ASSIGNING PROBABILITIES IN LOCAL AVALANCHE FORECASTING

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ABSTRACT: In some local forecasting programs there is a need to predict the probability of an avalanche encounter, i.e. the probability for an avalanche to reach a specific location in a given time period. Quantitative risk assessments require assigning a numerical probability of an event. Interviews of forecasters reveal that a frequentist interpretation of probability dominates in the forecasting group and this seems to be among the reasons for a reluctance to assign numerical probabilities. This also has implications for the evaluation of prediction accuracy and for learning opportunities.

KEYWORDS: Avalanche forecasting, probability assessment

1. INTRODUCTION

Risk analysts and those responsible for risk management often rely on information from outside experts. Prediction of local avalanche danger and encounter probabilities are essential for risk management for many susceptible roads, railways and developed areas.

The Norwegian Geotechnical Institute (NGI) operates several local avalanche forecasting programs where the service is asked to provide a daily danger assessment related to avalanche encounters on specific objects (Jaedicke, 2015). The level of danger is described using The European Danger Scale (EAWS), which is similar to the North American Danger Scale in that it describes qualitatively the danger potential on a five degree scale. These danger scales are originally designed and intended for use by the public service-like forecasting programs that provide a more general assessment of features such as the snow stability and expected avalanche magnitudes in a larger area, typically >100 km^2. These forecasts are often complemented with comments about the most relevant altitudes and aspects, and may also include descriptions of the nature of the current dominant avalanche problem. The assessment of a specific local slope is left to the user.

At the NGI there is an ongoing discussion about how to express and communicate the avalanche encounter probability for a specific endangered object. It can be argued that for local object-specific avalanche forecasting programs, the general danger scales such as the EAWS danger scale are of limited usefulness in decision making since they provide no indication of the actual encounter probability to the specific object in question. This also makes it difficult to use these scales in comprehensive risk analyses (Kristensen et al., 2013). Quantitative risk assessments (QRA) require assigning a numerical probability of an event in the given period of time, normally as a value between 0 and 1, or alternatively stated as a percentage.

A series of interviews with forecasters reveal some of the underlying assumptions that cause problems with assigning numerical probabilities in this type of avalanche forecasting.

2. PROBABILITY AND UNCERTAINTY

The interpretations of what the concept of probability means are many and have been debated at least since the 1700th century (Bernstein,1996).The debate is still ongoing, a fact that may cause confusion about the use of the concept when assessing natural hazards.

I engineering applications, the "frequentist" interpretation, where probability is derived from observed outcomes, and the "subjective", where the degree-of-belief about outcomes is based on all available knowledge, have emerged as the most used perspectives (Vick, 2002). The latter is also called a "knowledge based" (Aven et al., 2004) or "Bayesian" interpretation of probability, referring to the fact that it takes into account all available knowledge as well as updated information as this becomes available.

In the "subjective" degree-of-belief perspective, the probability assessment is seen as reflecting the uncertainty about the outcome (Aven and Reniers, 2013), i.e. the degree of belief of whether the event

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in question will occur or not. This probability is based on the amount and quality of available background knowledge. An uncertainty standard which focuses on the strength of knowledge has been proposed as a reference (Aven and Reniers, 2013).

Tbl. 1: Some different interpretations of probability and their relation to natural hazards (adapted from de Elía et al. 2005)

	Classical	Frequentist	Subjective
Main hypothesis	Principle of indifference	Relative frequency	Degree of belief
Conceptual basis	Hypothetical symmetry	Past data and reference class	Knowledge and intuition
Unique event?	Yes	No	Yes
Precise?	Yes	No	No
Used for natural hazards?	No	Yes	Yes

Table 1 shows the most common interpretations and their relation to assessments of natural hazards. It can be noted that under the frequency interpretation, assigning a probability to a unique event, such as an avalanche occurring at a location where none have been observed before, would make no sense.

3. FORECASTER INTERVIEWS

In November 2015, seven avalanche forecasters were interviewed at the NGI. The forecasters had between two, and at least 20 years of operational forecasting experience.

3.1 Utility of avalanche prediction for users.

All respondents emphasized that the utility for the clients was the local and the site specific aspect of the forecasting programs. The societal benefit is related to both an improved risk management as well as more efficient logistics. The forecasting program may reduce the risk for users and allow for expanded winter operation of vulnerable work places and transport lines. Since the general regional danger warnings are often not locally relevant, these programs aims to provide interpretation and local adjustment.

Even though the benefits related to logistics and risk management were emphasized, one respondent hinted at that a possible motivation for some clients for using an outside forecasting service could be the transfer some of the responsibility for the safety of their operation from their own organization.

3.2 Risk management

Respondents pointed out that different clients have different approaches to risk management. In many cases the forecaster have little knowledge about this, although they can observe how clients respond to alerts. The client's risk aversion or acceptance is often not stated explicitly and the risk assessments are usually not known by the forecaster. Most clients are assumed to have the mandatory safety systems in place, but the forecasting service has normally not been involved from the outset in any risk assessment.

Several respondents pointed out that a troubling aspect of an acute situation is that the forecasters may get involved in a discussion about what mitigation measures should be implemented. Some contingency plans call for increased monitoring of the situation by the forecasting service, including shorter intervals between alerts as a first step. The next steps often appear to be more unclear, but may involve request to the forecasters to give advice about specific measures, such as whether to evacuate a settlement or close a road or railway segment. Although several of the respondents say that increased avalanche danger sometimes trigger existing comprehensive contingency plans, specific measures may be discussed at length depending on how the danger and risk is perceived. This is compounded by diverging interpretations of the qualitative and verbal danger description.

Some of the respondents seem a bit unclear on the extent to which the forecasting service should be involved in consulting regarding risk, while others say they can engage in limited discussions about the comparative effects of possible risk reduction measures, for example whether allowing single vehicles to pass an exposed road segment is preferable to limiting road use to convoys.

One respondent says that the forecasting service can engage in a direct dialogue with the local decision-makers regarding which actions to take. In such cases the forecaster will not directly state that "you must evacuate now!", but tries to formulate a verbal statement along the lines that "it cannot be ruled out that in this situation an avalanche could reach the settlement". The respondent is nevertheless aware that the intent is to convey the same advice.

3.3 Reasoning behind the forecast

There seems to be an agreement that the assessment of avalanche hazards to a large degree is subjective, although more deterministic and frequentist approaches would have been preferable. The problem to be able to use the latter lies in the incompleteness of the data and the models. Experience with operational forecasting and the ability to recognize patterns are seen as important by all respondents. The cues can be diverse and difficult to categorize, but somehow contribute to an assessment of the situation at hand. In general, the use of a numerical probability assignment is not seen as desirable, as this gives an impression of an unrealistic high precision.

One respondent notes that in principle it is possible to create a chain of conditional probabilities, but quantifying beyond broad categories is still difficult. The accuracy in the prediction of important weather parameters is also seen as an source of uncertainty, especially in the case of precipitation forecasts for areas with a coastal climate. Discussions on how to indicate uncertainty in the avalanche forecasts are ongoing, but as one respondent said: "if we are reporting uncertainty, we only get a phone call with questions of clarification".

A lack of near real time feedback, especially about local avalanche activity, is generally seen as a problem.

4. DISCUSSION AND CONCLUSION

The interviews reveal that the frequentist interpretation of probability dominates in the forecasting group and this may be a major obstacle for assigning numerical probabilities of the events that are to be predicted. The main problem with providing a reasonably granular probability estimate is perceived to be hindered by data scarcity regarding snowpack features, representativeness of avalanche dynamic models and poor accuracy in the meteorological forecasts.

As early as in the 1970-ties, LaChapelle (1978) and others suggested the application of Bayesian statistics in avalanche forecasting. The use of a Bayesian approach will demand a prior probability to be set. McClung (2002) argues that base-rate data, based on knowledge about the distribution of outcomes in similar situations in the past, can constitute the prior probability when the forecasting is viewed as a Bayesian process.

Vick (2002) and Lacasse (2004, 2015) have also devised procedures for how plausible probability and reliability estimates can be made in the geotechnical domain using Bayesian approaches. Nearest neighbours and other on non-parametric methods, as well as machine learning have also been explored with some success in snow avalanche prediction (Pozdnoukhov et al. 2011).

The interviews indicate some communication issues which suggests that additional factors may be at play. Given the lack of involvement in the risk assessment before a forecasting program is initiated it is hardly surprising that forecasters sometimes feel uncomfortable in acute situations. Njå et al. (1998) emphasizes the importance that experts are well informed of the risk analysis purpose, starting point, delimitation and problem definition. In addition, Peter Sandman (2004) identifies several bias that affect how experts choose to convey uncertainty (or failing to do this). They include the bias against sounding ignorant when overemphasizing uncertainty, the bias against being too precise and assertive about uncertainty and the bias toward sounding more certain than you are.

Using vague verbiage in place of plausible numerical probability estimates is also a much used technique to avoid accountability, especially in "blame game" cultures (Tetlock et al., 2015). Verbiage expressions of probability is open to subjective interpretation and may function as a hedging strategy. Although this was not explicitly mentioned by the responders, the fear of ending up as a scapegoat is rather common in many societies and organizations. The trial of "the L'Aquila Seven", the well known case of the Italian earth quake researchers that were convicted in the aftermath of a destructive quake in 2009, provides a case in point. A careful study of this case reveals that the use of vague verbiage nevertheless can be seen as the real fault in the communication process (Alexander, 2014)

An important point is the lack of feedback and verification of the forecasts. Verification is obviously very important for meaningful skill tests and for learning. According to Tetlock et al (2015), prediction is a skill that can be cultivated through repeated tests and feedback. Technical developments have improved the possibilities for near real time avalanche observations that seem promising for use both as verification, and as a source of precursory data. For instance Schweizer et al., (2013) and Humstad et al (2016) describe advances using seismic monitoring of avalanche activity which eliminates the need of the visual observations often hampered by darkness and weather conditions. Skill scoring procedures such as the Brier skill score (Brier, 1950) are widely used in skill analyses of meteorological probabilistic forecasts of dichotomous events.

In conclusion, it is difficult to see that there are many objective advantages of using qualitative and vague verbiage assessments in the context of avalanche forecasting for specific objects, over using a quantified probability judgment. The utility for the users doing risk assessments depend on getting quantified probabilities. If numbers are provided it is possible in hindsight to research how the numbers are derived and it is also possible to assess and improve the forecasting skill by using skill score tests. The only remaining reason would seem to be the possibility for forecasters to evade accountability for their predictions. The societal benefit of this is not likely however to outweigh the costs.

The NGI has an ongoing project addressing the use of probability estimates. In the winter of 2015/2016 three qualitative probability classes (Low-Medium-High) regarding encounter danger of the object in question were introduced in some of the operations.

CONFLICT OF INTEREST

The author of this paper is an employee of the Norwegian Geotechnical Institute. The institute provides avalanche forecasting services, but the author is not at present involved in operational forecasting.

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