AVALANCHE HAZARD, DANGER AND RISK – A PRACTICAL EXPLANATION

Grant Statham*
Parks Canada, Banff, Alberta, Canada

ABSTRACT

A complete understanding of the fundamental concepts of avalanche hazard, danger and risk should become basic requirements for anyone undertaking avalanche prediction and risk control. However, existing definitions of hazard and risk (CSA, 1997) offer only limited value to operational practitioners such as avalanche forecasters and mountain guides. This discussion brings a field-based perspective to the underlying risk constructs of probability, consequence and exposure, and places them into a practical context that explains their relevance to everyday forecasting and mountain travel. It is hoped that a more universal understanding of these concepts will lead to an improved focus on risk in avalanche education, operational practices based on risk, and published standards for operational avalanche risk control. By aligning the practice of avalanche forecasting to be consistent with other risk-based disciplines, both professionals and the public will benefit from a clearer explanation and more thorough understanding of the fundamentals contributing to avalanche risk.

KEYWORDS: Risk, hazard, danger, probability, consequence, exposure

1. INTRODUCTION

Decisions for snow avalanches in Canada are risk-based (CAA, 2002). While this is a correct statement for mapping and engineering methods, it is generally incorrect for the operational avalanche risk control systems that are taught today. Intuitively, practitioners are indeed making risk-based decisions, but the systems that support their practice do not always represent a risk-based approach. A risk-based system means that some measure of probability and consequence has been considered in the process. Methods that employ the current avalanche danger scale or snow stability rating system as the overriding framework for decisions are not risk-based.

In 2007, a group of Canadian and American avalanche forecasters and researchers began working together to revise the Avalanche Danger Scale. One of their objectives was to make the system risk-based. Their first task was to clarify the terminology and definitions of avalanche hazard, danger and risk. Risk definitions vary among disciplines and for individual applications, thus any framework for risk must include definitions and any risk definition given will not be universally accepted (McClung, 2005). This is because risk must relate specifically to something of value *at risk*. Generalizations regarding risk are ambiguous, therefore any useful application of a risk definition requires it to be specific for that particular discipline. The following discussion is specific to snow avalanche risk.

* *Corresponding author address:* Grant Statham, Parks Canada, Box 900, Banff, Alberta, Canada, T1L 1K2; Phone: 403 762 1568; E-mail: grant.statham@pc.gc.ca

2. AVALANCHE HAZARD AND DANGER

Avalanche hazard and avalanche danger are synonyms. The term avalanche hazard is used from this point forward, but it's meaning is synonymous with avalanche danger. Avalanche hazard describes a source of potential harm, and is a function of the likelihood of triggering and the destructive size of the avalanche(s). Basically: what is the chance of an avalanche occurring, and how big will it be?

It is essential to understand that avalanche hazard is independent of any element at risk. The hazard can be high while nothing is at risk, which is a common situation. What links and differentiates *hazard* and *risk* is a key third term, *exposure*. To illustrate, a hazard is of no consequence to a person who is not at all exposed to it. Backcountry avalanches, therefore, should not concern anyone who avoids traveling in the backcountry. Avalanche hazards in mountainous terrain are common, but they represent a risk only to people using such locations when a certain depth of snow exists, thus presenting exposure to risk (O'Gorman, 2003).

2.1 Definition of Avalanche Hazard/Danger

Avalanche hazard/danger is the potential for an avalanche(s) to cause damage to something of value. It is a function of the likelihood of triggering and the destructive size of the avalanche(s). It implies the potential to affect people, facilities or things of value, but does not incorporate vulnerability or exposure to avalanches. Avalanche hazard is commonly expressed using relative terms such as high, moderate and low.

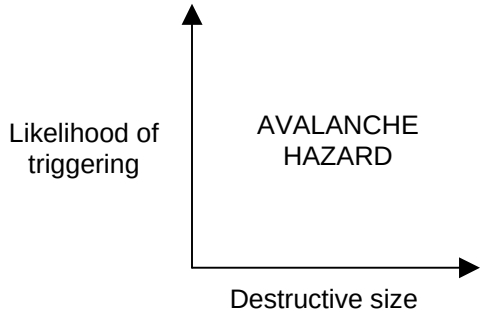

Figure 1: Avalanche hazard is a function of likelihood and size.

2.2 Likelihood of Triggering

This is a measure of the likelihood of avalanche initiation, and is done using both qualitative and quantitative techniques. Qualitative methods employed by practitioners make judgements that are inferred from evidence, and are represented using likelihood statements such as *possible* or *almost certain*. Quantitative techniques used in mapping and zoning measure avalanche frequency using statistical techniques based on either historical records, and/or a subjective investigation of avalanche return period. This kind of analysis combines probability values for both unstable snow conditions, and triggering. The resulting value (0-1) expresses the annual probability of avalanche occurrence.

2.3 Destructive Potential

Destructive potential is most commonly measured in Canada using the Canadian avalanche size classification system (CAA, 2007). This is a subjective measurement resulting in an estimate of avalanche size between 1-5. It is based on a qualitative assessment that imagines objects located in the track of the avalanche, and estimates the harm the avalanche could cause (CAA 2007). Engineering risk analysis sometimes uses a quantitative approach that considers destructive potential by calculating impact forces based on the measured properties of snowpack, terrain, avalanche motion and the element at risk.

3. AVALANCHE RISK

Avalanche risk must relate to a specific element at risk. This could be a person, group of people, forest, vehicles, or infrastructure – anything that is determined to be of value to someone at a specific time. Avalanche risk is determined by the exposure of that element, and its vulnerability to the avalanche hazard. This means that when an exposed element moves, the risk to it changes. This basic explanation is why terrain choice is the principal method of risk control in backcountry travel, when the exposure is dynamic and always changing.

3.1 Definition of Avalanche Risk

Avalanche risk is the probability or chance of harm resulting from interactions between avalanche hazard and a specific element(s) at risk. Avalanche risk is determined by the exposure of that element, and its vulnerability to the avalanche hazard.

Avalanche Hazard	&	Vulnerability & Exposure	=	Avalanche Risk

Figure 2: Avalanche risk is a function of hazard, vulnerability and exposure.

3.2 Vulnerability

Vulnerability is a concept that expresses susceptibility to the impacts of avalanche hazard, and it must relate to a specific element at risk. An old growth tree and a person standing side by side will have very different vulnerabilities to the hazard; therefore, while the hazard may be the same, the risk to each of them will be different. The person may be susceptible to Size 2 avalanches, whereas the tree might be susceptible to only a Size 4 – thus, the person has a higher vulnerability and subsequently higher risk.

This has relevant meaning when considering the use of safety equipment such as transceivers or Avalungs. All other things being equal, those who use transceivers are less vulnerable than those who don't. The same can be said for experience; professionals with years of experience in avalanche terrain are apt to respond immediately

when caught in an avalanche, as opposed to a beginner who may not recognize the situation as quickly and be swept away. In general, the professional has a lower vulnerability owing to their experience and training.

Engineering risk analysis considers vulnerability to different avalanche sizes. For example, a structure may withstand the impact force of a Size 2 avalanche, but not a Size 3. If the terrain can produce a Size 3, depending on the frequency, then this structure will have some degree of vulnerability, and the risk analysis will reflect that.

3.3 Exposure

Exposure is about where, and for how long the element at risk is positioned in the terrain. For backcountry travel, the exposure component of risk is the single most important consideration for controlling risk. This is because a person is capable of having complete control over where and when they travel, and is therefore charged with absolute responsibility for his or her own risk. Even during periods of high avalanche hazard, a simple reduction in exposure will reduce the risk. On small-scale terrain features, even minor adjustments in how one is exposed to the hazard will change their risk – a few meters in either direction can be the difference between a low and high-risk situation. As the classic old adage goes: terrain, terrain, terrain.

4. CONSEQUENCE IN AVALANCHE RISK

Consequence refers to the impact of a hazard, or the "if it goes, what will happen" question. This essential consideration is missing from the current versions of the Avalanche Danger Scale and Snow Stability Rating System.

In avalanche risk, consequence is determined by three factors: destructive size, vulnerability and exposure. However, because avalanche hazard is independent of anything at risk, we cannot consider vulnerability or exposure when assessing the hazard. Thus, destructive size potential alone should account for the consequence factor when determining avalanche hazard. Avalanche risk takes the next step, and factors in the additional consequences of vulnerability and exposure for the element at risk. This is why there can be hazard without risk, but not risk without hazard.

5. THE LANGUAGE AND UNCERTAINTY OF AVALANCHE RISK

Different objectives use different methods and language for evaluating risk. Engineering risk is often numerate, and assumes that all elements of risk may be represented in terms of probability (CAA, 2002). This means that all components of risk can be expressed probabilistically as a number between 0-1, and that risk calculations will result in numerical probability statements such as 0.20, or 20%. These calculations often form the basis for a qualitative description of the risk.

Operational avalanche risk control is not mathematical, and practitioners rely on evidence to infer their subjective judgement. In the case of day-to-day avalanche forecasting and mountain travel, avalanche risk is evaluated using qualitative terminology that relates to avalanche likelihood, avalanche size and terrain descriptions.

In either case, there can be significant uncertainty associated with any avalanche risk analysis. This inherent uncertainty requires that the avalanche specialist clearly state the underlying assumptions and the approximate nature of the results (CAA, 2002). It is better to be approximately correct, than exactly wrong.

6. AVALANCHE RISK CONTROL METHODS

Avalanche risk control involves deliberate actions taken to control the risk to a specific element. This is accomplished using methods that reduce any of the four factors discussed previously: likelihood of triggering, destructive size, vulnerability and/or exposure. The objective of avalanche risk control is to maintain risk levels between the lower and upper limits of acceptable risk, known as the Operational Risk Band (McClung, 2002).

Risk control for infrastructure is most easily accomplished at the planning stages by applying proper risk mapping techniques. This can reduce the risk to the infrastructure by specifying placement and/or structural protection for the element at risk. Standards and acceptable risk thresholds are defined in Canada (CAA, 2002).

Operational avalanche hazard reduction is accomplished using control techniques such as explosives and/or ski cutting. In real-time, these methods increase the likelihood of triggering by artificially inserting triggers, but in the longer term they reduce the likelihood and size of the potential

avalanche. This reduction in hazard contributes significantly towards reducing the risk to the exposed element. Closures eliminate exposure and therefore eliminate the risk, but not the hazard.

For backcountry applications where the hazard cannot usually be controlled, reductions in vulnerability and exposure will control the risk. The hazard is first assessed and coded, and the terrain is then chosen accordingly. Vulnerabilities such as a skier's ability are assessed and reduced with technology where appropriate, for example with the use of transceivers or inflatable airbags. Finally, and most importantly, real-time exposure to avalanche hazard is managed through specific terrain choices.

7. CONCLUSION

Decisions for snow avalanches in Canada are risk-based (CAA, 2002). Although presently a half-truth, hopefully this statement will be further supported in the near future through the adoption of standards that specify avalanche risk evaluation methods for practitioners, using risk-based structures and terminology. It seems a basic requirement that any practicing professional undertaking avalanche prediction or risk control should have a complete and unbiased understanding of the meanings of avalanche hazard, danger and risk. These are basic concepts that should be taught early, and built upon.

Risk-based systems explain how practitioners have been doing their work for years. Avalanche hazard evaluation illustrates the commonalities between forecasters and guides working in different domains, while avalanche risk control methods highlight the different, and specialized techniques that are unique to each particular operation.

Future modifications to the Avalanche Danger Scale will ensure it is risk-based, and used as a tool for communicating avalanche danger to the public. Although the danger scale contributes to the evaluation of risk, by itself it is not an evaluation of risk. Avalanche bulletins warn of danger, but only the public themselves can determine their own individual vulnerabilities and exposure, thus being in control of their own risk.

8. ACKNOWLDGEMENTS

Many thanks to the numerous people who have contributed to this work. They include: Karl Birkeland, Ethan Greene, Pascal Haegeli, Susan Hairsine, Clair Israelson, Bruce Jamieson, Greg Johnson, Alan Jones, John Kelly, Karl Klassen, Mark Klassen, Bruce McMahon, Chris Stethem, Bruce Tremper, and Brad White. In addition, the Avalanche Danger Scale project is funded by the Government of Canada through the National Search and Rescue Secretariat's New Initiatives Fund, administered by the Canadian Avalanche Centre, sponsored by the Parks Canada Agency, and supported by both the Colorado Avalanche Information Centre and the United States Forest Service. Each of these organizations is contributing in-kind resources.

9. REFERENCES

Canadian Avalanche Association, 2007. Observation Guidelines and Recording Standards for Weather, Snowpack and Avalanches. Canadian Avalanche Association, Revelstoke, B.C., 90 pp.

Canadian Avalanche Association, 2002. Guidelines for Snow Avalanche Risk Determination and Mapping in Canada. Edited by D.M. McClung, C.J. Stethem, J.B. Jamieson, and P.A. Schaerer. Canadian Avalanche Association, Revelstoke, B.C., 24 pp.

Canadian Standards Association. 1997. (Reaffirmed 2002 without change). Risk Management: Guideline for Decision-Makers, A National Standard of Canada. Canadian Standards Association CAN/CSA-Q850-97.

McClung, D.M. 2005. Risk-based definition of zones for land-use planning in snow avalanche terrain. Canadian Geotechnical Journal, 42: 1030-1038.

McClung, D.M. 2002. The elements of applied avalanche forecasting. Part l: The human issues. Natural Hazards, 26: 111-129.

O'Gorman, D., P. Hein, W. Leiss, 2003. Parks Canada's Backcountry Avalanche Risk Review. Parks Canada, Banff, A.B., 80 pp.