SUPPORTING SOUND DECISIONS: A PROFESSIONAL PERSPECTIVE ON RECREATIONAL AVALANCHE ACCIDENT PREVENTION IN CANADA

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ABSTRACT: Relative to recreationists, avalanche professionals in Canada have a high success rate for managing avalanche hazard and making sound decisions in avalanche terrain. This success invites the question: What can be learned from these successes relative to avalanche education, decision support and accident prevention for backcountry recreationists? I surveyed Canadian avalanche professionals using a mail-in questionnaire on core knowledge and skills for sound avalanche decision making, key areas of education that can improve avalanche decision making, effective methods to communicate avalanche hazard, and the potential of a recreational decision support framework to improve decision-making and result in fewer recreational avalanche accidents and fatalities. Respondents identified human factors and choice of terrain as the primary causes of recreational avalanche accidents and recommended that recreational education targeted in these two areas would effectively reduce avalanche accidents. Three meta-themes emerged to support sound decisions by recreationists; training and education, hazard communication and decision support. In this paper, I examine the results of this survey within the context of theories of adult learning and decision science. I offer an analysis of why it is important to look at avalanche accident prevention from a human sciences research perspective and propose a systemic approach to supporting sound recreational decision-making. Based upon these survey results, I advocate strong support for the implementation of a recreational decision support framework in Canada, although there were several complexities identified by survey respondents. It is clear that the integration of expertise from a wide range of disciplines will be required to design and implement an effective and integrated framework that will support sound decisions and reduce the number of avalanche accidents and fatalities in Canada.

Keywords: Avalanche education, decision making, human factors, hazard communication.

1. INTRODUCTION

In the ten-year period of 1994 to 2003, avalanche accidents in Canada killed an average of 15 people annually and injured 75 (Public Avalanche Safety Program Review, 2003. p. 2). Recently, in the winter of 2002/2003, 29 people died in avalanches while pursuing backcountry recreation in Canada – the highest annual backcountry avalanche fatality rate in Canadian history. Further, statistics from 1998 to 2003 show 82% of these fatalities occurred among recreational backcountry users while 18% occurred within commercial groups (Public Avalanche Safety Program Review, 2003. p. 7). This suggests a significant difference in avalanche fatality rates between avalanche practitioners and recreationists. Since winter backcountry use is increasing significantly in Canada, there is an urgent need for effective prevention methods to support sound backcountry recreational decisions and to protect lives.

In this paper, I use the word “commercial” to refer to situations when a trained avalanche practitioner or guide is ultimately responsible for the decision making on behalf of the safety of a group. I define avalanche “practitioner” as a person working in an active decision-making capacity in avalanche terrain. I differentiate this from “professional”, who is an avalanche practitioner and also a professional member of the Canadian Avalanche Association (CAA). I use the word “recreationist” to refer to a member of the general public who pursues winter backcountry activities as an un-paid recreational pursuit.

Researchers in the snow avalanche field have focused extensively on understanding the physical properties of snow avalanches, e.g., snow science, avalanche release dynamics, weather and terrain factors. Initiatives in public safety avalanche prevention and education have been designed around these complex physical factors. However, due to the limited understanding

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of human factors and decision processes in avalanche terrain, these initiatives have yet to address key human components and therefore may be lacking in their effectiveness.

Avalanche practitioners and researchers are now recognizing the significant role human factors play in avalanche accidents and several researchers have recently examined this area of avalanche phenomenon (see Fredstone, Fesler and Tremper, 1994; McCammon, 2002, 2000). "Since most avalanche accidents result from human errors, no description of avalanche forecasting is complete unless the human component is addressed" (McClung, 2002. p.1).

In order to provide solutions that will effectively reduce the number of avalanche accidents and fatalities, a complete understanding of all contributing factors is required. It is not sufficient to understand the physical properties of snow avalanches; we need to understand humans and the factors that affect their decision-making in avalanche terrain. This approach offers balance and perspective to all sides of the avalanche triangle.

Although a human ability to make sound decisions is supported by low accident rates within the community of Canadian avalanche practitioners, the statistics from avalanche accidents in Canada show winter backcountry recreationists are less successful in making sound decisions when traveling in avalanche terrain. Since avalanche practitioners in Canada have a relatively high success rate for managing avalanche hazard and making sound decisions, I suggest that the perspectives of these experts offer a great deal of wisdom towards deriving effective solutions to the problem of recreational involvement in snow avalanches.

In this paper, I report the results of a survey of avalanche professionals and practitioners in Western Canada. The objectives of my research were to capture the theoretical knowledge and experienced insight of Canadian avalanche professionals, and to use this knowledge and insight to derive effective solutions for improving the decision-making practices of winter backcountry recreationists.

2. METHODS

This is a social sciences study where I take an inductive, "grounded theory" approach (Creswell, 1998; Merriam, 2002; Palys, 2003) that emphasizes the generation of theory grounded in the data. "Action research" provides the foundation to this research (Glanz, 1998; Kemmis & McTaggert, 1988; Stringer, 1999), and is a collaborative, scientific approach to human problem solving and strategic action that has two intended outcomes; to improve practice and to generate additional knowledge and understanding in the area of inquiry.

To examine recreational avalanche accident prevention from an avalanche experts' perspective, I surveyed Canadian avalanche practitioners in five topic areas: recreational avalanche accident factors, education, hazard communication, decision-support and accident prevention. Respondents were asked to judge what they believed to be the:

- primary factors in recreational avalanche accidents,
- core knowledge and skills for sound avalanche decision making,
- key areas of education that can improve avalanche decision making,
- effective methods to communicate avalanche hazard,
- potential of a decision support framework to improve decision-making and result in fewer avalanche accidents and fatalities.

In the fall of 2003, the survey was sent by electronic mail to all professional members of the Canadian Avalanche Association (CAA; n=284). As well, it was given, in person, to a group of experienced helicopter ski guides attending a pre-season training session. In total, I received 79 completed surveys. 72 surveys were from Canadian avalanche professionals representing 26% of the total CAA professional population at the time the survey was administered. The remaining 7 surveys were from industry practitioners. Respondents represented a cross section of avalanche industry expertise (Figure 1) and held a high level of industry experience with 40% of respondents having 20+ years of experience, 35% with 10-19 yrs, and 25% with 1-9 yrs.

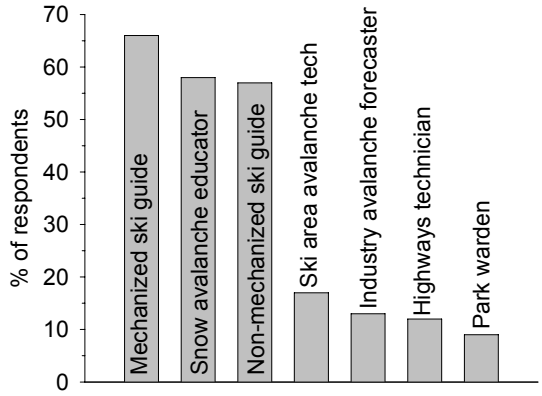

Figure 1. Area of expertise in the avalanche industry

The survey included both quantitative and qualitative questions. Quantitative questions involved ranking factors in the five topic areas using two methods; a five-step Likert type scale, (1 = To a very great extent to 5 = Not at all) and, ranking in order of importance (1 = most important to 5 = least important). To gain a comprehensive perspective for each quantitative question, I also asked respondents to include any additional factors they felt were important. A qualitative question culminated each of the study topics. e.g. "*Do you have any additional comments regarding decision support methods/tools for recreational backcountry travelers?"* These qualitative data were analyzed using meta-theme analysis, a procedure that captures the meaning in phrases and singular statements (Kirby and McKenna, 1989; VanManen, 1990). These meta-themes are shown in italics throughout this paper.

3. RESULTS

3.1 *Primary Causes of Recreational Avalanches*

Respondents identified "human factors" and "choice of terrain" as the primary causes of recreational avalanche accidents followed by "inadequate snowpack assessment" and "failure to recognize meteorological effects on the snowpack". Respondents also indicated that human factors are not a separate cause in avalanche accidents but are inextricably linked to the ability to make choices or evaluation.

3.2 *Human Factors*

The second section of the study focused on human factors. Ninety-seven percent of the respondents believed that human factors have a moderate or greater influence in recreational decision-making (Figure 2). Level of experience and training / education are two other key human factor themes that were identified as having significant impact on the decision processes of recreationists and are discussed in the next section. Human factor meta-themes from qualitative responses were:

- *"The human factor is really the greatest deciding factor. This is what determines what tools recreationists have and how they applied."*
- *"Human factors and decision making processes are the main hazard, not the snow."*
- *"Avalanche terrain is not a hazard until*

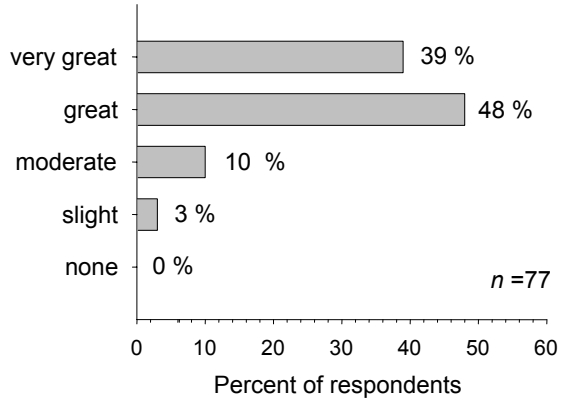

Figure 2. The extent that human factors influence recreational decisions resulting in avalanche accidents.

3.3 *Experience*

Eighty-four percent of respondents indicated that level of experience has a very great or great impact in recreational decision-making (Figure 3). Qualitative meta-themes included:

- *"Most decision makers can't practically make good self-evaluations on the validity of their decisions until they have developed 'appropriate' experience."*
- *"Ultimately wise decision making takes experience that comes with time."*

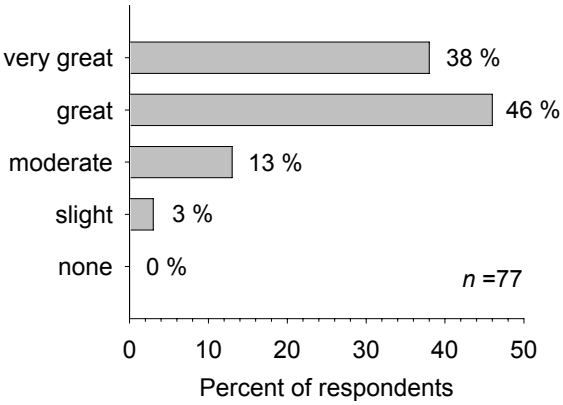

Figure 3. The impact of experience on recreational decision making.

3.4 ***Training and Education***

Sixty-seven percent of respondents felt that training and education has a very great or great impact in recreational decision-making. Two themes emerged from the qualitative responses: (1) recreational training in Canada could be more effectively designed to provide recreationists with better decision making capacities, and (2) that the curriculum currently taught in recreational avalanche training may provide recreationists with a false sense of security when making avalanche related decisions. These themes will be addressed in detail in the following sections.

3.5 ***The Impact of Media***

Sixty-three percent of respondents felt that "media extreme role modeling in snow terrain" had a moderate or greater impact on recreational decision-making. Qualitative meta-themes included:

- *"The tend toward 'extreme' activities with the corresponding proliferation of video's and print media seems to be driving decision making processes towards risk tolerance also in the range of 'extreme'."*
- *"Self-confidence and perceived risk levels in relation to terrain observation are greatly influenced by current role modeling of terrain use by mass media (text and video)."*

3.6 ***Knowledge, Skills and Education***

I asked respondents to identify the core knowledge and skill topics that would "effectively improve recreational decision making abilities therefore resulting in fewer avalanche accidents and fatalities." Terrain and route finding was selected as the area of greatest potential (Fig. 4),

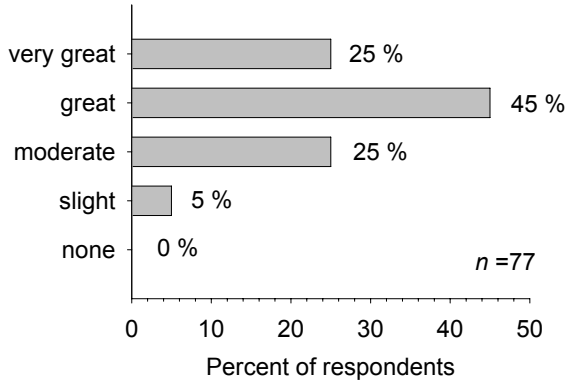

Figure 4. The extent that education in terrain and route finding will improve recreational decision-making and reduce accidents.

followed by human factors (Figure 5). The qualitative meta-themes included:

- *"Terrain and route selection should be a key emphasis in all avalanche courses."*
- *"Local courses in specific terrain are the best idea as it can increase specific terrain knowledge. Recreationists can also be*
- *encouraged to relate weather and avalanche events to specific terrain, build relevant local knowledge, and to encourage avoidance during avalanche cycles."*
- *" We should extend our educational focus in the realm of human factors, decision making and situational awareness."*

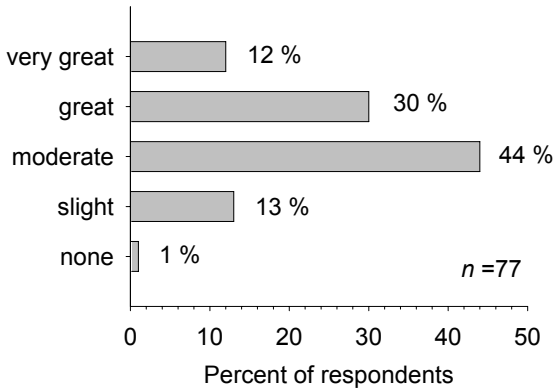

Figure 5. The extent that education in human factors will improve recreational decision-making and reduce avalanche accidents.

When asked about educating recreationists in the physical properties of the snowpack, qualitative and quantitative results were mixed. Quantitative results indicated that education in the physical properties of the snowpack will improve decision making and reduce avalanche accidents as shown in Table 1.

However, qualitative results suggested the opposite. These meta-themes included:

- *"Striving to develop recreational understanding of deeper instabilities and how to judge when the snowpack is strengthening or weakening is ineffective. These complexities are challenging enough for professionals to understand."*
- *"Courses need to focus on terrain selection because snowpack structure is complex and too changeable over time and terrain."*

Table 1. *The extent to which snowpack education will improve recreational decision-making and reduce avalanche accidents. Values represent the proportion of respondents by factor (i.e., rows add up to 100 %).*

Physical Properties of the Snowpack	To a very great extent	To a great extent	To a moderate extent	To a slight extent	Not at all
Meteorological effects	5	44	38	13	0
Snowpack characteristics	5	23	41	30	1
Snowpack tests/site selection	5	33	45	16	1

3.7 ***Hazard Communication and Graphical Mapping Tools***

I asked respondents the extent to which "increasing the frequency and regions of avalanche bulletins would result in a decrease in the number of avalanche accidents and fatalities". Eighty-one percent selected "to a very great" or "great extent" (Figure 6).

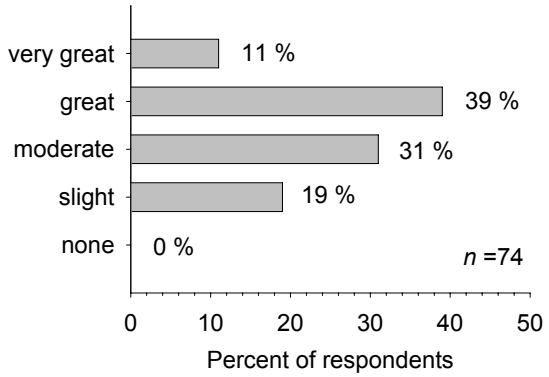

Figure 6. The extent that increasing the frequency and regions of avalanche bulletins will result in a decrease in recreational avalanche accidents.

This question generated a great deal of comments from survey respondents;

- *"Improve the scale of forecast areas from regional to local in high use areas".*
- *"Real results will only come from a complete re-visit to how the information is communicated to the public".*
- *"The best goal is to describe how to practically apply the bulletin to field decisions and to complement the bulletin with a basic factors checklist".*

Seventy-four percent of the respondents felt to a moderate or greater extent that "identifying hazardous terrain on graphical terrain maps would simplify a recreational travelers decision making process and result in a decrease in avalanche accidents and fatalities." In addition, respondents commented that the use of graphics in general would be an effective augmentation to avalanche bulletins and as key decision information at high use trailheads. Meta-themes included:

- *"Detailed information describing the specific nature and terrain locations of existing snowpack instabilities provides a useful tool for making terrain selection and routefinding decisions."*
- *"If mapping is provided in high use areas indicating hazardous and safe areas, the likelihood of accidents in those areas will be reduced."*

Although there was strong support for increased use of various mapping tools by respondents (e.g. Geographical Information Systems (GIS), oblique and terrain photos), there were significant complexities associated with their implementation and use. Meta themes of these complexities included:

- *"Many recreational travelers are lacking even basic map reading skills."*
- *"It takes some sophistication to be able to accurately identify on the ground specific areas that are marked on a map."*

- *"This may lead to potential liability and limitations to professional practice."*

3.8 ***Decision Support***

Eighty-three percent of the respondents felt to a moderate extent or greater that the "design and implementation of a recreational decision support framework for Canadian recreational travelers will improve decision making in snow covered terrain and result in fewer avalanche accidents and fatalities" (Figure 7).

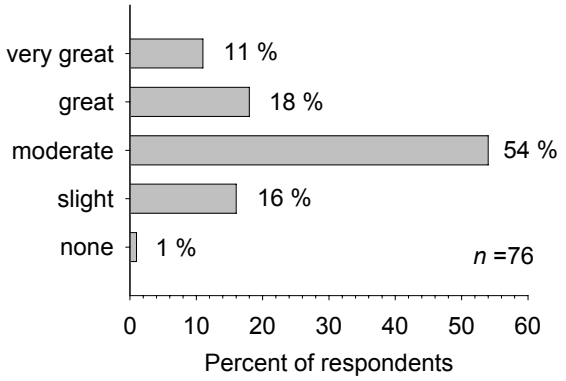

Figure 7. The extent that a recreational decision support framework will improve decision making and result in fewer avalanche accidents.

Qualitative meta-themes included:

- *"There is great potential here. Tools that help make better decisions or impart discipline could have significant effects."*
- *"A decision support tool may take some of the guesswork out of recreational decisions and make it easier to arrive at a decision without being influenced by other group or internal pressures".*

These avalanche practitioners articulated their concerns regarding the implementation of a decision support framework. Meta-themes included:

- *"Such a decision making tool is of value to statistically reduce the number of accidents in the population that is not highly experienced and educated. These tools would oversimplify the process for more experienced people and would not be an improvement for professionals. We have to be careful about a possible double standard and be clear that the rule-based methods are applicable to less experienced people only as a substitute for experience".*

4. DISCUSSION

Results of this study indicated two meta-factors that were identified by respondents as most important in recreational avalanche decision-making: human factors and experience. As well, three key themes emerged from this study for supporting sound decisions by recreationists: education and training, hazard communication and decision support. I discuss each of these factors separately in the following sections.

4.1 ***Meta-Factors in Recreational Avalanche Decision Making***

4.1.1 *Human Factors*

Respondents believed that human factors are the key influencing factor in the decisions that recreationists make in avalanche terrain. Since human factors are comprised of knowledge, skills and attitudes, it is important to note that they are not a separate decision factor but are inherent in all avalanche decision processes such as terrain selection or snowpack assessment.

Avalanche researchers observe that most recreational avalanche accidents occurred despite several obvious clues to the hazard being present prior to the avalanche (CAA, 2003b, ¶ 10,12,13, McCammon, 2002, p.2). Statistics from avalanche accidents in Canada between 1984 and 1996 state common failures in the decision process of recreationists include not recognizing the indicators of unstable snow and, either not understanding, or choosing to ignore fundamental principles of safe terrain choice (CAA, 2003b, ¶ 10, 12). Since decision science research indicates that humans generally have the capacity to make systematic and methodical decisions (Kahneman, 2003; Klien, 1998; Slovic, Fischhoff & Lichtenstein, 1977), this situation is perplexing to avalanche researchers. Human factors appear to play a strong role in these avalanche accidents since from an avalanche professionals' perspective, these are primary basics of avalanche awareness.

While the presence of human factors in avalanche phenomena has been recognized in the past, the necessity to implement frameworks to cope with these complexities has only come to the fore recently. Social science research into human behavior in avalanche terrain is a critical missing element in the informed design of these frameworks, and is needed to complement the extensive knowledge of terrain and snowpack. Tremper (1991) states, "It is not enough to know

the discipline, but how the discipline interfaces with people".

4.1.2 *Experience*

Respondents stated that recreational users do not have the same degree of knowledge and practical experience that enables avalanche practitioners to more consistently perform the complex, "knowledge-based" processes that are fundamental for safe decisions in winter mountain terrain. These avalanche practitioners identified experience as being the key enabling factor in sound avalanche decision-making.

Theories of experiential learning and decision science emphasize the role of experience in the creation of knowledge and the making of good decisions. Experiential learning occurs through interactions with our environment and involves an ongoing process of differentiating and integrating meaningful ideas and events (Cusins, 1996; Kolb, 1984; Zuber-Skerrit, 2002). Knowledge is constructed through a process of perceiving and understanding these experience and events, and then transforming this knowledge into changes in behaviour and life practice.

A broad experience base enables decision makers to identify and consider workable choices of action first and focus on assessing the nature of the situation, rather than comparing alternate courses of action (Klein, 1997, p. 241). Inexperienced decision makers are often victims of a wide range of harmful biases, such as failing to recognize a high stakes problem, ignoring the existing information about probabilities, and responding to complexity by accepting status quo, i.e. what has worked for them in the past (Kunreuther et al., 2002). It is important to recognize that backcountry recreationists in Canada have a wide range of experience levels, however experience is the key factor that differentiates between the decision capacities of recreationists and avalanche practitioners.

4.2. ***Key Themes for Supporting Sound Decisions***

Three areas to support sound avalanche decision-making and recreational accident prevention schemas emerged from this study: Training and education, hazard communication and decision support.

4.2.1 *Education and Training*

Two meta-themes resulted within education and training: refocusing curriculum in areas that practically enable sound avalanche decision-making, and increasing the qualifications of recreational avalanche course instructors.

Respondents spoke strongly for the need to revisit recreational avalanche curricula in Canada and focus core topics on meaningful outcomes that effectively enable recreationists to improve their decision making. As previously discussed, respondents selected human factors and choice of terrain as the two key factors in recreational avalanche accidents. These two topics were also identified as being the key areas in recreational education that would effectively improve decision-making and reduce avalanche accidents and fatalities. In addition, respondents suggested courses held in local terrain would enable recreationists to build local terrain and snowpack knowledge and could have a dramatic impact on improving decision making.

As the results in Table 1 suggest, respondents believed educating recreationists in physical properties of the snowpack offers the potential of reducing accidents, however this was the one area of the study where the quantitative results did not correlate with the extensive qualitative responses articulated. In fact, the results were the opposite. Qualitative responses emphasized the complexities of snowpack analysis and indicated the concern that recreationists may be mislead by inaccurate snowpack assessments in poorly selected locations. This finding shows the importance of recognizing the cognitive and experiential differences between recreationists and practitioners when designing effective educational curricula, and, when communicating avalanche hazard and risk.

Snowpack analysis and the effect of meteorological factors are complex decision processes that require knowledge-based processes. Although avalanche practitioners are constantly striving to refine snowpack analysis, this current emphasis in recreational curricula is felt to be ineffective at the recreational level. These study results suggest that the snowpack curricula in recreational courses should be carefully assessed to identify the core learning outcomes that can effectively and practically improve recreational avalanche decision-making capacities.

An interesting result of recent heuristics research, is in a majority of recreational avalanche

accidents in the United States, victims typically had a significant amount of avalanche education (McCammon, 2000, p.39). Considering the results of my research, I suggest that accident statistics such as these might be reduced if recreational curricula were designed around key factors identified as effectively enabling sound recreational decision-making. In addition, there are several decision-training methods that offer the potential to reduce the biases that McCammon has reported. These methods include de-biasing decision-makers resulting in reducing "decision traps" (Russo and Schoemaker, 1989, 2001), and developing and teaching prescriptive heuristics (Kunreuther et al. 2002), simple rules of thumb that enhance normative processing. However, the field of Naturalistic Decision Making (Klein, 1998) offers the greatest potential, through cognitive and decision-centered approaches that build decision expertise.

A second theme identified by respondents, was the need to set higher standards for Canadian recreational avalanche course instructors in order to ensure high quality of instruction, the instruction of informed and relevant field curriculum, and the appropriate modeling of terrain use and safe travel practices.

4.2.2. *Hazard Communication*

Communicating avalanche hazard and risk in a variety of forms was identified as having the potential to improve decision making and reduce avalanche accidents. Respondents suggested that the scale of avalanche bulletins be modified from regional to local in high frequency areas, and that hazard information be linked to specific use of terrain features. Opportunities then exist for recreationists to practically apply bulletins directly to the decisions they make in the terrain – a primary theme of this study.

Other comments included the addition of graphical mapping applications and hazard icons to complement the current text based products, and that these decision aids be made more widely available in a variety of locations, i.e., on the internet, in public areas frequented by recreationists and at the trailhead. Broadening the range of strategies utilized for avalanche hazard and risk communication appeals to different cognitive processes and learning styles, therefore has the potential of reaching a greater proportion of backcountry recreationists with more meaningful effect.

The communication of hazard and risk to the public is a matter of growing concern and debate, and is the subject of extensive literature. Strategies from content-oriented risk communication that is intended to persuade, to process-oriented risk communication involving public participation (Fischoff, 1995) are only a few of many perspectives aimed at effective methods to conceptualize and communicate risk. One theme that resonates throughout the literature is the critical importance of providing meaningful information, a theme consistent with my study. Respondents articulated a concern that the technical language and complex concepts used in bulletins are relevant to practitioner-level understanding, yet are not effectively and practically communicated to recreationists who often have limited technical and experiential background. Larkin and Pallister (1976) likened this communication gap as "reciting Gaelic poetry to deaf seagulls" (p.3).

Media is also involved in avalanche communication. The role of media extreme role modeling was identified as a significant influencing factor in recreational decision-making. Respondents felt this factor may be encouraging the increased extreme use of terrain that they have been observing in the field. Since avalanche accident statistics in Canada from 1984 to 2003 identify males in their 20's as the typical accident victim (CAA, 2003b), this is a factor worth consideration. Effective role modeling and use of mountain terrain is critical to positively influence safe practices within this demographic group.

4.2.3 *Decision Support*

Strong support was given by respondents in this study for the design and implementation of a recreational decision support framework in Canada (Figure 8). Respondents perceive recreationists are making decisions in isolation and are basing their decisions on passive, subjective interpretations of hazard terminologies such as "considerable" or "moderate". Decision Support Systems (DSS) and Naturalistic Decision Making (NDM) methods have been used extensively in related disciplines and are designed to improve decision-making effectiveness. In complex situations, DSS users perform significantly better than unaided subjects (Klein, 1998; Webby & O'Connor, 1994).

DSS and NDM approaches involve users in an active process of decision making and therefore reduces the influence of human factors and subjective perceptions in the decision process. Decision support frameworks for winter recreationists have been successfully used in

Europe over the past decade (e.g. Munter's 3X3). Canada does not have a framework in place although considerable interest in the concept has gained momentum over the past few years.

Respondents emphasized several concerns about the implementation of a recreational decision support framework. Perceived limitations to professional practice were a significant concern. However, respondents suggested stating the target audience on all tools, and clearly articulating the application for less experienced users as a substitute for experience could mitigate this. Respondents also described the possibility that a recreational decision support framework may encourage "absent or incomplete" thought processes in users and that DSS may hinder or delay the process of gaining more in depth knowledge and skills.

A systemic and integrated approach to recreational decision support that includes education, hazard communication and a field-based decision tool has the potential to improve recreational decision-making and reduce involvement in avalanche accidents.

5. RECOMMENDATIONS

The following recommendations summarize the suggestions advocated by survey respondents for improving recreational decisions.

5.1. ***Training and Education***

- Focus curriculum around factors that support and enable sound decision making; e.g. terrain analysis, route-finding principles, human factors and trip planning,
- Integrate decision skills training,
- Emphasize courses in local terrain,
- Ensure high instructional standards,
- Teach methods to practically apply avalanche bulletins to field decisions,
- Foster opportunities for mentoring,
- Build knowledge foundations in youth,
- Integrate education within a systemic decision support framework.

5.2. ***Hazard Communication***

- Improve the scale of bulletins from regional to local in high frequency areas,
- Use language that is meaningful to recreationists,
- Describe how to practically apply bulletins to field decisions,
- Broaden communication methods to include graphics, icons and mapping tools.
- Use graphical mapping to identify terrain traps, frequent performers, exposure from above, and existing snowpack instabilities,
- Identify non-avalanche terrain,
- Describe the probabilities and consequences of involvement,
- Utilize media for information dissemination and good role modeling,
- Integrate hazard communication within a systemic decision support framework.

6. A SYSTEMS APPROACH TO RECREATIONAL AVALANCHE ACCIDENT PREVENTION

To effectively reduce recreational avalanche accidents in Canada, I propose a systems approach to accident prevention. This systems approach has two components:(1) a key emphasis on social and human sciences research, and (2), a holistic and integrated decision support system consisting of recreational education, hazard communication and field decision support.

6.1. ***Social Science Research***

Human involvement in avalanches is a complex phenomenon that involves the interaction of three factors; terrain, snowpack and humans. The avalanche industry has a strong foundation in the physical properties of snow avalanches based in natural science research however, little is know about the human component of avalanche phenomena. As a result, a significant gap exists. Sarewitz (2000) identifies the interconnectedness of the elements of natural phenomena by stating "these problems are multivariate and nonlinear, and they comprise the behaviour not only of evolving natural systems but also of humans" (p.85). Furthering the understanding of the human component of avalanche phenomena is the fundamental objective of my ongoing research.

Human sciences research focusing on qualitative methods of study offers great potential in the avalanche industry for the effective reduction of human involvement in avalanche accidents. A key recommendation in a recent government report on natural hazards and disasters in Canada identifies the critical need to support theoretical and applied interdisciplinary research and knowledge transfer. This recommendation identifies the Social Sciences as the key emphasis, since they are likely to produce

the greatest benefits in mitigating risks (Etkin, Haque, Bellisario and Burton, p. 37, 2004).

6.2. *A More Holistic and Integrated Approach*

A more holistic mode of thinking is required for designing effective avalanche accident prevention schemas. The field of systems thinking (Knowles, 2002; Midgley, 2000, Wheatley, 1999) offers an integrated approach to deriving a balanced perspective of the complexities of avalanche phenomena. Systems thinking is a holistic mode of understanding where the world and the systems within it are not divided into different parts but into different groups of connections. It is important to consider this approach to understanding complexity when designing accident prevention schemas, since we are part of the very system that we strive to understand.

It is clear from this study that the integration of expertise from a broad range of disciplines will be necessary in order to develop a holistic understanding of the physical and human elements of avalanche phenomena. From this systemic approach, sound recreational decisions can be effectively supported through a systemic and holistic framework that integrates education, hazard communication and field decision support (Figure 8).

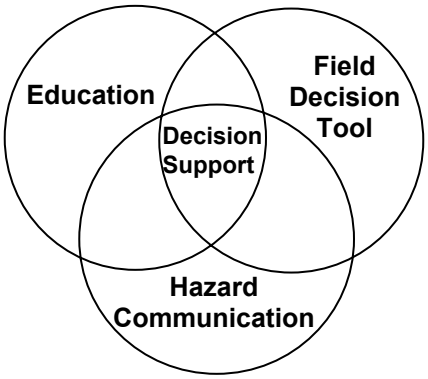

Figure 8. A proposed systems approach to decision support and recreational avalanche accident prevention in Canada.

7. ACKNOWLEDGEMENTS

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