UNCERTAINTY AND RISK, MERGING THEORY WITH PRACTICAL ADAPTATION IN AVALANCHE HAZARD MANAGEMENT

Steven Conger[1]*

[1]Snow Knowledge Inc., Golden BC Canada

ABSTRACT: Risk management has increasingly become the umbrella theme for avalanche hazard forecasting, control, and safety. Much has been written and introduced describing avalanche risk management recently. New international risk management standards have found their way into course and project work. Many struggle with the application of a paradigm shift in risk definition provided in the new standard. Limited work has been done to provide a useful map between such theory and present practice. This paper offers insight from experience gained through incorporating the recent advances with sound natural hazard analysis methods. An avalanche risk management process model is presented for use and further consideration, one that may find relevance in most aspects of avalanche risk management planning and operations. This paper concludes with discussion that highlights practical examples of uncertainty in managing avalanche related objectives.

KEYWORDS: avalanche risk management process, uncertainty analysis, ISO31000, vulnerability, hazard analysis, hazard evaluation, integral avalanche protection

1. INTRODUCTION

I believe the avalanche community has an issue with risk, a conundrum where we simultaneously work to reduce risk, invite risk, and increase risk. We are divided between seeing risk as "the probability or chance of loss or death (Canadian Avalanche Association, 2002) and "… situations …that, for all the risk involved, are ultimately exhilarating, even life-enhancing (Robbins, 2014)". We have been instructed to "learn to live with risk, manage it, and love it (McClung & Schaerer, 2006)" and to "target risk (Wilde, 1994)".

It was pointed out that the statement "decisions about snow avalanches in Canada are risk-based" is a half-truth to support adoption of risk-based evaluation methods by practitioners (Statham, 2008). Since this practical explanation of avalanche hazard, danger, and risk the following events have ensued:

a) New international risk management standards, e. g. CAN/CSA-ISO 31000-10, have been adopted for Canada (International Organization for Standardization, 2010).

b) These standards have found their way into CAA- Industry Training Program coursework, and

c) The Canadian Avalanche Association has adopted avalanche risk management as the primary descriptor in the scope of practice for avalanche hazard forecasting, control, and safety.

Agreed, risk management provides needed structure and prominence for avalanche work. The first part of this paper reviews risk management models and suggests a solution for avalanche risk management that incorporates current best practices.

However, risk wanes when it comes to adequately conveying what is most important in decision-making regarding the uncertain avalanche. The answer to this makes use of adopting the International Organization for Standardization (ISO) 31000 neutral definition of risk that fits well with the avalanche professional's enigmatic perspective and risk conundrum.

Risk is the effect of uncertainty on objectives. Effect being a deviation from the expected, positive and/or negative (ISO, 2009).

The second part of this paper presents use of the term *uncertainty* as a fundamental and communicable concept that can provide better articulation and framing of information that avalanche professionals base their expert judgment on and recreationalists use in their choice of risks.

* *Corresponding author address:*
Steve Conger,
Golden, BC, Canada;
tel: 250-344-2804;
email: steve@snowknowledge.com

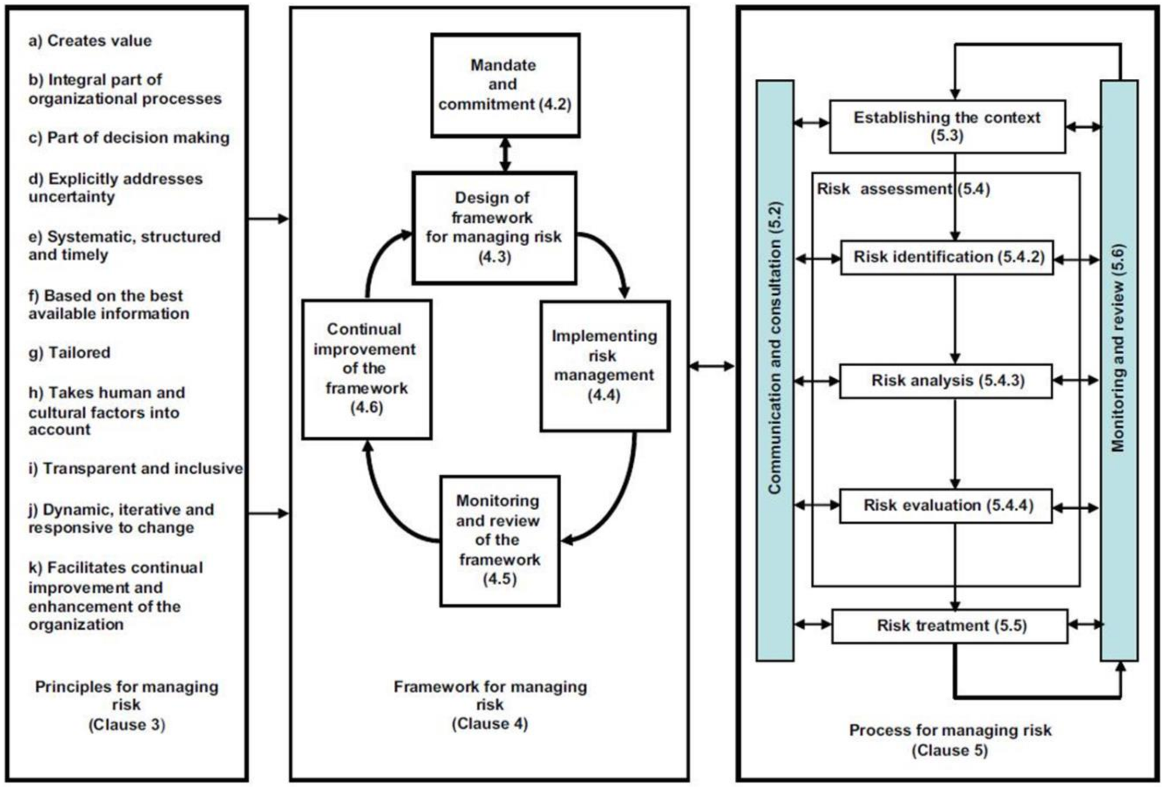

Figure 1. The three ISO 31000 risk management key components.

2. RISK MANAGEMENT MODELS

This section summarizes select risk management models with relevance to snow avalanches. ISO 31000 is presented as the blueprint for avalanche risk management. A report on Comprehensive Risk Assessment for Natural Hazards by the World Meteorological Organization (WMO) demonstrates the advantage of separate attention to the hazard component of risk assessment. A report by the Integral Risk Management of Extremely Rapid Mass Movements (IRASMOS) work group offers detail to risk assessment steps relevant and transferable to snow avalanches. The current and operationally-used conceptual model for avalanche hazard is briefly described. Each of these are depicted here as support of the risk management model outlined in the following section.

The ISO31000 management standard is made of three key components: 1) principles, 2) framework, and 3) process (Figure 1). The principles outline the benefits and role that risk management plays within an organization. The relationship between framework and process is clarified in that the process lies within the framework. The framework provides for embedding risk management in an organization and makes risk management scalable to the context. It is a plan-do-check-act cycle. The process is the main vehicle for delivery of risk management throughout the organization (International Organization for Standardization, 2010).

There are a number of ISO standards that relate to risk, hazard, and safety. Written as umbrella and general management guidance only, ISO 31000 is meant to be pertinent in all sectors or risk management applications. These can be an entire organization, multiple areas or levels, at any time, or for specific functions, projects and activities.

There is limited publication on the ISO 31000 / avalanche discussion. Jamieson & Jones (2013) support identifying risk as the effect of uncertainty, that conveying such all through an organization and its contractors is a method for thorough risk treatment strategies.

Avalanche risk management deals with a specific natural hazard, snow avalanches. There are various sources for risk management or risk assessment guidance specific to the discipline of natural hazards; I have drawn from two examples.

The Comprehensive Risk Assessment for Natural Hazards (World Metorological Organization, 2006) provides a definition for natural hazards as *those hazards produced by nature or natural processes*. This report was written with emphasis on identifying and presenting the various existing technologies used to assess the risks for natural disasters of different origins and to encourage their application. There is a short chapter on land-use planning in Switzerland that includes a limited conversation on snow avalanches.

The WMO report describes a framework for natural hazard risk assessment (Figure 2). This framework makes an important inclusion of hazard assessment (the evaluation of the potential occurrence of the hazard) as a separate step and parallel activity to vulnerability assessment (the evaluation of the value, resiliency, and the expected degree of loss).

It makes a valuable contribution describing that an inventory of the natural system is the basic data need for assessment of the natural hazard. Additionally, it describes a hazard map as indicating the magnitude and probability of the potentially damaging natural phenomenon.

Vulnerability is described by the WMO as a function of structure or land use under consideration, irrespective of the location (e.g. a wood frame building in an avalanche track has the same vulnerability as one outside of the path boundary but the potential for impact by an avalanche is exceptionally different).

The Integral Risk Management of Extremely Rapid Mass Movements (IRASMOS) working group has produced a number of reports focused around their intention to develop a holistic approach to risk management. The approach is theoretically based on “the risk concept” (Figure 3). It also sought to give equal attention to the steps of prevention, intervention, and recovery in development of tools.

IRASMOS highlights ISO 31000’s systematic approach and integration of the risk management process in a general risk framework in its description of integral risk management. The recommended requirements for an integral approach include:

- New approaches to be based on the risk concept or existing standards (e.g. ISO);
- Be clearly structured;
- Be actively managed;
- Be embedded in the environment;
- Is an ongoing task and has to contain steps of review and continuous enhancement. (irasmos, 2009)

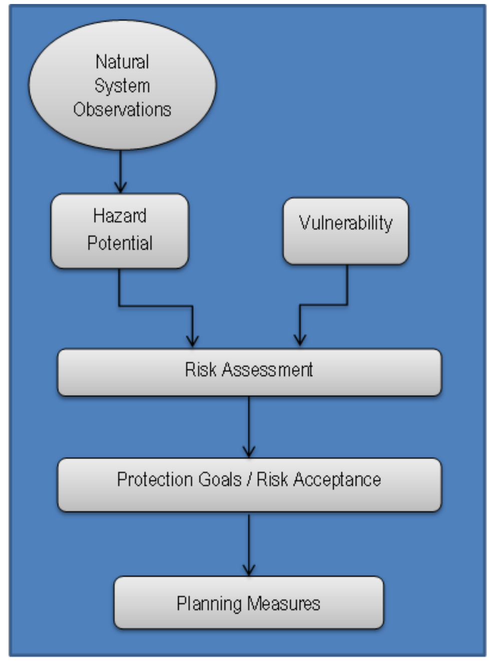

Figure 2. WMO framework for risk assessment and risk management (World Metorological Organization, 2006).

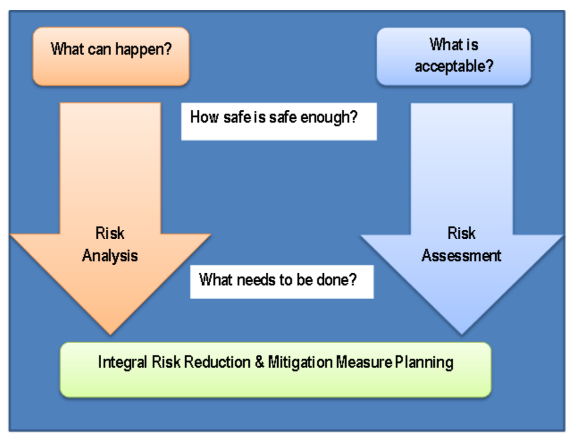

Figure 3. The risk concept used by IRASMOUS (Ammann, 2006).

A three level model for integral risk management of natural hazards (IRMAN) with similarities to the ISO31000 guidance (Figure 4) is suggested by IRASMOS. The risk management process is in the center, management level surrounds the process, and thirdly, both are embedded in the environment. Tradeoffs between risk management, society, nature, technology, and economy are represented by communication.

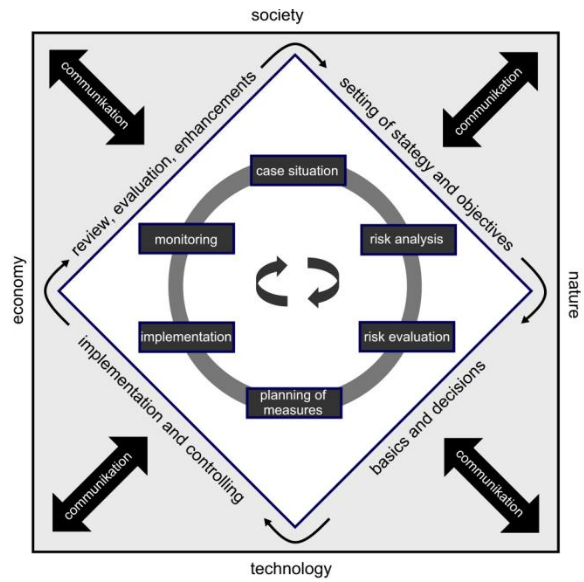

Figure 4. The IRASMOS integral risk management of natural hazards model (Romang 2008 as cited in irasmos, 2009).

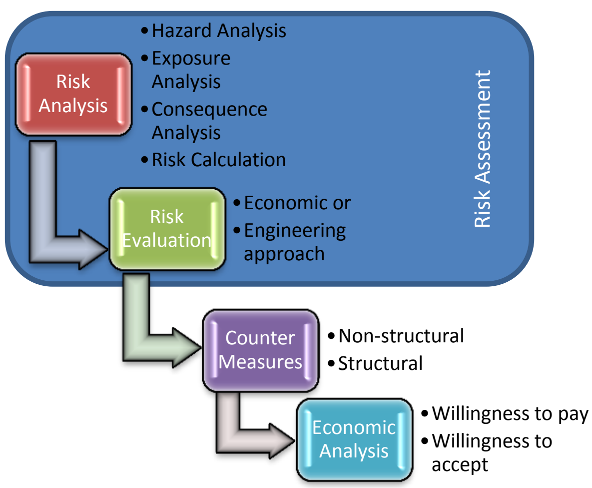

Figure 5. Key risk assessment and risk management elements of the IRMAN risk management process (after irasmos, 2009).

The balance of the IRASMOS work package 5 focuses on the components within risk assessment and discussion of counter measures and economic analysis. Their model is summarized in Figure 5 where hazard analysis is included as a routine within risk assessment. Though the integral risk management of natural hazards model mirrors the ISO 31000 guidance, the elements within the process target the IRASMOS definition of risk (the product of the probability of damage and the degree of damage). In their definition, the probability of damage combines probabilities of natural occurrence and presence of human aspects; and the degree of damage combines the natural impact on the objects, their value and vulnerability.

Avalanche hazard from a process-based perspective has been the core concept around which most discussion, planning, and safety actives have operated. Formal descriptions of planning efforts to address the threat of avalanches have existed for several decades (Wilson, 1975). A North American conceptual model of avalanche hazard (Statham, et al., 2010) that mimics the expert reasoning process and provides a hazard evaluation framework deconstructed into its base components (Figure 6) has been adopted in Canada. The incorporation of this widely used model as part of an overall avalanche risk management process is described in the following section.

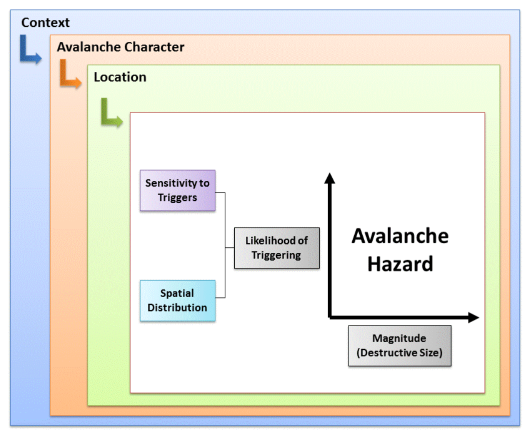

Figure 6. Conceptual model of avalanche hazard evaluation (after Statham, et al., 2010).

3. PRACTICAL ADAPTATION

This section attempts to provide a useful map between the described models and practice. This is based on learning, thoughtful consideration, and personal experience in applying the concepts outlined over the past several years.

Structurally, it is based on the ISO 31000 risk management process. An outline of the suggested method is presented in Table 1. There are references (in parentheses) for each step that point to the source lineage(s) of each.

Key and fundamental topics of hazard identification, analysis, and evaluation are given special attention, organizing them as separate steps in the process. A bifurcation occurs under hazard analysis with use of *planning hazard analysis* (after irasmos, 2009) and *operational hazard evaluation* reflecting its use in the CAA conceptual model.

Jamieson and Jones (2012) offer a vulnerability definition for snow avalanches as: the probability of loss of value or life given the element at risk is affected by the avalanche. We can infer from this the relationship between vulnerability (being the negative effect on objectives) and risk.

Useful definitions are suggested here and used in this paper for hazardous event and hazardous situation.

Hazardous event: a time period constrained event, during which occurs a significant release of a hazard that will result in harmful exposure if not controlled (after Johnansen, 2010).

Hazardous situation: a circumstance in which exposure to at least one hazard occurs (after International Organization for Standardization, 2007).

Table 1. Suggested avalanche risk management process.

1. Context (ISO 31000 & CAA)
1.1. Objectives (ISO 31000)
1.2. Internal (ISO 31000)
1.3. External (ISO 31000)
1.4. Risk Criteria (ISO 31000)
2. Risk Assessment (ISO 31000)
2.1. Risk Identification (ISO 31000)
2.1.1. Natural System Inventory & Observations (WMO)
2.1.2. Hazardous Situation (ISO 14121)
2.2. Risk Analysis (ISO 31000)
2.2.1(a). Planning Hazard Analysis (WMO & IRASMOS) or
2.2.1(b). Operational Hazard Evaluation (CAA)
2.2.1.1. Hazardous Event Analysis (IRASMOS)
(a) Probability and characteristics(IRASMOS)
(b) Location, character, and sensitivity to triggering (CAA)
2.2.1.2. Hazard Intensity Analysis (IRASMOS)
(a) Spatial distribution and variability and physical impact (IRASMOS)
(b) Spatial distribution and magnitude (CAA)
2.2.1.3. Exposure Analysis (IRASMOS)
• Elements at Risk (IRASMOS)
• Presence and coincidence (IRASMOS)
2.2.1.4. Consequence Analysis (IRASMOS)
• Vulnerability (IRASMOS)
• Protection factor (IRASMOS)
• Spatial probability of process (IRASMOS)
• Probability of presence (IRASMOS)
• Damage calculation (IRASMOS)
2.2.1.5. Risk Calculation (IRASMOS)
• Integral Avalanche Protection Analysis
- Non-structural & Structural (IRASMOS)
3. Risk Evaluation (ISO 31000)
3.1. Economic Analysis (IRASMOS)
3.2. Engineering Analysis (IRASMOS)
3.3. Uncertainty Analysis
4. Risk Treatment (ISO 31000)
5. Monitor & Review (ISO 31000)
6. Consult & Communicate (ISO 31000)

The model is intended to function sequentially as a process structure for both planning and operations.

4. UNCERTAINTY IS RISK

Where does uncertainty fit in all this?

First, the term *risk* spawns misunderstanding, no way around that. Consider the following example. The term *risk* appears in 72 of the 2009 titles listed in the Montana State University ISSW Proceedings Online Database, *risk* or *management* in 17 titles, *risk management* in 14 titles with 135 instances of *risk* being in the keywords. The context of use shows risk definitions vary greatly by discipline, users, stakeholder, or era even within the avalanche community. The use of *risk* creates ambiguity. Ambiguity does not counterweigh uncertainty (Hubbard, 2009).

Hubbard also suggests that ambiguity is introduced by the uses of the terms *risk management* and *risk analysis* and what he considers their established meaning of decision analysis and analysis of preferences.

Second, uncertainty is a fundamental and communicable concept that can provide better articulation and framing of information that avalanche professionals base their expert judgment on and recreationalists use in their choice of risks.

LaChapelle (1980)set the course for the present day understanding and codification of the avalanche forecasting method, stating that forecasting decisions are arrived at through inductive logic that carries with it uncertainty. He went on to describe that the strategy it follows is one of reducing uncertainty and that information used in making forecast decisions is organized by the degree of uncertainty conveyed about what is going on.

It is recommended that uncertainty must be included in the assessment of natural hazards due to its potentially large influence on the preference orderings among risk treatment options (Rougier, et al., 2010).

One of ISO 31000's principles, risk management explicitly addresses uncertainty, makes it ideal for adoption throughout the snow avalanche natural hazard discipline. *Uncertainty* is defined in ISO 31000 "as the state, even partial, of deficiency information related to, understanding or knowledge of, an event, its consequence, or likelihood (International Organization for Standardization, 2010)".

There are two types of natural hazard uncertainty for inclusion in assessment: 1) the inherent uncertainty of the hazard, and 2) uncertainty engendered by lack of knowledge (Rougier, et al., 2010).

Preferably uncertainty included in hazard analysis would be quantified, because rankings alone are not sufficient to order options in a risk evaluation (Rougier, et al., 2010).

At the process level of avalanche hazard evaluation we reduce uncertainty through observation. The objective of measurement is suggested to be the improvement of our current knowledge about an unknown quantity that is relevant to some decision (Hubbard, 2009), i.e. reduce our uncertainty.

Yet, we have an avalanche culture history of couching our observations and statements in ambiguity, descriptors of hazard and stability; of hedging our inaccuracies as due to stratigraphic structure and spatial variability.

5. UNCERTAINTY ANALYSIS

One cannot “manage” uncertainty beyond managing our contribution to ambiguity in observing, reporting, and recommending.

Methods that may be undertaken to add an uncertainty analysis to the decision or analysis of preferences include adopting: 1) uncertainty language, 2) uncertainty structure, and 3) uncertainty-based decision model.

Adopting the language and the philosophy of uncertain systems includes using calibrated probabilities to communicate your uncertainties (Hubbard, 2009). This also includes articulating and acknowledging uncertainties and doubts within discussions and reports.

An example of how this calibration may occur comes from a thought experiment I conducted with a group of avalanche technicians who were asked to consider the descriptor words used in their forecasts. They were asked to attribute a range of probability to select the words describing likelihood.

I interpreted the results to indicate that when hazardous conditions (are present or developing) that cause the forecaster to expect consequential avalanches are only “probable”, there is up to a 50% chance that consequential avalanches will occur due to the uncertainties the forecaster is dealing with. When conditions support the high expectation that consequential avalanches “will occur”, there is upwards of a 30% chance that such avalanches may not happen due to the uncertainties present.

It is the commonality of uncertainty, as the defining characteristic of the geotechnical field (Vick, 2002) and the avalanche hazard discipline (LaChapelle, 1980), that lends itself to the transference to avalanche work of subjective probability and degrees of belief.

In addition to calibrating probabilities within an organization the same is possible when communicating with stakeholders as shown in the efforts from the climate change community. Table 2 illustrates an example of a calibrated likelihood scale (IPCC 2005 adapted in Spiegelhalter & Riesch, 2011)

Table 2. An example of calibrated qualitative probabilities.

terminology	***degree of confidence in being correct***
virtually certain	>99% probability of occurrence
very likely	>90%
likely	>66%
about as likely as not	33–66% probability
unlikely	<33% probability
very unlikely	<10% probability
exceptionally unlikely	<1% probability

A promising structure has been suggested for addressing uncertainty when conduction model-based risk analysis such as done for climate (Spiegelhalter & Riesch, 2011). An adaptation of this structure for avalanche hazard forms the basis of the following steps for uncertainty analysis:

- The object and source of the uncertainty
    - A future event (residual unpredictability),
    - Limitations in initial condition information,
    - Process model (alternative models and limitation in formalized knowledge of phenomenon),
    - Indeterminacy (known limitations in understanding or process model),
    - Ignorance (unknown limitations or understanding).
    - Over-confidence
- The form of expression of uncertainty
    - A distribution,
    - Order of magnitude assessment,
    - List of possibilities,

  - Qualitative positive or negative effect statements,
  - Informal acknowledgement of uncertainty existence,
  - Denial of existence of uncertainty.
- Whom or what in the decision chain does the uncertainty effect?
- The affect, i.e. feelings associated with the uncertainty.

Practitioners have utilized uncertainty analysis within the hazard evaluation process for years. The use of data classes, as a filter in decision-making, increasingly weights evidence that is more direct and unambiguous (LaChapelle, 1985). The Bulls-Eye approach utilizes this method (Fredston & Fesler, 1994).

6. SUMMARY

Uncertainty is unambiguous. It lends itself to better decisions or analysis of preferences concerning risk. Consider the fundamental objective of an avalanche risk management practitioner: to determine or make a professional recommendation where, when, and for how long someone or something may be exposed to hazard in avalanche terrain. Articulating and acknowledging uncertainties, as they are, supports transparency in the decision or recommendation. It better imparts desired information through reducing negative effects of the feelings described by Slovic (Slovic, 2010) that drive risk decisions.

REFERENCES

Ammann, W. J. (2006). Risk concept, integral risk management and risk governance. Proceedings of the RISK21 Workshop, Monte Verità, Ascona, Switzerland, 28 November - 3 December 2004 (pp. 3-20). London: Taylor & Francis.

Canadian Avalanche Association. (2002). Guidelines for Risk Determination and Mapping in Canada. Revelstoke: Canadian Avalanche Association.

Fredston, J. A., & Fesler, D. (1994). Snow Sense - A Guide to Evaluating Snow Avalanche Hazard. Anchorage: Alaska Mountain Safety Center.

Hubbard, D. W. (2009). The Failure of Risk Management: Why it's Broken and How to Fix It. Hoboken: John Wiley & Sons.

International Organization for Standardization. (2007). Safety of machinery - Risk assessment - Part 1: Principles. Geneva: ISO.

International Organization for Standardization. (2010). CAN/CSA-ISO 31000 Risk management - Principles and guidelines. Mississauga: Canadian Standards Association.

irasmos. (2009). Best Practice of Integral Risk Management of Snow Avalanches, Rock Avalanches and Debris Flows in Europe.

ISO. (2009). ISO 31000 Risk management - Principles and Guidelines. Geneva: International Organization for Standardization.

Jamieson, B., & Jones, A. (2013). Impressions from Applying ISO 31000 to an Avalanche Mitigation Project. International Snow Science Workshop Grenoble – Chamonix Mont-Blanc - October 07-11, 2013.

Jamieson, B., & Jones, A. S. (2012). Vulnerability: Caught in an Avalanche – Then What are the Odds? Proceedings, 2012 International Snow Science Workshop, Anchorage, Alaska Volume 1 (pp. 1-8). Anchorage: ISSW.

Johnansen, I. L. (2010, June 14). Foundations of risk assessment. Trondheim, Norway.

LaChapelle, E. R. (1980). The Fundamental Processes in Conventional Avalanche Forecasting. Journal of Glaciology, 26(94), 75-84.

LaChapelle, E. R. (1985). The ABC of Avalanche Safety 2nd Edition. Seattle: The Mountaineers.

McClung, D. M., & Schaerer, P. A. (2006). The Avalanche Handbook, 3rd Edition. Seattle: The Mountaineers.

Robbins, T. E. (2014). tibetan peach pie. New York: HarperCollins.

Rougier, J., Sparks, S., Aspinall, W., Cornell, S., Crosweller, S., Edwards, T., et al. (2010). SAPPUR : NERC Scoping Study on Uncertainty and Risk in Natural Hazards Summary and recommendations. Bristol: Bristol Environmental Risk Research Centre.

Slovic, P. (2010). The Feeling of Risk. New York: Routledge.

Spiegelhalter, D. J., & Riesch, H. (2011). Don't know, can't know: embracing deeper uncertainties when analysing risks. Philosophical transactions. Series A, Mathematical, physical, and engineering sciences, 369(1956), 4730-50.

Statham, G. (2008). Avalanche Hazard, Danger and Risk - A Practical Explanation. Proceedings Whistler 2008 International Snow Science Workshop September 21-27, 2008 (pp. 224-227). Whistler: ISSW 2008.

Statham, G., Haegeli, P., Birkeland, K. W., Greene, E., Israelson, C., Tremper, B., et al. (2010). A Conceptual Model of Avalanche Hazard. Proceedings 2010 International Snow Science Workshop (p. 685). ISSW 2010.

Vick, S. G. (2002). Degrees of Belief. Reston: ASCE Press.

Wilde, G. J. (1994). Target Risk. Toronto: PDE Publications.

Wilson, N. A. (1975). Ski Area Planning for Avalanches. Reno: USDA Forest Service.

World Metorological Organization. (2006). Comprehensive Risk Assessment for Natural Hazards. WMO.