12	13 – 21	22 – 32	=33	**HIGH**

Figure 1. A modified score chart for the risk components in a winter rescue operation, applied for a computer spreadsheet.

*The trolley car dilemma is a thought problem in ethics where an out of control trolley car speeds down a track with five people tied to the track. A flip of a switch will send the car to a different track with only one person tied down. Which choice should one make?

assessment. The definitions of risk and benefit levels are given in an explanation of the chart.

Finally a risk/benefit matrix with suggested actions can be used (figure 2). As with the US Coast Guard version, the avalanche rescue adaptation is intended as a tool for making quick, tactical decisions at the field commander level (Kristensen, 2004, 2007).

Risk \ Benefit	***High***	***Medium***	***Low***
Low	**Acceptable,** common risk reduction measures. Continuously monitoring of risk factors	**Acceptable,** common risk reduction measures. Continuously monitoring of risk factors	**Acceptable,** common risk reduction measures. Continuously monitoring of risk factor
Moderate	**Acceptable,** common risk reduction measures. Continuously monitoring of risk factors	**Acceptable** with all available consequence reduction measures. Continuous monitoring and rescue preparedness. Limit exposure in time	Not acceptable at present. Wait until risk factors change.
Considerable	**Acceptable** with all available consequence reduction measures. Continuous monitoring and rescue preparedness. Limit exposure in time.	Not acceptable at present. Wait until risk factors change.	**Not acceptable**
High	Not acceptable at present. Wait until risk factors change.	**Not acceptable**	
Very high	**Not acceptable**		

Figure 2. The risk/benefit matrix tried by the NRC-SAR. The mission risks and benefits are given by the score chart.

2.1 Simulation/optimization approach

The risk matrix approach has some inherent weaknesses (see discussion in section 3.1). A step further is to use simulation techniques for optimizing decisions under uncertainty. This is done by using simulation and statistical data in a numerical model that allows assessing the expected utility and risk/benefit ratio by considering key variables affecting both rescuers and the buried subject(s). The large number of input variables, their probability and the interaction between the input variables lead to a level of complexity which is handled by this decision support tool.

The complexity of this problem reaches a level where an algebraic approach may not satisfy the requirements. Therefore a simulation based approach has been chosen, which allows incorporating a vast amount of variables from different fields of influence with various dependencies between the input variables.

The aim of the numerical simulation is to quantify and balance the collective survival chances of the population of buried subjects and the collective risk for the rescue operation (human loss only).

For each variable and event, likelihood and quantified influence to victim's survival chances and / or rescuer's risks are defined. Only variables which may be determined with an acceptable certainty are taken into account.

The survival chances of the buried subjects are mainly influenced by factors from two fields:

a) Survival chances within the debris.
Characteristics of the buried subject, burial location, and mechanical stress to the buried subject during the motion phase of the avalanche.*
b) Burial duration.
Detectability of the buried subject, burial depth, size of debris, number of buried subjects, availability, rescuer's competence level, and accident site access parameters.

The collective risk for the rescue crews is mainly influenced by:

a) Rescuer's related internal risks.
Competence level, physical fitness, active and passive personal protection measures.
b) Rescuer's related external risks
Duration and type of exposure to natural hazards, risks related to technical means of transport, risks related to uncertainty due to limited ability to evaluate terrain, weather, snow pack and other hazards.

The operational application of the simulation is an ongoing effort. For this, the simulation should provide a user-friendly user interface. Data entry in dynamic forms ensures that there is no valuable time lost in cases where key variables indicate that the victim's survival chances are high. The lower the survival chances and the smaller the decrease gradient of the survival chances, the more details need to be entered. Since the acceptable risk is low in such cases, the uncertainty should be rigorously reduced.

The current concept of the simulation only shows the operator the collective survival chances and the collective risk of entered parameters. However, the concept could in a later state be expanded to a simulation which shows to the operator a proposal of the three simulated approaches with the highest scores for the risk / benefit comparison.

* Survival chances of a buried subject are based on the Brugger/Falk (1994) survival curve and supplementary correction factors. New technologies like remote vital sign detection may reduce the uncertainty concerning survival chances.

3. DISCUSSION

3.1 Problems with risk matrices

As previously mentioned there are problematic mathematical properties of risk matrices. For instance they can assign identical ratings to quantitatively very different risks. Inputs to risk matrices require subjective interpretation, and different users may obtain different scores for the same quantitative risks. The limitations suggest that risk matrices should be used with caution, and only with careful explanations of embedded judgments. For instance it will often be necessary to state that a maximum score on one particular factor overrides all the others, or just stating that the method is not applicable in extreme situations. Another statement that often would be included is that when there is a very high uncertainty about one risk component, this should automatically receive a maximum value.

The simulation approach is promising as it eliminates some of the shortcomings of the matrix and is a better way of optimizing decisions under uncertainty.

3.2 Upper bound risk level for rescuers

As it happens, the statistics of accident rates for alpine and avalanche rescuers are greatly lacking. For general rescue work, some numbers are available, mainly from the USA. Death rates amongst US emergency personnel stand at 12.7/100000, police at 14.4/100000, and fire fighters at 16.5/100000 workers (Maguire, et al., 2002). Case fatality rates for alpine rescue are not available and this is something we would like to propose as a task for further investigations.

Although the concept of "acceptable risk" is not well-defined outside the context of cost/benefit assessments, there seems to be good reason to set an upper bound. Werner Munter (2003) asserts that a case fatality rate of 1/100000 is within an acceptable domain for mountain ski touring and guiding. This is among other things justified by the societal acceptance of road transport which has a similar case fatality rate.

4. CONCLUSION

Starting from the “romantic heroism”, which is to some degree probably still present in rescue organizations, it has been a long way towards quantitative risk analysis and decision making that is transparent and ethically defensible, especially when used in hindsight. A risk/benefit matrix is a first step towards this and the simulation/optimization approach holds promise.

Although a simulation is never perfect, it has the capability to filter out many of the most tragic situations that lead to severe injury or death of fellow rescuers in the past. Furthermore, the tool has a major effect on the awareness of rescuers and rescue leaders towards recognizing an acceptable risk / benefit balance and its contributing factors.

The authors hope to contribute to the reduction of severe accidents in avalanche rescue missions and hope to be able to further develop the strategies and tools in the future.

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6. REFERENCES

Bore, B.K. 2002, Redningsmannskaper anmeldt, article in Norwegian newspaper Dagbladet, 30.07.2002

Falk M, Brugger H, Kastner L. 1994. Avalanche survival chances. Nature 368:21 (1994)

Kristensen, K. 2004, 2007. Risk a Life to Save a Life? ICAR 2004, 2007 Avalanche Commission presentation (unpublished, web version available on Canadian Avalanche Association / Knowledge Centre / Research and Articles)

Maguire BJ, Hunting KL, Smith GS, et al. 2002. Occupational fatalities in emergency medical services: a hidden crisis. Ann Emerg Med 2002; 40:625–32.

Munter, W. 2003. 3x3 Lawinen, Risikomanagement im Wintersport, Verlag Pohl & Schellhammer

US Coast Guard, (undated) U.S.C.G. Aviation Risk Assessment http://www.uscg.mil/SAFETY/pdf_files/AviaitonRiskManag.pdf