ANALYSIS OF DECISION-MAKING FRAMEWORKS FOR AVALANCHE TERRAIN

Markus Landrø[1,2], Gerit Pfuhl[1]

[1] *UiT The Arctic University of Norway, Tromsø, Norway*
[2] *Norwegian Water Resources and Energy Directorate, Oslo, Norway*

ABSTRACT: To assist decision-making in avalanche terrain, several decision-making frameworks have been developed. These frameworks can have a more probabilistic approach, or are more knowledge based. All frameworks consist of different building blocks we call factors. However, the necessity and applicability of these factors can be disputed. In an online survey we asked experts (N = 100) about their knowledge and use of existing frameworks, including use and importance of the different factors. This work is part of a larger project regarding avalanche decision-making. Here, we focus on the discrepancy between knowledge and use of the frameworks, and illustrate the use and importance of the factor danger level.

KEYWORDS: Danger level, avalanche forecast, strategies, intuitive judgements, expert opinion

1. INTRODUCTION

When traveling in avalanche terrain, correctly assessing avalanche danger and consequently making the correct decision is crucial. Several different avalanche decision-making frameworks exist. These range from very well described approaches, to less formal and available strategies.

In these frameworks the decisions are typically based on an assessment of four types of factors: (1) physical factors, such as slope steepness or shape; (2) regional danger rating provided by the avalanche forecast; (3) signs of instability (alarm-signs) assessed in the field, for example shooting cracks, whoop sounds from the snow, and (4) group size affecting decision making.

Several countries have national umbrella organizations, such as the Swiss Core training team of snow sports avalanche accident prevention (KAT) or the Canadian Avalanche Association (CAA) who evaluate, recommend and in some cases develop decision-making frameworks. Others that are indicative of which methods being taught are mountain guide associations, alpine clubs and educational institutions.

Here, we included the most commonly used approaches in Europe and North America. These frameworks are well described in books or articles. Therefore, we will not give any description or do any comparison of the frameworks.

The ten decision-making frameworks in our study are: 3x3 (W. Munter, 1997), The Reduction Method (W. Munter, 2009), The After Ski Method (Brattlien, 2014), Snow-card (Engler, 2001), Stop or Go (Larcher, 1999), NivoTest (Bolognesi, 2000), The Avaluator 2.0 (Haegeli, 2010), The Graphic Reduction Method (Harvey, 2012), ALPTRUTh (I. McCammon, 2006) and The Systematic snow-cover diagnosis (G. Kronthaler, Mitterer, C., Zenke, B., Lehning, M., 2013).

The purpose of the study was to examine the knowledge and use of the existing decision-making frameworks and their factors among experts. Here, we present our first results.

2. METHODS AND DATA COLLECTION

For each of the ten different frameworks we mapped every factor included, resulting in 54 different factors. Many factors are shared by several frameworks, but there are differences in type, importance and number of factors included.

The factors can be thematically grouped into snow and avalanche factors, snowpack evaluation, stability tests, avalanche forecast, group factors, group management and terrain factors. Examples of factors that belong to theme terrain are: *5° intervals from 30°* and *discriminating between avalanche terrain and not avalanche terrain*. Examples of factors that belong to theme group management are: *30 m Safety distance descending* and *One-at-a-time from 35° when descending.*

Some factors have been discussed in peer-reviewed journals, such as Cold Regions Science and Technology and Natural Hazards. However, our main source were conference proceedings from the bi-annual International Snow Science Workshop (www.issw.com) and the German-speaking technical magazine Berg und steigen (www.bergundsteigen.at), providing the latest findings within the field.

* *Corresponding author address:*
Markus. Landrø, Norwegian Water and Energy Resources Directorate, Box 5091 MAJ., 0301 Oslo, Norway.
tel: +47 90201696
email: mala@nve.no

Since we wanted to know if experts are familiar with, and use the existing frameworks and the factors during trip planning, route choice and slope specific decision-making, we asked experts to participate in an online survey.

We aimed at having respondents that, although having different background and approach to avalanche assessment and decision-making, should be very skilled. We only invited persons who were thought to be on the highest level, the expert stage, according to the five-stage phenomenological model of skill acquisition by (Dreyfus & Dreyfus, 2005). In addition to mountain guides, avalanche forecasters and other avalanche experts we were interested in feedback from professional skiers and snowboarders. We reasoned that the groups might have a different approach in avalanche decision making.

Experts associated with different national avalanche forecasting services who are members of the European Avalanche Warning Services (EAWS) where contacted. Mountain guides, ski guides, mountain guide instructors and avalanche educators from Europe and North America where invited to participate. Through personal friendship, we recruited some professional free skiers who then gave us tips on others we could contact. This snowballing method was applied for the other expert groups too. All but the Canadian respondents, who were invited and encouraged by the Association of Canadian Mountain Guides, received a personal invitation to participate.

This method allowed good control of the kind of experts and level of expertise we aimed for, and at the same time allowed anonymous responding, as all users received the same link to the survey, created in Qualtrics (Qualtrics.com).

The survey was available in English, German, and Norwegian. Thereby we could get responses from different expert groups, in several countries, and who differ in their traditions and approach regarding decision-making in avalanche terrain. The survey was not translated to, nor distributed to any French or Italian speaking avalanche expert communities. Primarily this is due to limited translation capacity. Other relevant avalanche communities in e.g. Spain, Slovakia, Russia, Japan, Chile and New Zealand where left out due to limited translation capacity and lack of key persons who could initiate snowballing of the survey in their communities.

To reduce a possible priming effect, we asked the experts about use and importance of all the factors we mapped before asking questions on knowledge and use of existing decision-making frameworks. This way the experts had to reflect on what factors they actually use in their decision-making, each factors importance in different stages of an outing and not just recall the factors used in the frameworks.

3. RESULTS

In the following, we present an excerpt of our findings from the survey, focusing on the part about knowledge and use of existing decision-making frameworks. We also present our findings on one factor that is key in the majority of the frameworks: danger level.

3.1 Demographics

121 respondents started the survey of which 100 respondents finished it.

The participants were equally divided between Scandinavia, the German-speaking part of the Alps and North America. In average, the respondents had 28.5 years of experience in back-country skiing. The majority were men, 10% were women. On average, participants spent 50 days back-country skiing per season. Most participants have significantly more, a few slightly less. The average proportion of skiing days in avalanche terrain per season was 73%. Thus, our targeted recruiting was successful.

3.2 Analytic and implicit knowledge

Decision-making frameworks (DMF) can be divided into knowledge-based and rule-based approaches. All the frameworks in our study have components from both approaches that are intended to be used together in the decision-making process. We also included approach options not related to any existing frameworks, such as intuition and habit. To elicit an expert's general approach all relevant options could be selected in the survey.

89% apply knowledge-based, analytic decision-making where taking detailed observations and carefully weighing of factors is essential. 79% use intuition, described as gut feeling, difficult to explain, based on long-term experience. 32% perform risk calculations, i.e. likelihood of avalanches and potential consequences. 39% decide context / situation-dependent - if familiar situation use rule of thumb, if unfamiliar use analytic methods. 16% use rule-based decision-making. 4% stated habit and 1% deferred to more experienced / higher-up decision-making. Free-text field responses (3 users) did not introduce any new approach.

3.3 Familiarity with and use of existing frameworks

We asked the experts with which of the existing frameworks they are familiar. Multiple answering was possible. The overarching way of structuring the decision process into different stages, the 3X3 by Munter, was known by 68%. This method is an integrated part of the Reduction Method (RM), which was known by 68%, and is taught in combination with several other methods. The Canadian Avaluator 2.0 (A2.0) is a well-known framework amongst 61% of

the recruited experts. For the other frameworks originating from the German-speaking parts of the Alps the numbers are: Graphic Reduction method (GRM): 35%, Snow-card (SC): 42%; Stop or Go (SoG): 43%, Systematic Snow-Cover Diagnosis (SSD): 44%. The after ski method (ASM): 24%, NivoTest (NT) and AlpTruth (AT) were known by 27%. This lower percentage can be explained by the relative limited use outside their countries of origin (Norway, Switzerland and Canada). 16% list other methods and approaches not included in this study. Only one expert said that he did not know any of the frameworks.

Table 1 shows the discrepancy between knowing and using the frameworks. Notably, the SSD is used by 77% of the 44 that know this framework. When asked about the context of using the frameworks the SSD stands out, both when underway in private and in job related contexts. The numbers from the use / context answers from the other frameworks are too small to draw any conclusions. However, our findings indicate that those who use a framework use them in most settings and slightly more when giving avalanche courses.

Table 1: knowing and using of the DMF in absolute numbers (out of 100 respondents) and use in relative numbers. Multiple answers possible

Frame-works	know	Use / in %
3x3	68	25 / 37%
RM	68	9 / 13%
ASM	24	4 / 17%
SC	42	3 / 7%
SoG	43	5 / 12%
GRM	35	12 / 34%
NT	27	1 / 4%
AT	27	3 / 11%
A2.0	61	10 / 16%
SSD	44	34 / 77%

Many of our participants belong to groups that typically teach avalanche courses (i.e. Mountain guides, ski guides). But very few actually teach any of the included frameworks, with exception of those using the SSD (22 of 34). This limited use is striking, especially when several of these frameworks are targeted at beginners. The majority of these frameworks are mainly rule based, and considered to be well suited for novices. The SSD on the other hand is mainly knowledge-based, and traditionally thought to be less ideal for novices.

3.4 Use of frameworks in different stages of an outing

Even if one does not use the 3x3 by Munter, it is common to divide an outing into different stages. The stages can be seen as a decision-making process that starts with trip planning, continues with route selection and culminates with slope specific decision-making. The idea is that it helps to make thoughtful decisions and gives several possibilities to make changes to our plans given new information, thereby reducing the risk of an avalanche. According to Munter, a combination of his 3x3 and RM is a preconception to achieve the intended level of risk (W. Munter, 2009). 23 respondents confirm that they use the 3x3 when trip planning, but the use decreases in the next stages. Except for the 3x3 and SDD the use of frameworks in different stages is very limited. However, our results indicate that some of those who use A2.0 and GRM use them in trip planning and route selection. In slope specific decision-making the GRM is used by one expert and A2.0 by 4. Unlike the other frameworks the SDD increases in use from 8 in trip planning to 26 in route selection and 29 in slope specific decision-making. This is understandable because the factors included in SDD have to be observed and evaluated in terrain, whereas the other DMF include factors that can be acquired before an outing starts.

3.5 Importance

We asked: In practice, how important/useful are these methods in your slope specific decision-making? The alternatives being decisive, relevant and insignificant. The method “Intuition” received many decisive and relevant answers, i.e. experts rely on intuition, understood as gut feeling, based on long-term experience. The score for SSD is 9 for relevant and 23 for decisive. These results contribute to the impression that the SSD users have confidence in this framework.

3.6 Why or why not use the frameworks?

36% stated *I use a different approach* and 29% *They follow a structure that does not fit the way I make decisions*. Why do experts not use the frameworks? Nearly 1/3 of the experts stated that the DMF limit development and learning (29%) and stop the user from own thinking (18%). Besides mastering skies or snowboard, backcountry travel requires several skills, such as navigation, keeping warm and dry, avalanche danger assessment and decision-making. When 14 of the experts state, they are *Too complicated to use when out in the mountains* and it is *Hard to determine the factors used*, it is questionable if the novices have the surplus or capacity to use them.

More disturbingly, 14 respondents said that they don’t believe in the statistics used in the development, five claim they don’t seem to work, nine that the frameworks combine the wrong factors, and 8 that they are based on the wrong factors. Six of the experts agree with the statement *Too often the method says No, and people ski anyway and nothing happens*. These statements point at limitations the frameworks pose on the user. It may indicate that these experts think the frameworks accuracy is limited or that the safety margin is too large.

Finally, when asked why the decision-making framework they use is important, we found:

- It helps you actively go into a certain mindset.
- It helps to structure the decision process.
- It prevents you from overlooking important information. It underpins intuition and gut feeling.

3.7 *Use and importance of an avalanche forecast and factor danger level.*

When deciding where to go or planning an outing, an avalanche forecast is a useful source of information. Only 2% of the experts never use information from an avalanche forecast. 63% use it always and 35% sometimes. The forecast is primarily used during the planning (50%), less during route selection (30%) and slope specific decision-making (20%).

A forecast consist of several elements. We asked the experts which elements they use in different stages and the importance of these elements (fig.1). Danger level (DL) is traditionally regarded as the most important element in an avalanche forecast. This goes for avalanche warning services worldwide and the recommendations from EAWS (EAWS). Except for the NT and SSD, the DL retrieved from an avalanche forecast, is either a factor on par with other factors (AT and A2.0) or the most prominent factor and starting point in the decision-making process in the frameworks included in this study.

As figure 1 illustrates for experts the forecast elements such as avalanche problem and snowpack information are of greater importance (decisive) to decision-making than DL.

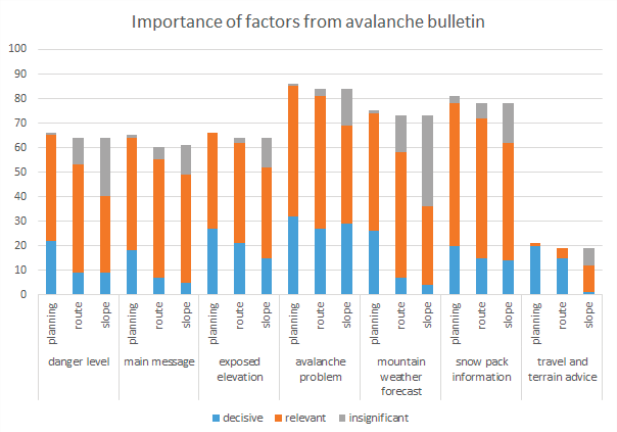

Fig. 1 Importance of elements in an avalanche forecast.

We also see that to many experts the use and importance of the factor DL gradually reduces through the different stages of an outing, with 1/3 stating DL being insignificant for slope-specific decision-making. This can partly be explained by the DL concept itself, how DL is determined and partly by how it is used in some DMFs.

Explanations put forward are:

a. the danger level is not suited for small-area or slope specific descriptions, nor was it developed for that purpose (Nairz, 2010);
b. in reality, danger level changes continuously, not stepwise like in the scale. The steps imply a certain danger level bandwidth;
c. (lack of) uniformity of the forecast (Müller, 2016);
d. uncertainty related to prediction (forecast) and systematic verification procedures regarding DL (J. Schweizer, 2010; Jürg Schweizer, Kronholm, & Wiesinger, 2003; F. Techel, Dürr, L., Schweizer, J., 2016);
e. since we are lacking the total number of people traveling in the backcountry, the use of DL as one key element in risk calculations along with avalanche accident data is problematic (G. Kronthaler, 2001; I. McCammon, Hägeli, P., 2005);
f. accident based risk calculations do not take into account all the cases where an expert has chosen not to enter a specific slope on the basis of his or her avalanche danger assessment. In a calculation, this should have counted as an event,
g. the avalanche problem has no *direct* influence on determining DL (e.g. calculations by (F. Techel, Winkler, K. , 2015) show that the relative risk is 50% higher at the same DL in situations with persistent weak layers than with other avalanche problems).

Thus, a recommendation is less emphasis on DL and more on the avalanche problem and snow pack information also for novices and intermediate backcountry skiers. These findings are corroborated by a recent study of the communication efficacy of avalanche warnings (Engeset), which also included novices and less skilled users.

4. CONCLUSION

The majority of experts apply a knowledge-based approach in their decision-making. Teaching novices should not be done by simplifications and rules alone. Emphasis on the complexity of the avalanche problem should be taught early on, as seen in the adoption of the SSD. Furthermore, future DMFs should allow the user to grow with experience, and not hamper development, preventing the transition between novice and expert.

The danger level is a good indication of the situation one most likely will meet. However, the avalanche forecast is more than DL and the avalanche problem and snow pack information should play a greater role in future DMFs in order to exploit its educational and safety potential.

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