A SYSTEMS APPROACH
TO
HUMAN FACTORS AND EXPERT DECISION-MAKING
WITHIN CANADIAN AVALANCHE PHENOMENA

By

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In

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We accept this thesis as conforming

to the required standard

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ABSTRACT

This action research project led a naturalistic decision-making inquiry into the influence of human factors in Canadian avalanche experts' decision making. Using cognitive task analysis and the critical decision method, I found that avalanche-related judgments and decisions occurred within a dynamic context influenced by individual, team, client, organizational, and socio-political human factors. Avalanche experts used a hierarchy of judgment and decision complexity that integrated rule-based, analytic, intuitive, and systems thinking modes of cognitive function. They applied strategies of pattern recognition, mental simulation, critical thinking, and metacognition within a highly developed systems approach to high-stakes judgment and decision-making. I offer six evidence-based recommendations designed to enhance avalanche judgment and decision-making capacities, and to counter the influence of negative human factors in the decision process.

ACKNOWLEDGEMENTS

I dedicate this thesis to the group of Canadian avalanche professionals who took the time to reflect upon and relate their experiences and insights to me. When I read their stories and facilitated the focus groups, I was deeply impacted by their words, and I realized how much we can all learn from their experiences of decision success and human error. This research is possible only because of their dedication and commitment to deepening our understanding of avalanche judgment and decision phenomenon.

My thanks are extended to the Canadian Avalanche Foundation, Selkirk College, and the Social Sciences and Humanities Research Council of Canada for providing financial support to my research. Thanks to Arc'Teryx for outdoor clothing and gear.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE –

FOCUS AND FRAMING

I. Introduction

This social science action research project led a naturalistic decision-making inquiry into the influence of human factors in Canadian avalanche experts judgment and decision-making processes. The general objective of my research was to extend the theoretical knowledge and experienced insight of Canadian avalanche experts to generate “action sensitive knowledge” (Van Manen, 1990, p. 21), that would enable avalanche professionals, practitioners, and backcountry recreationists to practically enhance their avalanche judgment and decision-making capacities, and reduce their involvement in snow avalanches.

My objectives were to: (1) examine and identify the judgment and decision processes of avalanche experts; (2) identify the human factors that influence avalanche experts ability to make sound judgments and decisions; and (3) explore how these findings may be used to develop strategies for decision skills learning strategies, decision support, and effective avalanche accident prevention. My hypothesis was that defining avalanche decision skills, identifying the human factors that influence decision processes, and identifying strategies to speed up the development of expertise, can improve avalanche-related judgment and decision-making, and reduce avalanche accidents.

I.1. The research question:

What are the human factors that influence avalanche expert’s judgment and decision making, and what insight do these findings offer for avalanche accident prevention strategies in Canada?

Sub-question:

What are the primary modes of cognitive function and decision strategies used by avalanche experts to solve high-stakes decision problems?

I.2. Goals of the Research

The results of this research have systemic implications for avalanche practitioners, backcountry recreationists, and avalanche protection agencies. A primary goal of the research was to generate a greater awareness of avalanche-related decision processes and human factor influences, in order to foster safe avalanche decision practices within individual and team human systems. A second goal was to inform the effective design and delivery of avalanche educational curricula, strategies for hazard communication, and decision support for accident prevention in organizational and community systems. This research is significant and has the potential to save lives.

I.3. Researcher Biography

I am an avalanche professional (Canadian Avalanche Association), a certified winter mountain guide (Association of Canadian Mountain Guides), and an adult educator with eighteen years of experience in the avalanche industry. At the time of writing, I instruct outdoor skills and mountain safety in the School of Renewable Resources at Selkirk College, and coordinate avalanche training at the Selkirk College Geospatial Research Center (SGRC) in Castlegar, British Columbia. I have sat as a member of the Education Committee for the Canadian Avalanche Association (CAA), and I am an instructor in the CAA professional training school.

During my career, I have been a resource specialist on several devastating avalanche and mountain accidents that have seriously injured people and claimed lives.

These experiences, coupled with my extensive knowledge and experience in the education and avalanche industry, have fuelled my desire to foster a greater understanding of human processes, decision making and risk management in avalanche terrain, and to design effective curricula and decision support systems that will save lives.

II. The Opportunity and its Significance

II.1. Human Involvement in Avalanche Accidents

Since 1970, 336 people have been killed in Canada by avalanches (CAA, 2003a, ¶ 3). In the ten-year period of 1994 to 2003, avalanche accidents in Canada killed an average of 15 people annually and injured 75 (Cloutier & Heshka, 2003. p. 2). 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. Clearly, avalanche safety is a significant public safety concern in Canada.

People are continuing to lose their lives in snow avalanche accidents, and this situation is of growing concern, as the number of people pursuing activities in the Canadian winter backcountry is increasing significantly. The increasing trend in backcountry use can be extrapolated from several indices: The public avalanche bulletin use increased from approximately 25,000 phone and internet users in 1994, to 775,000 in 2003 (Hein & Leiss, 2003, p.7). Winter trail use in Roger's Pass, one of Western Canada's most popular backcountry ski destinations, increased from 5,500 person days in 2002, to 6,500 in 2003 (Hein & Leiss, 2003, p.8). The total number of helicopter and snowcat skiers in British Columbia increased 26 % in the past nine years, from a total of 70,407 skier days in the winter of 1994/1995 to 88,500 in 2002/2003 (British Columbia

Helicopter and Snowcat Skiing Operators Association, personal communication, March 25, 2004). Since winter backcountry use is growing so significantly, it is vital that effective prevention methods are in place to support sound decisions, and to protect lives.

Statistics from 1998 to 2003 show 82% of avalanche fatalities occurred among recreational backcountry users while 18% occurred within commercial groups (Cloutier & Heshka, 2003. p. 7). This indicates a significant gap in the decision practices of avalanche practitioners and backcountry recreationists. 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. My research addresses this gap, by identifying the factors and processes that enable avalanche decision success in avalanche experts, and extending this wisdom to improving decision practice and reducing the accident rates experienced by both user groups.

In this thesis, 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, for example, national park public safety specialists, avalanche forecasters, ski area snow safety supervisors, and backcountry ski guides. I differentiate this from "professional" who is an avalanche practitioner, and also a professional member of the Canadian Avalanche Association (CAA). I define avalanche "expert" as an avalanche professional who has ten or more years of experience actively working in the avalanche industry.

II.2. Avalanche Phenomena

Human involvement in snow avalanches is a complex phenomena that involves the interaction of three factors; terrain, snowpack and humans (Figure 1).

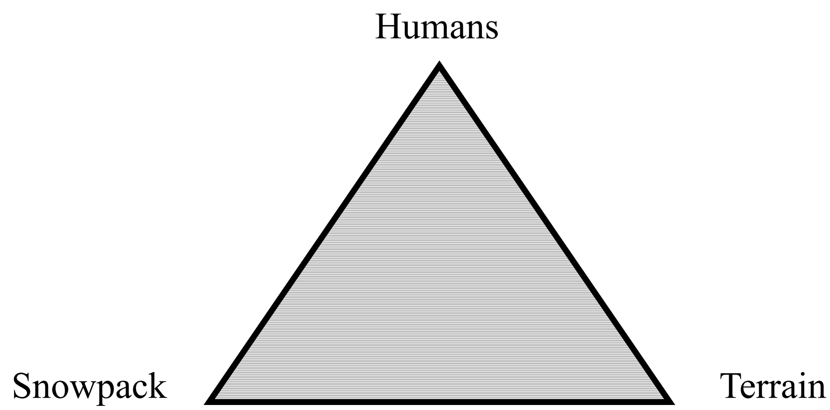

Figure 1. The avalanche triangle.

Researchers in the snow avalanche field have focused extensively on understanding the physical properties of snow avalanches, for example, snow science, avalanche release dynamics, weather and terrain factors (Collbeck, 1987; Föhn, 1989; Jamieson, 1995; McClung, 1987; McClung & Schaerer, 1993; Schweizer, Jamieson & Schneebeli, 2003). However, there is very little published literature examining the human component of avalanche phenomena, consequently our understanding of this topic is weak (Fredston & Fesler, 1994; McCammon, 2000; 2002; 2004; Tremper, 2001).

As a result, public safety avalanche prevention and education initiatives have been designed primarily around the complex physical and environmental factors. Due to the limited understanding of human factors and decision processes in avalanche terrain, these public safety and education initiatives have yet to address key human components, and therefore may be lacking in their effectiveness. "An increase in public awareness and education is necessary to prevent a continual rise in avalanche fatalities" (Cloutier &

Heshka, 2003, p.7).

In order to provide solutions that will most effectively reduce the number of avalanche accidents and fatalities, a complete understanding of all contributing factors is required. It is not sufficient to understand only the physical properties of snow avalanches and associated weather influences; we need to understand humans, and the factors that affect their decision-making in avalanche terrain. This approach offers balance and a holistic perspective to all sides of the avalanche triangle (Figure 1).

III. Systems Analysis of the Opportunity

III.1. A Social Sciences Perspective

It is of critical importance to consider avalanche accident prevention from a human sciences and systems thinking perspective. Avalanche practitioners and researchers are now recognizing the significant role human factors play in avalanche accidents. In a majority of avalanche accidents in Canada (87%), people trigger the same avalanches that kill them (McClung & Schaerer, 1993, p.15). "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).

Social science research is direly needed to understand humans and the factors that affect their decision-making in avalanche terrain. While the avalanche industry has a strong foundation in physical and environmental science research, little is known about the human component of avalanche phenomena. As a result, a significant gap exists (Figure 2). I suggest that understanding the complexities of avalanche phenomena requires considering the inter-relationships between the human, physical and environmental systems that inhere in avalanche phenomena. This approach utilizes a systems thinking perspective, and is considered essential to adequately studying and understanding complexity.

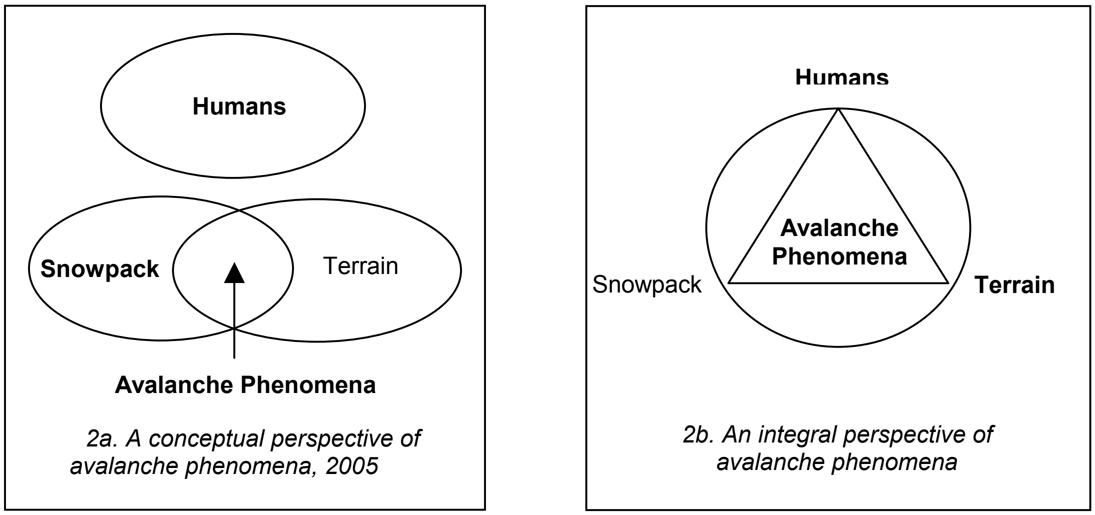

Figure 2. A conceptual and integral perspective of avalanche phenomena in Canada.

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, Bellisoria & Burton, 2004, p. 37). Furthering the understanding of the human component of avalanche phenomena was the fundamental objective of my research.

III.2. Avalanche Experts

Avalanche experts in Canada have a relatively high success rate for managing avalanche hazard, and making sound decisions in a natural hazard environment that is complex and constantly changing. The decisions these experts make are based upon temporal and spatial factors that occur over a range of scales (Figure 3). At the macro scale, sound decisions are supported by years of accumulated knowledge and extensive experience in annual, regional and local snowpack variability.

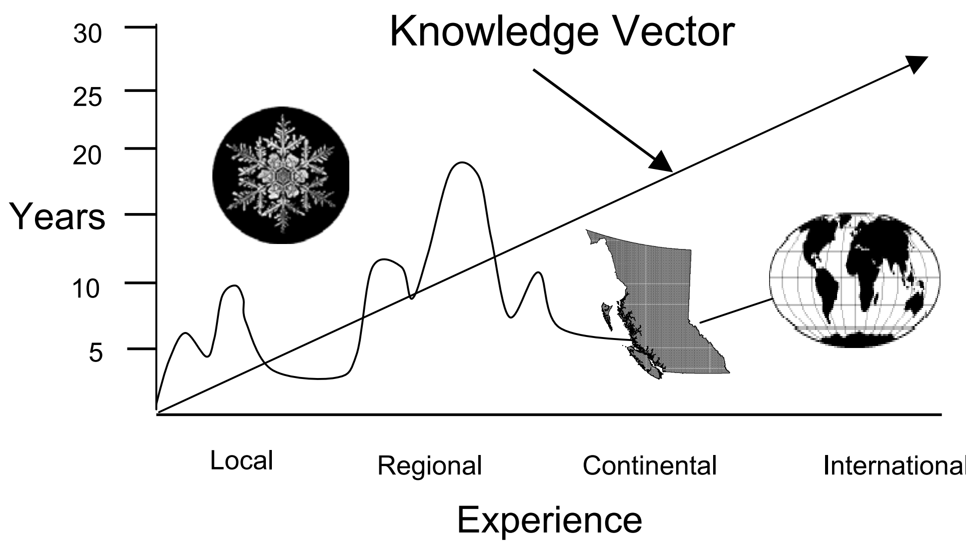

Figure 3. Experiential knowledge creation in avalanche experts.

At the meso scale, a systematic daily decision framework is utilized for considering key contributing factors to snow stability and instability. Practitioners and avalanche researchers have refined this framework over several decades of collaborative effort to improve avalanche decision capacities. A general overview of this framework consists of:

a) Snow stability forecast and evaluation summaries that consider three classifications of factors: stability factors, snowpack factors, and meteorological factors;

b) Nearest-neighbor conditions reported daily through an electronic industry exchange;

c) Mountain weather forecasts;

d) Terrain use determinations, for example, ski run color-coding schemas or terrain closures.

These decisions are then further refined at the micro scale, through direct field observations as changing conditions necessitate.

This decision success invites the question, what can be learned from these successes to further enhance the judgment and decision capacities of avalanche practitioners? As well, how can this insight be extended to practical use by backcountry recreationists? Two decades of Naturalistic Decision Making (NDM) research suggests that studying the skills that experts use to make decisions, can form the theoretical foundation of a highly effective decision skills training program for less-experienced decision-makers (Klein, 1997; Zsambok & Klein, 1997; Salas & Klein, 2001).

III.3. Recreationists

Avalanche experts recognize that recreational backcountry users do not have the same degree of knowledge and practical experience that enables avalanche practitioners to more consistently perform the complex, knowledge-based (Rasmussen, 1993) processes that are fundamental for safe decisions in winter mountain terrain (Adams, 2004). Statistics from avalanche accidents in Canada between 1984 and 1996 state common failures in the decision process of recreationists include not recognizing obvious indicators of unstable snow and, either not understanding, or choosing to ignore fundamental principles of safe terrain choice (CAA, 2003b, ¶ 10, 12). From an avalanche expert's perspective, these are primary basics of avalanche awareness.

Interestingly, in a majority of recreational avalanche accidents, victims typically had a significant amount of avalanche education and backcountry experience (McCammon, 2000, p.39). Since research indicates that humans generally have the capacity to make systematic and methodical decisions (Kahneman, 2003; Klein, 1997; Slovic, Fischhoff & Lichtenstein, 1977), this situation is perplexing to avalanche researchers and educators. Although this human ability to make sound decisions is supported by low accident rates within the community of avalanche practitioners, the statistics from avalanche accidents in Canada show winter backcountry recreationists are less successful in making sound decisions when traveling in avalanche prone terrain. My research strove to address this gap between the professional and recreational avalanche communities, and to enhance the decision practice of both user groups.

III.4. Eliciting Knowledge from Avalanche Experts

The field of Naturalistic Decision Making (NDM) offers great potential for enhancing avalanche decision-making and decision skills learning initiatives through eliciting the knowledge of avalanche experts. NDM research aimed at discovering how experts make decisions in high-stakes situations has lead to significant advances in decision-making capacities and decision-skills learning programs in the fields of aviation, military, firefighting and emergency medicine (Klein, 1997, 1998; Phillips, Klein & Sieck, in press; Pliske, McCloskey & Klein, 2001). In the NDM method, the strategies that are used successfully by experts are identified and described within the real-world context of the task. These findings are then utilized to teach less-experienced decision makers to learn like experts (Klein, 1997).

My research applied this theory to the avalanche domain, and focused on identifying and describing the critical cues, judgments, and decision processes that influence and enable sound judgments and decisions by avalanche experts. In the second phase of the research, avalanche experts attended an action research focus group, and discussed strategies for enhancing avalanche judgment and decision skills, and supporting sound avalanche decision-making. The research methodology and results will be discussed in detail in the following chapters.

IV. Organizational Context

IV.1. An Overview of Avalanche Prevention

The problem of human involvement in avalanche accidents is one that is inherent within mountain communities around the world. It is important to recognize that this public safety problem is not owned specifically by any single organization, nor is it a new problem in Canadian or international avalanche communities.

Avalanche accident prevention is fostered through numerous agencies, and these initiatives encompass the delivery of educational curricula, public safety awareness, hazard communication and terrain use guidelines. Many people believe a major barrier in Canada to avalanche prevention has been the lack of government funding commitment to this significant public safety problem. For example, in the winter of 2002/2003, the CAA received only $30,000 of government funding towards the total cost of $255,000 to produce the public avalanche bulletin (Cloutier & Heshka, 2003, p. 16). The funding shortfall of -$225,000 almost lead to the discontinuation of the PAB program in that year. This critical situation has recently been recognized and addressed with the spring 2004 announcement of increased funding and services for a National Avalanche Centre located in Revelstoke, British Columbia.

In Canada, avalanche education, public safety awareness and accident response is a collaborative effort that is carried out by non-profit, commercial, educational, and government organizations. Avalanche education is delivered at the professional and recreational level. Canadian avalanche practitioners complete their core training over an average of four years in a series of field and classroom courses administered by the Canadian Avalanche Association Technical Training Schools (CAATS) and industry apprenticeship training. After completion of the training program and a minimum of four additional years of avalanche forecasting experience, practitioners are then eligible to apply to the CAA for professional membership. These professionals further their knowledge through professional development or university courses (University of British Columbia, University of Calgary, Selkirk Geospatial Research Centre), and attending industry symposiums such as the biannual International Snow Science Workshop and the annual general meetings of the CAA.

Recreational avalanche training has long been delivered in one and two-day courses by the Canadian Ski Patrol System (CSPS) at ski areas, and since 1997 through the Recreational Avalanche Course curriculum developed and recommended by the CAA. In 2002, the Smart Risk Foundation launched Snow Smart (Mills, 2002), an educational program for young Canadians that focuses on an increased awareness of the risk and hazards associated with winter sports.

Current and forecasted avalanche conditions are communicated to backcountry users through public avalanche warnings. The CAA Public Avalanche Bulletin (PAB) describes conditions for five geographic regions in Western Canada and is updated three times each week. Parks Canada provides bulletins for park visitors that are updated daily for Banff, Glacier, Jasper, Kananaskis, Kootenay, Waterton, and Yoho National Parks. These bulletins are written from technical observations submitted daily by field observers and commercial operators who subscribe to an industry exchange (InfoEx), from information exchanged on the internet between independent guides (InformalEx), and from avalanche involvement reports filed with the CAA. In addition, many ski areas post daily avalanche warnings for conditions in adjacent terrain, and the Canadian Broadcasting System (CBC) provides radio broadcasts of the PAB in mountain communities.

IV.2. Fostering Shared Vision with the Sponsoring Organization: Selkirk College

The mission of Selkirk College is "to empower effective citizens" (Selkirk College, 2003a. p. 1), and the college has articulated the vision of being a valued educational partner that contributes to the intellectual, economic, ecological, cultural and social development of the communities it serves (Selkirk College, 2003b. p. 5). Since 1967, Selkirk College has developed a legacy of fostering public safety education in mountain safety and risk management, and has graduated learners who have pursued careers as park wardens, mountain safety specialists, avalanche technicians, forecasters and mountain guides. The college is currently working towards positioning the School of Renewable Resources (School of RRS) as "the BC and Western Canadian leader in natural resource and environmental technology programs" (Selkirk College, 2003c. p. 2).

In November 2003, the School of RRS launched a unique Canadian initiative, the Selkirk Geospatial Research Centre (SGRC), with the mandate to facilitate and support interdisciplinary applied research and professional training in physical, biological and social sciences. I was provided with a key role at the Centre to develop new curricula in avalanche forecasting and to foster avalanche research initiatives. Conducting this action research study under the sponsorship of Selkirk College offered the mutual benefits of fostering the instructional and research goals of Selkirk College while providing a challenging and supportive environment of academic excellence in which to carry out my research.

Selkirk College and the SGRC is a vibrant learning organization bringing together skilled academics from a wide variety of disciplines with the shared purpose of fostering knowledge and innovation. The Strategic Plan identifies the use of applied research as "a means of enriching curriculum and further connecting with industry partners" (Selkirk College, 2003c. p. 1). Applied research in this document is defined as "research that is action-oriented with a focus on solving problems identified by our constituents: learners, communities, business, and industry" (Selkirk College, 2003c. p. 1). My applied research project furthered the study of avalanche phenomena, and provides new insight and understanding into human factors and decision-making in avalanche terrain.

IV. 4. The Canadian Avalanche Foundation – Research Partners

The Canadian Avalanche Foundation (CAF) partnered in this research in a spirit of collaborative inquiry and discovery. The CAF is a non-profit society dedicated to public avalanche education, research, and safety initiatives in Canada. My research presented a unique opportunity for shared learning and new knowledge acquisition in the avalanche community, with the overlying objective focused towards deriving sustainable solutions to avalanche accidents that will save lives.

Avalanche accident prevention is a complex problem and the solutions to such problems of complexity often will lie not within one mind, but many. While the complexities of human factors and decision errors in avalanche accidents have been recognized for years, the necessity to implement frameworks to cope with this complexity has only arisen recently. It is clear that the integration of expertise from a wide range of disciplines will be necessary in order to fully understand the human, physical, and environmental elements of avalanche phenomena.

CHAPTER TWO –

LITERATURE REVIEW

My hypothesis was that defining avalanche decision skills, identifying the human factors that influence the decision process, and identifying strategies to speed up the development of expertise, can improve avalanche decision-making and reduce avalanche accidents. Four core topics are examined in this literature review to provide a foundation for my research: adult learning, risk psychology and management, expertise, and high-stakes decision-making (Figure 4).

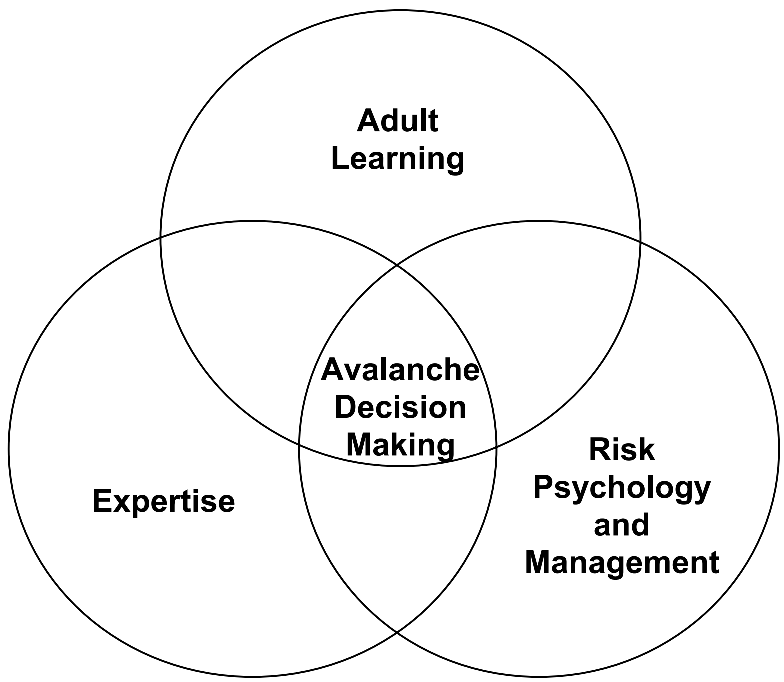

Figure 4. Conceptual model of the four core topics in the literature review.

The first topic of the literature review is an inquiry into adult learning. Action and experiential learning theories of how people learn, create knowledge, and develop understanding provides the focus. I chose adult learning as a limiting focus since my research is associated with avalanche expert's decision-making; an activity specific to adults. The second topic examines risk. Risk psychology, management, and communication provide the context for understanding risk perceptions, high-risk decision-making, and strategies for effective risk management in avalanche accident prevention. The third section of the review is an examination into expertise, including its characteristics and development. Providing insight into how this superior knowledge and performance is structured and acquired offers valuable insight into the development of schemas to foster and enhance the development of avalanche-related decision expertise. The fourth topic is a discussion of high-stakes decision-making and decision science. Theories of high-stakes decision-making are discussed, including effective methods of decision skills learning and decision support. Theories of systems thinking and communication provide an integral link to this work, and their application in avalanche-related judgment and decision-making is woven throughout the discussion.

I. Terminology

Given the specialized and complex nature of the field in which the research is situated, a glossary has been provided below to assist readers in understanding the context within which specialized terminology is used throughout this thesis.

Acceptable risk - A subjective judgment for the level of risk to which people are willing to expose themselves.

Avalanche-related decision-making - The cognitive process used to arrive at a decision action.

Avalanche Expert - an avalanche professional who has ten or more years of experience actively working in the avalanche industry.

Avalanche Practitioner - a person working in an active decision-making capacity in avalanche terrain.

Avalanche Professional - an avalanche practitioner, and also a professional member of the Canadian Avalanche Association.

High-stakes decisions - decisions characterized by high levels of time pressure, complexity, and uncertainty, and require complicated inferences and judgment for sound solutions.

Human Factors - The individual, team, client, organizational, and socio-political influences inherent in avalanche-related judgment and decision making.

Judgment - a subjective opinion about what was, is, or will be a decision-relevant aspect of the human, physical or environmental systems of influence.

*Mental model*s - conceptual structures in the mind that drive cognitive processes of understanding (Flood, 1999).

Team decision-making - a process where highly differentiated and interdependent members share information and diverse task perspectives in a decision process to achieve a common goal (Orasanu & Salas,1993).

Recreationist - a member of the general public who pursues winter backcountry activities as an un-paid recreational pursuit.

II. Review of Supporting Literature

II.1. Adult Learning -

The Construction of Meaning and Creation of Knowledge in Adults

Knowledge and understanding are a fundamental factor upon which humans base their decisions. Within this core topic, I examined the theories of adult learning and experiential knowledge creation in the context of identifying the critical knowledge and learning processes that enable sound avalanche-related decision-making and effective decision skills learning strategies.

II.1.1. Processes of Adult Learning

Discovering the true meaning of life experience through analysis and inquiry into this experience is the essence of adult learning (Knowles, Holton & Swanson, 1998; Kolb, 1984; Taylor, Marienau & Fiddler, 2000). Learning develops through interactions with our environment, involving an ongoing process of differentiating and integrating meaningful ideas and events. The nature of this development varies within individuals, and is influenced by our own unique experiences, opportunities, and circumstances of life. "The dynamic intersection between learning and development concerns the fundamental change in how meaning is made or *how we know what we think we know*" (Taylor et al., 2000, p. 13). We create and construct knowledge through a process of perceiving and understanding experience and events, and then transforming this knowledge into changes in our behaviour and life practice.

Malcolm Knowles (1980) spent many years defining adult learners, and identified the learners' experience as being the most valued resource in the learning process. This is consistent with the findings from a study of Canadian avalanche practitioners where experience was identified as the key enabling factor in sound avalanche decision-making (Adams 2004). Knowles identified that adults are motivated by the "need to know" that comes from real life experiences, and adults have a "readiness" and motivation to learn in order to live their lives effectively. Adults "learn new knowledge, understandings, skills, values, and attitudes most effectively when they are presented in the context of application to real life situations" (Knowles et al., 1998, p. 67).

Knowles et al. (1998) contrasted traditional learning process centred on pedagogy (teaching children) with "andragogy – the art and science of helping adults learn" (p. 61). According to Knowles et al., effective adult learning environments centre on the learner as an active participant, instead of a passive recipient in the learning process, where the analysis of experience is the true root of learning. The resulting knowledge occurs through a process of creative construction. "When adults realize that they construct their ideas and beliefs … they experience themselves and the world around them differently" (Taylor et al., 2000, p. 17).

II.1.2. Experiential and Action Learning

The process of learning, discovery, and growth that results from reflecting upon our experiences is called experiential learning (Cusins, 1996; Kolb, 1984; Zuber-Skerritt, 2002). During this reflective component, we critically analyze past events and experiences, with the goal of obtaining new insight and understanding that often results in a change in our future behaviour. The key learning comes from the process of gaining understanding, when we are attempting to make links between the individual pieces of information. This linking process forms trends and patterns from which our meaning grows.

Action learning (Marquardt, 1999) is an enhanced form of experiential learning that includes a natural sequence for creative problem solving, decision-making, and knowledge development that is stimulated through group discussion. The discussion process enhances the learning and decision making capacity of the individual and of the group, by adding information, resources, and diverse perspectives. Action learning processes offer a powerful potential for creative decision-making, enabling us to find the best solutions for complex problems that are faced in our lives and in our work. Guide and snow safety staff meetings that occur in the morning and evening of each day at ski operations are an example. Through the process of sharing information and perspectives in a real-world environment, dramatic shared knowledge and understanding is created.

David Kolb (1984) identified humans as "the learning species" (p. 1), having the unique ability to adapt to the physical and social world through an integrative and proactive process of creating and shaping the world we live in. He described learning as a holistic continuum that is the driving process of creating knowledge. "Learning is the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). According to Kolb, experiential learning occurs as a cycle of four adaptive learning modes – "concrete experience, reflective observation, abstract conceptualization, and active experimentation" (1984, p. 42). Learning and the creation of knowledge from his perspective, requires both understanding and transformation of the experience.

Cusins (1996) proposed a wave model of experiential learning that symbolizes the continual transformative progression of learning and growth. The model is placed within the context of past, present and future, and involves gathering information, making sense of the situation, and application planning with deeper insights for the future. The wave continues and the learning evolves when the next event occurs. According to Cusins, informed, creative decision-making is at the heart of the action learning process. He emphasized that the gathering of additional relevant knowledge is critical for understanding. "Decisions made without some attempt to update the current state of knowledge during the decision-making process may place an individual at a disadvantage" (Cusins, 1996, p. 23). In the avalanche domain, McClung (2002) stated, "the only entities that can truly reduce the uncertainty are more (new) information data of the right kind, or actions that deal with the resolution of variation in human perception" (p. 114).

Zuber-Skerritt (2002) contrasted the traditional learning processes of external and objective knowledge transfer to that of action learning, where learners create their own knowledge and own the solutions to the problems they face. "Action learning recognizes the possibility for learners to generate knowledge, rather than merely absorbing passively the results of research produced by specialists" (p. 115). Zuber-Skerritt suggested the key to the success of action learning is the immediate relevancy with the learner's practical life and work situation.

However, he emphasized the critical importance of a systematic framework for reflecting and understanding the experience. "Learning from one's experience can be powerful, but it can also be inefficient if it is not followed through by formal and systematic opportunities to conceptualize the effect of this experience" (Zuber-Skerritt, 2002, p. 115). He suggested questioning and thinking critically about new and taken-for granted knowledge is a key tool in this process. When these tools are utilized, action learning offers the outcomes of improved strategic thinking and creative problem solving, which enables people to develop new knowledge and to derive effective and practical solutions to the problems they face.

II.1.3. Hermeneutics; The Creation of Meaning

Hermeneutics is the study of how meaning is created; the processes of interpretation and understanding that is generated from within life experience (Boyles, 1994; Doud, 1999; Gottesman, 1996). We experience life within the context of individual moments of meaning. Each of these experiences is uniquely personal and occurs in a cumulative process over time. "Experience happens within our pre-reflective consciousness from which the main categories of humanistic thought are derived" (Dilthey, as cited by Doud, 1999, p. 9). Human understanding comes from how we interpret these experiences in relation to our personal perspective, one that is developed from uniting past moments with present experience and future awareness. Learning occurs in each of these moments and in every moment that precedes the moment of significance that results in a break-though of new understanding.

According to Doud (1999), the full context of meaning is created from inside of our own experience, expression, and understanding. In his view, meaning has a critical historical component. "It is a relationship of whole to parts seen by us from a given standpoint, at a given time, for a given combination of parts" (Doud, 1999, p.7). Doud suggested that there is no objective knowledge without subjective reference. "We take objective data given to us in the world and we absorb it according to our own subjectivity. We also check our subjective impressions against the emergent picture of objectivity as it unfolds before us" (Doud, 1999, p.3).

This continual process of meaning making is an expression of our inner life that requires the context of our past experiences in conjunction with a dimension for the future. We are constantly shifting the cognitive framework within which we interpret new experiences. Therefore the meaning that emerges and the knowledge that results are in a constant state of transformation. Knowledge creation requires the combination of understanding, interpretation, and communication that can be practically applied to new circumstances.

Boyles (1994) added a social dimension to the process of meaning making. "Members of society are dependent upon dialogue and interpretation for understanding to result" (Boyles, 1994, p. 13). He suggested that meaning making must also be considered as a process of co-creation that is influenced by cultural and environmental factors. Boyles brought forth the important point that these factors can influence us to construct "correct interpretations" under external dictates.

Gottesman (1996) argued that interpretation and understanding come from within a personally unique "horizon" of awareness (p. 3). What we *see* in our horizon is formed from our own system of cognitive schemas and values, and to understand an idea or an event we must first recognize it. This process of recognition is accomplished through the act of pairing or matching. "Every conscious perception is… an act of recognition, a pairing, in which an object (or an event, an act, an emotion) is identified by placing it against the background of an appropriate symbol" (Geertz, as cited by Gottesman, 1996, p. 5). An item or event that is different or unknown, to which no matches can be placed, will not be recognized and therefore holds no meaning in the present. "To successfully accommodate these new experiences requires a larger, more complex frame of reference" (Taylor et al., 2000, p. 11). Knowledge creation is therefore a continuum, and results from temporal and spatial shifts in our personal horizons.

This discussion of adult learning and knowledge creation provides the theoretical foundation to understanding the context of risk, expertise, and high-stakes decision-making that I present in the following sections of the literature review. These principles also provide the theoretical underpinning of the recommendations for avalanche-related decision support and decision skills learning strategies that are discussed in the conclusions and recommendations of this thesis.

II.2. Risk; Psychology, Perceptions, Communication, and Management

Risk can be thought of as an expression of uncertainty in the world. The presence of risk resulting from exposure to avalanche hazard is inherent in mountain snow environments. As a result, risk assessment, analysis, and communication is a fundamental component of the decision context when dealing with avalanche phenomena. The weighing of risk and it's associated benefits and consequences lie at the heart of the decision process (Aven & Kørte, 2003; McClung 2002; Wilde, 2001).

The avalanche risk analysis process strives to produce predictions of exposure that are complicated by inherent uncertainty resulting from complex physical (terrain), environmental (weather, snowpack), and human factors. As a result, risk is a multi-dimensional phenomenon, and how we think of it is complex and multi-faceted (Coleman, 1993; Tyler & Cook, 1984).

II.2.1. Conceptions of Risk

A conclusion from my review of risk literature is that there are multiple conceptions of risk. These varying conceptions exist at individual, organizational and societal levels, as well as between the physical and social sciences. In statistical modeling, for example, risk is a known parameter. A common definition of risk in physical sciences is the chance or probability that exposure to a hazard will result in damage, injury or loss of life (McClung, 2002). However risk, as viewed by social scientists, is a social construct that is invented to help us cope and understand the dangers and uncertainties of life (Mellers, Schwartz & Cooke, 1998; Slovic, 2001). Slovic (2001) argued that risk does not exist externally, waiting to be measured. "Risk assessment is inherently subjective and represents a blending of science and judgment with important psychological, social, cultural, and political factors" (p. 23).

It is important to differentiate between hazard and risk in this discussion. Hazard is defined as the nature or source of the harm, and in this research is identified as avalanche hazard. When exposure to avalanche hazard is present, avalanche risk exists. Exposure varies with terrain characteristics (aspect, elevation, terrain shape and size), and is further complicated by variations in snow cover and snow instability (probability of triggering an avalanche) (Bruns, 1997; McClung, 2002). As a result, avalanche hazard assessments are an order of magnitude more complex to estimate than snow instability (Bruns, 1997).

II.2.2. Risk Perception

We all experience different levels of perceived risk resulting from our attitudes, beliefs, feeling and cognitions about risk (Aven & Kørte, 2003; Coleman, 1993; Slovic, 2001). Perceived risk depends upon our knowledge of the hazard, our past experience with that hazard, our personal attitude towards risk taking, our assessment of the probability of exposure in the current situation and conditions, and our degree of decision confidence in relation to the level of situational uncertainty (McCammon, 2004; Slovic, 2001; Wilde, 2001). Our propensity to take risks also has a significant effect on our behaviours. Risk propensity depends upon individual factors such as our personality, life experience, and lifestyle, as well as social and cultural factors such as age, being part of a group, or having a family (McClung, 2002; Wilde, 2001).

The risk equation is qualitative and complex, resulting in a broad conception of risk across the population, especially between experts and laypeople (Dunwoody & Neurwith, 1991; Gurabardhi, Gutteling & Kuttschreuter, 2004; Slovic, 2001). Where experts may recognize *real* risks in hazardous situations, laypeople have a wider dimension of *perceived* risk (Coleman, 1993; Dunwoody & Neurwith, 1991). Gurabardhi et al., (2004) suggested that the risk assessment of laypeople is best described with subjective risk characteristics (such as dread or controllability), than with objective risk indicators (such as expected mortality). Slovic et al. (1977) reported that government policies for natural hazard management were unsuccessful since people did not perceive flood hazards the way that policy experts expected them too. As a result, Flynn and MacGregor (2003) highlighted the critical need for a viable framework in risk communication that provides some common ground for discussion between expert and lay interests.

Research indicates that we make very different risk assessments for ourselves as compared to when we are making those same assessments of others (Tyler & Cooke, 1984). Our tendency is to underrate our own vulnerability to risk, yet judge others as having a greater susceptibility (Gurabardhi et al., 2004; Tyler & Cooke, 1984; Weinstein, 1987). Tyler and Cooke (1984) described risk in the categories of personal and societal, and argued that the factors contributing to our personal sense of risk are not necessarily the same factors that contribute to our view of societal levels of risk. Slovic et al. (1978) suggested that societal risks are distinguished by their involuntary characteristics and perceived lack of controllability.

The sense of control we feel about accomplishing a behaviour is another variable in perceived risk (Litt, 1988; Slovic, 2001). People who have a high sense of control, or self-efficacy, are more likely to follow positive, healthy behaviours than those who have low self-efficacy (Litt, 1988). Bruns (1997) suggested that the degree of control is directly related to the extent of our risk perception, and that high sense of control is exercised by avalanche terrain avoidance, mitigation techniques, and conscious choice.

Risk perceptions are significantly influenced by external human factors such as media and social elements (Adams, 2004; Tversky & Kahneman, 1974). For example, the role of media extreme role modeling was identified as a significant influencing factor in recreational avalanche decision-making (Adams, 2004). Since avalanche accident statistics in Canada from 1984 to 2003 identify males in their twenties as the typical accident victim (CAA, 2003b), this is a factor worth considering in risk management strategies.

McClung (2002) identified human factors and variations in human perception and estimation as a key uncertainty in avalanche-related decision-making. Most avalanche deaths in North America and Europe result from people triggering the same avalanches that kill them (McClung & Schaerer, 1993). McClung suggested the root cause of these accidents was a failure in human perception, where the victim's perception did not match the reality of the avalanche danger (McClung, 2002).

Voluntariness in risk exposure is an important consideration in perceived risk.

Research suggests that our tolerance for risks that we choose to expose ourselves to is far greater than in those situations where we do not voluntarily make that choice (Wilde, 2001). While there is a risk of contracting brain cancer, a person does not voluntarily or consciously expose themselves to the associated risk factors. In contrast, the risk of lung cancer is very real for smokers; however smokers continue to knowingly engage in the behaviour directly associated with contracting lung cancer, leading to the assumption that their voluntarism means they have a higher tolerance for this risk.

In the avalanche domain, while the risk perceptions of winter backcountry users may vary widely, these users are voluntarily exposing themselves to the associated hazards inherent in winter mountain environments. This conscious choice is in contrast with people traveling on highways that are threatened by avalanche potential, since they may be completely naïve to the existence of avalanche hazard or their exposure to it. Thus, their risk tolerance is minimal. A third example lies somewhere in between, in situations in which people hire a guide to assume responsibility for their enjoyment and safety, and while they may have some awareness of avalanche hazard, they may have little active role in the assessment and associated decisions regarding their risk exposure.

Familiarity is another influence in perceived risk, since we tend to underestimate the frequency of familiar risks and overestimate the frequency and consequences of those that are unfamiliar (McCammon, 2002; Wilde, 2001). In a study of recreational avalanche accidents in the United States, McCammon (2002) found that 69% of avalanche accidents occurred on slopes that were very familiar to the accident victims. He suggested that in victims with avalanche training, familiarity with a slope tended to negate the benefits of knowledge and experience.

II.2.3. Risk Judgment

Risk judgment addresses the larger social and psychological context of risk. This context includes the cognitive and affective domains, as well as the characteristic and influences of direct and indirect risk communication, political and legal constraints, and the roles of public values and worldviews (Flynn & MacGregor, 2003). Risk judgment is defined as the way we evaluate and characterize hazardous activities in our cognitive and affective dimensions (Dunwoody & Neurwith, 1991; Slovic, 1987). For example, in the cognitive dimension, we assess our own likelihood of being exposed to the avalanche hazard, while the affective dimension describes the concern or dread that we feel about the risk of avalanches.

II.2.4. Avalanche Risk Assessment

Avalanche risk assessment must provide for a conservative estimate of loss in consideration of accurate data and evidence, for example weather and snowpack observations, as well as make predications for uncertainty. However, the traditional view of risk characterized by probabilities and consequences does not capture the subjective and contextual factors inherent in risk assessment. In reality, making judgments regarding the probabilities and consequences of avalanche occurrences under this inherent uncertainty is guided by social, ethical, legal and economic criteria (Aven & Kørte, 2003; Flynn & MacGregor, 2003; Slovic, 2001).

While the search for accurate and objective probability values is a goal of the risk assessment process, the process is driven by the boundary conditions of the decision problem (Aven & Kørte, 2003). Boundary conditions in the avalanche domain include the physical environment, the knowledge, values, and attitudes of the decision maker, the organizational goals and objectives, and societal values. Since risky decisions are multi-dimensional, subjective, value-laden and frame-sensitive, risks need to be assessed and characterized in the context of these boundaries. Including these secondary dimensions of risk may have a significant influence in the formation of attitudes towards risk (Slovic, 2001, p. 22).

The context of risk is an important consideration in accurately assessing risk. There are stochastic (random) occurrences for which we can accurately calculate risk over long time periods and broad scales using empirical data. An example is life insurance, where actuaries calculate the risk of someone dying based on exact and known risk factors. While these calculations have high levels of accuracy over broad temporal and spatial scales (e.g. for a ten year period across Canada), it does not mean that they can predict whether or when a specific individual will die (Dr. R. D'Eon, University of British Columbia, personal communication, November 1, 2004). In the same way, broad trends in avalanche activity are predictable to some extent, but no one can predict exactly when and where an avalanche will occur. Quantitatively predicting avalanche risk is therefore scale dependant.

This kind of quantitative assessment of risk can be described in relation to actual avalanche occurrences and return periods. Avalanche return periods are the frequency that avalanche debris reaches the run-out zone in a specific avalanche path classified in a temporal scale of years. The avalanche return period can vary significantly, from several times per year to one event per 300 years, and is used to determine the level of acceptable risk for human use and structures in the area (McClung & Schaerer, 1993). However in Canada, these empirical data of avalanche frequency vary widely in spatial and temporal density, therefore the risk assessment predictions are bound to be less accurate.

The physical properties of avalanche accidents and the demographics of avalanche victims have only been consistently recorded since 1979 in Canada (Schaerer, 1987, p.1), although sporadic data exists from a retrospective collection of accident data between the period of 1943 to 1978 (Stethem & Schaerer, 1979; 1980). However, an important consideration is that these data do not reflect the full extent of avalanche hazard due to innumerable unreported involvements that sustained either no or minor injuries as a result of their involvement (Schaerer, 1987).

Risk can also be described qualitatively, and this method is used in Canada with the Avalanche Danger Scale. This avalanche risk rating describes the probability of avalanches occurring in relation to the likelihood of triggering using qualitative descriptors of low, moderate, considerable, high and extreme. It is interesting to note that research indicates that expressions of terms such as likely or probable are vague, and that people have dramatically different ideas about what these terms mean (Hönekopp, 2003). Adams (2004) reported that avalanche professionals in Canada perceive that winter recreationists are basing their decisions on passive, subjective interpretation of hazard terminologies such as "considerable", and recommended that communicating avalanche hazard and risk in a variety of forms, such as icons, graphical mapping and GIS, has the potential to improve decision-making and reduce avalanche accidents.

II.2.5. Avalanche Risk and Decision Making

The avalanche risk assessment process is a dynamic process and the goals differ by context. Traditional risk assessments often utilize cost benefit analyses, however the benefit component is not constant in the equation. The difference between avalanche forecasting for backcountry skiing versus for highways public safety is an example. In backcountry skiing, the cost of exposure to avalanche hazard may result in injury or death, however the benefit of exposure is an exhilarating ski down a deep powder-covered mountain-side. Research shows that affective (emotional) responses to risk directly correlate with whether we over or underestimate our likelihood of harm (Dunwoody & Neurwith, 1991; Slovic, 1987; Wilde, 2001). McCammon (2004) identified two risk characteristics that significantly impact behaviour in winter mountain terrain: first, a great deal of control is exercised over exposure to avalanches, and second, this exposure is typically associated with highly positive, affective experiences.

Forecasting avalanches for highways has a different goal since drivers are not deriving any benefit from being exposed to avalanche hazard, other than avoiding a road delay. As a result, the onus is on the highways avalanche forecaster to make conservative estimates of the risk, and in some cases, close the highway to control the risk, in order to ensure that avalanches do not threaten unwary vehicle traffic.

2.5.1. Acceptable Risk

Acceptable risk is a subjective judgment for the level of risk to which individuals are willing to expose themselves. This level is uniquely personal and depends upon the variables I have discussed earlier in this section. Wilde (2001) proposed his Risk Homeostasis Theory to explain how humans conduct themselves when faced with risk. The theory describes how people accept a certain level of subjectively estimated risk to their health, safety and property in exchange for benefits they hope to receive from engaging in risky activities. A person assesses the risk they feel they are exposed to and then compares this with the amount they are willing to accept. These perceived and accepted risks are constantly compared in order to maintain a balance. Therefore, if the perceived risk is lower than the acceptable risk, people will increase their exposure to risk. If the perceived risk is higher than their acceptable risk, people will exercise more caution.

> People alter their behaviour in response to the implementation of health and safety measures, but the riskiness of the way they behave will not change, unless those measures are capable of motivating people to alter the amount of risk they are willing to incur (Wilde, 2001, p, 6).

Wilde (2001) then proposed his theory of Target Risk, suggesting that the target level of accident risk is determined by four categories of motivating factors: (1) The expected advantages of the risky behavior, for example an exhilarating ski down a powder-covered mountainside; (2) the expected cost of the risky behavior, for example injury or death from avalanche involvement; (3) the expected benefits of safe behavior, for example returning to family at the end of the day; (4) the expected costs of safe behavior, for example failure to ski a desirable line. As a result of these theories, Wilde suggests that the only way accidents will be effectively reduced is through attempts to reduce the level of risk accepted by people and society in general (Wilde, 2001, p. 32).

McClung (2002) proposed the Risk-Decision Matrix for backcountry skiing that displays the relationship between risk propensity, risk perception and decision-making (Figure 5). He suggested that error-free decisions fall within an operational risk band (ORB) that is delineated by two types of errors; accidents and excessive conservatism.

These decisions are achieved by estimating the costs associated with exceeding the band limits. Decisions that exceed the upper limit of the ORB result in injury, death or structural damage, while those exceeding the lower limit include loss of freedom, loss of credibility in forecasted warnings, or significant economic implications, for example excessive delays in opening roads or ski runs (McClung, 2002).

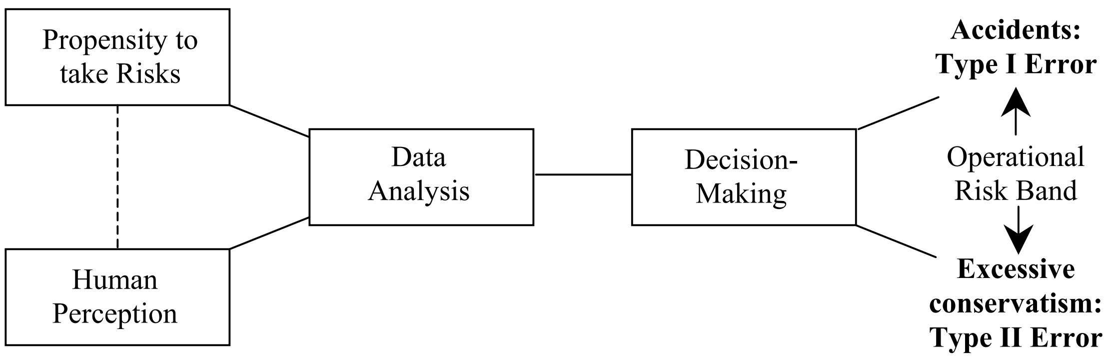

Figure 5. Schematic showing integration of human factors into decision making with error free decisions in the Operational Risk Band (ORB). Correct decisions fall within the ORB.

Note. From "The elements of applied avalanche forecasting: The human issues," by D.M. McClung, 2002, *Natural Hazards 25*, p. 117. Copyright 2002 by D.M. McClung. Reprinted with permission.

II.2.6. Communicating Avalanche Risk Effectively

Risk communication is an important societal need since it aims to exchange critical information regarding potential threats to people's health, safety or general well-being (Gurabardhi et al., 2004). The concept of communicating different hazards and risk contexts has been a central focus of risk management, however how to achieve this effectively has been an issue of debate amongst scientists and practitioners (Fischoff, 1995).

In an attempt to define the best way to conceptualize risk communication, researchers have tried to understand public risk perception in order to design more effective risk communication that could be used by practitioners (Gurabardhi et al., 2004; Wilde, 2001). A number of solutions resulted. Kunreuther et al. (2002) suggest the development of *prescriptive heuristics,* rules of thumb that enhance the accuracy of risk perceptions, can be an effective aid for good decision-making. Presenting risk as frequencies instead of probabilities (Karelitz & Budescu, 2004), adjusting the time frame to consider the immediate consequences (Slovic, Fischoff, & Lichtenstein, 1978), and framing the outcome, for example by describing mortality versus survival (Kahneman, 1991) are several examples of prescriptive heuristics. However effective these methods may be, utilizing methods that reduce the level of risk acceptance should be an underlying principle of risk communication and management strategies (Wilde, 2001).

II.2.7. A Systems Approach to Avalanche Risk Management

While formal assessment procedures such as snow stability forecasts and checklists are relied upon to minimize risk, it is important to recognize that these methods are fraught with complexity and uncertainty, requiring the exercising of considerable value-laden judgment (McClung, 2002; Stefanovic, 2003). Stefanovic (2003) argued that while scientific facts can be used to support one's position, the facts alone are not sufficient to ensure sound decision-making. "It is simply naïve to assume that the generation of data or interpretation of that data is ever value-free or presuppositionless" (Stevanovic, 2003, p. 241). In relation to avalanche forecasting, McClung (2002) stated, "the only entities that can truly reduce the uncertainty are more (new) information data of the right kind, or actions that deal with the resolution of variation in human perception" (p. 114).

Quantifying a phenomenon by breaking it down into its component parts is a reductionism approach that drives the thinking of contemporary natural hazards assessment (Stefanovic, 2003). Cost-benefit analysis is an example, and is often used in risk management, where the pros and cons of alternatives are identified, analyzed, and precisely measured. Stefanovic argued this focus is often pursued at the expense of a more holistic mode of thinking about natural disasters. The importance of understanding the relations between individual phenomena requires a systems thinking perspective, one that is considered integral to adequately studying and understanding complexity (Wheatley, 1999).

A systems approach is integral to the study of living system, for example ecology, however has only recently been applied to understanding human complexity (Senge, 1990; Flood, 1999; Wheatley, 1999). In the science of living systems, this concept is referred to as emergent properties. The concept is that we simply can't achieve a holistic understanding through reducing a system down to its component parts, since the system is more than the sum of the parts. As the system properties combine, different properties emerge that cannot be predicted by examining the sum of the parts. A classic example is water. Knowing about the component parts of hydrogen and oxygen tells us nothing about water, which is an emergent property of the system and bears no resemblance or similar properties to its parts. It is important to consider this approach to understanding avalanche phenomena, since we are part of the very system that we strive to understand.

This discussion of risk demonstrates that how we think about risk at individual, group and societal levels is indeed complex. It builds upon the discussion of adult learning and knowledge creation, and emphasizes the importance of understanding the complexities of risk from within a holistic systems thinking perspective. It is critically important to understand how risk is perceived and evaluated in order to design effective strategies for avalanche risk management. "There is no single body of knowledge that explains what works and what doesn't when it comes to helping people make better decisions in the face of risk" (McCammon, 2004, p. 2).

II.3. Expertise

Experts are those individuals who have achieved a level of exceptional skill, knowledge, and abilities in their domain of expertise, relative to the average person (Phillips, Klein & Sieck, in press; Shanteau, 1988). It is widely established in the literature on expertise and performance, that in most cases, a minimum of 10 or more years of experience is required to develop expertise (Ericsson & Charness, 1994; Ericsson, Krampe & Tesch-Römer, 1993; Klein, 1997; Simon & Chase, 1973). Early research attributed outstanding performance to genius, special gifts, and divine intervention (Murray, 1989). However, recent research has shown that the characteristics of expertise are acquired through experience and deliberate practice (Ericsson et al., 1993; Ericsson & Charness, 1994; Shanteau, 1988).

In my review of the literature on learning and expertise, experience stands out as the fundamental factor in the creation of intelligence, knowledge, and expertise. Intelligence, for example, is developed through our life experiences. "The common meaning of intelligence is the ability to learn or understand from experience" (Kalaidjieva & Swanson, 2004, p.147). This theme of experience is a key thread throughout this literature review.

Shanteau (1988) made three distinctions in types of expertise. First, is the difference between *perceptual experts*, who can perceive differences unobvious to others, and *cognitive* experts, who can discover relationships not found by others. His second distinction is between *knowledge experts*, who make decisions based upon large amounts of information, and *inference or diagnostic experts*, who can make decisions based on limited information in the face of uncertainty. The third distinction is between *advice experts* who are relied on to provide information to others, and *action experts*, who are skilled in carrying out decisions (Shanteau, 1988, p. 212).

II.3.1. Experiential Knowledge Creation of Experts

Research on expertise has shown that key characteristics of experts' performance are acquired through experience (Ericsson et al., 1993; Klein, 1998). Experience is also considered essential to objective avalanche forecasting, not only to accurately evaluate the snowpack, but also to aid complex decisions and avoid dangerous human biases (McClung 2002). How experts use their experiences to create knowledge is the fundamental factor in the development of expertise. "The primary distinction that separates experts from novices appears to be the breadth and depth of their domain –

specific knowledge" (Phillips et al., in press, p. 5).

II.3.2. Categories of Expert Knowledge and Expertise

Experts have superior knowledge, skills, and information processing capacities acquired through experience (Ericsson & Charness, 1994). How experts organize and access their knowledge distinguishes individuals at different levels of expertise (Anderson, 1983; Chi, Glaser & Rees, 1982; Klein & Militello, 2001; Phillips et al., in press). Cognitive psychology research has shown that experts are superior to novices in every aspect of cognitive functioning including memory, learning, problem solving, and reasoning (Anderson, 1981). This is the domain-specific expertise identified by Phillips et al., in press. In subsequent research, Anderson (1983) described two kinds of knowledge that sets experts apart. *Declarative* knowledge describes what experts know that others do not, and *procedural* knowledge describes what experts can do that others cannot (Anderson, 1983).

In their Naturalistic Decision Making research, Klein and Militello (2001) also identified the presence of different types of knowledge and how it is used as a key differentiation between experts and novices. In addition to recognizing the declarative and procedural knowledge described by Anderson (1983), Klein and Militello (2001) suggested experts have several additional categories of knowledge associated with expertise: (a) fine perceptual skills; (b) extensive mental models; (c) a sense of typicality and associations; and (d) extensive routines or tactics for getting things done (Klein & Militello, in press, as cited by Phillip et al., in press). These categories of knowledge appear to link with Shanteau's (1988) three types of expertise discussed earlier in this section.

However, the accumulation of experience as a single factor does not necessarily produce expertise. It is what we do with these life experiences that makes the difference. "The maximal level of performance for individuals in a given domain is not attained automatically as a function of extended experience, but the level of performance can be increased even by highly experienced individuals as a result of deliberate efforts to improve" (Ericsson et al. 1993, p. 366). In a study of battle-ground commanders, Serfaty, Macmillan, Entin and Entin (1997), found that expertise did not correlate with years of experience in their domain. Instead, they identified that expertise developed in individuals who actively used their experience to derive new insights and understanding.

Shanteau (1988) proposed a set of characteristics that encompass the abilities and decision style of experts. Experts (1) have highly developed perceptual and attentional abilities; (2) have a sense of what is relevant and irrelevant when making decisions; (3) have the ability to simplify complex problems; (4) can effectively communicate their expertise to others; (5) are better able to handle adversity and stress than novices; (6) are selective in choosing decision problems; (7) show strong confidence in their decisions-making abilities; (8) have current and extensive content knowledge; (9) are more creative in discovering new decision strategies; and (10) find it difficult to articulate the processes and strategies used to make their decisions (pp. 210-211).

II.3.3. Strategies of Expert Decision Makers

Research in expertise, performance enhancement, and Naturalistic Decision Making (NDM) concludes that experts have the capacity to quickly recognize and interpret complex patterns in situations and information (Dreyfus, 1997; Klein, 1998; Klein & Militello, 2001; Klein & Militello, in press; Phillips et al., in press). Experts use associative inferences and patterns to judge what is typical in a situation, and are able to quickly see anomalies that depart from this typicality.

This knowledge utilization strategy also enables experts to detect the early signs of problems. Experts use mental models and causal frameworks that explain how things happen, and to mentally simulate what will happen in the future. They have also developed extensive routines that permit them to make rapid judgments (Klein & Militello, 2001, pp. 181-182). Similarly, "experts' memory for representative stimuli from their domain is vastly superior to that of lesser experts" (Ericsson et al., 1993, p. 365). Novices face significant limitations since they lack the experientially created knowledge to perform skills and cognitive processes at this level.

Shanteau (1988) proposed six strategies that experts use to overcome the effects of cognitive limitations and make successful decisions: Experts (1) are willing to adjust their initial decisions in light of subsequent feedback; (2) rely on others to gain additional insight and perspective to assist them in making decisions; (3) learn from past decisions and make appropriate changes to future decision strategies; (4) have developed informal decision aids allowing them to avoid the biasing effects of heuristics; and (5) may make small errors when making decisions, however they generally avoid large mistakes (p. 209).

The following section discusses in further detail how experts use their specialized knowledge to perform strategies of pattern recognition, mental simulation, and metacognition for effective decision-making.

3.3.1. Pattern Recognition

Expertise is characterized by individual mastery of a large repertoire of familiar patterns and their associated responses (Cohen, Freeman & Wolf, 1996, p. 206). When faced with complex and uncertain situations, experts draw upon these patterns and analogous experiences and recognize the obvious way to make decisions (Klein, 1993, 1998; Shanteau, 1988). NDM research shows that experts in diverse domains have a heavy reliance on perceptual skill and recognitional strategies (Hoffman, Crandall & Shadbolt, 1998; Klein, 1998, 2003). For example, Bruns (1997) described how ski guides think in patterns and relate to them in an increasingly subconscious process as the decision complexity increases. He suggested that the most valuable database a guide can have for avalanche-related decision making is relating these patterns of snowpack evolution and distribution of natural activity over time.

In 1986, Klein, Calderwood and Clinton-Cirocco proposed the Recognition-Primed Decision Model (RPD) that integrates two decision processes: first, how decision makers judge the situation to recognize the sensible course of action, and second, how the action is evaluated through a process of mental simulation. After 15 years of extensive research in NDM, Klein (1998) concluded that 80-90% of the decisions made by experts in his studies utilized a recognition-primed strategy. The details of this model are discussed in Chapter Four, as they directly relate to the findings of my research.

Experts also have richer and more diverse mental models that enable them to detect anomalies early in the situation analysis. "The repertoire of patterns that allows experts to recognize situations as typical, also enables them to spot information that is expected but missing from the picture, and to detect anomalies that are present but not expected" (Phillips et al., in press). Identifying missing information and anomalies enables experts to adjust their judgments and decision actions accordingly.

3.3.2. Mental Simulations

Experts' use of mental simulations and envisioning has been extensively documented by decision researchers (Cohen, Freeman & Wolf, 1996; Klein, 1998; Klein & Crandall, 1995; Phillips et al., in press). Mental simulation is an envisioning strategy where people use their imagination to construct a sequence of events to observe the outcome. Kahneman, Slovic and Tversky (1982) identified this process in their heuristics and biases research, describing it as a simulation heuristic. "Experts can use their detailed mental models, coupled with their understanding of the current state of the situation, to construct simulations of how the situation is going to develop in the future, and thereby generate predications and expectations" (Phillips et al., in press, p. 9).

This strategy is particularly useful in new situations. In his NDM research, Klein (1998) found that in novel situations, experts were able to improvise much better than novices by creating effective, new strategies. "When pre-stored patterns prove inadequate, decision makers draw on more abstract structures for organizing information" (Cohen et al., 1996). Through their prior experiences, decision makers acquire abstract knowledge about the nature and relationships of events. This generic knowledge is used as a foundation and filter to evaluate the new situation, and then construct mental simulations to aid comprehension and action (Cohen et al. 1996). "Structural knowledge consisting of causal and intentional relations between events is used to construct narrative story structures" (Cohen et al, 1996, p. 208).

It is important to note that although this process is an effective decision aid for experienced decision makers, researchers suggest it is ineffective for novices. "Without a sufficient amount of expertise and background knowledge, it may be difficult or impossible to build an effective mental simulation" (Klein 1998, p. 57).

3.3.3. Metacognition and Situation Awareness

Situation awareness is our capacity to maintain an accurate perception of our external environment by detecting the source and nature of problems and situations that require action (Klein, 2003; Endsley; 1997). Metacognition extends situational awareness to our internal environment. Metacognition is our knowledge of, and ability to control, the state and process of our mind (Cohen et al., 1996; Gavelec & Raphael, 1985; Klein, 1998). It has also been described as our ability to take our own strengths and limitations into account (Phillips et al., in press). The use of metacognition strategies have been found to prevail in situations where experts recognize cognitive and affective patterns through repeated exposure to the numerous situations they have experienced during their years of practice (Cohen et al., 1996).

Cohen et al. (1986) proposed the theory of Metarecognition in time-stressed decision making that encapsulates recognizing, critiquing, and correcting processes. The metarecognition process assists the decision maker in understanding dynamic, uncertain situations and choosing appropriate actions. They argued that analogous, metacognitive skills are a critical component of effective problem solving and decision making, and suggested that pattern recognition (recognitional processes) must be followed with a process of critiquing and correcting (metacognitive processes) for proficient decisions (Cohen et al, 1996).

II.3.4. Improving Performance and Developing Expertise

In addition to compiling extensive experience banks, motivation to learn, deliberate practice, critical thinking, feedback, and reflection have been found to be most effective in improving performance and developing expertise (Ericsson et al., 1993; Klein, 1998, 2003; Phillips et al., in press). A discussion of these topics follows.

3.4.1. Motivation to Learn

Motivation appears to be the most cited condition in the literature on learning and skill acquisition. Motivation to improve practice must be closely connected to the goal of becoming an expert (Ericsson et al., 1993). Phillips et al. (in press) discussed the importance of motivation to learn in the capacity to achieve expertise, and suggested that experts have motivational characteristics that differ from their equally experienced partners. They are passionate about their task, they actively seek opportunities to learn, and they read and practice simulations frequently. Experts enjoy engaging in lengthy conversations about their experiences and use reflection to learn from their mistakes (pp. 15-16).

3.4.2. Deliberate Practice

Expert performance has been described in terms of acquired characteristics resulting from engaging in deliberate practice (Ericsson et al., 1993; Klein, 1998; 2003). Deliberate practice is an extension of experiential learning, where exceptional mental conditioning is achieved through practicing with specific objectives in mind (Klein, 2003). The central claim of the Ericsson et al. (1993) framework is that the level of performance a person attains is directly related to the amount of deliberate practice, and that expert performance is the result of an extended process of skill acquisition mediated by frequent (e.g. daily) deliberate practice. Deliberate practice includes engaging with full concentration in activities that have been specially designed to improve the level of performance.

These experiences are then transformed into increased knowledge and skills improvement with the aid of mentoring and reflective practice. The use of mentors, coaches, and teachers is key to the process to enable objective error diagnosis, informative feedback, and remedial training. Since deliberate practice requires time and energy, the individuals must be motivated by a desire to improve their performance. This practice occurs as a series of repeated experiences, where the individual attends to critical aspects of the situation, therefore incrementally improving their performance in a feedback-rich environment (Ericsson et al., 1993, pp. 370-387).

3.4.3. Critical Thinking

The use of critical thinking and critical practice enhances learning and builds expertise (Brookfield, 1997; Kolb, 1984; Marquardt, 1999). "Critical practice refers to any work people do that involves analyzing situations, reflecting on past experience, making judgments and decisions, and taking actions without the benefit of a standard protocol or uniform response that takes care of each and every problem they encounter" (Brookfield, 1997, p. 23). Critical thinking is integral to the process, and is a complex, logical reasoning process that involves creative and critical aspects of intellectual thought processes. Critical thinking actively involves us in recognizing and researching the assumptions that are fundamental to our thoughts and actions (Brookfield, 1987) and is integral to meta-cognition and situational awareness. Cohen et al. (1996) proposed a critical thinking program to develop meta-recognitional skills with a focus on considering alternative hypotheses about the nature of a situation. This is in contrast to normative approaches where the focus is on considering alternative courses of action (Klein, 1997).

By beginning with questioning and critical thinking, rather than using intuitive, experience-based knowledge as the first reference point, the decision maker can gauge if the available information is relevant and adequate to the current problem solving needs (Marquardt, 1999). While experience-based knowledge is important for good decisions, it is embedded in the past and may not be a precise match with the unique needs of the new problem or situation. "By focusing on the right questions rather than the right answers, [critical thinking and questioning] explores what one does not know, as well as what one does know (Marquardt, 1999, p. 30).

Critical thinking enables us to dramatically enhance our knowledge, and also provides us with the opportunity to effectively reorganize it for future use. Utilizing critical thinking in avalanche decision-making is therefore integral to objective and sound decisions, and offers a powerful strategy to build expertise and to counter the influences of potentially dangerous heuristic traps and biases in the decision-making process.

3.4.4. Feedback

Feedback is another critical component of developing expertise, since without effective feedback it may be impossible to achieve expert predictive or diagnostic abilities (Phillips et al., in press, p. 16). "In the absence of adequate feedback, efficient learning is impossible and improvement only minimal even for highly motivated subjects" (Ericsson et al., 1993, p. 367).

Providing feedback to avalanche decision-makers is challenging, since the quality of competence of these decisions is difficult to define. Standards for determining good avalanche related decisions currently do not exist within the avalanche domain. "External standards are seldom available for expert domains - that is why experts were needed in the first place" (Shanteau, 1992, p. 256). A resolution to this dilemma suggested by Shanteau, is relying on the views of acknowledged experts that are backed up by professional guidelines and commonly accepted standards.

Feedback must be obtained that is frequent, accurate, diagnostic, and reasonably timely (Klein, 1998; Pliske, et al. 1997; Phillips et al., in press). Consistent with the previous discussion of the role of metacognition in learning, in order to turn our experiences into expertise, we need to actively gather and interpret this feedback ourselves, instead of passively allowing another person to tell us if our actions were good or bad (Klein, 2003). In the domain of weather forecasting, for example, timely and accurate feedback on decisions and predictions is available on a daily basis, therefore facilitating the development of expertise. However, in the domain of avalanche forecasting, I suggest that feedback is often intermittent, and the development of expertise may be hindered by the lack of feedback and by poor decisions that are reinforced by non-event feedback.

Cognitive feedback, in particular, has been found to improve performance on judgment tasks, and consists of feedback about environment relations, relations perceived by the decision maker, and relations between the environment and the decision-makers perspectives (Phillips et al., in press).

3.4.5. Mentoring and Coaching

We need external feedback to provide a realistic picture of our effectiveness. It is difficult, if not impossible to probe our assumptions on our own. No matter how accurate we think we are, we are challenged by the reality that our personal interpretive filters may lead us into distorted and constrained ways of being (Brookfield, 1997). Stephen Brookfield (1997) emphasized the critical importance of enlisting the help of others to enable us to see our ideas and actions in new ways.

> Hearing the perceptions of our peers helps us to gain a clearer perspective on the dimensions of our thoughts and actions that need closer critical scrutiny. Talking to others helps us to become aware of how much we take for granted about our own ideas and actions. It also alerts us to our judgmental ways of seeing. Sometimes, it confirms the correctness of instincts that we felt privately but doubted because we thought they contradicted conventional wisdom (p. 19).

Employing a coach as an adjunct to practice was identified by Phillips et al. (in press) as a key learning tactic of experts. Coaching facilitates the strengthening of our intuitions and deepens our understanding of the intricacies and dynamics of tactical situations (Klein, 2003; Phillips et al., in press). An additional learning tactic is to observe, interview and / or study experts to identify what was successful in their process, especially in real-life incidents where they passed a judgment or made a decision that was different from ours (Klein, 2003; Phillips et al., in press). This enables vicarious and reflective learning and can be very effectively integrated into the learner-mentor relationship.

3.4.5. Reflection

It is widely recognized that learning cannot occur without questioning and reflecting processes (Klein, 1998; Kolb, 1984; Marquardt, 1999; Schön, 1983; 1987).

Experts enrich the learning that results from their prior experiences by using frequent reflection to derive new insights and understanding. Building upon our experience and knowledge with critical questioning and reflective insights results in valuable new learning. These processes are also necessary to achieve a holistic overview, and can make the critical difference in the quality of problem solving and in deriving effective solutions (Marquardt, 1999).

Klein (2003) suggested that reflecting upon difficult decisions, including those involving failure, is a particularly effective use of reflection. He suggests that we should focus on understanding the process behind the decision, for example, why we decided what we did, and how we made the decision. The process feedback that results from this reflection enables us to revise and improve on our intuitions. Klein stated that research is very clear that we learn a great deal from process feedback, for example, reflecting on how we made decisions, and how we could have spotted patterns more quickly. In addition, we learn much less from outcome feedback, where we pass judgment on whether it was a good decision or a bad one (Klein, 2003).

II.3.5. Eliciting the Knowledge of Experts

It is important to understand the components of expertise within a domain, in order to enhance expert decision-making capacities, and to train novices and less experienced individuals to build their expertise and their intuitions (Klein, 1998; Phillips et al., in press; Shanteau, 1988). We need to understand how experts are thinking and clarify their strategies and ways of perceiving situations (Klein, 1998). "To train experts successfully, it is necessary to recognize the special characteristics of experts, and to devise training programs which reflect those characteristics (Shanteau, 1988, p. 213).

Enhancing decision-making is achieved through a variety of processes including decision support and training schemas. These schemas are designed to support expert knowledge systems, therefore require an understanding of the cognitive skills, fundamental knowledge, and strategies that are necessary for proficient performance in the domain of interest (Klein & Militello, 2001; Phillips et al., in press; Shanteau, 1988).

The best information about the innate attributes characterizing experts can be gained by careful examination and analysis of the critical attributes that distinguish them from novices or less successful people (Ericsson et al. 1993). The cognitive requirements of the decision maker are a key component in the design of decision support schemas, and can be derived through diverse methods of knowledge elicitation (e.g. Cooke, 1994; Gordon & Gill, 1997; Klein & Militello, 2001). Therefore, deriving an understanding of avalanche experts' decision processes and developing methods to improve decision practice, requires eliciting the knowledge of avalanche experts.

Klein and Militello (2001) sorted knowledge elicitation methods into four categories: (1) interview methods; (2) observation methods; (3) modeling methods, and (4) experimental methods (p. 185). Cognitive Task Analysis and the Critical Decision Method are two interview methods used in my research with avalanche experts that have been found to be exceptionally effective in deriving this understanding.

Cognitive Task Analysis (CTA) seeks to understand how people use their cognitive skills to make critical judgments and decisions including interpreting situations, making perceptual discriminations, and generating plans (Klein, 1998; Klein & Militello, 2001; Hoffman et al., 1998). It is a method for capturing expertise and making it accessible for decision training and support (Klein, 1998, p. 173). Klein and Militello

(2001) developed a series of guidelines for CTA that include describing the types of judgment and decisions that are needed, describing the cues, patterns and strategies that go into these judgments, and designing effective interventions that will help rather than interfere with them. In the design of decision training programs, these researchers recommend the training be framed by these concepts and strategies, and that cognition be made clearly visible to learners through the identification of the specific critical cues, perceptual discriminations, and contextual elements required for decision proficiency (Klein & Militello, 2001, p. 187).

The Critical Decision Method (CDM) is used in the elicitation of expert knowledge, and was developed from a desire to capture the knowledge and experience involved in real-world decision making and problem solving (Klein, Calderwood & MacGregor, 1989; Hoffman et al., 1998). The CDM is a retrospective, case-based method where a participant recalls and describes a specific incident from their lived experience. CDM has many similarities with narrative inquiry, a research method that strives to describe a phenomenon through deriving an understanding of how people think and act (Czarniawska, 1997; Riesman; 1993).

In CDM, the researcher leads the participant through a process of progressive deepening by using probe questions to derive the presence or absence of salient cues, the nature of these cues, the situation assessment including the basis of the assessment, key decision points and the evaluation of options (Hoffman et al., 1998). The CDM is a process of knowledge creation and co-discovery that leads to new understanding in the domain.

People enjoy telling their stories of experience, however some researchers have reported that experts have difficulty articulating the tacit knowledge behind their procedures, perceptions and intuitive decision processes (Klein, 1998, 2003; Shanteau, 1988; Yates, 2001). A key success of CDM is that it enables the discovery of facets of cognitive skill and subtle perceptual cues that had not been previously recognized (Klein & Militello, 2001). In addition, the CDM research method captures data in the form of stories that can provide effective learning tools for novices and trainees. Stories, simulations and case studies can dramatically enhance the learning and development of knowledge and skills of novices and trainees (Hoffman et al., 1998; Klein, 1998). Expertise is a key factor in the ability to make sound avalanche-related decisions. In the following section, I build upon the earlier discussions of adult learning, risk, and expertise in an examination of high-stakes decision making within the context of the avalanche domain.

II.4. High-Stakes Decision Making

Life is a process of continual choice and the resulting decisions have significant impact upon our individual, societal, and global life experiences. Due to this significance, a large literature has evolved in the field of decision making. The nature of the decision process varies significantly by context, therefore this literature review focuses on decision science applied to high-stakes situations.

Avalanche related decisions fall within the class of problems defined as *high-stakes.* These decisions are characterized by high levels of complexity and uncertainty, and require complicated inferences and judgment for sound solutions. High-stakes decisions have two distinctive properties: the existence of large financial and/or emotional loss, and the presence of significant difficulties and high costs to reverse a decision once it is made (Kunreuther et al., 2002, p. 261). This section of my literature review explores some of the reasons why avalanche-related decision-making is so complex. Avalanche-related decision-making is a stochastic art, thus chance alone can turn a good decision into a poor outcome, or vice versa.

Decision-making in snow avalanche terrain is complicated, dynamic, and uncertain. Information about the probability of avalanche release is imprecise, and the presence of time pressures and risk is often high. The decision process involves making complex judgments about the nature of the situation, and then critical decisions regarding what actions will be taken. The ability to make rapid and effective judgments is particularly crucial to the process, however the resulting decisions are very difficult to make. "What makes these decisions challenging is not just the spectre of the possible consequences of error, but the awareness of the naiveté with which we are forced to approach them" (Kunreuther et al., 2002, p. 260). Decision making in the natural hazards domain, (for example, avalanches, earthquakes, and flooding), face the same stark reality - decision makers are in the business of estimation, not prediction.

II.4.1. Avalanche Decision-Making

Snow avalanches pose the greatest natural hazard to winter backcountry users in Canada. Avalanche experts make decisions associated with avalanche forecasting. The goal of avalanche forecasting is to minimize the uncertainty of snowpack instability, and to reduce the exposure of people and structures to avalanches (McClung & Schaerer, 1993; McClung, 2002). Avalanche experts forecast avalanches through a process of identifying and describing current conditions, and then predicting future events.

Forecasting avalanches deals primarily with predicting snow instability over time and, as it varies over the terrain. Therefore, high levels of complexity and uncertainty are inherent in the process. "A major fundamental physical uncertainty in avalanche forecasting resides in the usually unknown temporal and spatial variations of instability in the snow cover including their links to terrain" (McClung, 2002, p. 13). The uncertainties associated with predicting the probabilities of avalanche release are further complicated by these variations across the terrain, and any incremental changes resulting from snow and weather conditions (McClung, 2002).

Associated with the determination of instability is forecasting the danger of exposure to avalanche hazard to the public. This hazard determination is also complex. The hazard ratings are applied to the terrain over much larger areas, for example, alpine, treeline, and below treeline elevations. In addition, a fundamental challenge is to communicate the forecasted avalanche hazard effectively so that the human perceptions of users are congruent with the reality of avalanche danger (Bruns, 1996; McClung, 2002).

II.4.2. Human Factors in Avalanche-Related Decision-Making

It is widely recognized that human factors heavily influence the way we think and behave in life. Human factors are a significant influence in both the internal and external realms of avalanche-related decision-making. Stefanovic (2003) stated, "Natural disasters are more than external, random events. They emerge within a complex relationship that exists between human and environmental factors" (p.245). The internal human factors addressed in my research are the cognitive, physiological, and psychological realms. External human factors addressed are team, client, organizational, and socio-political realms.

II.4.3. Primary Systems of Cognitive Function

Decision makers use two primary systems of cognitive function; analysis (also known as reasoning) and intuition to make complex decisions (Figure 6) (Kahneman, 2003; Klein, 1998, 2003). Reason (1990) classified these two structural features of human cognition as working memory, and the knowledge base of mental models.

In the intuitive mode, decisions are made using the automatic and rapid operations of perception. Intuitive decisions occur at the pre-conscious level, as a pattern recognition process based on accumulated life experience and mental models (Klein, 2003). While these operations are associative and effortless, they may be influenced by habit, making them difficult to control or modify. In the analytic mode, deliberate effort and analytical processes requiring time are utilized. These operations are slower, and are more likely to be consciously monitored and deliberately controlled (Kahneman, 2003, p. 698).

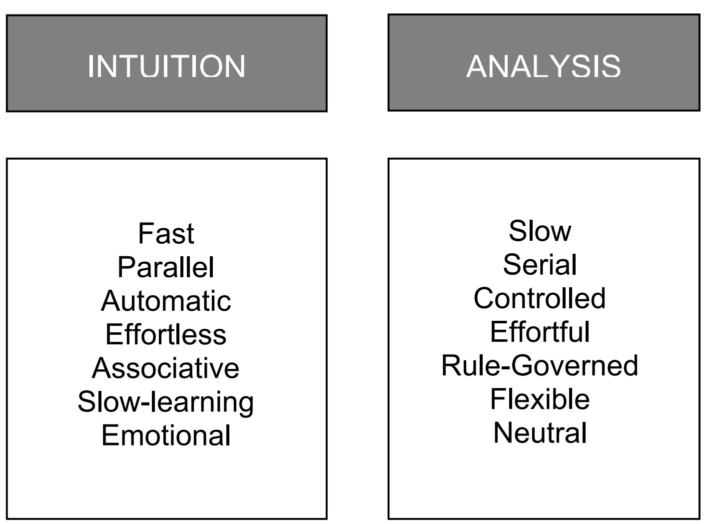

Figure 6. Primary modes of cognitive function. Adapted from Kahneman, 2003.

"Complex judgments and preferences are called intuitive in everyday language when they come to our mind quickly and effortlessly, like percepts" (Kahneman, 2003, p. 716). The highly accessible impressions that are produced by these intuitive processes control our judgments and preferences, unless they are modified or overridden by the deliberate operations of reasoning (Kahnemen, 2003).

4.3.1. Analytical Decision-Making

Conventional decision research has focused on normative and multi-attribute models of decision making that highlight rational choice theories of probability analysis, logical thinking, and statistical methods of reasoning (Jannis & Mann, 1977; Slovic, Fischoff & Lichtenstein, 1977). These methods favour analysis, a deductive process of problem solving where the decision-maker deconstructs a situation and performs logical methods to achieve sensible solutions. Rational choice models are one common example, where options are evaluated using a set of pre-determined criteria, and then rated to determine the best choice.

Normative theories focus on how people should be thinking and are based upon research behaviour analysis methods that set up conditions to analyze why people did not follow optimal procedures. The resulting prescriptions for decision making include task sequence diagrams or a complex series of steps that include identifying the range of options and objectives, carefully weighing the risks, examining the costs and benefits of the options, searching for and assimilating new evaluation information, re-examining the positive and negative consequences, and finally creating contingency plans in anticipation of risk occurrence (Jannis & Mann, 1977).

Analytic reasoning requires time and deliberate effort and therefore facilitates opportunities to utilize models of rule governance (Kahneman, 2003). Rule following is the application of a rule or norm to a situation with the goal of minimizing decision effort. The outcome is to provide solutions that are satisfactory, though not necessarily the best (Mellers, Schwartz & Cooke, 1998).

4.3.2. Intuitive Decision Making

Intuitive decision-making can be described as a process of knowledge and experienced-based decision making (Klein, 1998, 2003). Klein (2003) described intuition as the way we translate our experience into judgments and decision actions. Intuitive decision-making utilizes the extensive repertoire of patterns we accumulate and refine over years of experience. Sets of cues are unconsciously organized and grouped together to form patterns or knowledge chunks. In a future situation, when a few of these cues are noticed, we know that we can expect to find the others. We recognize the situation as familiar by matching it to a pattern encountered in the past, including the associated routine for responding with action.

As we acquire more patterns and strategies, our expertise increases. It becomes easier to make decisions, since we see new situations with a sense of familiarity and recognize how to act (Klein, 2003). This process explains why psychology and NDM researchers have observed that people can make effective decisions without a deliberate process of analysis (Klein, 1998; 2003; Simon, 1955).

Specific intuitions are defined as "judgments related to a particular task within a domain," while *general intuitions* are "knowledge and experience with a particular domain" (Phillips et al., in press, p. 17). The research findings of Phillips et al., suggest that a decision maker can identify specific intuitions easily; for example, estimating the time it will take to complete an avalanche control mission. However, general intuitions pose greater challenges to identify; for example, deciding when to open a previously closed area of avalanche terrain. Since general intuitions occur across a broad range of judgments and actions, it is difficult to isolate the discrete tasks that are associated with the decision action (Phillips et al. in press).

However, to use our intuitions accurately, we need to make our decisions based upon *informed* gut feelings (Klein, 2003, p. 8). This requires mental models that are based upon a strong experience base. Timely and accurate feedback about our judgments and decisions is necessary to build this strong base, however as I discussed earlier, is often challenging to acquire in the avalanche domain because of a lack of feedback. As a result, decision-makers may make intuitive decisions that are based upon distorted or biased experience. "Improving high stakes decisions will not simply be a matter of stamping out decision maker' biases. Rather, they must learn to intuitively recognize when biases are harmful to decision making, and when they may actually be helpful" (Kunreuther et al., 2002, p. 264).

A majority of decision researchers agree that we need both analytical and intuitive processes for good decision-making (Klein, 2003; Kahneman, 2003). Klein (2003) suggests starting the decision process with intuition to help us recognize situations and get a sense of our preference for action, and then use analysis to verify our intuitions, and ensure they aren't biasing or misleading us.

II.4.4. Decision Context

Situation context and familiarity are key influencers in the type of cognitive function used in decision making. For example, office based forecasting decisions have more time and information resources available, therefore enabling the decision maker to utilize a combination of analytical reasoning and intuitive processes. However, time pressured field decisions strongly favour intuitive strategies of decision making (Klein, 1998). In addition, extensive research in Naturalistic Decision Making (NDM) shows that the type of decision process utilized depends upon the level of expertise and the degree of situation novelty. "Experts can rapidly recognize and interpret complex patterns in a set of information in order to assess the situation more quickly and accurately than non-experts" (Phillips et al., in press, p. 8). In complex situations where novice decision makers lack the expertise to recognize and categorize the situation, analytical efforts are used to reason through it, however are often unsuccessful (Klein, 1998).

Klein (2003) reported that decision researchers have not been able to demonstrate that analytical methods actually help people make better decisions. He suggested that since analysis requires conscious thought processing of one variable at a time, it is difficult to consider simultaneous, multiple variables. In addition, decision makers will often overemphasize factors that are more easily quantified and leave important qualitative factors out.

II.4.5. Heuristics and Biases Models

In the 1970's, Amos Tversky and Daniel Kahneman proposed the theory of heuristics and biases, and demonstrated that human judgment processes occur within a system that is qualitatively different from the principles proposed by normative theories (Tversky & Kahneman, 1974). In a study of various types of judgment about uncertain events, they found that people rely on a limited number of heuristic principles to simplify their judgment operations when faced with the complexities of predicting critical factors and assessing probabilities. They defined heuristics as "principles, processes, or sources of cues for judgment" (Tversky & Kahneman, 1974, p. 1124). Several decades later, their definition of heuristic processes was made more explicit. "A judgment is said to be mediated by a heuristic when the individual assesses a specified target attribute of a judgment object by substituting a related heuristic attribute that comes more readily to mind" (Kahneman & Fredrick as cited by Kaheneman, 2003, p. 707).

Heuristics are shortcuts that help us solve different real world problems. Heuristic processes do not require the conscious awareness of the decision maker. They are pre-conscious processes in which internal and external knowledge and information is filtered and then selected, prior to moving into the conscious realm of decision making (Marsh, 2002; McCammon, 2002; Tversky & Kahneman, 1974; Slovic, 2001).

> Heuristics are cognitive shortcuts that enable individuals to make evaluations on the basis of one or a few simple rule or cues, thereby avoiding the processing and time costs related to exploring an exhaustive set of possibilities. They may be used to search for options to construct and categorize perceptions, or to choose between competing options (Marsh, 2002, p. 49).

Marsh (2002) identifies three categories of heuristics that work together in solving decision problems. *Search heuristics* look for meaningful information or cues that enable commonsense or default decisions. This shortcut reduces the effort of unstructured information searching. When using this heuristic, the decision maker recognizes similarities from a past problem, and will default to what has worked for them in the past. *Assessment heuristics* are then utilized to order and rank the information and create options. This process occurs within a specific criterion that is unique to each individual's immediate or specific needs. The third category is *selection heuristics,* that are used to select the option having the highest rank, or in familiar situations, the option that first meets or exceeds a pre-established level (Marsh, 2002, p. 50).

It is important to recognize that heuristic processes are created and modified in a uniquely individual ecology as people adapt and respond to their life experience and changing environments. Marsh (2002) describes that heuristics can be understood in two ways. First, in relation to understanding and solving problems within the context of our individual life history and second, in relation to how the dynamics of the situation are understood and solved by social forces or "ways of doing things" transmitted within our culture (Marsh 2002, p. 51).

4.5.1. Biases and Heuristic Traps

However useful heuristics can be in complex decision-making, they can also result in sacrifices in accuracy and severe errors and biases in judgment (Marsh, 2002; Tversky & Kahneman, 1974). Slovic et al., (1977) identified systematic biases in people's judgment resulting from limited information-processing capacities and ignorance of the rules for optimal information processing and decision making. Research has shown that generalizing from past experiences or presumed similarity can result in failure to accurately apprehend the situation or adapt to changing environments (March 2002, p. 55). These influences have been more recently referred to as heuristic traps (McCammon, 2002).

Kunreuther et al. (2002) furthers the discussion of decision biases, stating that decision science has "overlooked issues in decision-making where biases are the *source* of risk rather than simply an obstacle to its resolution" (p. 266). In a study of recreational avalanche accidents in the United States, heuristics were identified as a significant factor influencing the decisions of accident victims (McCammon, 2002). Following is a summary of the four heuristic traps identified in McCammon's study; scarcity, familiarity, social proof, and commitment.

1. Scarcity.

Our perceived value of opportunities that are limited increases, and we generate competition to acquire those opportunities. For example, getting first tracks on a powder slope.

2. Familiarity.

Our past experiences and action lead us to believe that the behaviour is appropriate in the current situation. McCammon reported that 69% (n=377) of avalanche accidents occurred on slopes that were very familiar to the victims.

3. Social Proof.

In this heuristic trap, the presence of other people engaging in the behaviour influences us to believe it is correct. The presence of tracks on a slope or other groups skiing in an area influenced accident victims to expose themselves to more hazard factors. This heuristic has the greatest influence in situations of uncertainty.

4. Commitment.

The commitment heuristic shortcuts complexity by influencing us to believe in behaviors that are consistent with earlier commitments. "Rather than sift through all the relevant information with each new development, we merely make a decision that is consistent with an earlier one" (McCammon, 2002, p. 4). He found that groups with high-commitment levels exposed themselves to greater avalanche hazard.

A central finding in a review of four decades of decision literature by a group of the world's top decision scientists is disturbing. "The presence of potentially catastrophic costs of errors does little to reduce the human tendency to make decisions using simplified heuristics (or rules of thumb) that, at times, yield decisions that depart significantly from those prescribed by normative models" (Kunreuther et al., 2002, p. 261). Paraphrasing from Kunreuther et al.'s research, the following departures from normative models are worthy of note:

1. Under-utilization of probability information and failure to differentiate among probabilities.

In this situation, people either use available probability information insufficiently or ignore it altogether. In the latter case, people effectively treat their probability as zero, or close to it, by assuming the event 'will not happen to me'.

2. An excessive focus on short time horizons.

Decision makers see only the immediate consequences of actions. As a result, they do not recognize high-stakes decisions or the future consequences of current actions.

3. Excessive attention to affectual cues.

When decisions are ambiguous or require difficult tradeoffs between attributes, decision makers often focus on the cues that send the strongest emotional or affective signal.

4. Distortions under stress.

High-stakes decision-making produces high levels of perceived stress that leads to greater use of simplifying heuristics.

5. Over-reliance on social norms.

Decision makers resort to using the decision strategies used by others or follow established social norms.

6. The tendency to prefer the status quo.

When presented with difficult choices and no obvious right answer, a common reaction is to make no decision at all or to transfer / relegate the decision to someone else.

7. Failures to learn.

In high-stakes decisions, there are few occurrences from which to learn. Decision feedback is sparse and potentially censored. An example from the avalanche domain is that accidents are the exception to poor decisions, therefore poor decisions may continue be reinforced through lack of feedback (List adapted from Kunreuther et al., 2002, pp. 261 - 263).

The matter of biases in decision making is further complicated by the fact that researchers recognize it is not always clear to determine whether biases are actually biases. Reflections of reasoning style or the occurrence of a generally useful heuristic are other possible interpretations (Christensen-Szalanski, 1993; Hoffman et al., 1998). As an educator, I found myself curious about the impact of learning styles in intuitive and analytic processes of decision making; however I was unable to source any literature addressing this area. Learning styles research in high-stakes decision-making offers the valuable potential of deepening our understanding of decision-making processes and decision skills training.

II.4.6. Naturalistic Decision Making

Naturalistic Decision Making (NDM) (Klein, Orasanu, Calderwood & Zsambok, 1993; Klein, 1997; 1998; 2003; Zsambok & Klein, 1997) research seeks to understand the kinds of knowledge, skills, and experience that is involved in real-world problem solving and decision making, within domains that require high-stakes, time-pressured decision making in situations of uncertainty and competing goals (Phillips et al., in press). The Critical Decision Method, which I discussed in the earlier section on expertise, is a research method of NDM.

NDM research describes how experts use strategies based upon their experience to make high-stakes field decisions under dynamic conditions, uncertainty, inadequate information and time pressures. Through studying expert decision makers such as firefighters, emergency physicians, neonatal nurses and military officers, NDM research shows that in field decisions, experts rarely compare options when faced with a difficult decision. Instead, experienced decision makers recognize a reasonable course of action as the first one considered. Researchers were able to show that decision makers noticed subtle cues in the situation without consciously realizing it (Hoffman et al., 1998; Klein, 1998).

In extensive NDM research in high-stakes situations, Klein (1998) observed that experts did not engage in a process of comparative evaluation when faced with complex decisions. In fact, the experts did not seem to be making *any* decisions that resulted from actively comparing two or more options. His results clearly showed that experts did not have to compare options since they could come up with a good action plan from the start using intuitive decision processes. He proposed that the experience these experts held enabled them to see even non-routine situations as a prototype, and skilfully know what to do without thinking of other options (Klein, 1998, p. 17). This efficient decision strategy is also known in other domains as "satisficing"; choosing the first option that works in the least amount of time and decision-making energy (Simon, 1955).

In a study of fire-fighting commanders, Klein, Calderwood, and Clinton-Cirocco (1986) developed a series of questions designed to elicit information about expert reasoning including perceptual cues, knowledge and choice points. The findings of this study also suggested that in dynamic, high-stakes situations, experienced decision makers do not generate and weigh multiple options before selecting the best action.

Phillips et al. (in press) proposed a set of NDM hypotheses about lawful relationships in expertise:

> First, that in most domains handled by experienced decision makers, most decisions will be made using recognitional strategies, rather than an analytic comparison of course of action. Second, as people gain experience, they make more decisions relying on recognitional matches rather than comparison of courses of action. Third, for decision makers with even moderate experience, the first option they generate is usually satisfactory. Fourth, options are more likely to be evaluated using mental

> simulation than by comparing the options on a generic set of criteria.
> Fifth, as decision makers gain experience, they shift from spending most of their time examining options, to spending the majority of the time assessing the situation (Phillips et al., in press, pp. 21-22).

NDM is in stark contrast to normative models that utilize methodologies that study why people are not following optimal methods of decision making and result in detailed prescriptive models of decision making that may not be practical in real world settings (Klein, 1998, 2003). The theoretical premise of expert decision-making in NDM, and the Recognition Primed Decision (RPD) model (Klein, Calderwood and Clinton-Cirocco, 1986), share many similarities with Tversky and Kahneman's heuristics and biases research, specifically the importance of similarity and mental simulation. However, the RPD model addresses the issues of representation and process that have received little focus in heuristics research.

> From a practical stance, the critical implication is that expert decision makers are not better than novices because their processing literally begins to look more like that of normative theories. Instead, expertise leads to a broader and more refined set of heuristic processes that promote exceptional performance on the specific task domains to which they are attuned (Phillips et al., in press, p. 15).

In the RPD model, processes of intuition and analysis synthesize. The process of pattern matching is intuitive, and provides the recognition of the situation and an understanding of how to react. The process of mental simulation, (imagining how those reactions will play out), is analytic, and provides the deliberate thinking that enables the decision maker to see if the reaction is going to work (Klein, 2003).

II.4.7. Dealing with Uncertainty in High-Stakes Decision-Making

Uncertainty is fundamental to the avalanche risk equation, and lies at the centre of the high-stakes decision-making process. I define uncertainty as a sense of subjectively created doubt that blocks or delays deterministic action. Uncertainty is subjective, since different individuals will experience different levels of uncertainty in the same situation, and it is inclusive, since it occurs in no particular form (Lipshitz & Strauss, 1997). Lipshitz and Strauss (1997) discussed uncertainty in the context of the issue that the decision maker is uncertain about. They identified three issue classifications; outcomes, situations and alternatives, and found that decision makers distinguish between three types of uncertainty within these issues: (1) inadequate understanding; (2) incomplete information; and (3) undifferentiated alternatives.

Klein (2003) also discussed uncertainty within the context of identifying its source. He identified five categories of uncertainty, missing information, unreliable information, conflicting information, noisy information and confusing information. Klein emphasized the importance of identifying and differentiating between the different sources of uncertainty, as a key step in choosing an appropriate response. For example, it is important to determine whether we are struggling with missing data, or struggling with making sense of the data when making an avalanche risk assessment. Klein suggests that sometimes we avoid admitting our limitations in interpreting and understanding the present data by trying to acquire more data (Klein, 2003, p. 123).

The search for more information is a key component of normative decision research models. Jannis and Mann (1977) suggested that decision makers can effectively reduce uncertainty through a complete information search, however this method is often problematic in high-stakes situations due to time constraints and lack of processing capacity (Klein, 1998). Collecting more information may not help the quality of the decision when the environmental uncertainty is high (Fredrickson & Mitchell as cited by Lipshitz & Strauss, 1997). McClung (2002) identified this point in his discussion of avalanche forecasting, and argued that more or redundant information will not aid an avalanche forecast, however identifying information that reveals snowpack instability and reduces uncertainty will.

Lipshitz and Strauss (1997) suggested decision-makers use three strategies for dealing with uncertainty; reducing, acknowledging and suppressing uncertainty. Collecting information, as previously discussed, or using assumption-based reasoning to extrapolate from available information can reduce uncertainty. Lipshitz and Strauss (1997) proposed assumption-based reasoning enables experienced decision-makers to act quickly and effectively with little information present. These findings correlate directly with the recognition component of Klein's RPD model. Utilizing mental simulations and scenario building can also reduce uncertainty (Klein, 1998; Lipshitz & Strauss, 1997).

Decision makers can acknowledge uncertainty by considering it when choosing a course of action or by preparing to avoid it (Lipshitz & Strauss, 1997). This strategy is utilized often in the avalanche domain; for example when a ski guide selects a very conservative ski line, or when a ski area avalanche practitioner closes an area of terrain. A third strategy used by decision makers to deal with uncertainty is to suppress it (Klein, 2003; Lipshitz & Strauss, 1997). Jannis and Mann (1977) described the Pollyanna effect, where decision-makers develop a false sense of security by believing that an avalanche involvement will not happen to them. The suppressing and denial strategy also includes tactics that decision makers use to align their goals, preferences, and beliefs with their decisions (Lipshitz & Strauss, 1997). An example is a ski guide on a multi-day tour explaining away instability data in order to rationalize their decision to cross a slope and get to the cabin that will provide the group shelter for the evening. While the strategy of suppressing uncertainty may seem somewhat irrational, decision researchers have argued that the strategy is a coping mechanism that helps a decision maker avoid the paralysis of being unable to effectively deal with uncertainty (Lipshitz & Strauss, 1997).

II.4.8. Supporting Decision Making and Building Decision Expertise

The following section extends the earlier discussion of building expertise to the domain of high-stakes decision-making.

Decision quality can best be enhanced by facilitating the development of substantive, domain-specific expertise (Cohen et al., 1996; Phillips et al., in press; Klein; 1998, 2003). Developing domain expertise offers enormous potential for improving decision-making, and has been found to alleviate potentially dangerous biases in the decision process (Phillips, et al., in press; Shanteau, 1989). However, opportunities to gain experience are not always present and take time to acquire. Therefore, a central goal in NDM research is to train people to achieve expertise more quickly through the use of effective training and decision support strategies (Klein, 1997; 1998; 2003; Phillips, et al., in press).

A widely used strategy to develop decision expertise is by building experience through the use of simulations and case studies. By engaging in realistic and detailed scenarios, decision-makers have the opportunity to critically assess situations, and build a sense of characteristic cues and common patterns in their domain.

Klein (1998; 2003) suggested simulations and case studies are an excellent method to develop perceptual expertise since decision makers can see how the cues appear in the context of the situation, and receive valuable coaching from the facilitator. He argued that well-designed simulations can provide more effective training value than direct experience. These Decision making Exercises (DMXs) are designed to capture the essence of difficult and uncertain situations and challenges decision makers to decide upon an effective course of action (Klein, 2003). Being able to stop the simulation at strategic points and discuss cues and strategies enables decision makers to develop new insights and growth. Simulations and case studies also enable people to learn vicariously from others experiences (Klein, 1997). "A major component of how knowledge becomes meaningful is determined by how learners perspectives change through human interactions" (Brockett, 1994, p.7). The key outcome of DMX's is to gather experiences and develop patterns and mental models that are essential to intuition (Klein, 2003).

Phillips, et al. (in press) stated six goals for acquiring decision making expertise and suggest scenario-based instruction as the most effective way to facilitate their development: (1) enhance perceptual skills; (2) enrich domain specific mental models; (3) construct a large and varied repertoire of patterns; (d) provide a larger set of routines; (e) provide a larger base of experiences; and (f) encourage an attitude of responsibility for one's own learning. (pp. 17-18).

In their research on the Critical Decision Method (CDM), Hoffman et al., (1998) described three methods designed to build decision expertise: (1) Illustrative stories to facilitate the recall of task instructions; (2) case accounts to assist trainees in developing skill at situation assessment and recognition; and (3) learning materials that describe taxonomies of informational or diagnostic cues (pp. 259 – 260). This third point is very important to consider in the avalanche domain. Since it is difficult for experts in high-stakes domains to articulate how they arrived at their decisions, this type of perceptual experience is seldom compiled or shared (Klein 1998, 2003). As a result, it is particularly challenging for less-experienced avalanche practitioners to master and integrate these taxonomies and cues into their decision practice. A central goal of my research was to address this gap by identifying these cues and strategies, and making them accessible for the design of decision training and support.

II.4.9. De-biasing Decision Makers

Classical methods of judgment and decision research proposes that decision making skills can be improved by following normative processes, and by using strategies to eliminate decision biases (Russo, Schoemaker & Hittleman, 2001). However logical these approaches may appear, laboratory research aimed at de-biasing subjects has had little success (Fischoff, 1985; Klein, 1998). In addition, NDM researchers state several concerns regarding this approach. First, the laboratory results on frequency and magnitude of biases have not been tested in natural settings. Second, for de-biasing to be effective, the procedures must be transferable and accessible to the natural setting, and to the confines of the decision makers' environment (Klein, 1998; Phillips et al., in press).

While normative and multi-attribute decision analysis models may be effective aids in office-based forecasting situations, decision science shows them ineffective in the field under situations of time pressure and uncertainty (Kahneman, 2003; Klein, 1998; 2003). As discussed earlier, extensive research in high-stakes natural field settings, concludes that people rarely compare options and seldom have the information or time required to apply normative models (Klein, 1998; Shanteau; 1992). Klein (1998) stated, "normative strategies cannot be used in many field settings because the boundary conditions in terms of data quality, and time available to perform the analyses are not met" (p. 342).

Analysis-based systems may effectively facilitate rule-based tasks, however they cannot approximate the highly complex cognitive tasks of human judgment. (Phillips et al., in press; McClung, 2002). Klein and Militello (2001) reinforced these findings, and suggested that complex decision making processes cannot be explained in terms of a series of steps or a set of rules to be followed. These conclusions are drawn from their NDM research in natural settings: "The strategies used in the field for managing uncertainty are quite distinct from probability judgment paradigms that are the focus of much research in JDM" [judgment and decision research] (Phillips et al., in press, p. 17).

Since decision makers use uniquely individual processes of decision making, strategies to support decision making and enhance decision performance need to be designed with flexibility and focus on problem-solving approaches that naturally lead them to appropriate choices (Hoffman et al, 1998; Klein, 1998; Kunreuther et al., 2002).

CHAPTER THREE –

CONDUCT OF RESEARCH

This chapter of the thesis lays out the conceptual framework within which I conducted my research. It was my goal to identify the structural and thematic aspects of human factors in avalanche-related decision-making through creating a substantive model grounded in the theory of avalanche experts lived experience.

In the first section, I discuss the philosophical and theoretical framework within which I designed and conducted my research. The research participants are then described, including a description of how they were invited to participate in the research process. In the third section, I outline the methods that I used to collect, analyze, verify and interpret the research data. In the fourth section, I provide a systems analysis of the ethical issues, and the ethical considerations under which I conducted this inquiry. The final section of the chapter describes the action research steps completed during the conduct of this study.

The research question:

What are the human factors that influence avalanche expert's judgment and decision making, and what insight do these findings offer for avalanche accident prevention strategies in Canada?

I. Research Approach

My inquiry was based in the philosophy of social science research that seeks an understanding of human behaviour through systematic study and analysis. Human science research studies "persons, or beings that have consciousness and that act purposefully in and on the world by creating objects of meaning that are expressions of how human beings exist in the world" (Van Manen, 1990, p. 4). Using a social sciences approach to understanding human behaviour in avalanche terrain offers great potential for the effective reduction of human involvement in avalanche accidents (Adams, 2004; Etkin et al., 2004).

I.1. Grounded Theory

This was a qualitative study where I took an inductive, grounded theory (Creswell, 1998; Merriam, 2002; Palys, 2003) approach to my research. Qualitative research emphasizes an inductive approach, where participants are observed and research data is gathered prior to the generation of concepts, hypothesis or theories. The fundamental goal of this approach is to understand human phenomena. This understanding is derived by striving to make sense of the behaviour and actions of research participants within the context of their real-world experiences. This approach is in contrast with deductive logic, where the researcher makes broad generalizations and hypothesis, and then tests whether the predictions are supported (Merriam, 2002; Palys, 2003).

The inductive approach to qualitative research emphasizes the generation of theory that emerges from within the research process of human inquiry and engagement. "For qualitative researchers, theory isn't something you start with, it's something you build" (Palys, 2003, p.12). This generative process is the essence of grounded theory, where the goal is to build a substantive theory that is grounded in the data (Merriam, 2002). "The intent of a grounded theory study is to *generate or discover a theory*, an abstract, analytical schema of a phenomenon, that relates to a particular situation"

(Creswell, 1998, p. 56).

Theoretical sampling guides the data collection, where the researcher collects, codes and analyzes the data, and then returns to the field to collect delimiting data to fill in the conceptual gaps. The constant comparative method is used to compare meaningful data between incidents, which results in the creation of conceptual categories. As these categories and the relationships between them emerge, an overall framework or substantive theory develops (Glaser & Strauss, 1967; Merriam, 2002).

I chose qualitative research and the grounded theory approach since there was no research that directly addressed the judgment and decision-making processes of avalanche experts. As a result, there was a lack of theory to adequately explain this phenomenon, and an inductive and exploratory approach was required to derive this understanding.

I.2. Action Research

Action research (Dick, 2000; Glanz, 1998; Kemmis & McTaggert, 1988; Morton-Cooper, 2000; Stringer, 1999) provided the foundation to this research. Action research is a scientific approach to human problem solving and strategic action that offered great potential for achieving the objectives of my research. "The primary purpose of action research is as a practical tool for solving problems experienced by people in their professional, community or private lives" (Stringer, 1999, p. 11). Action research links theory with practice and creates one whole, "ideas-in-action" (Kemmis & McTaggert, 1988, p. 6). The intended outcomes of action research are twofold; to improve practice, and to generate additional knowledge and understanding in the area of inquiry. Practice is improved by enhancing the capacity of the practitioners for discrimination and judgment in complex human systems (Elliott as cited by Morton-Cooper, 2000, p. 13).

Action research is a collaborative process that engages people as active participants in the research process. In this frame, action researchers refer to the traditional term of researcher as *facilitator* and to the research subjects as *participants* (Stringer, 1999, p. xix). The facilitator and the participants cohabit roles as creative investigators and problem solvers (Stringer, 1999, p.3). In this action research project, my research participants and I co-identified the key human factors and cognitive processes in avalanche decision-making, and derived potential tools and solutions to the problem of human involvement in avalanche accidents.

Action research is characterized and defined as a continuous, cyclical, and recursive process that includes a series of interrelated stages (Figure 7).

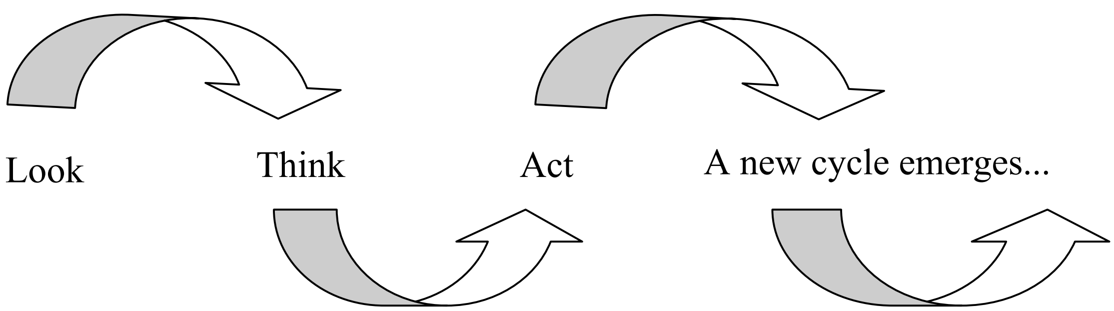

Figure 7. The action research cycle.

Adapted from Stringer, 1999, p. 19.

As the cycle unfolds, it feeds back upon itself to inform and re-inform the process of meaning making as an emergent phenomenon of this approach (B. Stevenson, personal communication, June 8, 2004). Stringer (1999) identified three key stages in the action research cycle. The first is *looking*, where the researcher gathers data and then describes the situation as I have done in the first and second chapter of this thesis. The second step is *thinking*, in which an exploration and analysis process leads to interpretation. *Acting* is the third step, and includes processes of reporting, implementing and evaluating (Stringer, 1999, p.18). At the culmination of this cycle, a new one emerges.

I.3. Hermeneutic and Phenomenological Focus

My research also had a hermeneutical and phenomenological focus, where my aim was to identify and describe the essence, meaning, and structures that inhere in the processes of avalanche-related judgment and decision-making. These themes developed through the analysis of reflection, dialogue, and discussion on lived experience. "Ideas and theories should emerge from interacting with and observing the phenomenon itself" (Palys, 2003, p. 42). I strove to understand avalanche decision-making within the context of avalanche professionals lived experience, and then to build upon the themes that emerged from this inquiry in several focus group discussions. "We try to unearth something *telling*, something *meaningful*, something *thematic* in the various experiential accounts" (Van Manen, 1990, p. 86).

This approach favours an interpretivist perspective, where the goal is to represent the phenomenon of interest as it occurs within the population of interest (Palys, 2003, p.75). My research engaged Canadian avalanche experts in a process of reflecting upon their life experience, and then articulating and sharing the inherent themes and meanings that have influenced and driven their own decision processes. "When we analyze a phenomenon, we are trying to determine what the themes are, the experiential structures that make up that experience" (Van Manen, 1990, p. 79). A key goal of this research was to generate "action sensitive knowledge" (Van Manen, 1990, p. 21), that would practically enable avalanche professionals, practitioners and recreationalists to increase their awareness of decision processes and influencing factors, and consequently extend their capacity to make sound avalanche-related decisions.

II. Project Participants

II.1. Research Participants

My research was conducted within the population of Canadian Avalanche Professionals (n=314). Avalanche professionals in this study were defined as avalanche practitioners who are also professional members of the Canadian Avalanche Association. I chose this group as research participants since they represented the highest level of experience and training of Canadian avalanche practitioners who work actively in a decision-making capacity in avalanche terrain. "An essential characteristic of any profession is the possession of expertise by its members" (Glanz, 1998. p. 4).

In the first phase of my research, all CAA professional members were sent a survey by electronic mail. I chose to encourage participation, and therefore did not set any limitations to the study size in this phase. However, I estimated between 30 and 35 research participants.

In the second phase, a total of 18 participants (9 in each of the two sessions) were invited to attend two focus groups from the population of avalanche professionals that participated in the survey phase. I chose this number based upon the principles of focus group inquiry (Krueger, 1994; Morse, 1994; Palys, 2003) that provide recommendations for optimum number of participants to enable the research inquiry to gather data of great depth.

I asked survey participants to indicate their interest in participating in the focus group segment of the research, and to indicate their location preference. Since I received interest from a greater number of participants than available spaces, I selected participants based upon the following three criteria:

(1) Experience. I selected participants with a minimum of 10 or more years of experience in accordance with the definition of experts (Ericsson & Charness, 1994; Ericsson et al., 1993; Klein, 1997; Simon & Chase, 1973).

(2) Avalanche industry expertise and geographic representation. I attempted to obtain representation from across the avalanche industry including area of expertise and geographic local;

(3) Gender. In Canada, the male to female ratio among avalanche professionals is approximately 10:1. I therefore attempted to obtain a representative gender mix.

Through the process of action research, my intent was to engage this community of experts in a collaborative inquiry to seek a deeper understanding of avalanche-related decision-making processes and influencing factors. My research aimed to extend the theoretical and experiential knowledge of these avalanche experts to inform decision skills training and strategies for avalanche accident prevention at expert and novice levels.

II.2. External Advisors

Two avalanche experts served as subject-matter experts in this research: Dr. Bruce Jamieson, NSERC Industrial Research Chair in Snow Avalanche Risk Control, and snow scientist in the Department of Civil Engineering and the Department of Geology and Geophysics at the University of Calgary; and John Tweedy, Senior Avalanche Technician for the Ministry of Transportation and Highways.

III. Research Methods and Tools

III.1. Methods

III.1.1. Naturalistic Decision Making

I used Naturalistic Decision Making (NDM) (Klein, Orasanu, Calderwood, & Zsambok, 1993; Klein, 1997; 1998; 2003; Zsambok & Klein, 1997) as the fundamental method of my research. NDM research seeks to understand the kinds of knowledge, skills, and experience that is involved in real-world problem solving and decision making, within domains that require high-stakes, time-pressured decision making in situations of uncertainty and competing goals (Phillips et al., in press). The research studies expertise in its real world context by examining what people actually know and do in their natural settings. NDM focuses on explaining decision phenomena through the use of a descriptive approach to defining decision processes within a domain. As a result, strategies to support decision practice and build decision expertise can be designed to enhance the natural processes occurring in human decision-making (Cohen, 1993; Hoffman et al., 1998; Klein, 1998).

III.1.2. Cognitive Task Analysis and the Critical Decision Method

In order to derive an understanding of avalanche expert's decision-making processes and the factors that influence their decisions, I used Cognitive Task Analysis (Klein & Militello, 2001) and the Critical Decision Method (Hoffman et al, 1998; Klein, Calderwood & MacGregor, 1989). CTA and CDM are research methods of NDM.

Cognitive Task Analysis (CTA) is a method for capturing expertise and making it accessible for decision skills training and support (Klein, 1998, p. 173). CTA seeks to describe the mental processes that people use to make critical judgments and decisions including interpreting situations, making perceptual discriminations, solving problems, and generating plans in natural settings (Klein, 1998; Klein & Militello, 2001; Hoffman et al, 1998). The method is directed at capturing expertise, and understanding the cognitive skills, knowledge, and strategies that are needed to achieve highly proficient performance (Klein & Militello, 2001).

The Critical Decision Method (CDM) is an approach to CTA, and is used in the elicitation of expert knowledge for applications of system development and instructional design (Klein et al., 1989; Hoffman et al., 1998). CDM "is a theory driven strategy that is based on the assumption that expertise emerges most clearly during non-routine events and focuses on these [events] as a prime source of information" (Klein et al. 1989, p. 471).

The CDM is a retrospective, case-based method where a participant recalls and describes a specific incident from their lived experience. By having experts in the subject matter relate an actual incident to the researcher, the perceptual cues, decision processes, and strategies are more easily accessed and described (Klein, 1998; Klein & Militello, 2001). CDM has many similarities with narrative inquiry, a research method that strives to describe a phenomenon through deriving an understanding of how people think and act (Czarniawska, 1997; Riesman; 1993).

After reviewing the initial incident description, the researcher using the CDM approach, leads the participant through a process of progressive deepening using probe questions to derive the presence or absence of salient cues, the nature of these cues, the situation assessment including the basis of the assessment, key decision points and the evaluation of options (Hoffman et al., 1998). The CDM is a process of knowledge creation and co-discovery that leads to new understanding in the domain.

A key success of CDM is it enables the discovery of facets of cognitive skill and subtle perceptual cues that had not been previously recognized (Klein & Militello, 2001). In addition, the CDM research method captures data in the form of stories that can provide effective decision skills learning tools. Stories, simulations, and case studies can dramatically enhance the learning and development of the knowledge and skills of novices and trainees (Hoffman et al., 1998; Klein, 1998).

III.1.3. Focus Groups

Focus groups bring together a purposive sample of participants to discuss the phenomenon in which the researcher is interested. Focus groups provide another level of data gathering and offer a perspective on the research problem that is not available through individual interviews (Palys, 2003, p. 161). The purpose is to uncover factors relating to complex behaviours or motivations, and to develop an understanding of complicated topics (Krueger, 1994, p. 45). In addition, focus groups provide insights into the attitudes, perceptions, and opinions of participants.

Palys (2003) suggests that focus groups are particularly useful for exploratory research, where preliminary findings can be brought to the focus group for further consideration and discussion. In this way, focus group settings place opinions and themes derived from individual surveys or case studies on the table for discussion and extensive group interaction. This format enables participants to "embellish on positions, discuss related dynamics, and articulate the rationale(s) underlying their perspective" (Palys, 2003, p. 162).

The focus group discussions in my research utilized "dialogue", a process of shared inquiry that is described as "the art of reflecting and thinking together" (Chartier, 2002, p. 99). Dialogue is very effective for developing deep understanding and new insight into complex issues. Isaacs (1999) describes dialogue as "a living experience of inquiry *within* and *between* people" (p. 9). The process unfolds as a holistic conversation with a centre, not sides, and is based upon the building blocks of four practices: listening, respecting, suspending and voicing (Isaacs, 1999).

III.2. Tools

Data were collected in two phases during the research project. In the first phase of my research, I used a qualitative, semi-structured survey and in the second phase, two avalanche expert focus groups. Prior to being administered to research participants, the research invitation, survey, and focus group questions were approved by the Royal Roads Ethical Review Committee and my supervisory committee, and then pilot-tested with 10 professional members of the CAA.

III.2.1. Qualitative Semi-Structured Electronic Survey

To examine avalanche decision-making from an avalanche expert's perspective, I asked Canadian Avalanche Professionals to reflect upon their lived experience as a practicing professional, and answer by electronic mail, two qualitative questions about their avalanche-related decision-making:

(1) Describe your most significant avalanche decision-making experience, including how experience, knowledge, skills and human factors influenced your decision(s).

(2) Describe the factors that enable you to make sound decisions when traveling in potential avalanche terrain.

The survey (Appendix A) concluded with general demographic information (years of work experience, area of expertise in the avalanche field, geographic local of avalanche work, highest level of formal training, and gender), which was used solely for the purpose of describing in this thesis, the composition of the participants who completed the survey.

III.2.2. Avalanche Experts Focus Groups

In the second phase of my research, 18 avalanche experts from phase one were invited to attend one of two focus groups to further the inquiry into avalanche-related decision-making (Appendix B). I had three reasons in choosing to hold two focus groups: first, to verify the themes from the survey phase of the research, second to replicate the study, and third, to provide flexibility for participant attendance.

The themes derived from the phase one survey formed the theoretical data upon which the focus group questions were designed. The questions were designed to deepen the inquiry into the themes emerging from the survey phase, and formed the context for discussion during the focus group sessions. I asked participants the following five questions during the focus group sessions:

(1) What decision strategies and processes are used by avalanche experts when making avalanche-related decisions?

(2) What are the factors that influence the decision making of avalanche experts (that participated in this research) that lead to close calls or avalanche accidents?

(3) What are the factors and conditions that enable avalanche expert decision success?

(4) What strategies can support sound decision-making in avalanche terrain?

(5) How can sound avalanche judgment and decision making skills be developed?

III.3. Procedures

III.3.1. Phase One: Qualitative Semi-Structured Electronic Survey

In August 2004, the survey was sent by electronic mail to all professional members of the Canadian Avalanche Association (CAA; n=314). The survey was included in the research invitation (Appendix A), and participants who chose to participate in the study self-selected and returned their completed survey to me. The survey was open for a three-week period, and I sent a reminder note to the CAA professional membership by electronic mail one week before the survey closed.

After reviewing the avalanche decision-making incident described in question one of each survey, I used a set of critical decision interview probes that were designed to obtain information at its most specific and meaningful level as described in Table 1 below (Klein & Militello; 2001). I asked the probe questions in cases where the participant had not addressed that specific content in their initial incident report.

Table 1: Critical Decision Interview Probes

Probe Type	Probe Content
Cues	What were you thinking, seeing, hearing…?
Knowledge	What information did you use in making this decision and how was it obtained?
Analogues	Were you reminded of any previous experience?
Goals	What were your specific goals at this time?
Options	What other courses of action were considered by or available to you?
Basis	How was this option selected/other options rejected? What rule was being followed?
Experience	What specific training or experience was necessary or helpful in making this decision?
Aiding	If the decision was not the best, what training, knowledge, or information could have helped?
Time Pressure	How much time pressure was involved in making this decision?

Note: Adapted from a list of CDM probe questions developed by Klein and Militello; 2001, p.466).

Participants recorded their responses to the survey and subsequent probe questions via electronic mail; therefore a process for verification was inherent in the procedure. Through a process of informed consent, I made a commitment to my participants that their identity and information would be treated confidentially, and that no disclosure of identities, directly or indirectly, would be made in the research reporting.

III.3.2. Phase Two: Avalanche Experts Focus Groups

In the second phase of this action research project, I convened two avalanche experts' focus groups. The first was held at the International Snow Science Workshop in Jackson Hole, Wyoming in September 2004, and the second at Selkirk College in Nelson, B.C. in October 2004. These focus groups were held during a 3.5-hour session. In the first half of the session, participants discussed the themes that resulted from the survey and deepened the examination of decision-making processes in avalanche terrain. In the second half, the discussion centred on processes and strategies for effective avalanche accident prevention in light of these discoveries.

Focus groups were audio taped and a research assistant took notes during the discussion. The themes from these sessions were analysed over a forty-day period and then compiled and sent to each research participant for reflection, verification and additional comments.

III.4. Information Analysis

Qualitative data collected during this research were analyzed using theoretical sampling (Glaser & Straus, 1967; Creswell, 1998), theme analysis (Kirby & McKenna, 1989; Van Manen, 1990) and the systematic, standard format of the constant comparative method in grounded theory research (Creswell, 1998, Merriam, 2002).

In the theme analysis process, I determined the themes and structures that occurred in the decision-making processes of the avalanche professionals participating in the study. Van Manen describes this analysis as "holding on to these themes by lifting appropriate phrases or by capturing in singular statements, the main thrust of the meaning" (Van Manen, 1990, p. 93). This analysis process involved theoretical sampling to control the emerging theory as the research progressed. The primary themes emerged from a detailed analysis of the avalanche incident reports. I collected, classified, and analysed the data in the survey phase of the research, and then used both the preliminary themes and the gaps to collect additional data in the focus groups.

I classified the data from the survey and focus groups into decision factor major themes and their associated sub-themes. Throughout the theming process, I applied the constant comparative method by continually comparing units of data (themes) with each other in order to derive the conceptual elements, categories and properties that form relationships in the development of theory (Glaser & Strauss, 1967; Merriam, 2002).

After the major themes and sub-themes were identified, I applied more specific codes that attempted to capture the specific nature and more subtle cues of each decision factor. This process involved compiling a critical cue inventory (Klein et al., 1989) consisting of all the decision information and perceptual cues that were described by research participants. After the data coding stage was complete, I used a frequency distribution to order the themes from most to least frequent. While determining the frequency is not a component of ground theory, I felt it would be a valuable perspective upon which to base recommendations for decision skills training.

III.4.1. Reliability and Validity

In order to increase the reliability and validity of my results, I conducted two phases of data collection using different tools, a semi-structured survey followed by two avalanche experts' focus groups. Major themes resulting from the survey phase were sent to participants for review, verification and additional comments. These themes formed the basis of the focus group discussions providing an in-depth opportunity to verify and validate the results. Themes resulting from the focus group sessions were compiled in two separate data sets and sent to each respective group of focus group participants for review and verification.

In both cases, I tried to achieve a balance between a general description of the themes using a conceptual diagram, and a particular description that consisted of text and several anonymous exact quotations from the raw data. I considered the themes to be successfully verified and internally valid when participants indicated that they agreed with the themes and that they made sense in light of the data presented. In addition, my supervisory committee assessed these themes prior to distribution to research participants.

Since human behaviour is not static, and what many people experience is not necessarily more reliable than what a single person experiences, reliability is problematic in the social sciences (Merriam, 2002). For example, while the methods of my study can be replicated, the exact circumstances of a semi-structured interview or a focus group can never be exactly repeated. It is important to emphasize that the goal of grounded theory is not to make generalizations with one's findings, since the strength of the method is in the depth the analysis and the detailed description that emerges from the data (Merriam, 2002). However if the findings resonate with a larger group e.g. peer review, they are considered to be reliable and valid.

IV. Ethical Issues

IV.1. Guiding Ethical Principles

This research was carried out under the principles, practices, and procedures described in the RRU Research Ethics Policy and Policy on Integrity and Misconduct in Research and Scholarship (Royal Roads University, 2000), the Tri-Council Policy Statement on Integrity in Research and Scholarship, and the Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans. In addition, the guiding principles of the Social Sciences and Humanities Research Council of Canada (SSHRC) were also adhered to throughout this research. The following eight principles were addressed and diligently considered throughout the conduct of my research project: (1) Respect for human dignity; (2) respect for free and informed consent; (3) respect for vulnerable persons; (4) respect for privacy and confidentiality; (5) respect for justice and inclusiveness; (6) balancing harms and benefits; (7) minimizing harm; and (8) maximizing benefits.

IV.2. Humanistic Ethical Considerations

I received a strong and passionate response from Canadian avalanche professionals to this topic of decision-making and accident prevention. This group is acutely aware of the serious consequences of involvement in avalanches from their experiences as ski area avalanche forecasters, mountain safety specialists, avalanche educators, ski guides, and resource industry avalanche experts. It was my hope that their active participation in this research will lead to a greater understanding of avalanche-related decision-making and discover new insight into avalanche accident prevention in Canada. "Active participation is the key to feelings of ownership that motivate people to invest their time and energy to help shape the nature and quality of their community lives" (Stringer, 1999, p. 38).

At all times my research occurred within an atmosphere of utmost respect for human dignity. Research participants were clearly informed of the purpose of my research prior to their participation including an accurate description of the time commitment required for participation. Participants were invited to participate at their own free choice and were informed that they may choose to withdraw from the research at any point. All participants in this research gave free and informed consent. Consent was given in the first phase when participants self–selected and returned their completed survey to me. Consent was obtained in written form prior to their participation in the focus group sessions, including their permission to audio tape the sessions. I protected the privacy of all participants by ensuring complete confidentiality, and kept all research data on a password protected computer and locked filing cabinet. These data and research notes were not discussed or shared with any individuals other than my supervisory committee.

These data were utilized solely for my research in decision-making in avalanche terrain and accident prevention. Participants were informed that my intent was to publish the results in my Master of Arts thesis at Royal Roads University, and in several trade periodicals including The Avalanche News and The Avalanche Review. In addition, I informed participants that the research results were to be presented at the Canadian Avalanche Association Annual General Meetings in May 2005 and at the biannual International Snow Science Workshop in the fall of 2006.

IV.2.1. Organizational and Community Impact

The recent and significant increase in backcountry avalanche accidents and fatalities has lead to a decrease in public confidence and an atmosphere of scrutiny within the avalanche community by government, legal and insurance officials. This situation presented new challenges in the form of resistance to the access and sharing of information to avalanche researchers, and to the open discussion of human factors and human error in avalanche-related decision-making.

> The 2002/2003 mass casualty avalanche incidents in British Columbia created a crisis of public confidence causing immediate economic impacts to regional, national, and international winter tourism. This loss of confidence resulted in $ 1 million worth of cancellations in the heli-ski industry alone and an estimated $10 million loss to supporting sectors (Cloutier & Heshka, 2003. p. 1).

As a result, the Canadian Avalanche Association, the Association of Canadian Mountain Guides and commercial winter operators are challenged to provide answers to innumerable questions about training and qualification levels, standard operating procedures, decision-making processes, and accident statistics. Restricted access to public land and limitations to professional practice are perceived to be at stake. As a professional member of both of these organizations, I endeavoured to ensure integrity, accountability, and confidentiality throughout my research process. All data and information that I requested was specific to my research in decision making in avalanche terrain was used solely for this purpose.

IV.3. Researcher Bias and Subjectivity

It is important to address that I bring myself to this human research and with this, a deeply personal interest that developed from my direct experience with the phenomena of focus for this study. I stand within this phenomenon and therefore offer a "strong, oriented" (Van Manen, 1990, pp. 135 –160) relationship to this study.

We humans are often described by social scientists as the *thinking species* and create our worlds from our perceptions. I approached this research from this understanding of my orientation and perspectives within the various systems that I am associated with, and that frame my realities and perspectives on this research work. I endeavoured to approach this project with the active engagement and personal commitment to its aims that is critical for action research (Morton-Cooper, 2000, p. 9). However, I recognized that I bring biases to the research process, and strove to be openly cognizant of my biases and subjectivity wherever they arose.

As an avalanche professional, I am responsible for the lives and safety of people, and it is the processes of critical decision-making that forms the heart of this work. I have also had the deeply humbling life experience of responding to avalanche accidents that have resulted from human errors in decision- making. Experiencing the destructive and fatal consequences of these accidents brings the focus of the inquiry very close to me. I feel strongly that a deeper understanding of avalanche decision-making processes and influencing factors will provide the avalanche community with a strong orientation upon which to enhance and support sound decision making at the recreational and professional/practitioners levels. In addition, this research has implications to me, since I know that my own decision-making will be stronger and more thoughtful through my participation in this research inquiry.

It is from the asset of this orientation that I strove, throughout this research, to gain a deeper understanding of the meaning each research participant brought to this inquiry, and to clearly interpret the data within the complexity of this topic. Palys (2003) argues, "we can understand matters only if we also understand something about how they're construed and about the context in which they occur" (p. 13). Action researchers emphasize the importance of this perspective in order to achieve the goals of action research. Zeni (1998) described effective action research as a process involving practitioners studying their own professional practice with the goal of assessing, developing, and improving their practice (p. 13).

V. Study Conduct

The following table summarizes the steps completed during the conduct of this action research project.

Table 2: Summary of Avalanche Experts Decision-Making Research Project

Action Research Steps	Completion Date
Planning Phase	
Major project research proposal submitted for approval	June, 2004
Initiation Phase	
Assessment plan and request for ethical review submitted for review and approval by faculty supervisor , project sponsor	June, 2004

and RRU ethics review committee.	
Secure research partners	July, 2004
Conducting Phase	
Research tools approved by supervisor and advisory committee.	July, 2004
Phase One	
Invite research participants and administer survey.	August, 2004
Deadline for phase one responses.	August, 2004
Theme data and verify.	September, 2004
Phase Two	
Submit focus group questions to faculty supervisor and RRU ethics board for review and approval	September, 2004
Select and invite avalanche expert focus group participants	September, 2004
Conduct first focus group in Jackson Hole, Wyoming at the International Snow Science Workshop	September 21, 2004
Transcribe focus group A	October 15, 2004
Conduct second focus group at Selkirk College in Nelson, British Columbia	October 17, 2004
Transcribe focus group B	November 5, 2004
Theme data and verify	December 20, 2004

Implementation	
Complete data analysis	December, 2004
Meet with sponsor to review research project progress	December, 2004
Complete formative assessment report	December, 2004
Submit thesis chapters as completed	Throughout
Closing Phase	
Submit Thesis for content approval	January, 2005
Submit Thesis for format and copyright reviews	March, 2005
Submit 2 signed copies of Thesis to RRU and RRU library	April, 2005
Final Activities	
Send web page link to thesis and resources to all research participants	May 1, 2005
Present research results at the Canadian Avalanche Association Annual General Meetings	Early May, 2005
Submit paper to The Avalanche News journal for Spring 2005 edition	May 1, 2005

CHAPTER FOUR –

ACTION RESEARCH PROJECT RESULTS AND CONCLUSIONS

I. Research Participants

Thirty-seven Canadian avalanche professionals participated in my research, representing 12% of the professional membership of the Canadian Avalanche Association (n=314) at the time the survey phase was conducted. Research participants represented a cross section of Canadian avalanche industry expertise (Figure 8) and possessed an extensive experience base (Figure 9). Eighty-nine percent of the participants were male (n=33), and eleven percent were female (n=4).

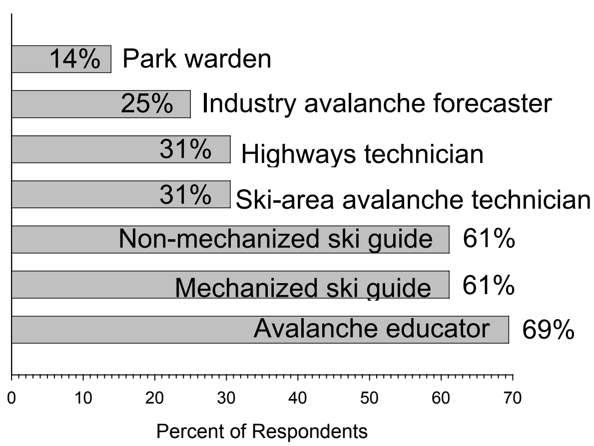

Figure 8. Area of expertise in the avalanche industry.

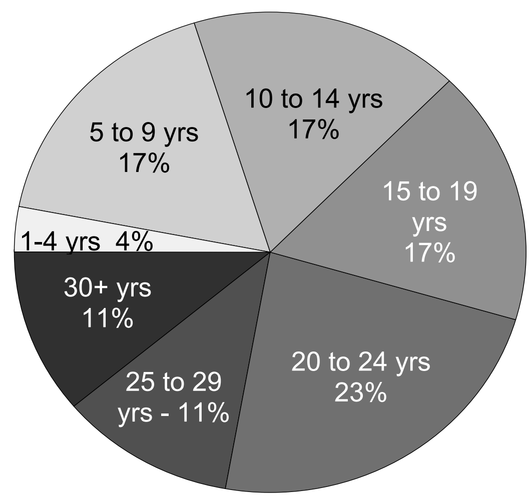

Figure 9. Years of professional experience working in the avalanche field.

Eighty percent of the research participants met or exceeded the minimum of ten years of experience cited as a requirement to develop expertise within a domain (Ericsson & Charness, 1994; Ericsson, et al., 1993; Klein, 1997; Simon & Chase, 1973). The highest level of formal education achieved by participants is shown in Figure 10. In addition, 46% of the participants were professional members of the Association of Canadian Mountain Guides (ACMG). Representation from across the main mountain ranges and snow climates of Western Canada was achieved in this study (Figure 11).

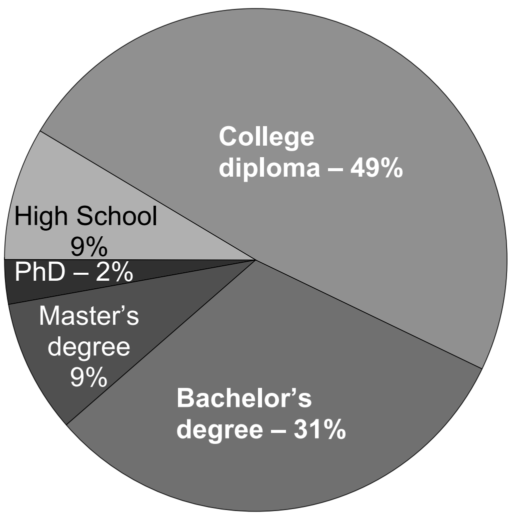

Figure 10. Highest level of formal education achieved by study participants.

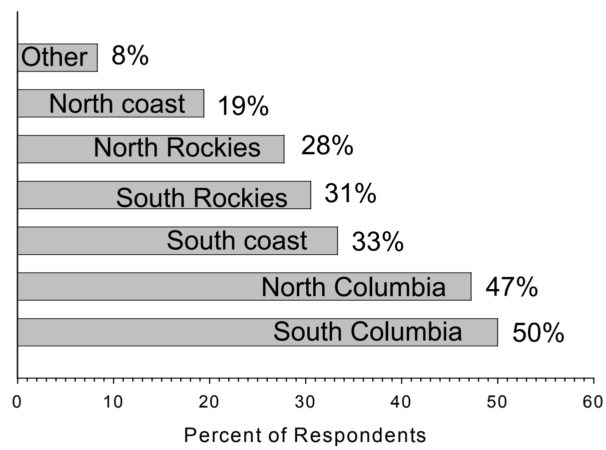

Figure 11. Geographical region of participants avalanche work.

Note: Numbers total more than 100 since most participants worked in several regions.

I.1. Avalanche Experts' Focus Groups

I invited 18 Canadian avalanche experts to participate in the two focus groups from the 37 people who participated in the survey stage of my research. I define avalanche experts as Canadian avalanche professionals who had ten or more years of professional experience working in the avalanche field. Participants were selected according to three criteria: (1) experience, (2) avalanche industry expertise and geographic representation, and (3) gender representation. Fifteen (three were unable to attend) avalanche experts attended the focus groups; eight participants in Jackson Hole, Wyoming, and seven participants in Nelson, British Columbia.

II. Study Findings

II.1. Context of the Study Findings and Thematic Analyses

Research participants in the survey phase described forty-one avalanche-related critical incident decision-making summaries (CIDS). Fifty-nine percent (n=25) of these incidents described experiences of critical decision expertise and success. Forty-one percent (n=17) described critical decision incidents that resulted in close calls or avalanche accidents. The context of the CIDS described by research participants included: highways avalanche forecasting; ski area avalanche forecasting; national parks public safety; ski tour guiding; helicopter-ski guiding; avalanche safety for extreme ski events; avalanche safety for film-making; avalanche safety programs for resource extraction (mining, forestry); and ski guide exams.

My research generated findings that I classified into nine thematic areas: (1) systems of influence in avalanche judgment and decision making; (2) the foundation of avalanche judgment and decision expertise; (3) the judgment and decision-making processes of avalanche experts; (4) avalanche experts' approach to dealing with uncertainty; (5) avalanche experts' attitude and approach to practice; (6) team decision-making; (7) developing expertise in avalanche judgment and decision-making; (8) the influence of human factors in avalanche experts' decision-making; and (9) avalanche experts' systems approach to judgment and decision-making.

The evidence provided by the participants in each of these thematic areas are presented and discussed independently in the following sections. Quotations from participants CIDS are cited by participant numerical code, for example (CIDS 1). Focus group quotations are cited as (FG1) for the first focus group, and as (FG2) for the second.

Part 1: Systems of Influence in Avalanche Judgment and Decision Making

Part 1 Findings and Discussion

1.1. Systems of Influence

In their CIDS's and subsequent focus groups, participants described the processes they used to make avalanche-related judgments and decisions. They also described, in detail, the factors that influenced these judgments and decisions. Three systems of influence emerged: human, physical, and environmental (Figure 12).

Avalanche-related judgment and decision-making lies at the centre of these three dynamic systems of influence. Each of the human, physical, and environmental systems is comprised of complex sub-systems, and the inter-relationships between them form unique conditions and emergent properties that are in constant flux. It is important to consider the connections between the human and natural systems in order to fully understand the context within which avalanche experts make their decisions. Since human behaviour is best understood in the social and natural frameworks within which it occurs, the findings suggest that sound avalanche-related judgment and decisions cannot consider one of these systems in isolation.

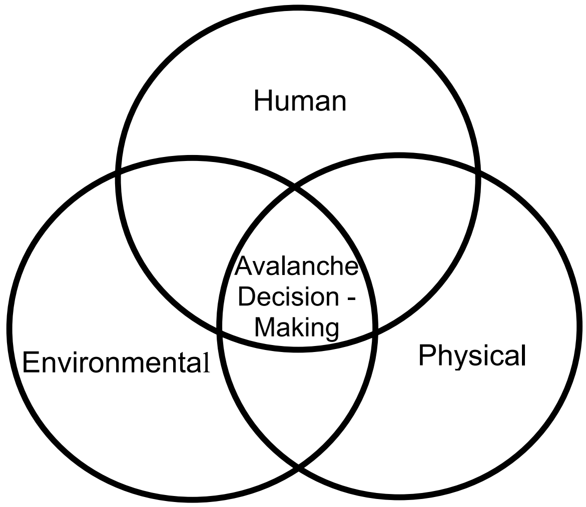

Figure 12. Systems of influence in avalanche decision-making.

For purposes of the analyses, the human system contains the individual, team, client, organizational, and socio-political realms. The physical system contains the terrain, including geographic location, slope aspect, angle, shape, and ground cover. The environmental system contains the snowpack and the weather conditions that create it and influence its instability.

1.2. Human Factor Influences

Five categories of human factors influenced the avalanche-related decisions of the avalanche experts in this study, and were key factors described by participants in the CIDS that resulted in close-calls and avalanche accidents, and the CIDS resulting in decision success (Figure 13). These findings will be presented in Part 8.

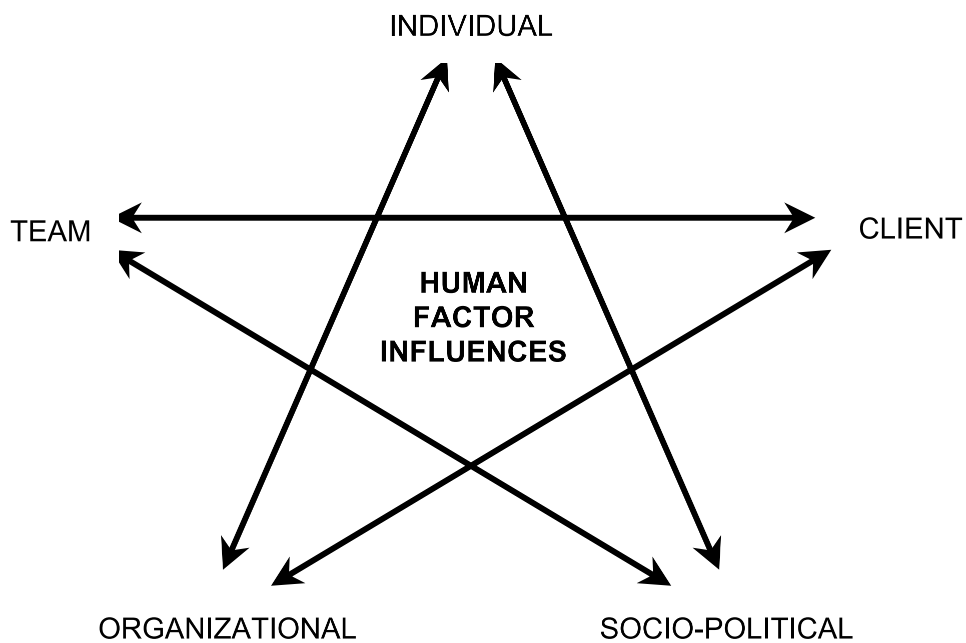

Figure 13: Human factors influencing the avalanche-related judgments and decisions of the avalanche experts in this study.

I present this systems perspective at the outset of this work, since it provides critical insight into the theoretical lens through which these findings are viewed and presented. Utilizing a systems approach to understanding the complexity associated with avalanche decision-making is vital, since we are part of the very system that we strive to understand.

Within this contextual framework, I focus my research findings to an examination of the human system. The discussion of physical and environmental factors will be limited to findings where they influenced the human system, or when they appeared as a perceptual cue that aided the decision process. While it is difficult to make complete separations between these influencing factors within the complex nature of avalanche judgment and decision-making, I have strove to do so in this thesis in order to aid the discussion.

Part 2: The Foundation of Avalanche Judgment and Decision-Making Expertise

> " Time in avalanche terrain has provided me with a large range of experiences and knowledge of terrain choices under varying conditions – the ability to manage the hazard" (CIDS 5).

Findings of Part 2

Three themes emerged as the critical foundation of these avalanche experts' capacities for making sound avalanche-related decisions; experience, knowledge and skills, and relevant information specific to the three systems of influence (human, physical, and environmental).

2. 1. Experience

Experience was extensively discussed by participants as the fundamental core of their avalanche decision-making capacities. "For me it is experience that plays the biggest role in my ability to make good decisions" (CIDS 7). Past experience and the knowledge and skills that developed as a result of experience provided the basis for these avalanche experts' judgment and decision-making processes. A helicopter ski-guide described this phenomenon stating "experience is a huge factor in avalanche decision-making, as the accumulated mileage gives me a conscious and unconscious base of knowledge which to draw from" (CIDS 13).

Participants described how they accumulated avalanche experience temporally over years, and spatially, in different geographic regions and snow climates. For example, a focus group participant explained,

> Exposure to a variety of regions and snowpack conditions helps round out my thinking. When I encounter coastal conditions in the Rockies, or buried facet layers in the Coast range, I can adapt my thinking and decision- making based on what I'm observing at the time (FG 1).

These avalanche experts had developed fine perceptual skills that enabled them to recognize subtle cues, and form meaningful patterns within and between the human, physical, and environmental systems of influence. For example, an avalanche expert related to me how he relied less upon snow profiles, and more upon observations and subtle perceptions as his avalanche expertise increased over the years. In another case, a helicopter ski guide related, "the least important factor [in my ability to make sound avalanche decisions] is profiles, shear tests, compression tests, and rutschblocks. These usually just confirm my previous assessments" (CIDS 34).

2. 2. Knowledge and Skills

These experiences synthesized to build the knowledge base that enabled these avalanche experts to make sense of their experiences, and the situations and conditions they strove to interpret. "Knowledge is the accumulation of experience, for example, the association of a particular slope angle to its likelihood of sliding in certain conditions, or the influence of wind and snow deposition on slab formation when the air temperature is at a certain value" (CIDS 7).

The avalanche experts in my study described how their experiences enabled them to practically apply and understand the knowledge and skills they had gathered throughout their industry training and professional development programs. For example, a ski-area avalanche forecaster related to me how he used his knowledge and skills during a difficult avalanche control mission in unusual conditions. "Thankfully our skills learned through training and experience aided us to place ourselves in a location that reduced our likelihood of becoming involved in the avalanche. I believe this action saved our lives" (CIDS 28).

2. 3. Information Relevant to the Human, Physical, and Environmental Systems

Having information and data relevant to the three systems of influence was the third element in the foundation to avalanche experts' decision-making success. During the focus groups, participants discussed the critical importance of having a "data-rich environment" (FG 1 & 2) in which to support avalanche-related decisions. Their CIDS's included extensive references to the need for relevant current and historical data and information in the decision process, for example, site-specific snowpack data, influencing weather conditions, nearest neighbour conditions, client information and history, organizational logistics and culture. A ski-area avalanche forecaster explained to me: "Few avalanche observations and control routes were occurring above tree-line prior to the incident, and this [lack of information] negatively affected our decision making" (CIDS 27).

Experience, knowledge and skills, and information relevant to the human, physical and environmental systems enabled participants to build strong mental and situational models upon which to exercise their judgments and decision actions. This foundation led to greater confidence in their decisions, and to better decisions when faced with situations of high uncertainty. For example, a mountain guide explained to me, "most importantly, experience allows me to be increasingly more comfortable with my untested decisions" (CIDS 7).

Discussion of Part 2 Findings

2. 4. The Foundation of Avalanche Judgment and Decision Expertise

Experience, knowledge and skills, and information relevant to the three systems of influence (human, physical, and environmental) formed the foundation supporting the avalanche-related judgment and decisions in the avalanche experts' in this study.

2.4.1. Experience.

These avalanche experts identified experience as the core element in the creation of their knowledge, skills, and decision expertise. This finding is consistent with the literature on experiential learning (Cusins, 1996; Kolb, 1984; Marquardt, 1999; Shanteau, 1988) and expertise (Ericsson et al., 1993; Klein, 1998; Shanteau, 1988), suggesting that key characteristics of experts' performance are acquired through experience. How experts use their experiences to create knowledge is the fundamental factor in the development of expertise (Ericsson & Charness, 1994; Phillips et al., in press; Shanteau, 1988). "The primary distinction that separates experts from novices appears to be the breadth and depth of their domain – specific knowledge" (Phillips et al., in press, p. 5).

2.4.2. Knowledge and skills.

The knowledge and skills of these avalanche experts developed through a process of perceiving and understanding their avalanche-related experiences and events, and then transforming this knowledge into strong mental models and changes in their behaviour and decision practice. Mental models are internal representations that depict the avalanche domain. Rich mental models provide knowledge of the relevant elements of the system, a way of integrating these elements to form meaning, and a system for using the understanding to project future states relative to its current state (Endsley, 1997).

This process appears to occur as a continuum, where participants were consciously and unconsciously forming links between individual pieces of data and information to form trends and patterns from which their knowledge and decision expertise grew. This finding supports those of Yates (2001), who suggested that domain-specific knowledge and experience forms detailed mental models of how the entire domain functions. When faced with a situation requiring decision action, the decision-maker employs his or her mental model and it is immediately obvious what decision options make sense (Klein, 1998; Yates, 2001).

2.4.3. Relevant information.

Information relevant to the human, physical, and environmental systems of influence formed the third element within the avalanche experts' judgment and decision foundation. Participants identified site-specific information, synoptic scale information (e.g. nearest neighbour conditions, weather forecasts), and human information within this theme. McClung (2002) differentiates between two information types in the context of avalanche forecasting: *Singular information* that is specific to the current state of the snowpack, and *distributional information*, consisting of knowledge of avalanche outcomes resulting from similar situations in the past.

My study results support McClung's (2002) information types, however I suggest that broadening the context to include the human system would provide a more holistic and accurate perspective in which to solve avalanche decision problems. A more detailed discussion of the human system, and an examination of the human factors that influenced the avalanche experts' decision-making in my study are presented in Part 8 of this thesis.

Summary of Part 2 Key Conclusions

In summary, the following six key conclusions can be drawn from the results of Part 2 related to the foundation of avalanche expert's judgment and decision-making expertise:

1. Experience, knowledge and skills, and relevant information formed the foundation supporting avalanche experts' judgments and decision-making.
2. Information relevant to the human, physical, and environmental systems was critical for sound avalanche judgments and decision actions.
3. Participants accumulated avalanche knowledge and experience temporally over years, and spatially, in different geographic regions and snow climates.
4. As avalanche experts gained knowledge and experience, they developed more expansive mental models (internal representations of the avalanche domain).
5. Detailed mental models enabled these avalanche experts to make sense of their experiences, and the situations and conditions they strived to interpret.
6. These avalanche experts had developed fine perceptual skills that enabled them to recognize subtle cues, and form meaningful patterns within and between the human, physical, and environmental systems of influence.

Part 3: The Judgment and Decision-Making Processes of Avalanche Experts

> "When I am familiar with the terrain, the previous and prevailing conditions, and the avalanche history, I seem to "know" the course of action. When the situation is unfamiliar to me, I trend towards looking at creating and comparing options, and trying to answer all of my questions. I base this process on my knowledge and past experience" (CIDS 9).

Findings of Part 3

3.1. Primary Modes of Cognitive Function in Avalanche Decision-Making

Consistent with the literature on decision-making (Kahneman, 2003; Klein, 1998), I found avalanche experts in my study used two primary modes of cognitive function, intuition and analysis, to make judgments and execute decision actions. For the purposes of these analyses, I define judgment consistent with Yates (2001) as a subjective opinion about what was, is, or will be a decision-relevant aspect of the human, physical, or environmental world. I define decision-making as the cognitive process used to arrive at a decision action.

3.1.1. Intuitive decision-making.

Intuitive processes of decision-making were utilized extensively by the avalanche experts in this study. Intuition is a process of experienced and knowledge-based decision-making. In the intuitive mode, decisions are made using the automatic and rapid operations of perception, utilizing mental models of patterns and information chunks that are accumulated and refined over years of experience (Kahneman, 2003; Klein, 1997, 2003; Phillips et al., in press). Ninety-five percent of participants described using intuitions in their CIDS, and in 83 % of these cases, intuitive decision-making was the primary mode of cognitive function used (Table 3).

Table 3: Summary of Avalanche Experts' Judgment and Decision Processes in High-Stakes Field Decisions.

Finding	Percent of Participants
Primary Mode of Cognitive Function:	
Intuition	83
Analysis	17
Judgment and Decision Processes:	
Pattern Recognition	88
Mental Simulation	76
Critical Thinking	85
Metacognition	
- Decision Success	63
- Close calls and avalanche accidents	12

Note: Findings from avalanche experts' critical incident decision summaries (CIDS). The use of metacognition was the only decision strategy where I found a difference between the CIDS of decision success compared to those of close calls and avalanche accidents.

Using Cognitive Task Analysis (Klein & Militello, 2001; Hoffman et al., 1998) and the Critical Decision Method (Klein et al., 1989; Hoffman et al., 1998), I analysed the CIDS's of participants to determine the cognitive modes and strategies used to make judgments and execute decision actions (Table 3). I divided the data into two sets: Decision success, when the participant recognized the influence of human factors or uncertainty prior to executing the decision actions and effectively managed these influences to result in a positive outcome. Close calls and avalanche accidents comprised the second data set. The analysis of data sets resulted in little difference between the use of cognitive modes and strategies with the exception of metacognition. Therefore, the findings in Table 3 display results from the total data set of 37 participants, with the exception of metacognition where the percentile use is displayed separately for decision success, and for close calls and avalanche accidents.

Intuition alerted these avalanche professionals to recognize potentially dangerous situations, such as the helicopter ski guide who related, "my experience enabled me to have a 'bad feeling' while I was still on top of the run surveying my surroundings" (CIDS 10). A ski area forecaster explained to me, "I had this compelling hunch the whole snowpack was about to let go" (CIDS 12). In another case, an avalanche professional relied on intuition to make critical decisions while in charge of avalanche safety for a crew of eighty film personnel in a high-risk location. He related, "I relied on a 'gut feeling' to warn me when the time to leave the location would come" (CIDS 6).

Intuition also signaled the need for analytic processes when these avalanche professionals faced situations of uncertainty. "I tend to know if my choice is acceptable.

If the consequences are serious, I feel a niggling doubt or 'gut feeling'. Then I'll try to get more information and usually the right choice becomes evident" (CIDS 16).

3.1.2. Analysis.

Participants described processes of analysis as their primary mode of cognitive function in 17% of the high-stakes field decisions described in the CIDS's (Table 3). However, analysis was the primary mode used when making meso-scale decisions from non-field locations. These avalanche experts described a standard operating procedure used for morning forecasts that included analyzing synoptic-scale weather and snowpack information, and then considering local conditions and observations that resulted in their snow stability and terrain use determinations. For example, a helicopter ski guide explained how he "gathered weather history, snowpack data, and client information in the hopes of gathering as much information to make as sound a decision as possible" (CIDS 22).

3.2. Cognitive Strategies

I observed the following cognitive strategies were used in the CIDS's provided by the avalanche experts in my study.

3.2.1. Rule-based decision-making.

The avalanche experts in this study described the use of rule-based decision-making systems at the individual, organizational, and professional levels. A highways avalanche forecaster related, "In critical times, it is important to follow procedure rather than attempting to cut corners" (CIDS 20). Rule-based systems include standard operating procedures to be carried out in specific conditions or situations. Examples discussed by focus group participants included traveling one at a time in areas exposed to avalanche terrain, or following organizational standard operating procedures, for example, Canadian Mountain Holiday's *Mountain Operations Manual* (2004).

3.2.2. Pattern recognition.

Eighty-eight percent of the participants described pattern recognitional processes in their CIDS (Table 3). For example, "As time goes by I am able to spot the trends of events that are leading down the dark road of a difficult decision" (CIDS 7). Pattern recognition enabled these avalanche experts to make sense of a situation by comparing it with their past experiences, or by seeing subtle relationships between the complex factors that were currently influencing snow instability. A senior avalanche forecaster for highways emphasized the extent to which his current decisions were based upon an internal data-base of accumulated patterns: "The success of that week [of avalanche forecasting and control] of very large, continuous avalanches was based in my knowledge of the terrain and how it performs in a storm such as this" (FG 2). In another incident, a ski-area avalanche forecaster noted the patterns in snowpack instability across the terrain within his ski area: "I did not trust the slope because of the previous releases we were seeing in similar terrain" (CIDS 29).

In some situations, participants described this as a conscious, analytical process, such as in the case of this ski area avalanche forecaster: "I make my observations and then reflect upon similar conditions to recall if those similar conditions produced avalanches or not" (CIDS 12). In another case, a national park forecaster related how seeing patterns in avalanche activity gave him confidence when making his decisions (CIDS 5). However, as discussed earlier, in a majority of the high-stakes field decisions described in the CIDS (83%), the process was subconscious and intuitive (Table 3). For example, an experienced ski guide described, "when I am familiar with the terrain, the previous and prevailing conditions, and the avalanche history, I seem to 'know' the course of action" (CIDS 9).

Just as experience enabled these avalanche professionals to recognize patterns from their past experiences, they were also able to recognize when things were abnormal. Recognizing patterns and critical anomalies was the key factor that enabled one expert to provide critical advice to the leaders of another group to change their trip plan from the area they had planned to ski-tour one day. "My knowledge of current and building conditions in the area led me to think about the lack of releases on these north faces, and that the possibility of them coming down was high" (CIDS 15). Later that morning, a massive avalanche released on that north-facing slope, in the exact area the group had originally planned to be.

In another CIDS, a ski-area forecaster in the Rocky Mountains described the impact that unusual conditions had on his teams decision-making confidence: "Most of our anxiety was created by the foreign avalanche behaviour in some of our usually less-active lower mountain terrain" (CIDS 27).

3.2.3. Mental simulation.

Seventy-six percent of participants described using processes of mental simulation to aid their decisions in their critical incident decision summaries (Table 3). Mental simulation is an envisioning strategy where people use their imagination to construct a sequence of events to observe the outcome (Klein, 1998; Ericsson & Charness, 1994). When this theme was discussed at the focus groups, participants unanimously agreed that they used mental simulations extensively when making avalanche-related decisions. For example, one expert stated, "the question of 'what if' occurs every time I come across avalanche terrain. For me, assessing the consequences is very important in my decision making and determines my perception of risk on the terrain" (CIDS 9).

Participants emphasized how effective the application of mental simulation is in complex avalanche-related decisions. "The same terrain cannot be treated the same way since snow conditions are constantly changing" (CIDS 21). Mental simulations also enabled these avalanche experts to analyse the potential results of a decision action. "I rely heavily on creating a picture in my mind of the potential damage a likely or worst case scenario would exact" (CIDS 12).

I found that participants used mental simulations as an analytical process that enabled them to check an intuitive decision, and to see how the actions would play out. For example, an avalanche expert explained his decision processes; "The snow analysis was fairly rational, but analyzing the snow was prompted by my intuition / experiential / emotional reaction to the consequences of an avalanche in the bowl" (CIDS 1). In another situation, a helicopter ski guide described landing at the top of a ski run and noting that "it didn't feel right" (CIDS 13). Since he was unable to rationalize his initial unease (intuition), he decided to gather more information (analysis). He left his group in a safe spot, and then assessed the snowpack conditions and terrain configurations. His observations confirmed his initial feeling of unease and he hiked back up to the group, called the helicopter back to the landing, and flew the group back to the lodge.

3.2.4. Critical thinking.

The use of critical thinking emerged as a predominant theme in this study (Table

3). We think critically when we apply standards to the cognitive structures that are inherent in our thinking. For example, a senior avalanche forecaster discussed the importance of critical thinking in his decision-making process when forecasting for public safety in National Parks: "Working in the avalanche industry forces critical evaluation on a daily basis and includes a large range of snowpack and weather parameters" (CIDS 5).

Eighty-five percent of the CIDS in this study included descriptions of critical thinking processes such as raising vital questions, analyzing self and peer assumptions to determine whether they were justified, evaluating other points of view, or examining the reasoning process for consistency in interpretation when drawing conclusions. Comparing information received from external sources with personal assessments was a method participants frequently used when assessing snowpack instability in an unfamiliar area of terrain. For example, a participant explained, "We checked with friends who worked for the nearby heli-skiing operation. Their information and ours indicated the storm snow had stabilized" (CIDS 1).

An avalanche forecaster working in the movie industry discussed how his extensive knowledge and experience with avalanches caused him to think critically and be more "suspicious" of weaknesses, particularly deep snowpack instabilities. He described several principles that he implemented to guide his decision processes; minimizing 'snap' decisions by requiring 24 hours notice for a location change, and self-assessing hazards physically at the field location in order to develop his own "impression" of the snowpack conditions before reviewing data from other sources (CIDS 6).

In another incident, an avalanche forecaster was preparing terrain for an international extreme ski event. His snowpack assessment resulted in significant concern due to the presence of a deep snowpack instability. However, after conducting extensive explosive control and observing helicopter skiing in the adjacent area, there were no avalanche releases observed. Still questioning, he sought additional information from a local helicopter ski group. He related, "the local guides seemed totally unaware of the deep snowpack instability, and gave no meaningful feedback" (CIDS 17). The next morning, one of the slopes had released in a 250 cm deep slab avalanche. He called event management and told them the event was off. In his CIDS he explained, "it is easy to say YES and have your clients love you. I am ultimately paid to say NO, and that is the hardest of decisions, but so far has never been the wrong one" (CIDS 17). Three weeks later, the entire helicopter skiing industry in that region cancelled the remainder of their season due to snow stability concerns.

3.2.5. Metacognition and situation awareness.

Sixty-three percent of participants described metacognition in their CIDS of decision expertise and success. Interestingly, only 12 % explicitly reported using metacognitive awareness in the cases that involved close calls and avalanche accidents (Table 3).

Metacognition can be thought of as 'seeing clearly' in respect to our internal and external environments. It is a higher-order of judgment and decision making complexity related to systems thinking. For example, a ski-touring guide described using metacognition as a regular process in his decision-making: "I take the time to absorb the surroundings and the mood in the air while my clients get ready. It's a process that I regularly go through, as I like the subconscious approach before I go through my rationale thinking approach" (CIDS 13).

Metacognition also aided a ski-area avalanche forecaster to be conscious of how stress and fatigue may be influencing his decisions: "I try to keep a gauge on my stress level and fatigue so that I am methodical and thorough when making my decisions" (CIDS 27). Another participant discussed his self-awareness in relation to stress, external pressure, and motivations:

> It is valuable for me to understand how I operate under stress and what is motivating the choices I am making. This is important because I find it keeps me honest and allows me to focus on objective conditions rather than subjective opinions or emotions (CIDS 16).

These avalanche experts also used metacognition as an analytic process to check potential biases arising from affective or social influences. "When my senses are alert to the environment, I am aware of when I need to control distractions such as emotions or the need to explain or justify a decision" (CIDS 6).

Discussion of Part 3 Findings

3.3. Systems Thinking

Participants used a systems thinking perspective within which to solve the avalanche decision problems they faced. Using this approach, the human, physical, and environmental systems that influence avalanche decision-making were understood as an integrated meta-system of related and interacting elements, and attention was given to the inter-relationships within. I found these avalanche experts had developed capacities to recognize subtle changes within the meta-system, and respond by adjusting their decision actions accordingly. As avalanche domain experience and knowledge grew, participants' cognitive capacities evolved in qualitatively new ways of thinking and knowing that integrated earlier levels. This notion is consistent with Piaget (1952, 1969), who suggested that cognitive changes are orderly and directional, resulting from adaptation to the demands of the domain in which the individual is involved. This evolving process resulted in constant adaptation within the judgment and decision processes used by avalanche decision-makers in my study, and a continual refinement of the decision framework utilized by avalanche experts, operations, and organizations (a point that is discussed further in Part 9).

This finding is significant since, as avalanche experts gain knowledge and experience, they develop more expansive mental models and they use increasingly higher levels of decision complexity. Thus, the avalanche decision-makers in my study evolved through a hierarchy of judgment and decision-making complexity. Initially judgment and decision actions are rule-based and include an increasing use of analytical processes. As their experience, knowledge, and skills grew, intuitive decision-making becomes more prevalent.

I suggest that when avalanche decision-makers are able to recognize subtle perceptual cues, and maintain a metacognitive awareness of the conditions within the human, physical, and environmental systems, they have evolved into systems thinking processes (Figure 14). This hierarchy can be seen as a cognitive continuum where higher levels of judgement and decision complexity incorporate the lower one(s). This concept is consistent with the literature on Systems Thinking (Flood, 1999; Wilber, 2001; Wheatley, 1999) and Spiral Dynamics (Beck & Cohen, 1996).

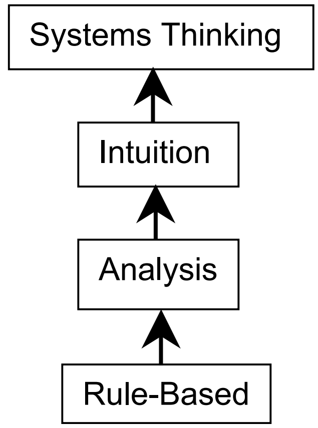

Figure 14: Hierarchy of avalanche judgment and decision-making complexity.

3.4. Primary Modes of Cognitive Function

3.4.1. Intuition.

In the critical incident decision summaries described in this study, most avalanche experts used intuitive processes as their primary mode of decision-making in high-stakes field decisions. I propose this was due to the extensive avalanche industry experience possessed by this group of participants. This finding is consistent with the literature on high stakes decision-making that identifies intuition as the primary mode of cognitive function used by experts in natural settings (Klein, 1998; 2003). I define high-stakes decisions as those characterized by high levels of complexity and uncertainty, and require complicated inferences and judgement for sound solutions. These decisions have two distinct properties: the existence of large financial and/or emotional loss, and the presence of significant difficulties and high costs to reverse a decision (Kunreuther et al., 2002, p. 261).

Intuitive decision-making utilizes the mental models and extensive repertoire of patterns that we accumulate and refine over years of experience. Sets of perceptual cues are unconsciously organized and grouped together to form patterns of knowledge chunks. In a future situation, when a few of these cues are noticed, we know that we can expect to find the others (Klein, 2003; Phillips, et al., in press). We recognize the situation as familiar by matching it to a pattern encountered in the past, including the associated routine for responding with action. As we aquire more patterns and strategies, our expertise increases (Shanteau, 1988). It becomes easier to make complex decisions, since we see new situations with a sense of familiarity and recognize how to act (Klein, 2003).

These avalanche experts explained to me how subtle perceptual cues play an increasingly greater role in their judgment and decision-making, such as in the case of this forecaster who stated: "I've found less and less of a need through the years to stop and dig, although I watch for the subtle changes that alert me, e.g. feeling for wind slabs or scanning ridgelines for cornices" (CIDS 34).

While intuitions can be valuable, we need to use them accurately, and make our decisions based upon informed gut feelings (Klein, 2003). This requires mental models that are based upon a strong experience base, and not upon distorted or biased experience.

It is interesting to note, that while these avalanche experts used intuition so extensively, few could describe the specific process they used to make intuitive decisions. Researchers in expertise and Naturalistic Decision Making (NDM) have reported that experts have difficulty articulating the tacit knowledge behind their procedures, perceptions, and intuitive decision process (Klein, 1998; Shanteau, 1988;

Yates, 2001). In most of the CIDS resulting in decision success, I found avalanche experts simply knew what to do. They were not aware of the cognitive mode that was pre-consciously driving their decisions. However, there were examples of metacognitive awareness, where participants were aware of the factors that were influencing their judgments and decision actions. This finding suggests that avalanche experts have a heavy reliance upon tacit knowledge - knowledge that is not easily verbalized.

I suggest that the intuitive decisions that appeared to be made so effortlessly by these avalanche experts were based upon past knowledge and experiences that were accumulated over a range of scales (including past and recent past). These knowledge and experience events encompassed the accumulation of historical experiences (e.g. years in the avalanche industry) and recent events (e.g. morning meetings) in which an extensive analytic process created the context within which the intuitive decision was made.

3.4.2. Analysis.

I observed analytic processes to be used by these avalanche experts as the primary mode of cognitive function in office based forecasting and avalanche program planning stages. However, participants seldom (17%) reported using analysis as the primary decision mode in their field decisions. In the analytic mode, deliberate effort and reasoning processes are utilized to make judgements and decisions. These operations require significantly more time than intuitive processes, and are more likely to be consciously monitored and deliberately controlled (Kahneman, 2003).

These findings suggest the context of the situation, degree of time pressure, and level of uncertainty were key influencers in the type of cognitive function used by these avalanche experts. In high-stakes field decisions intuitive modes prevailed. However, I found that when these experts identified uncertainty in one or all of the systems of interest, or when an anomaly was observed, they shifted their mode to reasoning and analysis. This included, whenever time-possible, consultation with others. In office-based forecasting, participants had more time and information resources available, therefore facilitating analytic modes. These findings support those made by Naturalistic Decision-Making researchers (Klein, 1998, 2003; Phillips et al., in press; Hoffman et al., 1998).

While I suggest the primary mode of cognitive function is determined by these three variables (context, time-pressure and level of uncertainty), it is important to note that one process did not occur in the absence of the other. These avalanche experts chose a decision solution that worked in the least amount of time and energy when faced with time pressured, high-stakes field decisions. I noticed these avalanche professionals often used the non-primary mode as a quality control check for the primary mode, forming an inter- relationship between the use of intuitive and analytic reasoning processes. Intuition was used as a quality control check for analysis, such as in the case of a ski-area forecaster who described the morning analysis process and then stated: "The final point is – how do I feel about it?" Similarly, analysis was used to check intuitive decisions as a gauge to whether the intuition was based in knowledge and informed experience, or potentially misleading biases.

3.5. Cognitive Strategies

The avalanche experts in this study described use of the following cognitive strategies in their CIDS's:

3.5.1. Pattern recognition

Participants reported using pattern recognitional processes in a majority (88%) of their field decisions. NDM research indicates that experts in diverse domains have a heavy reliance on perceptual skill and recognitional strategies (Hoffman et al., 1998; Klein, 1998, 2004), and they are able to quickly recognize and interpret complex patterns in situations and information (Dreyfus, 1997; Klein, 1998; Klein & Militello, 2001; Klein & Militello, in press; Phillips et al., in press). When faced with complex and uncertain situations, experts draw upon these patterns and analogous experiences and recognize the obvious way to make decisions (Klein, 1993, 1998; Shanteau, 1988).

A focus group participant who had over 30 years of experience in the avalanche industry described this process as a "decision flow" where a current of experience, perceptual cues, and relevant data formed meaningful links to support his intuitive decisions (CIDS 14). This notion is consistent with how Rasmussen (1993) described decision making: "Decisions emerge when the landscape is well enough shaped so the water flows in only one proper direction" (p. 169). Bruns (1997) described how ski guides think in patterns and relate to them in an increasingly subconscious process as the decision complexity increases. He suggested that the most valuable database a guide can have for avalanche-related decision making is relating these patterns of snowpack evolution and distribution of natural activity over time.

3.5.2. Mental simulations.

Participants frequently used strategies of mentally simulating the potential outcomes of their high-stakes field decision actions prior to implementation. Rasmussen (1993) called this cognitive strategy "thought experiments" (p. 168). Mental simulation was originally introduced by Einhorn and Hogarth (1981) resulting from research on anchoring and adjustment strategies. In situations where avalanche experts in my study were faced with new situations or uncertainty, they applied this cognitive strategy to play out their plan of action to see if it would work. For example, a ski guide explained to me how the analysis of terrain and terrain traps is the first thing that he thinks about when deciding whether or not to take his group into a specific piece of terrain. This expert, like many others in my research, had integrated mental simulation as a key component of his decision practice.

Experts' use of mental simulation and envisioning has been extensively documented by decision researchers (Cohen et al., 1996; Einhorn & Hogarth, 1981; Klein, 1998; Klein & Crandall, 1995; Phillips et al., in press). Kahneman and Tversky (1982) identified this process in their heuristics and biases research, describing it as a simulation heuristic. "Experts can use their detailed mental models, coupled with their understanding of the current state of the situation, to construct simulations of how the situation is going to develop in the future, and thereby generate predications and expectations" (Phillips et al., in press, p. 9).

Two recent tools that facilitate mental simulations offer great promise to support sound avalanche-related decisions. Research describing the characteristics of avalanche fracture (Birkeland & Johnson, 1999; Van Herwijnen & Jamieson, 2004; Schweizer, Jamieson & Schneebeli, 2003) has provided statistically significant correlations, and suggests using descriptive information to characterize the triggering potential and characteristics of avalanches. For example, a sudden fracture that crosses the entire column (30 x 30 centimetres) and easily releases the overlying block (sudden planar) provides a visual indication of the fracture character that can be extrapolated to simulate the potential and type of avalanche release in surrounding terrain.

Atkins (2004) proposed an avalanche characterization checklist that defines avalanche regimes and their associated risk management strategies. An increase in the awareness of the character and distribution of likely avalanches, for example, large, dry, deep slabs on basal persistent weak layers, can be translated directly into improved terrain management (Atkins, 2004).

My findings support Klein's (1998) recognition-primed decision model that described how decision-makers use their experience and mental models to make rapid decisions in time-pressured and uncertain conditions that precludes the use of analytical strategies (Figure 15). Klein's model integrates the way decision-makers assess the situation to recognize which course of action makes sense, and the way they evaluate that course of action through mental simulation. Decision-makers assess whether the situation is typical or not. If needed, they diagnose the situation. They understand what types of *goals* make sense, which *cues* are important, what to *expect* next and the typical ways of responding with *action*. If expectancies are violated in the case of an anomaly, they may build a mental simulation , modify the course of action, or reject it and look for another option.

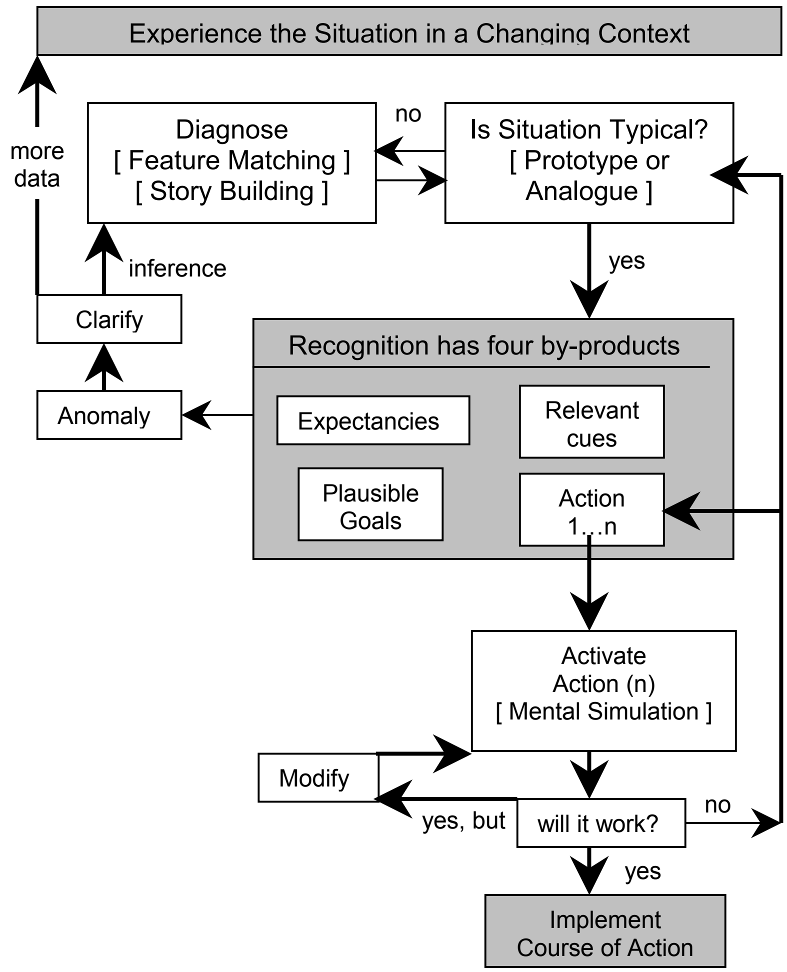

Figure 15: Integrated version of the Recognition-Primed Decision Model (Klein, 1998).

Note: From *Sources of Power: How People Make Decisions* (p. 27), by G. Klein, 1998, Cambridge, USA: The Massachusetts Institute of Technology Press. Copyright 1998 by Klein Associates Incorporated. Reprinted with permission.

3.5.3. Critical thinking.

Critical thinking was integrated throughout the judgments and decision actions in 85% of the critical incident decisions described in this study. Participants applied critical thinking to check the information and their associated inferences for relevancy, accuracy, and biases. Participants described this process as an aide to information interpretation, and to the reduction of uncertainty in the decision-making process. This finding suggests that utilizing critical thinking in avalanche decision-making is integral to objective and sound decisions, and offers a powerful strategy to build expertise and to counter the influences of potentially dangerous heuristic traps and biases in the decision-making process.

While experience-based knowledge is important for good decisions, it is embedded in the past and may not be a precise match with the unique needs of the new problem or situation (Brookfield, 1997; Marquardt, 1999). By beginning with questioning and critical thinking, the decision maker can gauge if the available information is relevant and adequate to the current problem solving needs (Marquardt, 1999). Critical thinking enables decision-makers to dramatically enhance their knowledge and expertise, and also provides the opportunity to effectively reorganize it for future use (Brookfield, 1997). "By focusing on the right questions rather than the right answers, [critical thinking and questioning] explores what one does not know, as well as what one does know" (Marquardt, 1999, p. 30).

3.5.4. Metacognition and situation awareness.

Metacognition and situation awareness are focused extensions of the processes of critical thinking. While 63% of the avalanche experts explicitly reported using metacognition and situation awareness in the CIDS leading to decision success, only 12% reported applying these cognitive strategies in situations that lead to close calls or avalanche accidents. This finding suggests that the use of metacognition and situation awareness in avalanche-related decision-making is a key factor in decision success.

Situation awareness (SA) is our capacity to maintain an accurate perception of our external environment by detecting the source and nature of problems and situations that require action (Klein, 2003; Endsely, 1997). SA capacities evolve through three levels of complexity: (1) perception of the elements of the environment, (2) comprehension of the current situation, and (3) projection of future status (Endsley, 1997).

Metacognition extends SA to our internal environment. Metacognition is our knowledge of, and ability to control, the state and process of our mind (Cohen et al., 1996; Gavelec & Raphael, 1985; Klein, 1998). It has also been described as our ability to take our own strengths and limitations into account (Phillips et al., in press). The use of metacognitive strategies have been found to prevail in situations where experts recognize cognitive and affective patterns through repeated exposure to the numerous situations they have experienced during their years of practice (Cohen et al., 1996). Thus, metacognitive strategies are an effective pre-condition from which avalanche experts can develop confidence in their intuitive judgments and decision actions.

Metacognition and SA enabled the avalanche experts in my study to have a more accurate perception of the human, physical, and environmental systems of influence, and to make better decisions within this awareness. This finding is consistent with aviation research, where pilots strive to maintain an awareness of each other and how their actions fit into the overall objectives of safe flight (Sexton, 2004).

It is important to note that the proportion of participants that reported using metacognition and SA in the situations leading to decision success was significantly fewer than the proportional use of pattern recognition, mental simulation, and critical thinking. I suggest metacognition and situation awareness are critical decision strategies to reduce the influence of human factors and the impact of uncertainty that inhere in avalanche judgment and decision-making. Thus, enhancing the understanding of metacognition and situation awareness, and integrating the use of these strategies in decision skills training would improve the quality of judgments and decisions made by these avalanche experts.

Cohen et al. (1996) proposed the theory of Metarecognition in time-stressed decision making that encapsulates recognizing, critiquing, and correcting processes. The metarecognition process assists decision makers in understanding dynamic, uncertain situations and choosing appropriate actions. Cohen et al., (1996) argued that analogous, metacognitive skills are a critical component of effective problem solving and decision making, and suggested that pattern recognition (recognitional processes) must be followed with a process of critiquing and correcting (metacognitive processes) for proficient decisions.

Summary of Part 3 Key Conclusions

In summary, the following ten key conclusions can be drawn from the results of Part 3 related to the judgment and decision-making processes of avalanche experts in my study:

1. As avalanche experts gain knowledge and experience, they develop more expansive mental models, and they use increasingly higher levels of decision complexity.
2. Using a systems thinking approach, the human, physical, and environmental

systems that influenced avalanche judgments and decision-making were understood as an integrated meta-system of related and interacting elements.

3. These avalanche experts used their experience to have greater confidence in their intuitive and analytic decisions, and to make better decisions when faced with uncertainty.

4. These avalanche experts had developed capacities to recognize subtle changes within the human, physical, and environmental systems of influence, and respond by adjusting their decision actions accordingly.

5. Intuitive processes were the primary mode of decision-making used in high-stakes field decisions.

6. Analytic processes were the primary mode of decision-making used when making meso-scale decisions from non-field locations (e.g. forecasting and terrain use planning).

7. When avalanche experts encountered decision problems that rule-based or intuitive decision-making processes were unable to handle, they reverted to analytic processes.

8. The context of the situation, degree of time pressure, and level of uncertainty were key influencers in the type of cognitive function used by avalanche experts.

9. Pattern recognition and mental simulations were key cognitive strategies used in judgment and decision-making.

10. Critical thinking and metacognition were integral to objective and sound decision-making, and offered a powerful strategy to counter the influences of potentially dangerous heuristic traps and biases in the decision-making process.

Part 4: Avalanche Experts' Approach to Dealing With Uncertainty

"The mountains have always been, and will always be, a place of the unknown - full of beauty and destructive forces" (CIDS 16).

Findings of Part 4

Dealing with uncertainty within the human, physical, and environmental systems of influence was a key theme that resonated throughout the critical decision incident summaries and focus group discussions in my research. Uncertainties in the abilities of clients, in the state of snowpack instability, or in the prevailing weather are examples of factors that influenced the judgments and decision actions of participants. For the purpose of my research, I define uncertainty consistent with Lipshitz and Strauss, (1997) as a sense of subjectively created doubt that blocks or delays a deterministic action.

4.1. The Impact of Uncertainty

A participant explained to me how the variability of uncertainty in snowpack instability across the terrain presented great challenges in managing avalanche risk: "It is easy to identify the safe areas, and it is easy to identify the unsafe areas, but it is difficult to manage the grey areas" (CIDS 6). Participants' emphasized how cognitively challenging it is for them to make decisions that fall within this zone of uncertainty. For example, a rescue specialist explained, "none of us on scene really knew for sure that there would not be another release. In the end, I decided that the need to complete the rescue outweighed the risks" (CIDS 21). This quote illuminates the conflicting challenges these avalanche experts faced when dealing with uncertainty in their daily practice. In another situation, a national parks safety specialist related,

> I require a period of adjustment to make safe decisions if I move into mountain ranges and snow climates I am less familiar with. In that case, I experience a kind of nervous energy, make cautious decisions, and try to collect enough information to feel more comfortable in the new terrain and snow conditions (CIDS 5).

How to effectively manage uncertainty within the human, physical, and environmental systems appeared to be the quintessential challenge faced by this group of avalanche experts.

4.2. Managing Uncertainty

> "It is our job to expect the unexpected, plan for the worst case and simply be aware that surprise events occur" (CIDS 33).

The avalanche experts in this study used a consistent strategy to manage the uncertainty they faced within the three systems of influence – exercising caution and adjusting their decisions towards the cautious side. As one participant related, "I step back in the face of uncertainty" (CIDS 7). Another participant explained to me, "It's those in-between times when the decision making becomes harder. At these times, I tend to become more conservative in my decision making to reflect the high uncertainty of the conditions" (CIDS 34).

I found that the presence of uncertainty determined the level of decision confidence in participants. For example, a ski area forecaster described how uncertainty in the physical and human systems impacted his decision confidence and actions:

> My decision process involves looking at the snow, terrain, and movement of people in it on a micro and macro scale. Once I have some clarity on a

> micro level, and the macro picture is consistent with my observations, then my confidence goes up and I feel like the decision I am making is sound. If there is any discrepancy or inconsistency in what I am observing, or if I don't understand it, I adjust my decision to the conservative side (CIDS 27).

In another case, a ski guide explained to me, "we need to leave a buffer when making decisions in this complex and ever changing medium – a certain amount of space for the grey zone which has been, and will be there forever" (CIDS 16). Another participant related, "since we are operating in a hazardous reality, it is up to us to create the boundaries, by making decisions that allow for misinterpretation and give us space from the grey zone" (CIDS 24).

4.3. Minimizing Avalanche Risk

I found that in conditions of uncertainty, the decision actions of these avalanche experts were consistently tied to minimizing risk and exposure through terrain use. Higher perceived avalanche risk resulted in terrain selection that minimized or eliminated exposure. For example, a helicopter ski guide explained, "our decision was to significantly limit our exposure and select terrain accordingly" (CIDS 23). A national park safety specialist described how he applied a greater safety margin when faced with uncertainty: "My safety margin means reducing choice of terrain and exposure to risk when there is a question of avalanche probability" (CIDS 31). In another case, a ski guide explained how he integrated the awareness of human error into his terrain selection. "Regardless of snow stability, choosing terrain that has lower consequences if you are wrong can make a big difference in the long run" (CIDS 7).

4.4. Decision Modes and Strategies

As discussed in Part III, the context of the situation, degree of time pressure, and level of uncertainty were key influencers in the type of cognitive function used by avalanche experts. Systems thinking and intuitive decision processes prevailed in high-stakes field decisions. However when participants experienced uncertainty within one or all of the three systems of influence, a shift to analytic processes occurred. For example, a helicopter ski guide explained how he gauged his level of uncertainty upon the amount of analysis he used while making field decisions. "If I have to think much about [the decision], the margin of safety is probably too narrow anyways" (CIDS 7). Focus group participants described this process as a shift from unconscious to conscious decision-making.

Discussion of Part 4 Findings

Uncertainty is fundamental to the avalanche risk equation, and lies at the centre of the high-stakes decision problem. The avalanche risk analysis process strives to produce predictions of exposure that are complicated by inherent uncertainty resulting from complex human, physical (terrain), and environmental (weather, snowpack) factors. Uncertainty is a subjective factor, since different people will experience different levels of uncertainty in the three systems of influence (human, physical, and environmental) when faced with the same situation. It is also inclusive since it occurs in no particular form (Lipshitz & Strauss, 1997). McClung (2002) identified human factors and variations in human perception and estimation as a key uncertainty in avalanche-related decision-making. As a result, avalanche risk is a multi-dimensional phenomenon, and how we think of it is complex and multi-facetted (Coleman, 1993; Tyler & Cook, 1984).

This discussion begs the question; why would humans expose themselves to avalanche hazard in the first place? Research indicates that people accept a certain level of subjectively estimated risk to their health, safety, and property in exchange for benefits they hope to receive from engaging in risky activities (Wilde, 2001). Avalanche risk assessment is a dynamic process, and the goals of avalanche-related decision-making vary widely by context. While traditional risk assessments often utilize cost benefit analyses, it is important to recognize that the benefit component is not constant in the avalanche equation. The difference between backcountry skiing and avalanche forecasting for highways public safety is an example.

In back-country skiing, the decision problem is oriented to providing the best quality of skiing while minimizing exposure to avalanche hazard. While the cost of exposure may result in injury or death, the benefit of exposure is an exhilarating ski down a deep powder-covered mountain-side. Backcountry ski guides and their clients are therefore faced with a tangible trade-off between the quality of skiing and client satisfaction, and increased exposure to avalanche hazard. The physical, aesthetic, and social elements of winter backcountry environments are highly prized by winter mountain users across the world, and this poses an additional complexity in the avalanche risk equation.

Conversely, avalanche decision-making for public highways has a different context. Drivers and their passengers are deriving little benefit from being exposed to avalanche hazard, other than avoiding a road delay. In this case there is less tangible benefit to increasing their exposure. The onus is on the highways avalanche forecaster to make conservative estimates of the present and forecasted avalanche risk. Highways forecasters are therefore faced with a different kind of trade-off, where the cost of increased exposure does not provide equally perceived increases in benefits.

4.5. The Impact of Uncertainty

Time-pressured judgments and decisions that must be made under conditions of uncertainty exert significant limitations on the cognitive capacities of avalanche experts. The ability of avalanche experts to make rapid and effective judgments is particularly crucial to successful decision-making. However, the resulting decisions are very difficult to make. "What makes these decisions challenging is not just the spectre of the possible consequences of error, but the awareness of the naiveté with which we are forced to approach them" (Kunreuther et al., 2002, p. 260).

Avalanche-related judgment and decision-making is very complex. Even when the decision problem is well understood, the information upon which avalanche decision-makers depend may be more or less precise. Interpretation of this information involves the integration of complex data from a variety of sources, and occurs within a dynamic interaction of human systems that bring widely different perceptions and values to the decision process. I concur with the notion made by McClung (2002), "the only entities that can truly reduce the uncertainty are more (new) information data of the right kind, or actions that deal with the resolution of variation in human perception" (p. 114).

4.6. Managing Uncertainty

When faced with high levels of uncertainty in their decision-making, participants adopted a cycle of three strategies to manage it (Figure 16).

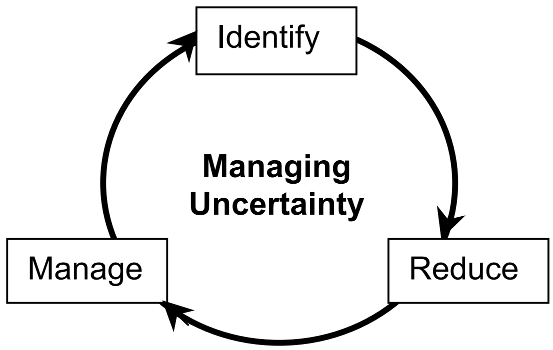

Figure 16: Avalanche expert's system for managing uncertainty.

They (1) identified the source and nature of the uncertainty within the human, physical, and environmental systems of influence, (2) attempted to reduce or resolve it, and (3) managed the uncertainty by adjusting the goals and objectives of the avalanche program accordingly. Since uncertainty within the human, physical, and / or environmental systems is in a state of dynamic flux, the cycle is continuous.

Once avalanche experts identified whether the source lay in the human, physical, or environmental systems, they determined if the type of uncertainty was a result of inadequate understanding, incomplete information or conflicting information. In order to meet the boundary conditions of time and cognitive economics, the goal of these experts was to identify the most important factors concerned, not every possibility that may exist.

This finding emphasizes the importance of using the three-step process to manage uncertainty effectively (Figure 15). Exploring uncertainty in this focused way enables avalanche decision-makers to efficiently reduce or resolve the uncertainty they face, and then manage it appropriately. These findings support conclusions made by Klein (2003) and Lipshitz and Strauss (1997), who emphasised that trying to understand the situation is considerably more effective than generating options for how to deal with it.

4.7. Decision Modes and Strategies

This cycle integrates the cognitive modes (systems thinking, intuition, analysis, rule-based), and decision strategies (pattern recognition, critical thinking, metacognition, situation awareness, mental simulation) that I discussed in Part 3. While identifying the source and type of the uncertainty was a critical first step, the degree of time pressure determined whether participants attempted to reduce the uncertainty, or whether they moved directly to managing its presence by exercising caution in their decision actions. Thus, the extent to which this cycle was completed was a function of the degree of time pressure present.

Empirical research in decision science indicates that collecting additional information or using assumption-based reasoning to extrapolate from available information is an effective method to reduce uncertainty (Lipshitz & Strauss, 1997). The search for more information is a key component of normative decision research models (Jannis & Mann, 1977). However, this method is often problematic in high-stakes situations due to time constraints and the lack of cognitive processing capacity of the decision maker (Klein, 1998). McClung (2002) identifies this point in his discussion of avalanche forecasting, and argues that more or redundant information will not aid an avalanche forecast, however identifying relevant information that reveals snowpack instability and reduces uncertainty will.

4.8. Minimizing Avalanche Risk

An increase in uncertainty within any or all of the three systems of influence (human, physical, environmental) caused a decrease in the decision confidence of participants. The resulting action taken by these avalanche experts was an increase in caution (Figure 17). The level of caution was a function of the perceived severity of the consequences of avalanche involvement. Resulting decision actions included increased mitigation, reducing terrain exposure, or choosing terrain closure or avoidance. As I have discussed, the level of uncertainty experienced is unique to each individual and is based upon experience, knowledge and skills, and relevant information. This explains why one avalanche decision-maker may execute different decisions than another when encountering the same situation.

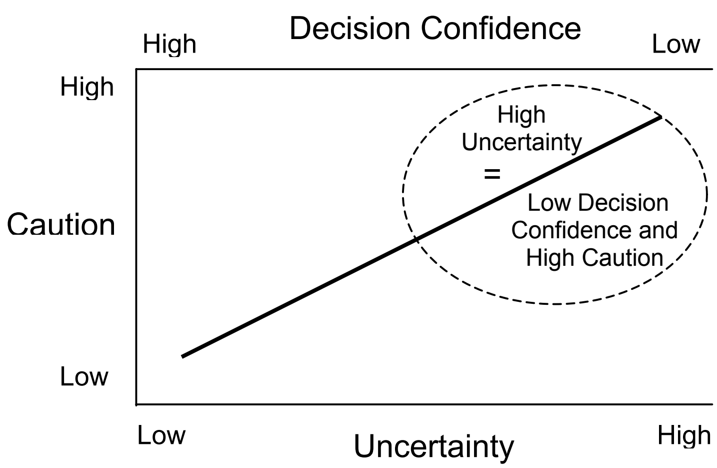

Figure 17: The impact of uncertainty in the judgment and decision actions of avalanche experts.

Note: As uncertainty in the human, physical, or environmental system(s) increased, decision confidence decreased resulting in more cautious actions. The level of caution was a function of the perceived severity of the consequences of avalanche involvement.

Avalanche–related decision-making strives to minimize uncertainty, and to match the human perception with reality (McClung, 2002). Reducing exposure or choosing avoidance was the fundamental method these avalanche experts used to manage uncertainty in the human, physical, or environmental system(s). These decision actions included reducing exposure to avalanche terrain, or choosing terrain avoidance. Examples from my research included modifying route and ski-run selection in the back-country, reducing access to or closing terrain within ski area boundaries, or removing film crew or highway traffic from areas of perceived exposure. Thus, uncertainty was effectively managed through active and continual modification of the goals and objectives of the avalanche program, in relationship to the identified level(s) of uncertainty within the three systems of influence (Figure 18).

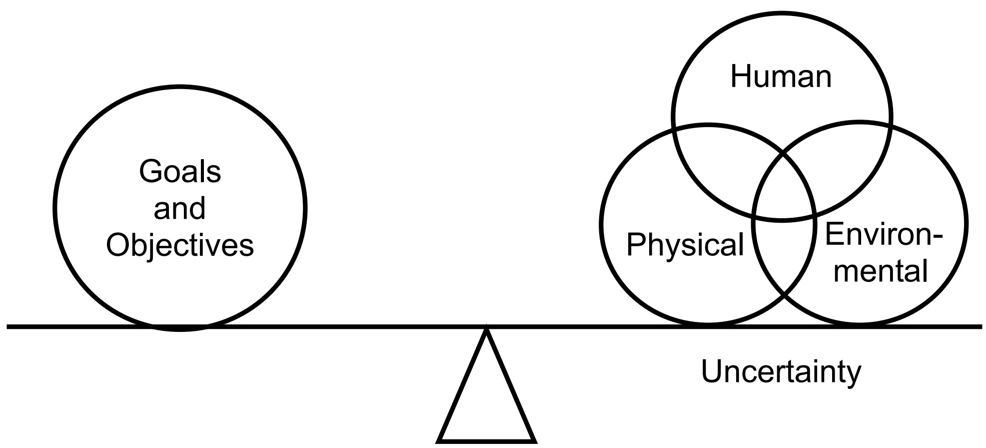

Figure 18: Managing uncertainty: a tradeoff with goals and objectives.

Note: Managing uncertainty is achieved by avalanche experts by maintaining constant balance between the goals and objectives of the avalanche program, and the level of uncertainty within the three systems of influence; human, physical and environmental.

My findings support those made by Lipshitz and Strauss (1997), who suggested that decision-makers acknowledge uncertainty in two ways: (1) by taking it into account in their decision actions, or (2) by preparing to avoid it. In this way, controlling the sources of variability that reduces predictability is an effective method to manage uncertainty.

4.9. Failure to Manage Uncertainty

I found that when these avalanche experts did not effectively manage the uncertainty they faced, they used several negative strategies to cope; denying the presence of uncertainty by explaining it away, or not dealing with the presence of uncertainty by continuing with their original goals and plans without modifying their decision actions. These findings will be discussed in Part 8 – The Influence of Human Factors in Avalanche Experts Judgment and Decision-Making.

Summary of Part 4 Key Conclusions

In summary, the following eight key conclusions can be drawn from the results of Part 4 related to how avalanche experts deal with uncertainty:

1. Uncertainty is a subjective factor, since different people will experience different levels of uncertainty in the human, physical (terrain), and environmental (weather and snowpack) systems of influence when faced with the same situation.
2. Avalanche experts managed uncertainty by identifying the source and nature of the uncertainty (human, physical, and / or environmental), attempting to reduce or resolve it, and then managing it accordingly.

3. In order to meet the boundary conditions of time and cognitive economics, the goal of these avalanche experts was to identify the most important factors concerned, not every possibility that may exist.

4. As uncertainty within the human, physical, and / or environmental systems of influence increased, decision confidence decreased and resulted in more cautious decision actions.

5. The level of caution was a function of the perceived severity of the consequences of avalanche involvement.

6. Reducing exposure or choosing terrain avoidance were the primary methods these avalanche experts used to manage uncertainty.

7. Uncertainty was effectively managed through active and continual modification of the goals and objectives of the avalanche program, in relationship to the identified level(s) of uncertainty within the human, physical, and environmental systems of influence.

8. When avalanche experts did not address and/or effectively manage the uncertainty they faced, they used several negative strategies to cope; denying the presence of uncertainty by explaining it away, or not dealing with its presence by continuing with their original goals and plans without modifying their decision actions.

Part 5: Avalanche Experts' Attitude and Approach to Practice

> "Experience, an unconscious feel for the situation, and a commitment to safety overriding all other factors - another day in the life of an avalanche professional" (CIDS 13).

Findings of Part 5

I found that the avalanche experts in this study held an attitude of deep respect for the complexities of avalanche phenomenon, and for the imperfect nature of human decision-making. Their attitude and approach to avalanche-related decision-making had developed through their extensive experiences in the avalanche domain, and through life in general. As one participant related, "We need to leave a buffer when making decisions in this complex and ever changing medium – a certain amount of space for the grey zone which has been and will be there forever" (CIDS 16). A list that describes the fundamental principles within which these avalanche experts approached their practice is provided in Appendix C.

5.1. Knowledge of Limitations

Participants described how their ability to objectively manage avalanche hazard and risk was a direct result of their knowledge that was created through a transformation of their experiences. "Experience, combined with age perhaps, has tempered my personal drives to a degree" (CIDS 5). This ability included recognizing that errors in human judgment and decision-making were possible such as the case of this avalanche expert who related, "I recognize I have made past errors and will do so in the future" (CIDS 1). Another participant described the importance of, "maintaining a margin of safety that is just a hair bigger than what I think I need" (CIDS 12).

All of the avalanche experts in this study had experienced close calls during their career as an avalanche professional. These experiences had increased their respect for the uncertainties associated with avalanche phenomena, and the serious consequences of involvement. For example, a ski area forecaster expressed his personal philosophy towards his practice:

> Humility is critical. I try to always be careful and remember everything around me is bigger than I am. Things move and shift in the mountains because of balance. I see this as a physical law, and I must try to understand, interpret, and work with these laws as much as I can. (CIDS 27).

These experiences reinforced the importance of including a buffer zone of safety within their decision actions. For example, one participant described how he incorporated an awareness of human error in his decision practice; "Anticipate the unexpected, prepare for the worst case scenario, and be prepared to be wrong or fooled" (CIDS 33).

5.2. Fundamental Commitment to Safety

The avalanche experts in this study held a commitment to safety that was the fundamental factor in their decision actions. For example, a participant explained, "I have a willingness to sacrifice thrill and objectives for a wide margin of safety – e.g. a willingness to turn around" (CIDS 5). In another case, a ski guide described how she reversed her decision and climbed back up to her group that was awaiting instructions at the top of the slope. "I was 100 m down the slope when I got an easy shear down 60 centimetres. It was going to be a brutal hike up through deep powder, and it was my first day guiding after having had the flu. Back up I went" (CIDS 10).

This theme of reversing decisions was a topic of much discussion in this study. Participants described the tremendous human factor challenges they faced from themselves, peers, clients, or their organization to reverse a decision once the decision action had begun. A safety specialist related to me, "once we were committed, it would have taken a strong indicator to change our course of action" (CIDS 5). A focus group participant summed up the discussion by advising, "do not underestimate the difficulty in changing your decision, once you "green light" a location" (CIDS 6).

An awareness of these limitations, combined with an attitude of safety, enabled participants to modify their goals and objectives in order to achieve balance within the changing conditions in the three systems of influence (Figure 18).

5.3. Challenges Faced by Avalanche Experts

While these avalanche experts described how their attitude and approach shaped their practice, they also related to me how they experienced internal conflicts as a result of their judgments and decision actions. Since expert judgment and decisions rely heavily on tacit knowledge (knowledge that is difficult to verbalize), these avalanche experts found it difficult to articulate their no-go decisions to clients, managers, and stakeholders. For example, a ski guide related, "Going with my initial unease that I can't rationalize, and with the shape of the slope and the steam vents present, I was not too keen to ski this slope" (CIDS 13).

When they made decisions not to ski a slope or open an area of terrain, their decisions were often not validated in a tangible way (e.g. an avalanche release), which often resulted in a lack of feedback for their decision quality. For example, a national parks forecaster related, "It is hard to assess what 'might' have happened. The most significant decision may have been a simple one made on a number of mornings over many winters to just not go into the backcountry and spend the day in town instead" (CIDS 5).

The following quote from a ski area forecaster illuminates these conflicting challenges:

> It was logistically difficult to close this slope in the middle of a busy spring day of skiing. I began to be overcome with a swelling fear that the slope would avalanche if I didn't close it. I decided to close this side of the mountain to the public. We used hand charges to control the slope, but it did not fail. I wish the slope had failed, which would have validated my decision, but it did not. After many years of successful forecasting, I was left feeling a bit sheepish about my sudden paranoia (CIDS 12).

Conversely, participants related how it was exceptionally confirming and reinforcing when they had the rare opportunity to experience direct feedback for a sound, expert decision. For example, a mountain film safety specialist described how he felt several days after he made the decision to limit film crew access to an area of avalanche prone terrain. "I flew past the location 2 days later and saw a very significant, size 3 avalanche deposit laying on top of our previous location. I was tempted to fly the manager over to see this but I never did. In hindsight I should have" (CIDS 6).

These avalanche experts also described the internal struggles they experienced when their decision was more conservative than their teammates. For example, a ski guide described, "I got the heebie-geebies while watching my partner head up a small gully with a ditch at the bottom. I felt guilty for undermining my partners decision, but my main goal was to come home - so I lived with it" (CIDS 26). In another case, a participant related:

> I skied down and expressed my concerns about the slope to my partner. He was more experienced and had skied the bowl before. After listening to my concerns, he proposed continuing, however I was still nervous about triggering a large avalanche in the bowl. That evening, I felt uncomfortable having persuaded an experienced friend with more local knowledge to leave our descent route. In subsequent weeks, I decided the decision was reasonable given [my analysis], and since then I have read of other incidents in which skiers triggered a fracture [in similar conditions]. I am grateful that he listened to my concerns (CIDS 1).

These quotations reflect the internal struggles that these avalanche experts experienced as a result of the complexities and systemic challenges of avalanche decision-making. The influence of human factors on the judgment and decisions of participants will be discussed further in Part 8 of my thesis.

Discussion of Part 5 Findings

The avalanche experts in this study held an attitude of deep respect for the uncertainties inherent in avalanche phenomenon, for the consequences of involvement, and for the imperfect nature of human decision-making. Knowledge of these limitations and a deep commitment to safety was fundamental to how they approached their practice. These avalanche experts were sensitive to their own limitations and as a result, were able to make continuous and subtle adaptations to their decisions. Klein and Militello (in press) reported that expert's ability to take their strengths and limitations into account is a key metacognitive strategy in successful decision-making.

However, it is important to note that the task of avalanche decision-making is complex and difficult, and that avalanche experts occasionally experienced internal conflicts and external doubt from clients and management as a result of their decision actions. I suggest that personal mastery appears to play a significant role in the quality of competence for avalanche decision expertise. Personal mastery involves making decisions based upon a strong set of core values and principles (Covey, 1989; Flood, 1999; Kouzes & Posner, 1995; Senge, 1990), and reduces the influence of human factors in the judgment and decision process. Thus personal mastery is a key foundation for these avalanche experts' capacities to make objective and principle-based decisions. A further discussion of personal mastery is included in Chapter five of this thesis.

Summary of Part 5 Key Conclusions

In summary, the following five key conclusions can be drawn from the results of Part 5 related to the attitude and approach to practice of the avalanche experts in my study:

1. Participants possessed an attitude of deep respect for the complexities of avalanche phenomenon, and for the imperfect nature of human judgment and decision-making.
2. Avalanche experts held a commitment to safety that was the fundamental factor in their decision- making. As a result, they incorporated a buffer zone of safety within their decision actions.

3. An awareness of these limitations (metacognition), combined with an attitude of strong principles, enabled participants to modify their goals and objectives in order to achieve balance within the changing conditions in the human, physical and environmental systems of influence.
4. The task of avalanche decision-making is complex and difficult, and avalanche experts recurrently experienced internal conflicts and external pressures from clients and management as a result of their cautions decision actions.
5. Personal mastery involves making decisions based upon a strong set of core values and principles, and was a key foundation for these avalanche experts' capacities to make objective, sound decisions.

Part 6: Team Decision-Making

> "We do not need to get much better at our knowledge about snow, as much as we need to know ourselves and the people we work with better" (CIDS 18).

Findings of Part 6

Participants occasionally described decisions that were made in isolation, such as in the case of a lone ski-touring guide with a private group, or a single avalanche forecaster hired for snow safety at a winter mining operation. However, avalanche-related decisions more frequently occurred in a team environment. I define team decision-making in keeping with Orasanu and Salas (1993), as a process where highly differentiated and interdependent members share information and diverse task perspectives in a decision process to achieve a common goal.

6.1. The Team Mind

A primary theme in this study was that collective knowledge, experience, resources, and diverse perspectives resulted in improved avalanche-related decision-making. For example, an avalanche expert and owner of a helicopter ski company related,

> I feel strongly that one of the major factors enabling sound decision-making is the collection of data and information by all guides on a continuous basis. This information goes into a database, and provides both history and current information at daily morning guides' meetings over a very large area that would be very difficult to obtain on ones own (CIDS 14).

A ski-area avalanche forecaster described the routine that he consistently followed in the morning before heading out into the field. After reviewing the InfoEx and weather synopsis, he met with his team members and they shared relevant information and observations with one another in what he described as a "very objective and observant" process. Checking the consistency and alignment between the judgments of other team members was crucial in his decision process (CIDS 27).

In addition to personal experience, the vicarious experiences of others influenced and aided participants' avalanche-related judgments and decisions. Information and events regarding the human, physical, and environmental systems that were experienced by another person and shared through formal (e.g. InfoEx, notable reports) or informal (e.g. discussion and stories) methods added valuable information to the database that these avalanche experts drew upon. For example, an avalanche expert related how he recalled the actual experience of a respected peer when he was skiing in unfamiliar terrain. "In the previous ten or so years, there had been two close calls in the bowl, both involving experienced people, one of whom we both knew" (CIDS 1). This vicarious experience aided his decision to leave the bowl due to suspected snow instability, and descend via a route with no avalanche exposure.

A senior forecaster for National Parks described how collective experience, trust, and simply knowing his partner enhanced their decision-making and reduced the influence of biases in the decision process. "Communication is almost telepathic as shown through the timing of our decisions and follow up discussions. We trust each other to make the appropriate decisions, and are aware of the other person's mental state" (CIDS 5).

Participants explained to me how cumulative experience working with team members augmented their judgment and decisions, such as in the case of this National park safety specialist; "My partners had high levels of avalanche knowledge and similar years/types of experiences. We were a small group who understands the risks and know each other well and each person's reaction in risk situations" (CIDS 5).

The collective knowledge of snow science and terrain, coupled with an understanding of the human components of the group gained through shared experiences, resulted in shared mental models and exceptional decision-making. A safety specialist emphasized how her team members were "aware of the other team members mental states" (CIDS 37). Thus, collective metacognition enabled the team to employ critical thinking to ensure judgment accuracy and sound avalanche-related decisions were achieved amongst the group members.

6.2. Collaborative Decision-Making

Participants described how they "bounced ideas off one another" to gauge a collective feel for the explosive requirements for the day, or engaged in extensive discussions to determine how to practically deal with a terrain feature or identified hazard within the logistical parameters of the day (FG 1 & 2). These discussions enabled participants to share observations, information, and diverse perspectives in a collaborative process of decision-making. For example, a ski area forecaster explained how "noting observations from other teams is critical for observing trends or assessing the current state of conditions"(CIDS 27). In another case, a ski guide explained, "I like to ask other guides [how they would deal with a specific situation] e.g. 'how did you deal with this feature or hazard'?" (CIDS 13). In this way, these avalanche experts engaged in a co-creative process of pattern recognition, and used processes of mental simulation to arrive at sound decision conclusions. In addition, these interactions enabled participants to broaden their judgment and decision capacities.

After various information and different points of view were explored by team-members, conclusions regarding decision actions were often based upon the most conservative perspective that existed. For example, a ski guide explained, "we adhere to a guiding standard that says if one person on staff vetoes an area, we all respect this [perspective] and do not use that terrain on that day" (CIDS 4). In another situation, an avalanche expert related, "I am grateful that my partner listened to my concerns and agreed to err on the side of caution, even though he thought my preference to leave the bowl was very or overly cautious" (CIDS 1).

6.3. Communication

Participants emphasized the critical importance of an atmosphere of open communication within which to encourage and share diverse perspectives. As one participant explained, "communication is very important in our program. We always talk about what we are seeing and thinking before an action is taken" (CIDS 29). Co-creating meaning and understanding through feedback, dialogue, and group discussion enabled the avalanche experts in this study to develop shared situation models and make better decisions. For example, a ski area forecaster related, "peer feedback, good communication, and discussion is critical to my decision process. I use any opportunity to bounce ideas off of others" (CIDS 27).

Respect and encouragement for differing opinions in an atmosphere of open communication was a consistent theme throughout both phases of my research. For example, a senior examiner for the Association of Canadian Mountain Guides emphasized that the team decision-making process should not focus on achieving consensus. Rather the emphasis is on communication, critical thinking, considering a variety of observations and experiences, and exploring the reasoning process from different points of view (FG 2).

I found that a deficiency in communication was a key factor in the close calls and avalanche accidents in this study (Part 8). This finding implies that effective communication is fundamental to successful avalanche decision-making. In this section, I have limited my findings and discussion of team decision-making to the processes involved. An examination and discussion of the influencing human factors in team environments will be discussed in Part 8.

Discussion of Part 6 Findings

6.5. The Team Mind

Team decision-making dramatically enhanced the learning and decision-making capacities of these avalanche experts, by adding information, resources, and diverse perspectives. Discussions at morning and evening meetings, and in high-stakes field situations, enabled these avalanche experts to develop shared mental models of the situation and collectively reduce uncertainty. This finding suggests that team decision-making improved the judgement and decision actions of these avalanche experts, and reduced subjective biases that may have been present in an individual decision-maker.

6.6. Collaborative Decision-Making

Collaborative decision-making enhanced the judgment and decision actions of study participants. Collective knowledge of snow science and terrain, coupled with an understanding of the human elements of the group gained through shared experiences, resulted in shared mental models through which these avalanche experts could exercise exceptional decision-making. These findings are not unique to the avalanche domain, as similar results have been reported in emergency medicine, aviation, military operations, and rescue (Klein, 1998; Sexton, 2004). Sexton (2004), reported that heedful interactions (considering ones actions in relation to others) in high-risk environments allows teams to optimize cognitive resources, knowledge, and experiences by capitalizing upon the redundancies of the team as opposed to individual members.

6.7. Communication

The quality of the interactions within the team had significant effects upon the outcomes of the critical situations described by participants in this study. Effective communication was a critical requirement for these avalanche experts to share their knowledge and perspectives, and to establish a common understanding of the decision problem. This common understanding resulted in shared situational models providing participants with a shared picture of current conditions within the human, physical, and environmental systems, and the associated goals and objectives of the avalanche program.

I found that good communication led to shared mental and situational models, and to greater solutions to the decision problems faced. In addition, greater levels of communication within avalanche teams resulted in less uncertainty, richer situational models, and higher levels of decision confidence. In contrast, poor or ineffective communication was a main factor in the CIDS of close calls and avalanche accidents. This finding correlates with results of the *Group Interactions in High-Risk Environments* research project, where improving communication was one of two key recommendations to reduce human error and improve team performance (Sexton, 2004).

Participants emphasized the importance of having an open atmosphere that encouraged discussion and critical thinking. Questioning was a key element of the process, and provided participants with an opportunity to explore assumptions and ensure that the information used in determining decision actions was accurate and relevant. Sexton (2004) reported that teams who asked a lot of questions to clarify uncertainties and improve predictability resulted in higher subsequent performance. Thus, the importance of establishing and maintaining an atmosphere of open communication amongst avalanche decision makers and stakeholders cannot be overemphasized.

These findings suggest that an environment that encourages effective and open communication within the group members is crucial to the development of sound judgment and decision actions. This notion is consistent with those reported in the aviation industry by Sexton (2004) who stated, "In high-risk situations the quality of human interaction is critical to the minimizing of human error" (p. 5).

Summary of Part 6 Key Conclusions

In summary, the following seven key conclusions can be drawn from the results of Part 6 related to team decision-making:

1. Team decision-making enhanced the learning and decision-making capacities of these avalanche experts, by adding collective knowledge, information, resources, and diverse perspectives.
2. Team decision-making and collective metacognition reduced subjective biases that may have been present in an individual decision-maker.
3. The vicarious experiences of others influenced and aided participants' avalanche-related judgments and decisions.
4. Conclusions regarding decision actions were often based upon the most conservative perspective that existed amongst group members.
5. Teams used co-creative process of pattern recognition and mental simulations to arrive at sound decision conclusions.
6. Greater levels of communication within avalanche teams resulted in less uncertainty, richer mental and situational models, and higher levels of decision confidence.
7. An environment that encouraged effective and open communication within the team members is crucial for decision-making success.

Part 7: Developing Avalanche Judgment and Decision Expertise

> "It is easy to say YES and have your clients love you. I am ultimately paid to say NO, and that is the hardest of decisions, but so far has never been the wrong one" (CIDS 17).

Findings of Part 7

7.1. Experiential Learning and Deliberate Practice

These avalanche experts used their experiences and those of others to aid their judgments and decisions, and subsequently learned from these experiences to generate new knowledge, insights, and behaviour for their future practice. For example, a participant related how his decision-making had improved by learning from others. "Learning from others has proved to help me make better decisions, as I see how others respond to conditions and group decision-making" (CIDS 34). In another case, a ski guide described to me how his most significant experience came from the "good fortune" of working with an ACMG Mountain Guide in the same terrain for several winters (CIDS 22).

7.1.1. Feedback and reflection.

Participants cited decision feedback related to successful decisions, accidents, close-calls, and case histories as a critical component of their experiential learning. For example, a National Parks safety specialist explained to me how he engaged in a process of reflection and "critical self-evaluation" after executing his decisions that included an "analysis of mistakes made by oneself and others" (CIDS 31). Peer feedback and subsequent reflection resulted in the creation of strong mental models for future decision practice.

7.1.2. Enhancing knowledge capacities.

These avalanche experts actively engaged in deliberate activities to improve their expertise and decision capacities, such as in the case of this forecaster who related, "I'm constantly trying to expand my knowledge base by reading books, taking courses, and spending time with other experienced professionals" (CIDS 34). The extensive knowledge of these avalanche experts was generated through a transformation of their experiences. These experiences included attending lectures by scientists and practitioners at industry symposiums such as the International Snow Science Workshop, or the CAA annual general meetings.

These knowledge transfer events had a powerful impact upon participants learning. The new information was transformed to meaningful knowledge as these avalanche experts made links between past and present understanding, and then integrated this expanded awareness into their avalanche practice. Exposure to new ideas and practices resulted in improved judgments and a greater capacity to gather and communicate relevant information. I observed that a deep motivation to learn was shared by all of the participants in this study, as in the case of a ski area forecaster who expressed, "I am always trying to learn – there is so much to learn!" (CIDS 19).

Discussion of Part 7 Findings

"When you read and are taught, you gain knowledge;

when you take action, you gain experience;

when you reflect, you gain an understanding of both"

(Anonymous, as cited by Marquardt, 1999, p. 7).

7.2. Experiential Learning and Deliberate Practice

The knowledge and expertise of these avalanche experts was created and constructed through a process of perceiving and understanding relevant experiences and meaningful events, and then transforming this knowledge into changes in perception, judgment, and behaviour. This finding is supported by extensive research in adult learning that identifies experience as the most valued resource in the learning process (Knowles et al., 1998; Kolb, 1984; Taylor et al., 2000). Participants used their experience to develop strong mental models (Klein & Militello, 2001) upon which to exercise the processes of pattern recognition, mental simulation, critical thinking, and metacognition (Part 3).

I found that as avalanche domain-specific knowledge increased, participants developed increasingly fine perceptual skills that enabled them to recognize subtle cues, and form meaningful patterns within and between the human, physical, and environmental systems of influence. In this way, these avalanche experts demonstrated the characteristics of *perceptual experts*, having the ability to perceive differences that are unobvious to other less-experienced people, and of *cognitive experts*, who have the capacity to discover relationships and patterns that are not found by others (Shanteau, 1988).

How experts organize and access their knowledge distinguishes individuals at different levels of ability and expertise (Anderson, 1983; Chi et al., 1982; Klein & Militello, 2001; Phillips et al., in press). In my study, I found that avalanche decision-makers evolved through a hierarchy of judgment and decision-making complexity that commences with rule-based decision-making and evolves through analysis and intuition to systems thinking (Figure 13).

However, the accumulation of avalanche domain-specific experience as a single factor does not necessarily produce expertise or enable higher orders of decision-making complexity. It is what these avalanche experts did with their experiences and events that made the difference. This finding is consistent with those of Ericsson et al., (1993), who stated that the maximum level of performance is not automatically attained as a function of experience.

7.2.1. Motivation to learn.

The finding that participants had a deep motivation to learn is significant since motivation appears to be the most cited condition in the literature on learning and skill acquisition (Brookfield, 1997; Ericsson et al., 1993; Phillips et al., in press). Research indicates that motivation to improve practice must be closely connected to the goal of becoming an expert (Ericsson et al., 1993). Participants engaged in deliberate practice, feedback , critical thinking, and reflection. These activities have been found to be the most effective in improving decision performance and developing expertise (Ericsson et al., 1993; Klein, 1998, 2003; Phillips et al., in press). Deliberate practice is an extension of experiential learning, where exceptional mental conditioning is achieved by engaging with full concentration in activities that have been specifically designed to improve the level of performance.

Participants also demonstrated high levels of motivation to evaluate and improve their judgment and decision capacities. Motivated self-evaluation of performance cues decision-makers when their performance may be unsatisfactory, and allows attention to be refocused, thereby increasing performance (Baumann, Sniezek & Buerkle, 2001). This finding is important since it suggests that avalanche decision-makers at all levels can significantly improve their decision-making capacities by engaging in targeted activities and decision-skills training.

7.2.2. Mentoring, feedback and reflection.

The avalanche experts in my study had transformed their experiences into increased knowledge and improved skills with the aid of feedback, mentoring, and reflective practice. Feedback is a critical component of developing expertise, since without effective feedback it may be impossible to achieve expert predictive or diagnostic abilities (Phillips et al., in press). We need external feedback to provide a realistic picture of our effectiveness since it is difficult, if not impossible to probe our assumptions on our own. No matter how accurate we think we are, we are challenged by the reality that our personal interpretive filters may lead us into distorted and constrained ways of being and thinking (Brookfield, 1997). Focus group participants emphasized the need to provide more mentoring and feedback opportunities to less-experienced avalanche decision-makers (FG 1 & 2).

It is widely recognized that learning cannot occur without questioning and reflective processes (Kolb, 1984; Marquardt, 1999; Schön, 1983; 1987). We learn a great deal from reflecting upon the process behind the decision, for example, why we decided what we did, and how we made the decision. However, we learn far less from outcome feedback, such as when we pass judgments on whether it was a good decision or a bad one (Klein, 2004).

Summary of Part 7 Key Conclusions

In summary, the following seven key conclusions can be drawn from the results of Part 7 related to developing avalanche judgment and decision-making expertise:

1. As avalanche domain-specific knowledge and experience increased, participants developed increasingly fine perceptual skills that enabled them to recognize subtle cues, and form meaningful patterns within and between the human, physical and environmental systems of influence.
2. Participants demonstrated high levels of motivation to evaluate and improve their judgment and decision capacities.
3. These avalanche experts used their experiences and those of others to aid their judgments and decisions, and subsequently learned from these experiences to generate new knowledge, insights and behaviour for their future practice.
4. Decision feedback related to successful decisions, accidents, close-calls and case histories was a critical component of their experiential learning.
5. Mentoring, peer feedback and reflective practice transformed participants' experiences into strong mental models of the avalanche domain.
6. Exposure to new ideas and practices resulted in improved judgments and decisions, and a greater capacity to gather and communicate relevant information.
7. Avalanche experts actively engaged in deliberate practice activities such as reading, taking courses, and participating in informal discussions to improve their expertise and decision capacities.

Part 8: The Influence of Human Factors in Avalanche Experts' Decision-Making

> "Once a person has a good understanding of the avalanche phenomena, decisions that result in involvement are almost always a result of human factors" (CIDS 7).

Part 8 Findings

Individual, team, client, organizational, and socio-political human factors influenced the avalanche-related judgments and decisions of the avalanche experts in this study (Figure 13). These human factor influences are presented independently in the following sections.

8.1. Individual Human Factors

Three categories of individual human factors influenced the avalanche-related judgments and decisions of study participants (Figure 19). I define individual human factors as the cognitive, psychological, and physiological influences that are directly related to the decision-maker. Cognitive influences relate to perception and understanding, and include experience, knowledge and skills, and information. Psychological influences relate to processes of the mind, and physiological influences relate to human functioning.

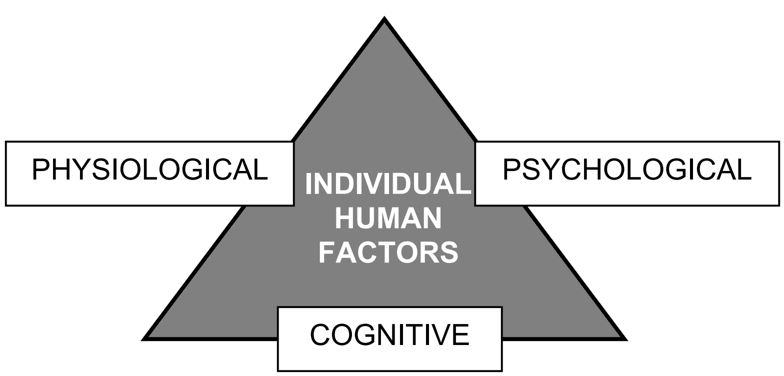

Figure 19: Individual human factors influencing the decisions of avalanche experts.

8.1.1. Cognitive factors.

In Part I of these findings, I described how experience, knowledge and skills, and information relevant to the three systems of influence were the foundation of sound avalanche-related decisions in study participants. A deficit within these core foundations had significant, negative impacts to participants' judgment and avalanche decision capacities.

A. Experience.

Participants cited a lack of relevant experience as a key factor that negatively influenced their avalanche decision-making capacity. For example, a helicopter ski guide explained how his lack of terrain experience influenced his decision-making: "This was an alternate landing that I had not used before" (CIDS 10), and in another case, "I had only skied there on one day the year before" (CIDS 7). A lack of relevant experience with the snowpack characteristics was another related factor, such as in the case of this avalanche forecaster who described, "our experience with a snowpack like this was minimal. We theorized about many possibilities, but had few answers" (CIDS 23).

Non-event feedback from prior experience had negative influences on judgment and decision-making, and resulted in close-calls and avalanche accidents. Participants described how "my previous experience getting away with it reduced my caution" (CIDS 19) and in another accident summary, "it was obvious, in retrospect, that non-event reinforcement had played a large roll in moving us closer to more serious terrain" (CIDS 23). A ski-touring guide explained to me how non-event feedback influenced his decisions:

> As long as we ski and nothing releases, it is impossible to know how close we were to a release. This leads to a positive learning episode: if I could ski this slope in the present conditions, it is obviously safe. Repeated episodes of this kind will lead us inevitably to pushing the envelope" (CIDS 30).

B. Knowledge and skills.

A deficiency in knowledge and skills was a second finding that negatively influenced the judgment and decision actions of avalanche experts in my study. For example, a highways avalanche forecaster described, "my knowledge did not include snowpack or weather conditions characteristic of the day of the involvement" (CIDS 20). Several additional findings related to the cognitive functioning of participants were not recognizing a key piece of data (e.g. instability cue), and underestimating avalanche potential. A forecaster explained to me "the one sign that was overlooked was the hollow spaces around exposed rocks above the site. These areas were noted in our approach, but were not given sufficient importance in our decision-making" (CIDS 34). In another situation, a safety specialist working on a film related "we failed to recognize the potential for over-running crew positions on the slope (CIDS 31).

C. Information.

A lack of information relevant to the three systems of influence (human, physical, and environmental) was the third individual human factor with negative influences. For example, a ski-touring guide explained how he had not been briefed about the history of a group who had skied with other guides in the area in the past (CIDS 9). A helicopter ski guide described how an avalanche accident occurred on the first run of the morning before he had a good 'feel' for the snow conditions (CIDS 7). In another case, a ski-area forecaster described how "there was no wind and snowfall data available, and no information regarding alpine conditions other than visual observations which were limited due to weather" (CIDS 28).

8.1.2. Physiological factors.

Mental and/or physical stress in the form of fatigue and time pressure was another key theme that negatively influenced participants' avalanche-related decisions. As one participant explained to me "stress, ego, competitiveness, and exhaustion all played a role in this incident" (CIDS 23). In another situation, a ski-touring guide described, "it is amazing how fatigue starts whispering, oh it will be ok, the other [safer] route is so long" (CIDS 26). This theme of fatigue and stress had two distinct timeframe characteristics. In the first, participants described the effects resulting from a long day or several days of challenging decisions, and in the second, the cumulative effects after working throughout a season.

The theme of time-pressured decisions also emerged within this finding, and was identified by a majority of participants in the CIDS. One participant related, "the day was getting on and we were cresting into total unknown terrain. I could really feel some time pressure now" (CIDS 26). In another case, a ski-touring guide related, "the accident happened late in the day. I was feeling somewhat tired, but wanting to please the guests and 'squeeze' another run in on the way back" (CIDS 9). A ski area forecaster explained the critical effects of time pressure on his decision-making and how his awareness of the potential consequences enabled him to manage the influences of this factor.

> The clock is my personal nemesis. I am never more likely to put myself at risk than when I pay too much attention to the time our avalanche control operations are taking. I never let the clock push my teams into danger, however, I sometimes let the clock push me. That is my biggest weakness at work, but at least I'm aware of it (CIDS 19).

8.1.3. Psychological factors.

I found that incongruence between goals and objectives, and the conditions within the human, physical, and environmental systems of influence resulted in a negative influence to participants' judgement and decision-making. For example, a national parks forecaster described how group goals influenced their decision. "I believe the decision to enter the slope in the first place was influenced by our desire to complete the trip as planned. It would have been new ground for all of us and establish the aesthetics of the line we were attempting" (CIDS 5). In another case, a ski-area avalanche forecaster related how his personal goals influenced his decision making: "Before attempting the ski cut, I thought about going and getting hand charges but dismissed the idea as I had plans for the evening and didn't want to work late that day" (CIDS 7).

Affective (emotional) influencing factors were another related finding, such as in the case of this ski guide who expressed, "the beauty, snow, and calmness that covers the mountains in winter shows little sign of the monster sleeping, and the white rush that we get is a powerful force that beckons us on" (CIDS 16). In another situation a participant related, "the skiing quality was stellar, the weather was perfect, and the group was very motivated to ski this sub-alpine line" (CIDS 12).

Pride, ego, and overconfidence also had a significant impact upon participants' judgments and decisions, such as in the case of this participant who stated "the reward of being a hero led to taking unreasonable risk" (CIDS 18). Another participant explained, "after 20 years I had a flawless track record therefore I believed my systems were dialled – WRONG" (CIDS 16). In another situation a highways forecaster related to me, "I thought I had more ability to forecast the extent of the activity than I actually did. This misconception, combined with an eagerness to serve the clients, led me to err on the side of recklessness rather than caution" (CIDS 20).

These five categories summarize the individual human factor influences. In the following sections I present the findings related to team, client, organizational, social and political factors.

8.2. Team Human Factors

Inadequate communication, resistance to differing opinions, and being influenced by the judgments and decisions of others were team human factors that had negative impacts to the decision processes and capacities of study participants.

8.2.1. Inadequate communication.

Avalanche experts in this study described how inadequate communication negatively influenced their capacity to gather critical information and resources, to engage in critical thinking, and to arrive at an objective and well-informed decision. For example, an avalanche safety specialist for extreme ski events related, "this was probably the most stressful mountain decision of my life, due to enormous outside pressures and lack of confident peer exchange" (CIDS 17a). In another situation a helicopter ski guide explained, "I had asked the guides for advice on an alternate line I had been eyeing with little response. After the avalanche incident, another guide said, "I never ski there unless the slope has slid." That single piece of advice would have prevented my close call" (CIDS 17b).

Inadequate communication was also described within the context of the atmosphere within the team. Participants explained how the atmosphere created by the lead guide, team supervisor, or dominant member in the group often set the tone within which the exchange of information and resulting decision-making occurred. For example, a ski area forecaster related:

> It makes a huge difference if team members are respectful and investigative, rather than self-focused and judgmental. If the environment is non-supportive and dismissive of input, then I am prone to withhold information or take an observing role rather than contributing (CIDS 27).

Participants described a culture of pride and self-sufficiency that existed within some operations, and expressed the serious implications this had upon their ability to inquire for information in order to reduce the uncertainty they were experiencing during field and office-based decisions. One participant expressed "it was not until after the accident that I really started pressing for information. Before this, I felt like I needed to make my own evaluations and it felt like cheating to ask. Now it really counted" (CIDS 26). Focus group participants described how some operations discouraged radio discussions during field-work, resulting in a reluctance to inquire or share information to aid in the decision process (FG 1).

8.2.2. Resistance to differing opinions.

Resistance to differing opinions was a second human factor related to teams. For example, a ski touring guide related:

> At the morning meeting, another guide was adamant about not skiing a piece of terrain. I found myself frustrated and trying to manipulate his decision. He was correct in his decision not to expose people to a hazard that was totally unnecessary in an unusual year. The human element was definitely what failed me in this situation (CIDS 4).

8.2.3. Influenced by the perceptions, judgments, and decisions of others.

The judgment and decision actions of others were another factor that resulted in negative impacts to the judgements and decisions of the avalanche experts in this study. A helicopter ski guide explained how he resolved his uncertainty about the snowpack stability of a particular slope by observing the actions of a respected peer: "It must be okay if the lead guide is going there" (CIDS 17). In another situation, a guide described how assumptions about what team-mates were thinking resulted in a close-call:

> This near miss was the result of group-think, where each guide based their opinion of the morning terrain selection on what they thought the other guides were thinking. For example, I was thinking that if guide 1 and guide 2 are comfortable with that slope I guess it must be okay. I suspect that in turn guide 1 was thinking, if guide 2 and guide 3 think it is okay then it must be okay. I considered all of us experts and had a great deal of respect for the other guides. I feel these factors all contributed to this case of group-think (CIDS 24).

8.3. Client Human Factors

Client human factors were another negative human factor influence resulting from this study. I define clients as the people for whom avalanche safety services are being provided; for example, visitors to national parks, public traveling on highways, film crews, or ski resort, helicopter, snowcat or ski touring guests.

8.3.1. Pressure to access avalanche – prone terrain.

Pressure from clients to access avalanche-prone terrain was the most commonly cited client negative human factor in this study. Participants described the tremendous pressure they experienced from ski resort guests demanding terrain to be opened, highways vehicle traffic needing to continue their journeys, or backcountry ski and snowboard guests requesting to be guided in more aggressive terrain. For example, a participant described, "we were serving the clients desires to ski difficult terrain – more than what was practical and safe" (CIDS 18). A ski-touring guide explained how client pressure during high avalanche hazard resulted in him being seriously injured in an avalanche accident.

> I chose to take my group into some conservative terrain where I had dug a snow profile several days before. The group was not very happy with that decision since they had skied there once before, and suggested I find some different terrain where they had not been. I wanted to stay conservative, but at that point was pushed into pleasing my guests on their last day (CIDS 16).

During the first focus group, a ski-area forecaster explained the decision-making challenges he faced as a result of very demanding guests during conditions of terrain closures. Even with guarded control lines, these aggressive guests would jump the lines to access untracked powder, therefore placing themselves and his avalanche control teams who were working in the area in potentially perilous situations (FG 1). Clients' reluctance to follow terrain use guidelines or to be guided resulted in high levels of stress for these avalanche experts', since the safety of clients who are in avalanche-prone terrain is ultimately their responsibility.

8.3.2. Inadequate communication.

Inadequate communication with clients was a key factor in the close-calls and avalanche accidents in this study. For example, a helicopter ski guide related:

> It was one of the largest avalanche cycles of the season. Giving directions, in my mind, I had everyone skiing one at a time to the right of my tracks. I failed to mention 'to the right' and everyone skied to the left of my line. As conditions warranted, I should have been very precise with my directions as I was guiding the edge (CIDS 22).

In another incident, a ski-touring guide explained how a groups' reluctance to be guided influenced his communication. He was given a group that had skied unguided at the same lodge for the previous five years, however the lodge owners had concerns regarding the groups' avalanche skills and assigned them a guide that season. "On our first descent, they all took off on their own. I take the blame for not being more clear about the experience of being guided even before setting foot on the slopes" (CIDS 9).

Loss of visual contact was another related factor to inadequate communication, such as in the case of this ski-touring guide who described:

> I went a bit too far down the run and realized I had lost sight of the group. I called back up to the group to let them know that I was coming back up. All they heard was an incomprehensible voice so they assumed it was a

> go. A skier began his descent above me and triggered an avalanche on his second turn, which caught and partially buried me (CIDS 9).

8.4. Organizational Human Factors

Organizational human factors included lack of risk comprehension by management, and financial, logistical, and time pressures.

8.4.1. Lack of risk comprehension by management.

Avalanche programs that were managed by people who did not understand the phenomena presented great challenges to the decision making of the avalanche experts in my study. For example, one expert explained to me, "the factors are much more complex than they appear. It is impossible to explain these to a production manager or film director who is pre-occupied with other things" (CIDS 33). In another situation, an avalanche forecaster hired at a mine site explained how difficult it was to secure management support for his decision to close the access road during a mid-winter storm when avalanche conditions were threatening miners at the site. "No avalanches reached the road through December and most of January, and the new foreman of the operation became more and more sceptical of the avalanche program" (CIDS 14). A safety specialist working on a mountain film described a similar experience:

> I told the boss the risk was too great. There was a cornice overhanging a steep rock face directly above. If it fell off, it would probably sweep across the upper glacial bench with enough momentum to carry on down the ice tongue to where 80 people were destined to be. My opinion was the likelihood of it occurring was possible, that the magnitude of destruction could be a large number of fatalities, and that the risk of being

> under it with an 80 person crew for 12 hours was unacceptable. He thought it would have fallen by now if it was going to, and that besides, it probably wouldn't [reach] the film crew location. I disagreed because it felt like a decision based on "by guess and by god", that the likelihood of a disaster was 50/50. I was overridden by the boss and moved on to the next task – minimizing the risk now that we were going there (CIDS 33).

8.4.2. Financial pressure.

Financial pressure was another organizational human factor influence. As one participant related, "I told the foreman to close the road [after a major snowstorm hit the area], and he complained bitterly that this would cost upwards of $ 20,000 per day" (CIDS 14). In another situation, a ski-area forecaster described, "due to budgetary restraints, the ski patrol efforts focused on daily ski area operations, not weather, snowpack and avalanche observations" (CIDS 28). A helicopter ski guide related, "We'd been dodging clouds all day, when the pilot saw a stake and said he could put me there. In order not to burn more $'s we landed there, got out, and the helicopter headed for the bottom" (CIDS 10).

The head forecaster for a large ski area described to me how a lack of knowledge and skills that resulted from financial pressure, negatively impacted the capacity of his teams' ability to make sound decisions. "Team knowledge in an atmosphere of high turnover, relatively youthful staff (often with mostly in-house training), and a competitive wage structure are the first hurdle in the decision making process" (CIDS 19). He explained how this situation put him at a significant disadvantage, since he was ultimately responsible for the final decisions that had significant implications to public safety within the ski area.

8.4.3. Logistical pressure.

Participants described the organizational logistical pressures they faced when making avalanche-related decisions. A highways avalanche forecaster explained, "There was great pressure on the avalanche crew to keep the road open. I allowed this pressure to override safety concerns" (CIDS 20). In another case, a ski-area forecaster explained, "It was logistically difficult to close off this slope in the middle of a busy spring day, which added weight to keeping it open" (CIDS 28). Pressure to meet the organizational logistical requirements was another related finding as described by this participant: "I was working on a mountain safety crew for a big-budget Hollywood feature film shooting footage from exceptionally dramatic real wilderness locations. The pressure was on for us – it better be a wild place" (CIDS 33).

8.4.4. Time pressure.

Organizational time pressure was a key-influencing factor present in a majority of the CIDS described to me by participants. For example, a ski-area forecaster related: "We are expected to open everything as quickly as possible, with as little staff as possible, and under budget of course" (CIDS 19). In another situation, a film safety specialist explained, "There was pressure to get the crews in and the blast rigged before the light failed" (CIDS 31).

8.5. Social / Political Human Factors

Social and political human factors influenced the judgements and decisions of the avalanche experts in this study. Participants described how a collective sense of professionalism and pride in accomplishing the complexities of their craft influenced their decisions. For example, a mountain safety specialist described the pressure he experienced:

> Our professional pride is what cranks up the pressure to venture forth into the fine line where the acceptable risk is blending with the unacceptable risk. That is why we are hired – to make the ultimate decision. Can we do it or not?" (CIDS 33).

8.6. Coping strategies.

I found that participants used several negative strategies in their high-stakes field decisions to deal with the human factor pressures they faced and uncertainty within the three systems of influence; denial by explaining away negative influencing factors, and not dealing with the negative influencers by continuing forward without modifying their actions. For example, a ski-touring guide explained:

> There were a number of factors indicating avalanche potential, yet the data I collected started to outweigh the potential and point to a better picture. Was this a matter of my perception? The group had the vision of experiencing one more great run, and I twisted the picture to justify my decision and give them what they wanted (CIDS 16).

As one participant related, "I was very uncomfortable but kept on going" (CIDS 17) and in another case, "I knew I was pushing what was safe to ski cut but did it anyways" (CIDS 7). These situations are examples of how participants were unable or reluctant to manage the uncertainty and human factor pressures they faced, therefore they resorted to continuing with their original goals in hopes that the worst-case scenario wouldn't occur.

Discussion of Part 8 Findings

"The human factor was definitely what failed me in this situation" (CIDS 4).

It is widely recognized that human factors heavily influence the way we think and behave in life. As the findings of this study suggest, human factors are a significant influence in both the internal (individual), and external (team, client, organizational, and socio-political) realms of avalanche related decision-making. These findings corroborate those of Reason (1990), who argued that human error is the result of intrinsic (cognitive biases and attentional limitations), and extrinsic factors such as the structural characteristics of the decision problem and context effects (p. 59).

8.7. Individual Human Factors

8.7.1. Cognitive factors.

I found that avalanche-related judgements and decision actions resulted from how avalanche experts in my study interpreted the current situation in relation to their mental model and personal perspective. Mental models, which can be thought of as a lens through which one views the world, are developed from domain-specific experience. They are conceptual structures in the mind that drive cognitive processes of understanding (Flood, 1999). Decision makers unite their mental models with the present information and situation, and then consider the context of future actions. James Reason (1990) stated, "Errors are the penalties that must be paid for our remarkable ability to model the regularities of the world and then to use these stored representations to simplify complex information handling tasks" (p. 17).

Maturana and Varela (1980) suggested that all knowledge is known from a particular standpoint. We experience life within the context of individual moments of meaning, and each of these experiences is uniquely personal and occurs in a cumulative process over time (Boyles, 1994; Doud, 1999; Gottesman, 1996). Knowledge, therefore, cannot be objective since it is created through a subjective process of reference. “We take objective data given to us in the world and we absorb it according to our own subjectivity. We also check our subjective impressions against the emergent picture of objectivity as it unfolds before us” (Doud, 1999, p. 3). As a result, we are constantly shifting the cognitive framework within which we interpret new experiences and formulate decision actions.

A. Decision Quality

Deficiencies in the foundation of avalanche judgments and decisions, (relevant experience, knowledge and skills, and information relevant to the three systems of influence) resulted in uncertainty, and were the primary factors in the close calls and avalanche accidents in my study. This finding is consistent with those in aviation accidents where a lack of relevant knowledge led to misdiagnosis of problems, and to the choice of a poor solution (Orasanu, Martin & Davison, 2001). I found the level of uncertainty directly influenced the complexity of decision-making these avalanche experts faced. This strong relationship illuminates the need for avalanche decision-makers to actively acknowledge and manage uncertainty in order to achieve successful decision actions. This finding is consistent with Gottesman (1996), who posits that information or events that are different or unknown, to which no matches can be placed, will not be recognized and therefore hold no meaning in the present.

8.7.2. Physiological influences.

The impacts of physiological influences on judgment and decision-making have long been recognized as a key factor in our ability to execute decision strategies (Klein, 1993; Orasanu, et al., 2001). My research is consistent with this notion. Mental and physical stress had a significant impact on the cognitive capacities of these avalanche experts and was a key factor in the CIDS's in this study. These negative affects can produce a narrowing of attention, a failure to search for new alternatives (Fiedler as cited by Mellers et al., 1998), and may interfere with recognizing the inappropriateness of actions (Orasanu, et al., 2001). In addition, decision accuracy is often decreased through faster and less discriminate use of information (Mellers et al., 1998). Stressful conditions increase the use of heuristics and decision strategies. These strategies often yield satisfactory results, however when high-levels of uncertainty exist, more thorough analysis may be required for a safe decision (Klein, 1997).

8.7.3. Psychological factors.

While I have identified experience as the fundamental component of the avalanche expert's decision foundation, all avalanche-related experiences are not equivalent in their capacity to develop good judgment and decision capacities. As I discovered in this study, repeated experiences of non-event feedback or false positive events, can result in dysfunctional strategies for future decision-making. For example, instabilities exhibit spatial variability within the snowpack, and areas within which it is possible to trigger a propagating fracture for a slab avalanche may be as small as one metre (Schweizer, Jamieson & Schneebeli, 2003). If a skier does not make contact with this area, the slope may not release resulting in a false positive result for the decision-maker. As one participant related to me, "positive reinforcement is a powerful learning impetus."

Research has shown that if a person repeatedly makes dysfunctional decisions, those dysfunctions would become automatized (Yates, 2001). For example, Orasanu et al., (2001) found that pilots experience and success in risky situations in the past (e.g. making a landing in poor weather conditions) influenced their expectations to succeed the next time with the same response. In a study of recreational avalanche accidents in the United States, the familiarity that resulted from past experiences and actions led avalanche accident victims to believe their behaviours were appropriate in the current situation (McCammon, 2002).

I suggest that past experiences and non-event feedback were a key factor leading to the overconfidence in knowledge and abilities that I observed within some of the CIDS in this research. Overconfidence in decision-making has been extensively reported in the literature (Slovic et al., 1977; Mellers et al., 1998). A key factor in overconfidence is that the decision-making environment is not structured to provide feedback or to show our limitations. Many decisions made are insensitive to errors in estimating what we want (utilities), or what is going to happen (probabilities); therefore errors are difficult to detect (Slovic et al., 1977, p. 6).

Conversely, I observed participants exercised caution as a fundamental response to dealing with uncertainty in a majority of the CIDS of decision success. The difference in these findings can be attributed to the fact that observed overconfidence is simply regression to the mean (Mellers et al., 1998). These results suggest the critical importance of seeking external feedback when available, and reflecting upon our judgment and decision actions in order to build accurate mental models for future decision-making.

The fear of appearing incompetent and uncertainty regarding performance resulted in anxiety that influenced judgment and decision actions. This finding is consistent with the notion that the anxiety leads to a narrowing of attention resulting in impaired performance (Baumann et al., 2001). This finding also suggests that risk preferences are uniquely personal to the individual decision-maker and are subject to affective responses. Research shows that affective responses to risk directly correlate with whether we over or underestimate our likelihood of harm, or in this case, involvement in avalanches (Dunwoody & Neurwith, 1991; Slovic, 1987; Wilde, 2001). Our propensity to take risks depends upon individual factors such as our personality, life experience and lifestyle, as well as social and cultural factors such as age, being part of a group, or having a family (McClung, 2002; Wilde, 2001).

I suggest incorporating metacognitive awareness may provide an effective means for addressing these issues, and I observed its successful use in my research. For example, an avalanche expert related, "I have learned to recognize the seductive call of my ego." Using metacognitive awareness is a fundamental approach to the correction of biases in intuitive judgments (Kahneman, 2003).

8.7.4. Biases and decision traps.

It is widely reported in the literature that our judgments are subject to systematic biases resulting from limited cognitive processing capacities, and a lack of understanding regarding methods to optimize information (Slovic et al., 1977; Kunreuther et al., 2002; McCammon, 2002).

When faced with difficult choices or no obvious right answer, I found participants adopted several strategies to cope. (1) Managing the uncertainty as I discussed in Part 4, (2) sticking with the status quo by continuing with their original goals, (3) explaining away the hazard, or (4) being influenced by the judgment and decisions of others. Cognitive economics and human factors influences appeared to be equally influential in my research.

These findings are consistent with those reported by other authors in decision science. For example, Kunreuther et al. (2002) noted that decision-makers might respond to complexity by ignoring information about probabilities that do exist, or by accepting the status quo. Slovic et al. (1977) suggested that decision-makers may have a clearer understanding of what they want to do (goals and objectives), in comparison to assessing more cognitively complex factors within the decision problem. This factor has also been referred to as the commitment heuristic (McCammon, 2002).

While explaining away the hazard may appear to be an irrational response relative to normative frameworks, we must consider the dynamic and widely varying influences of the individual, team, client, organizational, and socio-political realms. There are many task goals in dynamic decision situations that may be in conflict with each other (Maule, 2001), and generating reasons enables us to justify decisions to ourselves and to others (Mellers et al., 1998).

Status or conformity pressures exert strong influence against checking one's assumptions (Orasanu & Salas, 1993). I found that participants were influenced by the decisions of respected others in situations of uncertainty. Groupthink (Jannis and Mann, 1977) is the most well-known failure in team decision-making, and occurs when an individual and/or group suspends its judgment in order to maintain group cohesion. This finding is also consistent with heuristics research; for example, McCammon (2002) reported this human factor as the 'expert halo.'

These findings suggest limitations of cognitive and emotional processing are inherent in avalanche-related decision-making, and the need to consider behavioural assumptions cannot be ignored. Human error has traditionally been examined within the context of rational choice theory. However, the concept of rationality is now being re-examined in a more holistic manner in order to discover efficient, adaptive, and satisfying solutions to the decision problems we face (Mellers et al., 1998; Stefanovic, 2003).

8.8. External Human Factors

Decision actions do not stand alone as events that can be judged independent from the broader situational and task features (Orasanu et al., 2001). As stated, clients, teams, organizations, and socio-political human factors influenced the avalanche experts in this study. I found that it was how these factors were recognized, considered, and managed that made the critical difference between decision success, and close-calls or accidents. This finding illuminates the conflicting challenges that avalanche decision-makers face as they strive to achieve a balance between the widely varying goals and objectives within the realms of human influence, and the constantly changing conditions in the physical and environmental systems. It also highlights the fact that these experts need a high level of personal mastery (Senge, 1990; Flood, 1999) and strong leadership capacities to avoid being overly influenced by these factors.

This finding is significant since research indicates that decision-makers often focus on the cues that send the strongest emotional or affective signal when faced with difficult tradeoffs. While in retrospection, a majority of the participants recognized the human influences present in their CIDS, they simply succumbed to the excessive pressure they faced.

8.9. Communication

Communication emerged a consistent theme throughout this research. Effective communications lead to greater understanding and shared mental models between decision makers, clients, teams, and organizations. The end result was better decision-making. Conversely, lack of communication and / or poor communication was a key factor in the CIDS and a topic of detailed conversation during the focus groups. Participants unanimously agreed that the quality of communication correlated directly with the quality of decision actions. The importance of communication has been widely recognized in the literature in many domains, and improving communication has been identified as a fundamental method of reducing human error in high-stakes decision-making (Sexton, 2004).

This finding suggests that methods to improve communication should be a primary focus of avalanche decision-makers. Recommendations to improve communication are discussed in Chapter Five of this thesis.

8.10. Perceived Risk

I found the existence of varying perceptions of risk between individual, clients, teams, organizations, and socio-political realms to be a significant influence in participants' judgment and decision complexity. For example, participants described strong pressure from clients and organizations to access avalanche-prone terrain in order to meet their goals and objectives. These situations were often compounded by extreme time pressure.

Perceived risk depends upon our knowledge of the hazard, our past experience with that hazard, our personal attitude towards risk taking, our assessment of the probability of exposure in the current situation and conditions, and our degree of decision confidence in relation to the level of situational uncertainty (McCammon, 2004; Slovic, 2001; Wilde, 2001). This finding is significant since it clearly frames the boundary conditions within which avalanche decision-makers must consider the decision problem. Since risky decisions are multi-dimensional, subjective and value laden, they need to be assessed and characterized within the context of these boundaries (Slovic, 2001).

8.11. Residual Risk

In this discussion of human factors and human error, it is important to consider residual risk since some of the avalanche experts were truly surprised by the close calls or avalanche accidents they reported in their CIDS. Avalanche experts strive to make accurate determinations of snowpack instability and to reduce the exposure of people and structures to avalanches (McClung & Schaerer, 1993; McClung, 2002). However residual risk is always present in avalanche phenomenon. For example, a ski guide related, "close calls will happen to all guides who live a lifetime in the mountains" (CIDS 17).

The uncertainty from residual risk added an additional layer of complexity to the decision problem these avalanche experts faced. Coping tactics included incorporating a buffer zone into decision actions and simply hoping luck is on their side. "Like my grandfather said after I expressed the lack of room for error [in avalanche decision-making], 'a little luck is always a good thing in the mountains'" (CIDS 26).

Summary of Part 8 Key Conclusions

In summary, the following twelve key conclusions can be drawn from the results of Part 8 related to the influence of human factors in avalanche expert's judgment and decision-making:

1. Avalanche experts faced conflicting challenges as they strove to achieve a balance between the widely varying goals and objectives within the realms of human influence, and the constantly changing conditions in the physical and environmental systems.
2. Human factor influences included individual, team, client, organizational, and socio-political realms.
3. The individual human factor influences included cognitive, physiological and psychological categories:
    a. Cognitive factors included deficiencies in the foundation of avalanche expert's decision-making: lack of relevant experience, lack of relevant knowledge and skills, and lack of information relevant to the human, physical, and environmental systems of influence.
    b. Physiological factors included fatigue and environmental stress.
    c. Psychological factors included goals, ego, pride, and overconfidence.
4. The fear of appearing incompetent and uncertainty regarding performance resulted in anxiety that influenced judgment and decision actions.
5. Repeated experiences of non-event feedback or false positive events can result in dysfunctional strategies for future decision-making.

6. Team human factors included inadequate communication, resistance to differing opinions, social pressures, and being negatively influenced by the perception, judgments and decisions of others.

7. The quality of communication within teams correlated directly with the quality of decision actions.

8. Client human factors included pressure to access terrain, inadequate verbal communication, and loss of visual contact.

9. Organizational human factors included lack of risk comprehension, and financial, logistical and time pressure.

10. Social and political human factors included the current state of the industry and related associations.

11. These experts need a high level of personal mastery and strong leadership capacities to avoid being overly influenced by human factors.

12. Residual risk is always present in avalanche phenomena.

Part 9: Avalanche Experts' Systems Approach to Judgment and Decision Making

In the survey phase of my research, I asked participants to "describe the factors that enable you to make sound decisions when traveling in potential avalanche terrain." I found these avalanche experts had developed, and consistently utilized, extensive routines for making avalanche-related judgments and decisions. Based upon a meta-analysis of the findings, I created a model to illustrate the systems approach used by the avalanche experts in my study to formulate judgments and execute decision actions (Figure 20).

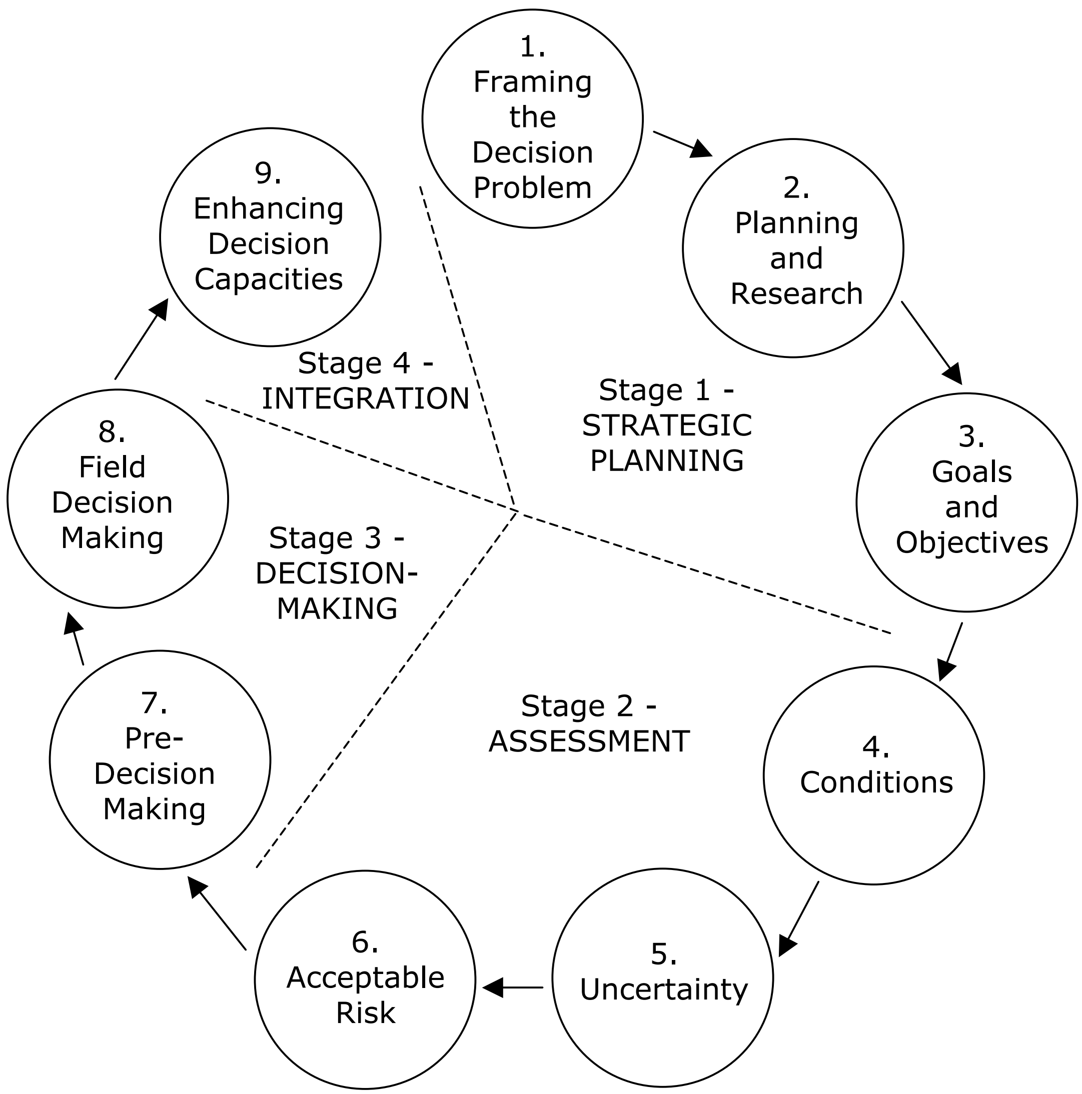

Figure 20: A systems approach to avalanche expert's judgment and decision making.

The model consists of four stages with nine interrelated components.

9.1. Strategic Planning

Stage 1 - Framing the Decision Problem

As I discussed in Part 4, avalanche decision problems differ by context and goal, thus the decision problem needs to be framed within these considerations (Figure 21). Research indicates that framing effects, stimulus contexts, and environments profoundly shape decisions (Payne et al., as cited by Mellers et al., 1998). A recurring theme in the literature is that effective decision-makers are distinguished by their ability to frame the problem well (Means, Salas, Crandall & Jacobs, 1993).

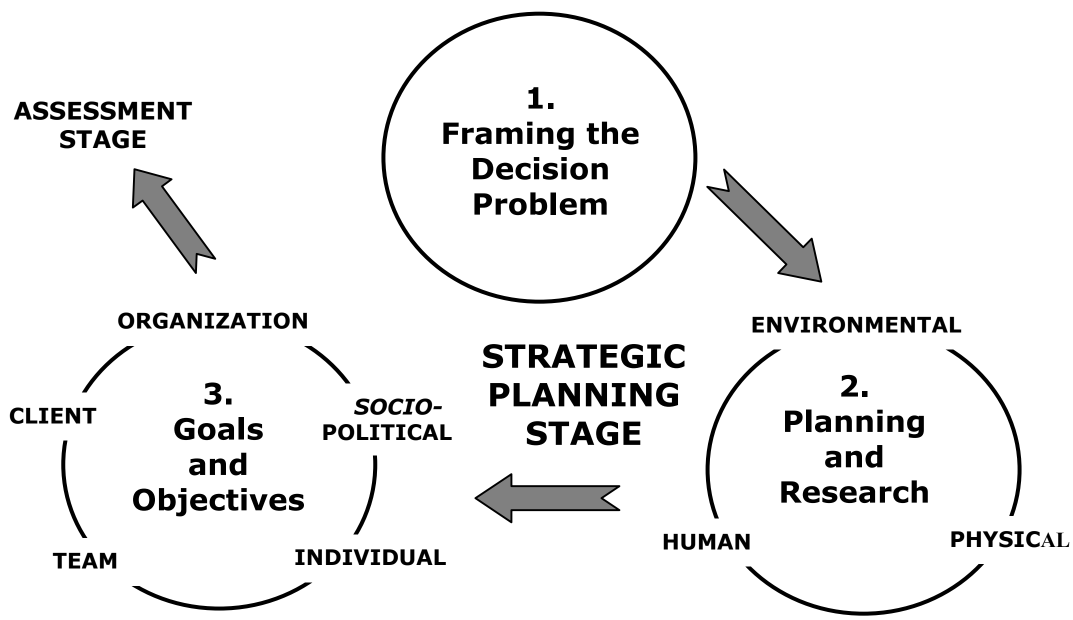

Figure 21: Strategic planning stage of the avalanche expert's systems approach.

Avalanche decision problems can be described as construction decisions (Yates 2001), where decision makers attempt to use information related to the human, physical, and environmental systems of influence to determine the most suitable course of action given existing conditions and constraints. These decision problems are complicated by inherent uncertainty resulting from complex human, physical, and environmental factors. Knowledge of one's situation and the role requirements in this situation are an important frame within which to solve the decision problem (Lipshitz & Strauss, 1997).

It is important to note that these avalanche experts start at different steps of the model depending upon their familiarity with the decision problem. For example, a ski tour guide going to a new mountain range may start at the beginning of the cycle, whereas an experienced ski-area avalanche forecaster is more likely to start at the second stage – planning and research

Stage 2 - Planning and Research

Once the decision problem has been framed, avalanche experts collect and update information relevant to the three systems of influence. Research within the human system includes the knowledge and skills of clients, liasing with team decision-making members, following standard operating procedures (e.g. CAA *Observation Guidelines and Recording Standards for Weather Snowpack and Avalanches* (2002); Association of Canadian Mountain Guides *Terrain Guidelines* (2003); Canadian Mountain Holiday's *Mountain Operations Manual* (2004), and ensuring mitigation measures are in place. Maintaining a perception of the state of the snowpack through the season through the observations and information conveyed by other professionals (e.g. InfoEx, Informalex, CAA avalanche bulletins) is a key goal in this process.

Physical research is specific to the terrain and includes incline, aspect, elevation, shape, size, and ground cover. The history of avalanche occurrences, the presence or lack of support, and terrain trap consequences are additional considerations. Environmental research includes synoptic scale weather data, local microclimates, and the spatial and temporal components of snowpack structure (Figure 21).

Stage 3 - Goals and Objectives

The goals and objectives of the decision-maker, team, client, organization, and socio-political realms are then considered and integrated into the decision problem.

9.2. Assessment

Stage 4 - Conditions

The avalanche expert now researches and assesses conditions within the three systems of influence (Figure 22).

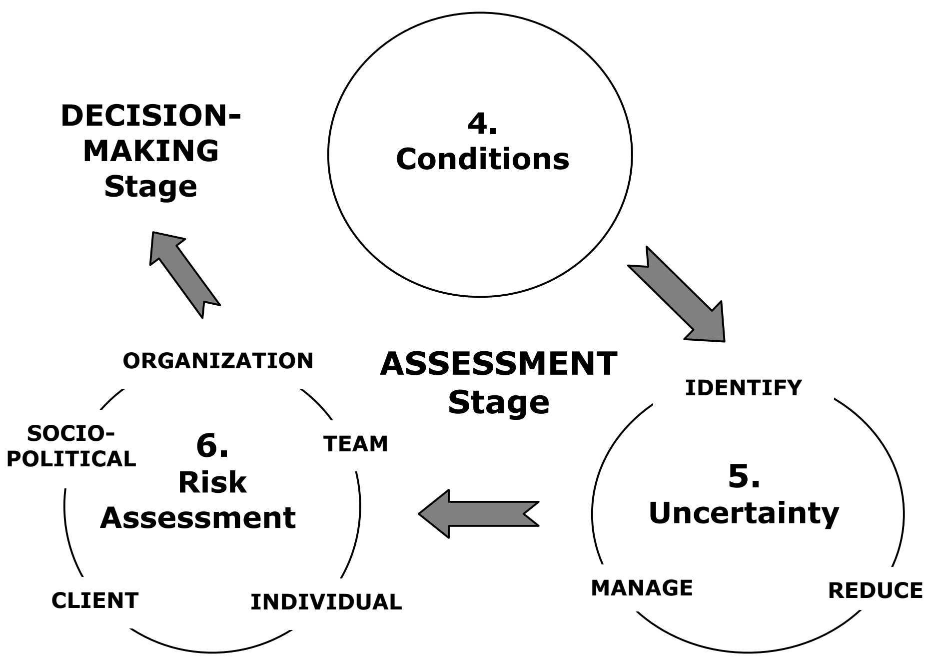

Figure 22: Assessment stage of the avalanche expert's systems approach.

In this stage, the human system includes personal physical and mental health, perception of instability, team dynamics, familiarity with clients, organizational logistics, and socio/political influences. Physical and environmental research includes weather forecasts, weather and avalanche data from local and regional sources (e.g. nearest neighbors, InfoEx), and avalanche characteristics including fracture initiation and character.

Stage 5 - Uncertainty

High levels of uncertainty and complexity are inherent in avalanche decision problems. At stage five, the avalanche expert determines the level of uncertainty within the three systems of influence (Figure 22). It is essential to identify and differentiate between the different sources (human, physical, or environmental) and types (inadequate understanding, incomplete information, and undifferentiated alternatives) of uncertainty, as a key step in choosing an appropriate response (Klein, 2003; Lipshitz & Strauss, 1997). For example, it is important to determine whether we are struggling with missing data in the three systems of influence, or struggling with making sense of the data when making an avalanche-related judgment.

Stage 6 - Acceptable Risk

An accurate determination of the level of acceptable risk should be made within the context of the entire system; individual, team, clients, organization and socio-political (Figure 22). This determination is relative to the level of uncertainty determined in the previous stage. Values-based leadership is fundamental to understanding the differing needs of these constituencies, to reframe the decision problem, and to choose decision actions that are responsive to the needs of all (O'Toole, 1996).

Acceptable risk is a subjective judgment for the level of risk to which people/humans are willing to expose themselves. As discussed in the literature review, we all experience different levels of perceived risk resulting from our attitudes, beliefs, feeling and cognitions about risk (Aven & Kørte, 2003; Coleman, 1993; Slovic, 2001). For example, where experts may recognize *real* risks in hazardous situations, laypeople have a wider dimension of *perceived* risk (Coleman, 1993; Dunwoody & Neurwith, 1991).

9.3. Decision-Making

Stage 7 - Pre-Decision Making

The previous six stages of the model have emphasized decision-related judgments. At this stage, the model shifts towards planning the decision actions. The decision-maker determines his or her level of decision confidence resulting from the previous six stages, and then modifies the goals and objectives of the avalanche program in order to achieve a balance within the current conditions in the human, physical, and environmental systems of influence.

The process of pre-decision making involves anticipating and identifying critical decision conditions or points, and then planning associated decision actions (Figure 23). Pre-decision making includes activities such as planning options, making determinations about specific terrain use, logistical planning. For example, a group of helicopter ski guides may specify the requirement for avalanche activity to be observed in the terrain above a landing zone before the affected area can be skied. Another example of identifying a critical decision point is in the case of a ski-touring guide who identifies specific terrain features and how s/he will manage or avoid them depending upon current conditions in the three systems of influence, and the time of day when the feature is reached. Thus, if emergencies or challenging situations are encountered, decision-makers do not have to increase their cognitive workload by having to commit additional resources to determine what to do (Orasanu & Salas, 1997).

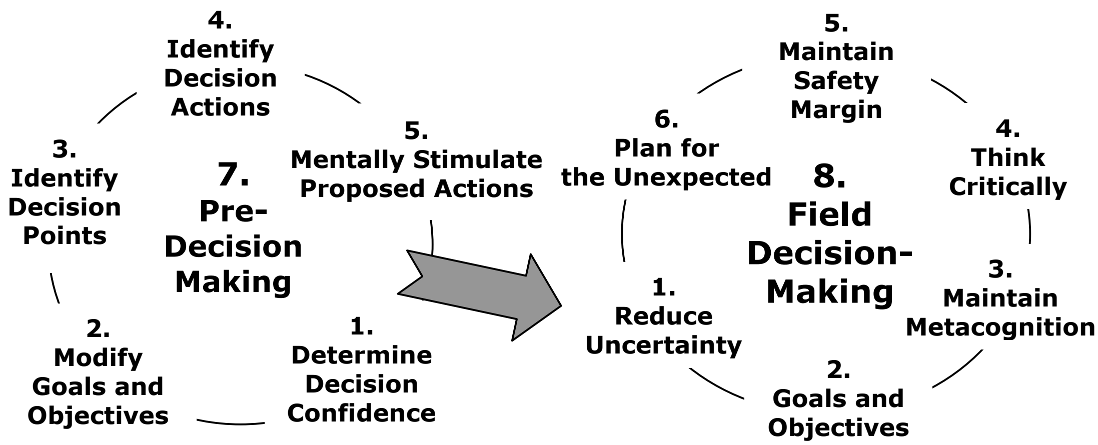

Figure 23: Decision-making stage of the avalanche expert's systems approach.

As earlier discussed, 95% of participants used knowledge and experience-based decision-making (intuition) as the primary mode of cognitive function in their field CIDS summaries. Pre-decision making builds a database of mental and situational models through which these avalanche experts form patterns and are able to exercise their intuitions and make exceptional decision actions. Pre-decision making also incorporates processes of critical thinking and mental simulation. By mentally simulating proposed decision actions prior to their requirement for execution, avalanche experts are able to use analysis to determine the effectiveness of the proposed decision action. In addition, pre-decision making enables avalanche experts to effectively reduce the influence of potentially dangerous human factors and biases that may be faced if they encounter an unanticipated decision problem while in the field.

Stage 8 - Field Decision-Making

The model now shifts to judgment and decision actions in field settings (Figure 23). The avalanche expert initially focuses on reducing the types of uncertainty identified in stage five. Ongoing assessments are made regarding whether the goals and objectives of the avalanche program are congruent with observations of current conditions within the three systems of influence, for example the amount of new snow, the degree of wind loading or the abilities of clients. Metacognition and situation awareness are used to maintain an internal and external awareness. The level of uncertainty experienced by the avalanche expert determines their decision confidence, and results in decision actions that are appropriately modified though terrain use. Finally, avalanche experts maintain a margin of safety within their decision actions and plan for the unexpected.

9.4. Enhancing Decision Capacities

Stage 9 - Integration

Peer feedback, careful reflection upon judgment and decision actions, deliberate practice, and continued professional development offers the outcomes of improved knowledge and decision-making capacities (Figure 24).

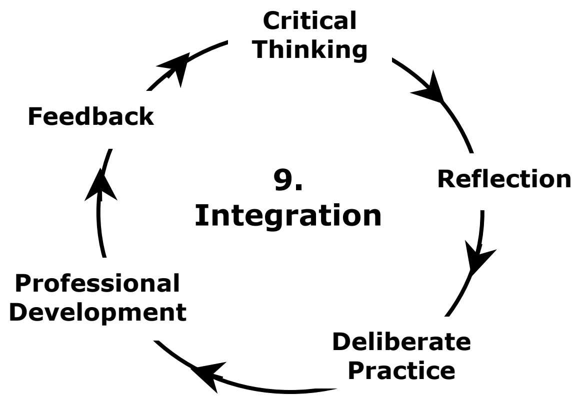

Figure 24: Integration phase of the avalanche expert's systems approach.

9.5. Summary Remarks

I have attempted to aggregate and synthesize the judgment and decision-making processes of the avalanche experts in my study within this systems model. It is an explicit description of the systems and processes utilized by avalanche experts in their real-world practice. My goal was to offer a systems depiction that would shed light upon how these avalanche experts made judgments and executed decision actions. However, this sequential decomposition may depict an oversimplification of these complex cognitive stages. While such a model may be useful as an aid to the avalanche decision process, it is not a substitute for human judgment. Thus, avalanche decision-making remains both an art and a science.

III. Study Conclusions

III.1. A Systems Perspective of Avalanche Decision-Making

Avalanche-related decision-making occurs at the centre of three systems of influence; human, physical, and environmental (Figure 12). The importance of understanding and considering the inter-relationships between these phenomenons requires a systems thinking perspective. This holistic perspective is considered integral to adequately studying and understanding complexity (Stefanovic, 2003; Wheatley, 1999). Since human behaviour is best understood in the social and natural frameworks within which it occurs, sound avalanche-related judgment and decisions cannot consider one of these systems in isolation.

The avalanche decision-making process involves making complex judgments regarding the current conditions and the level of uncertainty within the three systems of influence. It then requires making critical decisions regarding what decision actions will be taken. These judgments and decisions occur within a dynamic and complex decision process, and are embedded within a broad situational and human context. Thus, decisions are not made as discrete events or isolated moments of choice, and understanding the context that surrounds the decision process is essential (Orasanu & Connolly, 2001; Lipshitz, 1993). "Practical decision-making is not the resolution of separate conflicts, but a continuous control of the state of affairs in a dynamic environment" (Rasmussen, 1993, p. 158).

III.2. Factors Influencing Avalanche Judgment and Decisions

The avalanche experts in my study did not execute avalanche-related decisions as isolated events or individual moments of choice. Judgments and decisions occurred within a dynamic context that was influenced by six categories of factors: one category encompassed the physical and environmental realm, whereas the following five encompassed the individual, team, client, organizational, and socio-political human realms. These realms represent a systemic perspective of the factors influencing avalanche judgment and decision-making. They are a fundamental source of uncertainty and a causal factor in the decision-makers cognitive, physiological, and psychological domains.

As I have demonstrated, human factors exert both positive and negative impacts in avalanche judgment and decision-making. While human factors have received considerable interest in high-stakes decision-making domains, much of the focus has been on their negative influence in judgment and decision processes. It is curious how little research has been directed towards examining human factors in light of their positive influences.

III.3. A Conceptual Model of Avalanche Expert's Decision Making Modes and Strategies

I constructed a conceptual model that describes the judgment and decision making modes and strategies used by the avalanche experts in my study. This model integrates the elements of judgment and decision-making within a holistic system (Figure 25).

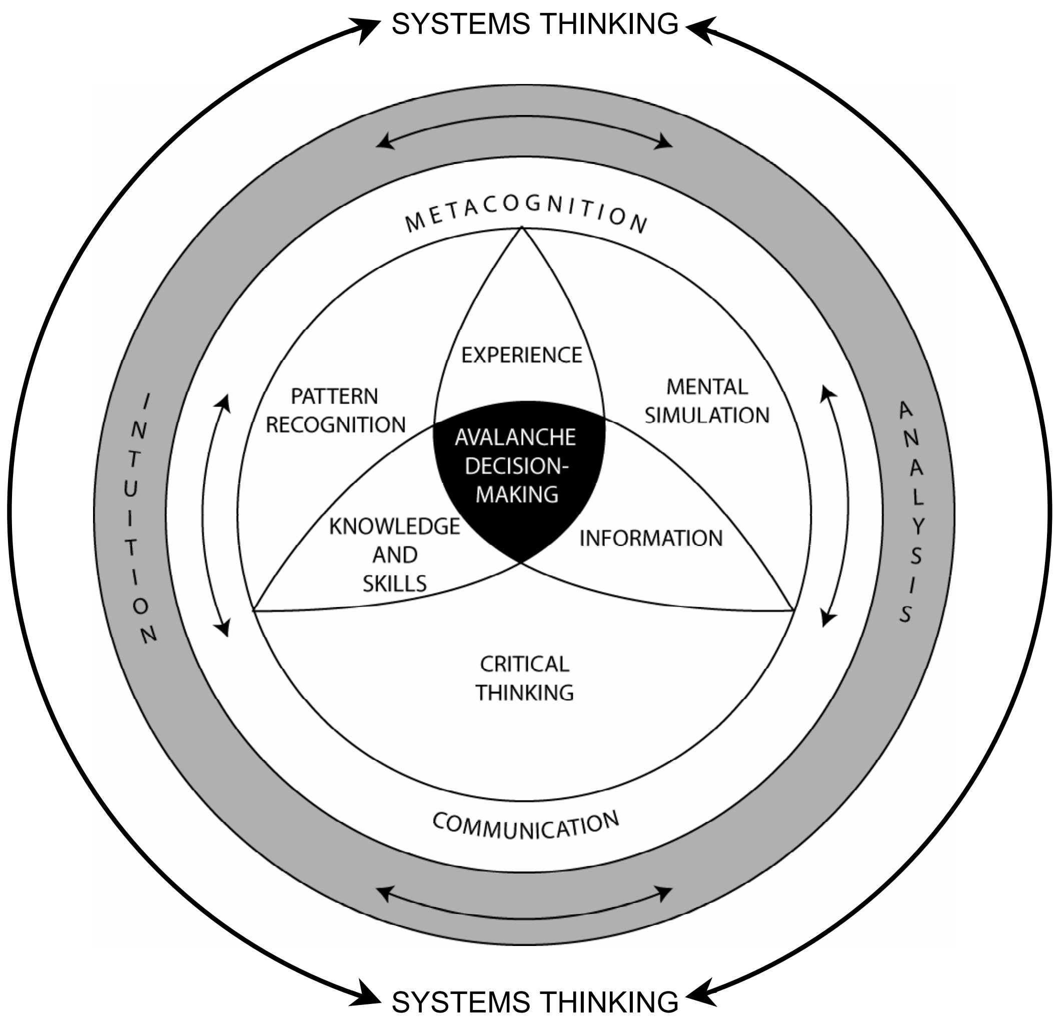

Figure 25: Conceptual model of avalanche experts' decision making modes and strategies.

Avalanche experts' decisions are made within a systemic process that unfolds from the centre of the system. Experience, knowledge and skills, and information relevant to the human, physical, and environmental systems of influence provide the foundation to sound avalanche decisions. The cognitive strategies of pattern recognition, mental simulation, and critical thinking are driven and fed by this foundation. Through the use of metacognition, avalanche experts are internally and externally aware of the factors that influence their judgment and decisions. Effective communication fosters and enhances the quality of judgments and decisions. Intuitive and analytic decisions result within a dynamic systems thinking perspective.

III.4. The Role of Experience and Mental Models

Experience lies at the heart of sound avalanche-related decision-making and results in superior knowledge, skills and information processing capacities (Ericsson & Charness, 1994; Shanteau, 1988). Experience is considered fundamental to objective avalanche decision-making, not only to accurately evaluate the snowpack, but also to aid complex decisions and avoid dangerous human biases (McClung, 2002).

Experiences and knowledge events specific to the avalanche domain resulted in highly integrated knowledge structures and rich mental models depicting how the avalanche domain functions. These mental schemata guide avalanche experts to key aspects of the decision problem and filter out irrelevant information. The use of these mental models results in reduced information management, since the avalanche expert is able to notice subtle perceptual cues and does not need to process all of the available information in order to make an effective decision. Their knowledge of critical cues in the environment enables them to make very fine classifications (Endsley, 1997). As avalanche experts develop richer and more expansive mental models of the avalanche domain, they adapt their judgment and decision-making capacities into a holistic, systems thinking perspective.

III.5. Avalanche-Expert Judgment and Decision-Making Modes and Strategies

The avalanche experts involved in my study had evolved their judgment and decision-making processes beyond considering concrete systems (terrain and snowpack) to considering and synthesizing conceptual systems (higher-level information), which is a key component of the systems thinking perspective (Kalaidjieva and Swanson, 2004; Wheatley, 1999). Thus, avalanche decision-makers evolve through a hierarchy of judgment and decision complexity that commences with rule-based processes and leads to integral systems thinking (Figure 14). This notion is consistent with Rasmussen (1993) who suggested that decision-making modes progress and expand as the structure of the underlying representation (mental model) shifts from a set of separate models to a holistic representation.

In addition to systems thinking, avalanche experts used three fundamentally different modes of cognitive function; rule-based, analysis, and intuition. These modes occur within a cognitive continuum. Rule-based processes are consciously controlled by a stored rule or procedure (Rasmussen, 1993), analysis utilizes a conscious process of reasoning (Kahneman, 2003), and intuition pre-consciously utilizes the repertoire of patterns stored within our mental models (Klein, 2003).

The level of expertise of the decision-maker and familiarity with the current situation determines the application of these modes (Lipshitz, 1993). Additional factors include the systemic context of the situation, the degree of time pressure, and the level of uncertainty within the human, physical, and environmental systems. My study findings concur with the work of Endsley (1997) who suggested that single decision problems are often solved using different modes, even though one mode may appear to be more dominant. For example, an avalanche expert may use systems thinking and intuitive processes for the parts of a problem for which adequate knowledge and mental models exist, while rule-based or analytic processes may be used to solve other parts of the problem.

These modes complement one another to produce effective decision actions. For example, when avalanche forecasting (e.g. office-based morning meetings), these avalanche experts used analysis as their primary mode of cognitive function, while in high-stakes field decisions, intuitive processes prevailed. In any situation, when avalanche experts encountered decision problems that rule-based or intuitive decision-making processes were unable to handle, they shifted to analytic processes. This finding is consistent with Yates (2001). Where possible, consultation with other team members was integrated into this process.

The avalanche experts in my study used pattern recognition to make effective judgements, and processes of mental simulation and critical thinking to analyse whether their judgments were accurate and if their planned decision actions would work. The systemic perspective of metacognition was used to monitor and regulate the thought processes of attention, situational awareness, comprehension, and biases, and resulted in enhanced judgments and decision actions.

III.6. Situation Awareness and Metacognition

It is widely recognized by high-stakes decision researchers that situation awareness and metacognition are fundamental to sound decision-making (Endsley, 1997; Klein, 1998; 2003; Orasanu & Salas, 1993). Endsley (1997) argued that situation awareness involves much more that simply perceiving information in the environment, since it requires understanding the information in relation to the decision-makers goals, and then projecting the future actions of the environment. Metacognition enables decision–makers to be aware of their thought processes and control them appropriately. Thus, metacognitive skills are crucial for proficient problem solving and decision-making.

III.7. Dealing with Uncertainty

How to effectively manage uncertainty within the human, physical and environmental systems appeared to be the quintessential challenge faced by this group of avalanche experts. Lack of information relevant to the three systems of influence, time pressure, dynamically changing risks, and human factor influences resulted in uncertainty, and exerted significant limitations on the cognitive capacities of the avalanche experts in my study. Uncertainty is a subjective factor in the avalanche judgment and decision-making process, since different people will experience different levels of uncertainty within the three systems of influence when faced with the same situation.

Baumann et al., (2001) suggested that uncertainty is also experienced as a function of the decision-maker's assessment of their personal resources available to meet the task demands. Greater uncertainty regarding task performance increases anxiety and therefore impairs cognitive performance. In my study, uncertainty resulted in decreased decision confidence, which resulted in more cautious decision actions. The level of this response occurred as a function of the perceived severity of the consequences of avalanche involvement. Resulting decision actions included increased mitigation, reducing terrain exposure, or choosing terrain closure or avoidance.

Avalanche experts draw upon their mental models that result from context-based domain experience in order to manage the uncertainty they face. Domain-specific expertise reduces uncertainty, and enables decision-makers to anticipate likely events, and avoid worrying about those that are unlikely (Baumann, et al., 2001). Rich and coherent mental models also compensate for incomplete, unreliable or ambiguous information (Klein, 1998; Rasmussen, 1993; Orasanu & Connolly, 2001). These mental models enable experts to have access to default information relevant to their domain, which yield more effective decisions than novices, who are challenged by missing information (Endsley, 1997).

A majority of the critical incident decision summaries (CIDS) in my research included time-pressured decisions. In order to effectively manage uncertainty, the avalanche experts in my study focused their attention on understanding the situation, and not comparing options. Developing an accurate perception of the situation enabled participants to arrive at a decision solution that would work in the least amount of time and energy when they were faced with time pressured, high-stakes decisions. However, upon retrospection, they explained to me that the decision action may not have been the best possible. Choosing the first option that works is an efficient decision strategy called 'satisficing' (Simon, 1955).

In his research on expertise, Shanteau (1988) reported that experts use this strategy to overcome the effects of cognitive limitations in high-stakes situations, and suggested that while experts may make small errors when making decisions, they generally avoid making large mistakes. In his NDM research, Klein (1998, 2003) showed that experienced decision-makers recognize a reasonable course of action as the first one considered. He proposed that the experience these experts held enabled them to see even non-routine situations as a prototype, and skillfully know what to do without thinking of other options. This principle can be demonstrated in the following optimal decision threshold (ODT) model (Figure 26). As avalanche decision-makers gain experience, develop expansive mental models of the avalanche domain, and evolve their cognitive capacities, they experience reduced cognitive effort while optimizing decision success.

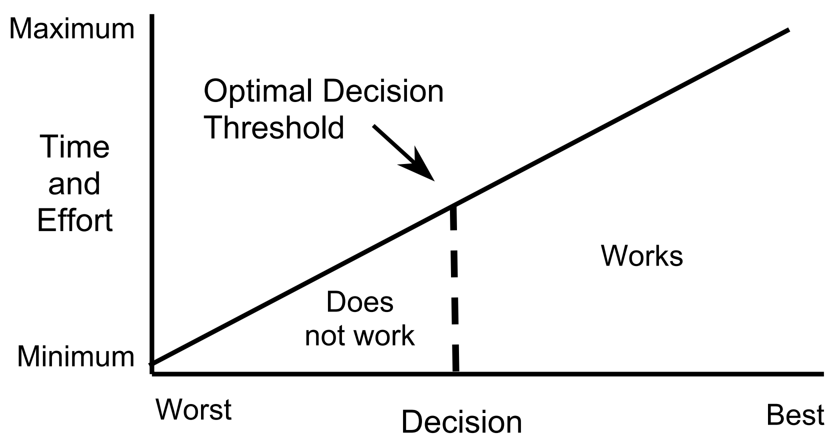

Figure 26: The Optimal Decision Threshold

Note: The ODT illustrates how workable decisions were made by these avalanche experts using the least amount of time and cognitive effort.

Developing an accurate perception of the human, physical, and environmental factors in the situation was achieved through a continuous cycle of identifying, reducing, and managing the uncertainty they faced (Figure 16). This is consistent with a review of nine Naturalistic Decision-Making (NDM) models that suggest decision-making in realistic settings occurs as a process of constructing and revising the situations representations, more often than evaluating the merits of potential courses of action (Lipshitz, 1993). Effective and successful decision-making is critically dependent upon attaining a good understanding of the situation (Lipshitz, 1993). Thus, building strong mental models and developing accurate situation awareness should be a key focus of avalanche decision skills training programs.

Avalanche experts managed the uncertainty by striving to achieve a constant balance between the goals and objectives of the avalanche program, and the identified level of uncertainty within the three systems of influence; human, physical, and environmental (Figure 18). The successful reduction of uncertainty is cognitively taxing, and requires time, motivation and structured thinking processes (metacognition and critical thinking). High levels of motivation to achieve the goal of successful resolution of situational uncertainty leads towards success, while low levels may lead to negative consequences (Baumann et al., 2001).

As a result of complex situational and human factor influences, it is unrealistic to assume that uncertainty can always be reduced or managed effectively. In some situations, participants in my study failed to effectively manage the uncertainty they faced. Denying its presence by explaining it away, or not dealing with the uncertainty and continuing with original goals and plans are several examples. Research suggests that decision-makers often find it difficult to change their plans when faced with uncertainty, since the presence of expensive consequences, for example canceling a day of helicopter skiing, requires high confidence levels (Orasanu et al., 2001).

These conclusions illuminate the complexities inherent in avalanche decision-making. Actively identifying and managing uncertainty within the human, physical, and environmental systems of influence is critical for sound decision-making. When faced with high uncertainty, a simple solution employed by these avalanche experts that requires limited cognitive economics is to reduce or eliminate exposure to avalanche terrain. This simple tactic can be executed by decision-makers of any level of expertise in the avalanche domain, resulting in higher levels of safety.

III.8. Team Decision-Making

While an individual avalanche expert may bear the final responsibility for the decision action, team members often contributed to the final product. Team environments add information, resources, and diverse perspectives to the avalanche decision problem. In this way, teams operate as cognitive systems (Klein, 2003; Orasanu & Salas, 1993). The building of shared mental models and the collective consciousness of the team mind (Klein & Thordsen, 1988) creates a highly efficient context within which avalanche judgement and decisions can occur.

Performance is determined by the way teams use their resources, and how they communicate essential information (Orasanu & Salas, 1993; Sexton, 2004). Shared mental models provide a context within which information and tasks can be interpreted, as well as a basis for predicting the needs or behaviours of team members (Orasanu & Salas, 1993). Research indicates that team decision-making is preferred when tasks are extremely complex, as no single individual possesses all of the relevant knowledge with which to discover adequate solutions (Klein, 1998; Orasanu & Salas, 1993).

However, I found the capacity of teams to make effective decisions was a direct function of the quality of interactions amongst team members. Inadequate communication, failure to challenge assumptions about goals or values, inaccurate perceptions, and social pressures to conform significantly degraded the team decision-making process. Orasanu et al., (2001) suggested that implied expectations amongst team member may encourage risky behaviour, and may result in people behaving as if one is an expert, while in fact they may lack the knowledge to effectively execute an independent decision. An example provided by focus group participants described how assistant guides are often expected to assume complex tasks of significant responsibility such as snow safety for helicopter ski operations with limited supervision or discussion.

While these experiences offer tremendous learning experiences for less-experienced avalanche decision-makers, they may result in high levels of performance anxiety and acute stress (Baumann et al., 2001). Uncertainty regarding performance, and the fear of consequences of failure separately contributes to the level of anxiety experienced, and results in negative performance effects (Baumann et al., 2001).

The experience of negative team interactions was particularly strong in situations involving supervisors, lead guides, or individuals with higher status. Orasanu and Salas (1993) reported a similar finding in their aviation research, stating "high status can be used effectively to manage a team or it can lead a team to disaster" (p. 338). In addition to the social factors described above, they found that the pilot's point of view carried more weight, regardless of whether s/he was correct or not (Orasanu and Salas, 1993).

This discussion emphasizes the critical role that avalanche team supervisors have in leading their teams towards decision success. Verbalizing thoughts so the entire team can develop a shared situational model, encouraging diverse views, and providing positive feedback and direction during difficult tasks are examples of exemplary team leadership. Thus, individual skills and knowledge alone are not sufficient for successful team performance (Orasanu & Salas, 1993; Sexton, 2004). Communication, therefore, must be a key emphasis within the team decision-making process.

III.9. Communication

Communication was fundamental to the creation of shared mental models in individuals, teams, organizations, and professional associations in my study. Environments that encouraged effective and open communication resulted in improved judgment and decision actions, and reduced subjective biases that may have been present in an individual decision-maker. Research indicates communication is central to team performance, and is especially critical in non-routine tasks (Klein, 2003; Orasanu et al., 2001; Sexton, 2004).

High quality communication is also associated with high-quality solutions and team performance. Research indicates that higher rates of verbalization result in better decision-making, such as task specific information exchange, suggestions of intent, acknowledgements, and disagreements (Orasanu & Salas, 1993; Sexton, 2004). When teams have strong, shared mental models they are able to create shared situational models, which are critical when situations and conditions demand non-habitual responses (Klein, 1998; Orasanu & Salas, 1993).

Greater levels of communication within the five human realms (individual, team, client, organization, and socio-political) resulted in less uncertainty, higher levels of decision confidence, and reduced human factor influences experienced by decision-makers. In addition, effective communication fostered shared mental models regarding goals and conditions between decision-makers and management, and resulted in collective understanding and higher levels of support for the decision-maker's judgments and decision actions. The importance of communication has been widely recognized in the literature, and along with enhancing predictability, has been identified as the primary method of reducing human error in high-stakes decision-making (Sexton, 2004).

Conversely, inadequate communication, resistance to differing options, and group-think (Jannis & Mann, 1977) were key factors in the critical incident decision summaries (CIDS) of avalanche accidents and close calls in my study. This finding correlates directly with research in the aviation field showing that minimal communication, negative expressive styles, and low task motivation results in poor coordination and high performance errors (Orasanu & Salas, 1993). Thus, I suggest that an emphasis upon effective communication within all of the human realms has significant potential in decreasing human error and increasing decision success.

III.10. Decision Success

As the results have demonstrated, experience, knowledge and skills, and information relevant to the human, physical, and environmental systems are the foundation of avalanche judgment and decision success. Rich mental models developed from extensive avalanche domain-specific knowledge and experience, resulted in exceptional perceptual and cognitive expertise within the avalanche experts in my study.

These experiences resulted in participants having an attitude of deep respect for the uncertainties inherent in avalanche phenomenon, for the consequences of involvement, and for the imperfect nature of human decision-making. Knowledge of these limitations appeared to be an invaluable tool that enhanced the judgment and decision capacities of these avalanche experts. Maintaining an attitude of safety, being metacognitively aware, and incorporating a buffer zone in decision actions were primary strategies in achieving successful decisions.

The avalanche experts in my study possessed a deep motivation to learn and to improve their knowledge and decision-making capacities. They engaged in deliberate practice activities such as feedback, critical thinking, reflection, and professional development, which have been found to be key learning tactics of experts for improving decision performance and developing expertise (Ericsson et al., 1993; Phillips et al., in press). These tactics result in the strengthening of intuitions and a deeper understanding of the intricacies and dynamics of the avalanche domain (Klein, 2003; Phillips et al., in press).

The finding that participants were motivated, self-directed learners is an important result of this study, since it suggests that avalanche decision-makers of all levels can significantly improve their judgment and decision-making capacities by engaging in targeted activities and decision-skills training. Recommendations specific to building and supporting avalanche-related judgment and decision-making are discussed in detail in Chapter Five.

III.11. Time Pressure

The theme of time pressure resonated throughout this study and was a fundamental variable that determined the primary mode of cognitive function used to solve the decision problem, the degree that heuristic strategies were utilized, and the level of anxiety experienced by the decision-maker. While time pressure is a reality in avalanche decision-making, prior preparation and metacognition is fundamental to ensuring cognitive workload is not exceeded during time-pressured decision-making.

Building a strong mental model of the avalanche domain, a shared situational model of the current conditions, and choosing appropriate goals and objectives prior to the occurrence of decision events, prepared these avalanche experts and their teams for greater success. In addition, maintaining a high level of systems thinking and metacognitive awareness throughout judgment and decision actions, enabled the avalanche experts in my study to perceive the situation with greater accuracy resulting in sound decisions.

III.12. Decision Errors and Human Factor Influences

While a central proposition of traditional decision research is that decision errors result from the individual strategies or cognitive capacities of the decision-maker, recent research identifies the critical importance of understanding decision errors through an examination of the contextual factors that were present (Orasanu et al., 2001; Rasmussen, 1993; Reason, 1990; Stefanovic, 2003).

The biases and decision traps that I have reported may appear to be an irrational response when compared to normative frameworks. However, we must consider the strong influences of the individual, team, client, organization, and socio-political realms in these processes. Fear of appearing incompetent, social pressures within teams, pressure to open avalanche prone terrain by clients, logistical and financial pressure from organizations, and desires to maintain cultural cohesion within associations are examples that resulted from my study. Additionally, varying perceptions of risk, and varying levels of acceptable risk exist within these human realms.

Selecting appropriate avalanche program goals and objectives should include considerations for all of the human realms, including the level of acceptable risk. An additional consideration of key importance in reducing human error is the reality of the dynamically changing conditions that exist within the physical and environmental realms. These findings are significant since they clearly frame the boundary conditions within which avalanche decision-makers must consider the decision problem.

While in retrospection, a majority of the participants in my study recognized the human influences present in their CIDS's, they simply succumbed to the excessive pressure they faced. My research illuminates the conflicting challenges that avalanche decision-makers face as they strive to achieve a balance between the widely varying goals and objectives within the realms of human influence, and the dynamically changing conditions within the physical and environmental systems.

I suggest that a systems approach to identifying contributing factors in decision errors is to focus on the process and not the outcome, and to examine the interrelationships between individual human factors, situational and task influences, and external human factor influences. This notion is consistent with recent literature emphasizing the need to understand the systemic causes underlying decision processes instead of casting blame upon decision-makers for the outcome (Orasanu et al., 2001; Rasmussen, 1993; Reason, 1990).

In the following sections, conclusions regarding the realm of the individual decision maker are offered within this systemic awareness.

12.1. Cognitive factors.

Lack of relevant knowledge, experience, and information were the fundamental factors contributing to close calls and avalanche accidents in this study. "Lack of knowledge can lead to both misdiagnosis of a problem and to choice of a poor solution" (Orasanu et al., 2001, p. 217). For example, although the avalanche experts in this study had extensive experience in the avalanche domain, they may lack specific knowledge when faced with a novel situation. The deep persistent instability in the 2002 / 2003 snowpack was an example cited by numerous participants in my study.

A failure to simulate consequences when experiencing time pressure or increased cognitive workload was an additional related factor in my study. This was particularly prevalent when conditions in the physical, environmental or human systems were undergoing subtle changes. This notion is consistent with Klein (1993) who reported that failure to simulate outcomes frequently leads to errors in choosing decision actions.

12.2. Physiological influences.

Physiological influences such as fatigue and environmental stress degraded these avalanche experts' capacities to make sound judgments and decisions. Narrowing of attention, failure to seek alternatives, less discriminate use of information, and increased use of heuristic strategies when inappropriate are examples of the resulting consequences. When suffering from the effects of physiological influences, avalanche decision-makers can improve their judgments using metacognition, however the stark reality is they are operating at a cognitive deficit when faced with situations that require increased cognitive workload.

In addition, modulating variables such as fatigue and stress, coupled with communication patterns, interact with individual variables such as knowledge and skills to result in unintended actions of the decision maker (Patel & Arocha, 2001).

12.3. Psychological influences.

Decision errors can often be attributed to the situation assessment as opposed to the selection of actions (Endsley, 1997; Klein, 1998). "Decision-makers make the correct decision for their perception of the situation, but that perception is in error" (Endsley, 1997, p. 270). While accurate perception is fundamental to good decision-making, goals and mental models are integrally linked and are critical to the formation of accurate situational models (Endsley, 1997; Orasanu et al., 2001).

Endsley (1997) argued that a decision-maker's goals and expectations influence how their attention is directed, and how information is perceived and interpreted within their mental models. He suggested that decision-makers select actions that line up their perception of the environment with their goals and objectives. Orasanu et al. (2001) reported similar findings, identifying the intended goals or outcome as key indicators, since decision-makers strive to achieve their goals through their decision actions. Thus, balancing the goals and objectives of the avalanche program with the conditions within the three systems of influence (Figure 18) is of critical importance to ensure sound avalanche decision-making.

The impact of goals and mental models on judgment and decision-making is particularly problematic in the high-stakes avalanche domain. Since avalanche accidents and close calls are infrequent, they are an insensitive indicator to decision quality feedback. As a result, false positive feedback experiences may become reinforcing experiences of poor decision actions, and may lead to overconfidence. Repeated experience develops mental models and expectations about future events that predisposes decision-makers to perceive information that is in agreement with their mental models

(Endsley, 1997). For example, in a study of recreational avalanche accidents in the United States, the familiarity that resulted from past experiences and actions led avalanche accident victims to believing their behaviours were appropriate in the current situation (McCammon, 2002). Research indicates that the use of metacognition reduces the overconfidence bias by requiring decision makers to think about the reasons and assumptions that underlie their judgments and choices (Pilske, et al., 2001).

The fear of appearing incompetent and uncertainty regarding performance resulted in anxiety that can lead to a narrowing of attention resulting in impaired performance. Research indicates that social factors exert a significant influence on judgment and decision-making, and creates goal conflicts that can result in an unwillingness to admit lack of knowledge, and to continue even in the face of uncertainties (Orasanu et al., 2001). Applying metacognitive awareness is a fundamental approach to the correction of biases in intuitive judgments (Kahneman, 2003).

III.13. Concluding Remarks

Avalanche-related judgment and decision-making is very complex and occurs at the center of three systems of influence; human, physical, and environmental. Even when the decision problem is well understood, the information upon which avalanche decision-makers depend may be more or less precise. Interpretation of this information involves the integration of complex data from a variety of sources, and occurs within a dynamic interaction of human systems that bring widely different perceptions and values to the decision process.

A major goal of my research was to decouple the judgment and decision processes of avalanche experts, and to illuminate the cognitive modes and strategies used in real-world settings. I suggest that a more complete understanding of these processes and the systemic factors that influenced successful judgments and decisions will enable avalanche decision-makers and training organizations to take a strength-based approach and focus upon the enhancement of these capacities at expert, and where appropriate, novice levels.

A second objective was to shed light upon the boundary conditions and human factors that posed significant challenges to avalanche-related judgment and decision-making in this group of avalanche experts. I suggest that a more complete understanding of the influence of potentially negative human factors will enable avalanche decision makers and stakeholders to recognize and manage their presence, therefore reducing the frequency of human factor decision errors in avalanche accidents.

IV. Scope and Limitations of the Research

This qualitative, social sciences study represents the thoughts and experiences of thirty-seven Canadian avalanche professionals from across Western Canada. The professional avalanche community in Canada possesses strong cultural characteristics that are unique to this study group. I define culture consistent with O'Toole (1996) as the shared ideas, customs, assumptions, expectations, philosophy, traditions, and values that determine how a group behaves (p. 72). As I have emphasized, human behaviour is best understood in the social and natural frameworks within which it occurs. Therefore, a true understanding of avalanche decision-making must consider the boundary conditions within which these judgments and decisions occur.

While this study achieved broad representation of expertise from across the Canadian professional avalanche community, the boundary conditions that I have described are particular to the judgment and decision-making process of this group of research participants. Thus, while the results may resonate with other avalanche practitioners and professionals, they may not be generalized to other groups, especially those of other countries where the boundary conditions of cultural and human factor influences may differ significantly.

While I have reported findings that are consistent with those reported in expert and high-stakes decision-making in other domains (Klein 1997; Klein et al., 1989; Klein & Militello, 2001; Hoffman et al., 1998), I know of no published literature that is specific to the topic of avalanche expert's judgment and decision-making in high-stakes situations. Therefore, the results of my research will be strengthened by future research to corroborate the findings.

It is important to note that the conclusions and recommendations of this research are specific to adults. Clearly, adults and children learn and make decisions in qualitatively different ways. Youths are potential avalanche accident victims in Canada and mountain countries around the world. Hence, further research is needed to understand this demographic and to provide insight into more effective awareness and prevention programs.

I have reported that the avalanche experts who participated in my study possessed a strong motivation to learn and improve their decision practice. I suspect this motivation was a key factor in their decision to participate in this study. Thus, the findings should be considered within this context.

Thirty-three avalanche professionals in my study were male and four were female. While this ratio is representative of the gender ratio that exists within the population of Canadian avalanche professionals, the results of this study provide a dominant male perspective. While I suspect that qualitative differences exist between how males and females develop mental models, perceive their environments, and execute decision actions, I was unable to source any literature that examines this area in relation to high-stakes decision-making. As a result, I did not address this topic in my research, and it remains one of interest for future research.

CHAPTER FIVE –

RESEARCH IMPLICATIONS

The findings of my research suggest a new set of implications for avalanche thinking in Canada; emphasizing systems thinking and social science research, knowledge acquisition, personal mastery, communication, and decision-skills and human factor training. In the following section, I offer a set of six evidence-based recommendations designed to support and enhance avalanche judgment and decision-making capacities, and to counter the influence of negative human factors in the decision process. In the second section, I discuss the research implications to commercial organizations, avalanche research, avalanche skills education, avalanche professionals, and recreationists. In the third and final section, I discuss the implications to future avalanche research.

I. Study Recommendations

1. Integrate a systems thinking perspective.
2. Capture avalanche domain knowledge and expertise.
    - 2.1. Bank systems knowledge of the avalanche domain;
    - 2.2. Identify the architecture of good decisions;
    - 2.3. Record human factor influences in avalanche accidents and close calls.
3. Enhance personal mastery and leadership capacities.
4. Build and support avalanche decision skills and expertise.
    - 4.1. Develop rich mental models of the avalanche domain;
    - 4.2. Increase situation awareness and perceptual capacities;

4.3. Develop critical thinking and metacognitive skills;

4.4. Increase skills in mental simulation;

4.5. Reduce cognitive limitations;

4.6. Integrate decision skills learning initiatives;

4.7. Integrate human factors training;

4.8. Increase pre-decision making;

4.9. Engage in deliberate practice.

5. Improve communication.

6. Develop team decision-making capacities.

1. Integrate a Systems Thinking Perspective

Avalanche judgments and decision actions occur within a dynamic and complex decision process, and are embedded within a broad situational and human context that includes influences from physical, environmental, individual, team, client, organizational, and socio-political realms. Viewing avalanche decision problems through the holistic perspective of systems thinking provides a comprehensive understanding within which avalanche decision-makers and stakeholders can fully understand the decision context and derive safe and effective solutions. "The essence of the discipline of systems thinking lies in a shift of the mind: seeing interrelationships rather than linear, cause-effect chains, and seeing processes of change rather than snapshots" (Senge, 1990, p.73).

2. Capture Avalanche Domain Knowledge and Expertise

Knowledge is now recognized as being the single, greatest asset of individuals, teams, and organizations. Recent research indicates that knowledge doubles every three to four years; therefore a focus on the acquisition, creation, storage, transfer, and utilization of knowledge (mentofacturing) is fundamental to support effective decision-making (Marquardt, 1999). Capturing key knowledge and information that describes historical and current avalanche system dynamics (human, physical, and environmental) provides a virtual mental model to support decision-making, individual, team, and organizational learning, and future systems design.

2.1. Bank Systems Knowledge of the Avalanche Domain

Knowledge banks are computer databases that creatively capture and preserve the knowledge and experiences of experts in order to enhance the capacities of the team mind. Knowledge banks extend the personal memory of an individual decision-maker, to form transactive memory (Orasanu, et al., 2001) through the vicarious experiences and knowledge of other contributing decision-makers. NDM research in decision skills training suggests that resources and information which direct decision-makers' attention to critical aspects of the decision problem, illustrate mental models of the domain, and provide domain-specific knowledge are key learning tools to support sound decision making (Anderson, 1983; Phillips et al., in press).

An example that has been used very effectively in the avalanche domain is digital terrain photographs, which have proven the proverb that a picture does in fact tell a thousand words. Terrain photographs illustrate and describe ski runs, avalanche paths, areas of hazard, avalanche occurrence information, preferred avalanche control placements, weather stations, landings, pickups, rescue and fuel caches. The avalanche experts in my study emphasized the effectiveness of this visual tool, since critical information can be discussed in the context of specific terrain features. The result is the creation of highly accurate mental models and situational models (FG 1 & 2).

While avalanche operations have used photographs to display avalanche information for decades, several operations have recently integrated digital imagery and data projection as key tools for planning meetings. In addition, these knowledge databases are invaluable for avalanche practitioners who are new to the industry or the area, as they depict key information to support the creation of shared mental and situational models. I suggest the integration of Geographic Information Systems can build upon this success; as an interface to capture and visually display avalanche knowledge and experiences in the specific terrain to which it is pertinent.

2.2. Identify the Architecture of Good Decisions

Debriefing exceptional decisions is a tremendous learning tool for decision capacity enhancement, and should be a key emphasis for individuals, teams, and organizations. The qualities that define the architecture of good avalanche judgments and decision-making processes have not yet been defined in the avalanche domain. Examining successful decisions takes a strength-based approach to understanding and improving avalanche decision-making rather than a problem-based focus.

Avalanche decision-making has a heavy reliance on tacit knowledge; knowledge that is not easily verbalized. Deliberating upon and deconstructing good decisions is necessary in order to expose this tacit knowledge, and to understand the underlying architecture and causal models that are integral to good decision-making. In addition, defining the qualities of good avalanche decision-making is necessary for constructing explanations and models from which decision skills learning programs can be effectively designed.

2.3. Record Human Factor Influences in Avalanche Accidents and Close Calls

In order to gain a deeper understanding of the influence of human factors in avalanche judgment and decision actions, descriptive empirical data is needed. Current methods of avalanche accident data recording describe the physical properties of the avalanche and associated demographics of accident victims; however criteria for recording human factors contributing to the accident have not yet been defined. I suggest that defining criteria for the recording of human factors in avalanche accident records and implementing this process will offer critical insight and greater accuracy in avalanche risk assessment, avalanche decision-skills learning initiatives, hazard communication, and accident prevention strategies.

3. Enhance Personal Mastery and Leadership Capacities.

As the findings have demonstrated, avalanche judgments and decisions are subject to internal (cognitive, physiological, and psychological) and external (team, client, organizational, and socio-political) influences. As a result, avalanche experts are tasked with the challenge of deriving effective solutions in a way that is responsive to the boundary conditions of the situation, and to the long term needs of all stakeholders. I suggest that successful avalanche decision-making requires decision-makers to have a high level of personal mastery and leadership capacity.

Personal mastery is about developing one's own proficiency (Flood, 1999). It embodies clarifying what is truly important, making values-based actions, and continually learning how to see the current reality more clearly (Senge, 1990). These qualities are key in order to achieve an accurate perception of the factors influencing the decision problem, to be aware of the biases and assumptions that are present, and to make suitable decisions in light of this awareness.

Personal mastery and leadership starts with the self, and requires discipline, motivation, and courage. Quinn (1996) argued that moral power and a strong sense of values and integrity is fundamental to our capacity to face uncertainty, and to function effectively in times of stress and anxiety. As we discipline our talents and become more aware of our values and our environment, we deepen the accuracy of our perceptions and are able to make better choices to the problems we face (Flood, 1999; Senge, 1990; Quinn, 1996). O'Toole (1996) explained that successful leadership and sound decision-making emanates from strong ideals and values, and requires an understanding of the differing and conflicting needs of stakeholders.

While personal mastery is undertaken by individual decision-makers, it should be encouraged and supported by learning organizations that are committed to continuous change, renewal, innovation, and learning (O'Toole, 1996). Learning organizations foster individual, team, and organizational learning through sharing information, creating a sense of community, and fostering open communication (O'Toole, 1996; Senge, 1999).

4. Build and Support Avalanche Decision Skills and Expertise

4.1. Develop Rich Mental Models of the Avalanche Domain

Avalanche decision-makers of all levels can improve their judgment and decision-making capacities through the development of rich and expansive mental models. Mental models consist of highly integrated knowledge structures that depict the avalanche domain, and guide avalanche decision-makers to key aspects of the decision problem. "Our mental models determine not only how we make sense of the world, but how we take action" (Senge, 1990, p. 175). Compiling extensive mental models was a key recommendation for acquiring and supporting decision-making expertise, as reported in a review of the literature by Klein (1998). Well-developed mental models provide for the dynamic direction of attention to critical cues, expectations regarding future states of the environment, and a direct link between recognized situation classifications and their typical actions (Endsley, 1997). I recommend a set of tools for building mental models in the upcoming section on decision skills learning strategies.

4.2. Increase Situation Awareness and Perceptual Capacities

The key to effective avalanche judgment and decision-making rests in an ongoing, accurate perception of the conditions within the human, physical, and environmental systems. Research in decision science indicates that situation awareness, mental models, and metacognition are the primary input to the decision process, and are the fundamental components that guide the selection of decision strategies (Endsley, 1997; Orasanu et al., 2001; Rasmussen, 1993; Zsambok & Klein, 1997). Therefore, they should be a key focus for avalanche decision-makers and for decision skills learning strategies. In addition to the learning strategies that I propose, I have compiled a list of the approach to practice reported by avalanche experts in my study (Appendix C). An awareness of this approach and the critical cues reported in Chapter Four may enable future avalanche decision-makers to vicariously enhance their thinking, resulting in an enhancement of their judgment and decision accuracy.

4.3. Develop Critical Thinking and Metacognitive Skills

I recommend building capacities in critical thinking and metacognition. Critical thinking actively involves avalanche decision-makers in recognizing and researching the assumptions that are fundamental to their thoughts and actions (Brookfield, 1997), and is integral to meta-cognition and situation awareness. Utilizing questioning instead of answer finding, considering how assumptions are shaping points of view, and searching for information that opposes the position, as well as information that supports it are several examples. Critical thinking enables avalanche decision-makers to dramatically enhance their knowledge, and provides the opportunity to effectively reorganize it for future use.

Metacognition is fundamental to accurate avalanche-related judgment and decision actions. The use of metacognition increases accurate situation awareness and reduces potentially dangerous biases by requiring decision makers to think about the reasons and assumptions that underlie their judgments and choices (Pliske, et al., 2001). Cohen et al. (1996) proposed a set of specific metacognitive skills for complex decision-making. Based upon the findings of my research, I suggest these strategies can improve avalanche decision-maker's performance by acquiring effectively structured domain knowledge and skill in questioning and revising that knowledge:

a) going beyond pattern matching in order to create plausible stories for novel situations;

(b) noticing conflicts between observations and a conclusion;

(c) elaborating on a story to explain a conflicting cue rather than simply disregarding or discounting the cue;

(d) having sensitivity to problems in explaining away too much conflicting data;

(e) attempting to generate alternative coherent stories to account for data; and

(f) having a refined ability to estimate the time available for decision making.

(adapted from Cohen et al., 1996, p. 207).

4.4. Increase Skills In Mental Simulation

The avalanche experts in my study effectively used mental simulation to construct narrative story structures and to envision how their proposed decision actions would play out; for example, the consequences of avalanche release in a specific terrain feature. Mental simulation facilitates the discovery of new and effective interventions, and increases the decision maker's repertoire of patterns and associated actions for future use. For example, the integration of fracture character (Birkeland & Johnson, 1999; Van Herwijnen & Jamieson, 2004; Schweitzer & Jamieson, 2003), and the avalanche characterization checklist (Atkins, 2004) into avalanche decision-making and hazard communication, offers powerful tools to facilitate mental simulation and support successful avalanche-related decisions.

4.5. Utilize Strategies to Reduce Cognitive Limitations

The findings of this research have demonstrated that avalanche decision-makers experience significant limitations in their decision processes when their cognitive workload is increased as a result of uncertainty in the human, physical, and environmental systems, and from human factor influences. Shanteau (1988) proposed a set of strategies that experts use to successfully overcome the effects of cognitive limitations and make sound decisions. My research corroborates these findings; therefore I suggest avalanche decision-makers emphasize the use of the following strategies in order to reduce cognitive limitations in the decision process:

1. Be willing to adjust initial decisions in light of subsequent feedback.

2. Rely on others to gain additional insight and perspective to assist in making decisions.

3. Learn from past decisions and make appropriate changes to future judgment and decision strategies.

4. Develop informal decision aids in order to avoid the biasing effects of heuristics (List adapted from Shanteau, 1988, p. 209).

4.6. Integrate Decision Skills Learning and Training Strategies

Decision-making is a fundamental and ubiquitous activity for avalanche professionals, practitioners, and recreationists. However, it is only recently that an awareness of the importance these skills has arisen in professional or recreational avalanche training programs in Canada. Decision skills learning interventions can help avalanche decision-makers of all levels acquire and enhance critical skills, perceptual cues, and knowledge more quickly, through the development of decision skills, avalanche domain mental models, and experience (Klein, 2003; Phillips et al., in press).

I suggest the emphasis must be placed on the fundamental premise of action learning – learning how to learn in realistic settings (Marquardt, 1999). In addition, the emphasis must be on supporting and enhancing the decision modes and strategies used by decision-makers in natural settings, rather than training that conforms to models of optimal procedures under ideal circumstances (Klein, 1997). Focusing on improving the learning process through an emphasis on context-specific rather than generic skills, and encouraging decision makers to identify their own requirements for improving their judgment and decision skills, will result in an acceleration of the growth of expertise (Klein, 1997; Phillips et al., in press). These are key principles, since it is only through testing ideas and strategies in practice, that decision-makers are able to know whether the strategies are effective or practical.

The avalanche experts in my study demonstrated the use of a wide range of decision-making modes and strategies that have been reported by researchers in decision-making and expertise. However, I observed that varying understandings of these decision processes and of strategies for effective use existed within study participants. For example, while some of the avalanche experts spoke enthusiastically of the benefits of intuitive decision-making, others who lacked an understanding of the process appeared to dismiss it as unscientific or un-expert. I propose that if avalanche experts are encouraged to develop a greater understanding of how to effectively use the various modes of cognitive function I have reported, their decision skills capacity will increase.

Scenario-based approaches.

Based upon a review of the literature, the following decision-skills learning strategies have proven to be very effective in increasing capacities in high-stakes decision-making. Thus, I suggest their design and application be considered as key learning tools to enhance avalanche decision-maker's judgment and decision capacities.

As I previously discussed, ongoing NDM research reports that scenario-based approaches combined with effective coaching enriches mental models and offers great promise for developing and enhancing judgment and decision skills (Klein & Militello, in press). For example, simulations and case studies enhance the learners vicarious experience base and enrich their mental models through a process of studying and reflecting upon how decisions were made under specific circumstances (Phillips et al., in press). Creatively designed scenarios enable judgments and decisions to be examined and learned in the context within which they naturally occur, rather than in isolation from the realistic situation. Extensive research in NDM decision skills training indicates that well designed simulations can provide more learning value than direct experience, since the action can be stopped at strategic points in order to see what went on (Klein, 1998). In light of these findings, and in consideration of the extent of my personal learning that resulted from the critical decision summaries reported by the avalanche experts' in my research, I recommend this method should be the key focus of decision skills learning strategies for avalanche decision-makers of all levels.

Cohen et al. (1996) and Cohen et al. (1998) developed an approach to decision skills training called Critical Thinking Training (CTT). The CTT method requires learners to develop alternative explanations, identify conflicting evidence, and describe actions they would take at specific points during the simulation. Thus I recommend that CTT would be very effective in developing avalanche decision-maker's skills of critical thinking, situation awareness, and metacognition, in order to aid in the identification of negative human factor influences.

Pliske, McCloskey and Klein (2001) designed a set of six tools for decision-skills learning that builds upon the successful strategies used by experts. I suggest these tools offer a comprehensive set of strategies to build avalanche decision skills and to enhance leadership skills and team communication. (1) Decision Making Games provide simulated, domain-relevant experiences that encourage learners to practice their recognitional decision-making skills; (2) The Decision Making Critique facilitates reflection regarding what went well and not so well during an exercise; (3) The Decision Requirements Exercise helps learners explore the challenging decisions they faced in order to maximize their learning; (4) The PreMortem Exercise, which is used to identify key vulnerabilities in a plan; (5) The Commander's Intent exercise, which provides learners with the opportunity to practice their skills for communicating a leader's rationale underlying a plan of action; and (6), The Situation Awareness Calibration Exercise, which provides insight into how different team members perceive the same environment (Pliske et al., 2001, p. 42-46).

4.7. Integrate Human Factors Training

The findings of my research identified the boundary conditions and human factors that negatively influenced the judgment and decision actions within this group of avalanche experts. Integrating human factors into professional and recreational learning curricula will bring an awareness of the influence of the positive and negative elements of human factors in the avalanche judgment and decision process. Thus, avalanche decision makers and stakeholders may increase their capacities to recognize and manage their presence, potentially resulting in a reduction of the frequency of human factor decision errors in avalanche accidents. This strategy is of critical importance, since the more negative human factors that are present in a situation, the harder it is to apply good judgment and decision-making.

4.8. Increase Pre-Decision Making

Pre-decision making involves anticipating and identifying critical decision conditions or points, and then planning strategies and options for associated decision actions prior to their occurrence. Pre-decision making is essential to the creation of mental models and shared situational models, which are fundamental to efficient decision-making. This strategy serves a critical function in reducing cognitive workload in field situations, and reduces the influence of human factors that inhere in the avalanche decision process. Prior research suggests that the more preparations and information analysis that decision-makers engage in before entering stressful situations, the less anxiety they experience (Driskell & Johnston, 1998). Since anxiety levels correlate directly with performance levels, pre-decision making is an important tool for avalanche decision-makers.

Pre-decision-making is a fundamental part of the systems approach to decision making used by avalanche experts' in my study (see Figure 24). However, an increased emphasis in this area within all levels of decision-making offers direct support to ensure better decisions in field situations.

4.9. Engage in Deliberate Practice

Deliberate practice includes feedback, mentoring and coaching, reading, engaging in conversations with other decision-makers, and participating in courses, training programs, and knowledge exchange events. Deliberate practice is critical to transform experience and knowledge events into expertise. Frequent reflection is fundamental to this process, and enables us to derive new insights, richer mental models, and an understanding of causal influences that may not have been identified at the time (Klein, 1997; Schön, 1983; 1987). Developing programs aimed at helping people become reflective practitioners is a key focus of NDM research (Klein, 1997). Schön (1983) argued that the ability to reflect on one's thinking while acting is a key characteristic that distinguishes the exceptional professional.

Feedback is a critical component of sound avalanche judgment and decision-making, since without effective feedback it may be impossible to achieve expert predictive or diagnostic abilities (Phillips et al., in press, p. 16). Obtaining feedback that is accurate, timely, diagnostic, and process-focused is a fundamental method to enhance judgment and decision expertise (Klein, 1998; Phillips et al., in press). Cognitive and process feedback are two methods that have proven to be very effective in improving high-stakes decision-making. Cognitive feedback provides information regarding interrelationships between the environment and the decision-makers' perceptions (Klein and Militello, in press), while process feedback provides information on how decision-makers can make effective adjustments to their approach (Cannon-Bowers & Salas, 2001). Reflection on processes generates learning and may stimulate a break-though in thinking (Flood, 1999).

Enlisting the help of others enables decision-makers to see their ideas and actions in new ways (Brookfield, 1997), and to grasp the intricacies and dynamics of strategic and tactical situations (Phillips et al., in press). A key recommendation of focus group participants was to implement mentoring more formally into the avalanche domain (FG 1 & 2). This would require the identification of goals, the creation of structures, and definitions of roles and responsibilities for both the mentor and the protégé (Sprafka & Kranda, 2000).

Effective mentoring and coaching actively engages less-experienced decision-makers in building their mental models and decision skills. Mentoring also fosters two-way learning in a mutual search for new insight. Since the mentor must decouple the decision problem and process, and articulate the components to the protégé, they also receive valuable insight into the decision process. Participants articulated a concern for the time commitment required to be a mentor, however it is important to note that the protégé should take a leadership role in their own learning. Several examples include observing, interviewing, and/or studying avalanche experts in order to understand how they successfully arrived at judgment and decision action (Phillips et al., in press).

5. Improve Communication

Effective communication within and between all of the human realms (team, client, organization, and socio-political) is essential to develop the shared mental and situational models necessary to support avalanche judgments and decision-making. Focus group participants recommended that communication skills training should be a key focus in team decision-making environments, and should include an emphasis on leadership skills for those in supervisory positions (FG 1 & 2). This finding supports research by Shanteau (1988), who suggested a key characteristic of expertise is the ability to communicate thinking and expertise to others. This recommendation is also consistent with the GIHRE (Sexton, 2004) key findings, which identified improving communication as a primary strategy to improving team performance and reducing human error.

6. Enhance Team Decision-Making Capacities

The characteristics and qualities of successful avalanche decision-making teams have not yet been identified, thus defining these qualities and using that information as a guide for training offers great promise. Research in NDM indicates team decision-making can be enhanced through effective management of information resources and workload, coordination of actions, and more effective communication (Orasanu & Salas, 1993). Team decision-making can also be improved by enhancing predictability, which helps team members and stakeholders to set expectations, plan for future contingencies, share a common mental model, reduce ambiguities, and decrease stress levels (Sexton, 2004).

Focus group participants discussed the importance of personally modeling the behaviors that foster team performance (personal mastery), and encouraging the sharing of different points of view (FG 1 & 2). Senge (1990) suggested the discipline of team learning is based upon reflective inquiry using dialogue, where people suspend their views and enter into deep listening to explore mental models of other team members.

Teams produce the best results when group members exhibit the following attributes, thus I recommend them as a key focus for avalanche teams:

1. A commitment to solving the problem,
2. An ability to listen and to question oneself and others,
3. A willingness to be open and to learn from other group members,
4. A respect for other's point of view,
5. A commitment to taking action and to achieving success,
6. An awareness of one's own and others ability to learn and develop.

(List adapted from Marquardt, 1999, p. 29).

II. Implications of this Research

The recommendations of this research present opportunities and implications for commercial organizations, avalanche research, avalanche skills education, avalanche professionals and practitioners, and recreationists.

II.1. Implications for Commercial Avalanche Organizations

The recommendations of my research describe six key methods that commercial avalanche organizations should consider implementing to create meaningful progress towards supporting and improving the avalanche judgment and decision skills of their members and/or staff.

Capturing the key knowledge and expertise of avalanche practitioners, supporting the growth and exchange of wisdom through mentoring and deliberate practice activities, fostering communication, and the implementation of decision-skills and human factors learning initiatives offer the direct benefit of improved individual and team decision-making, and a reduction in the number of close calls and avalanche accidents experienced. These methods are key strategies of learning organizations (Senge, 1990; Flood, 1999), where learning is a continual and strategically used process that enables organizations to adapt, renew, and revitalize themselves in response to changing environments. Learning organizations create a culture and a strong morale for learning (Marquardt, 1999).

Systems thinking is of key importance at the organizational level, since it offers a holistic perspective of the structures and influencing factors that are present within the complexities of avalanche-related decision-making. The findings of my research have demonstrated that professional avalanche decision-makers experience considerable cognitive limitations to their judgment and decision accuracy when faced with external pressures and goal conflicts from clients and organizations. "It is systemic structures that explain events, not the actions of individuals" (Flood, 1999, p. 22). An awareness of these influencing factors, the creation of congruent policies, and a commitment to open and effective communication can result in a shared understanding of the situation and unequivocal support for safe decision actions, even if costs accrue as a result. A reluctance to consider this holistic view may result in a failure to be responsive to critical system needs, to provide avalanche decision makers with suitable support, or to recognize valuable points of leverage for systems change and improvement.

II.2. Implications for Avalanche Research

Currently, avalanche research is heavily dominated by the physical and environmental sciences. There is a paucity of published literature examining the human element of avalanche phenomena; consequently our understanding of this matter is weak. A systems approach that emphasizes an increase in funding for social science research is direly needed in order to understand humans and the factors that affect their behaviour and decisions in avalanche terrain. This holistic perspective is vital to inform the effective design and delivery of avalanche curricula, strategies for risk communication, and public safety initiatives. A key recommendation in a recent government report on natural hazards and disasters in Canada identifies the social sciences as the key emphasis, since they are likely to produce the greatest benefits in mitigating risks (Etkin et al., 2004, p. 37).

II.3. Implications for Avalanche Skills Education

The recommendations resulting from my research suggest a new set of implications to avalanche-skills education, which emphasize decision-skills, human factors, and systems thinking as integral components of avalanche curricula at the recreational and professional levels in Canada. Avalanche education in Canada has historically contained a strong emphasis on the physical and environmental sciences such as terrain, snowpack, and weather. Curricula related to the human component of avalanche phenomena have focused on pre-trip planning, routefinding, and rescue techniques. While the importance of human factors and decision-making has been recognized in the international avalanche community for several decades, these complex topics have received only limited attention in Canadian avalanche curricula in the past few years.

The learning methods I recommend take a strength-based approach to facilitating the development of key decision skills and learning strategies that are used by high-stakes decision makers. These methods offer a meaningful opportunity to enhance avalanche curricula and continuing professional development programs with vital new tools to improve avalanche-related judgment and decision-making. Thus, a reduction in human involvement in snow avalanches is implied.

II.4. Implications for Avalanche Practitioners and Professionals

I suggest that all professional avalanche decision-makers can improve their decision practice through reading the findings (Chapter Four), and learning from the experiences and perspectives of their peers who participated in this study. In addition, the recommendations resulting from these findings (Chapter Five) offer a focused approach to expanding our awareness of the avalanche domain, and include an integrated set of focused strategies to increase our skills in avalanche judgment and decision-making. The recommendations of systemic thinking, personal mastery, decision skills learning, and deliberate practice are foundational to the creation of avalanche judgment and decision expertise.

I have offered a systems perspective of the factors and human realms that influenced the avalanche judgments and decisions of the avalanche experts in my study. Simply knowing of the existence of these influences can enhance our mental model of the avalanche domain, and increase our chance of recognizing their presence and minimizing their impact. I suggest building upon the findings of this study, by identifying the factors and decision contexts that are specific to your situation and/or organization. Richer, more detailed mental models facilitate further refinement of this recognition-primed awareness, and are fundamental to expert decision-making.

In addition, knowledge of the cognitive modes and strategies used by this highly experienced group of Canadian avalanche experts can enhance our capacities to strategically apply these processes with greater accuracy and success. Consequently, improved decision making and reduced human involvement in snow avalanches is implied.

Avalanche professionals and practitioners ought to emphasize systemic thinking, metacognition, critical thinking, and situation awareness, since they are key cognitive strategies that are essential to recognizing, identifying, and reducing uncertainty and human factor influences. These cognitive processes also help us to see if our mental models are flawed by missing critical feedback or invalid assumptions (Flood, 1999). In addition, personal mastery enables us to use this expanded awareness to make values-based decisions, and to not be overly influenced by these inherent factors. Personal mastery is also considered to be fundamental to team learning, since exceptional teams are comprised of individuals who strive to be more self-aware (Senge, 1990).

While the benefits of implementing these recommendations may be clearly obvious at the individual and team level, it is important to recognize the associated costs. In team environments, individuals must be willing to align themselves with their team members, think insightfully, communicate openly, and coordinate their actions towards shared goals. Developing skills in all of the strategies I have recommended requires a commitment of time, motivation, and disciplined thinking. Motivation to learn and to improve practice is a critical component for success, for those who lack motivation will never perform at the level of experts (Phillips et al., in press).

II.5. Implications for Recreationists and Recreational Educators

I took a NDM approach to this research, which was to examine the processes that avalanche experts use to make decisions, including the factors that influence these decisions, in order to offer key insight into the design of decision skills learning for less-experienced decision-makers (see Klein, 1997; 1998). The recommendations that I have offered regarding decision-skills learning initiatives focus upon this fundamental approach.

Personal mastery, communication, and strategically building decision skills are key recommendations of my research that are applicable to recreationists. Recreationists' knowledge, skill, and experience vary significantly, from novice to highly experienced backcountry users. Therefore, these qualities and cognitive capacities must be a key consideration when choosing to adopt recommendations from this study of avalanche experts. Consequently, there are several implications to which I would like to draw specific attention:

Avalanche domain-specific experience and knowledge results in descriptive mental models of the avalanche domain, and are the key resource used by and upon which avalanche decision-makers of all levels base their judgments and decision actions. Thus, the thoughtful construction of mental models that are rich with essential principles and primary cues should be a key focus for recreationists and avalanche educators. Of particular emphasis for recreational avalanche educators, is to offer well-designed simulations at an early stage in the learning process. This is of key importance, since repeated experiences of poor decision-making or false positive events can result in dysfunctional strategies for future decision-making. Reflecting upon the list of perceptual cues used by the avalanche experts in this study may enable recreationists to learn how more experienced avalanche decision makers see the world, and to further develop their thinking.

I believe the high levels of motivation that encouraged these avalanche experts to evaluate and improve their judgment and decision capacities were a key factor in the development of their expertise. Exposure to new ideas and techniques, peer feedback, and reflective practice resulted in improved judgments and decisions. In addition, greater levels of open communication resulted in less uncertainty, richer situational models, and higher levels of decision confidence. Clearly, the implementation of these fundamental learning strategies can be a powerful tool to build and enhance the decision skills of recreationists.

As I have discussed, there is a cost/benefit component to these activities, including the requirement of motivation to pursue them. I suspect the benefits clearly outweigh the costs for professional avalanche decision-makers. However, it is unclear whether recreationists would be willing to devote the time, money, and effort required to engage in these activities. Avalanche decision skills learning initiatives are a critical need that must be accessible by recreationists. Thus, securing funding from industry sponsors and granting agencies to develop and deliver creative learning strategies for recreationists should be a key focus of avalanche public safety initiatives.

I suggest that recreationists can learn a great deal from the individual and team human factor influences that were reported by the avalanche experts in my study. While the context of the decision problem is significantly different between that of avalanche professionals and recreationists, I suspect that the impact of the physiological, psychological, and even cognitive influences may be similarly experienced. An awareness of these factors, including how they influence avalanche-related judgments and decision-making, is the first step in recognizing and managing their presence. In addition, pre-decision making, critical thinking, knowledge of personal limitations, and personal mastery (values-based decision-making) can be effectively used by recreationists to counter the influences of potentially dangerous heuristic traps and biases in the decision-making process.

A principle finding of direct application to avalanche decision-makers of all levels is how these avalanche experts dealt with the presence of uncertainty and /or human factor influences. When avalanche experts recognized that uncertainty regarding the terrain, weather, snowpack, or human influences was significant and/or increasing, they became more cautious and chose to reduce exposure or avoid avalanche terrain. If time permits, the highly effective analytic strategy of identifying the source and nature of the uncertainty (human, physical, and / or environmental), attempting to reduce or resolve it, and then managing it through terrain use is also relevant to recreationists. The application of these fundamental strategies encourages safer decision actions. Thus, by reducing exposure to avalanche terrain, a reduction in the probability of involvement in an avalanche is implied.

The findings of this research indicate that avalanche expert's judgments and decision processes are highly refined, complex, and dynamic. Consequently, it is important to state that the use of intuitive processes should not be encouraged in novice recreationists. The experts in this study had developed extensive mental models and increasingly fine perceptual skills that enabled them to recognize subtle cues, and form meaningful patterns within and between the human, physical, and environmental systems of influence. Novices lack the experience-base and mental models that are essential to perform at this level of cognitive function, and to accurately recognize and interpret complex patterns in a set of information or a high-stakes decision situation. As a result, their intuitions may be strongly based in the affective (feeling and emotions) domain, which may result in potentially dangerous biases in their judgment and decision processes.

This recommendation is consistent with cognitive science research, which indicates that experts are different from novices in nearly every aspect of cognitive functioning (Shanteau, 1992; Klein & Militello, 2001). As my findings demonstrate, avalanche experts evolve through a cognitive hierarchy of decision modes. Thus, recreationists should choose to utilize decision modes and strategies that are appropriate and effective for their level of knowledge and experience, in order to ensure they are making accurate judgments and sound decision actions.

III. Implications for Future Research

As I have argued, a strong need for social sciences research exists in the avalanche domain. Developing an understanding of the human realm is fundamental to the creation of a more complete and holistic perspective of avalanche phenomena. I suggest it is only from this systemic perspective that effective solutions can be derived to address the problem of human involvement in avalanches.

As previously stated, I know of no published literature that has specifically addressed avalanche expert's judgment and decision-making in these high-stakes situations. Therefore, many questions remain unanswered and additional research in this area will further strengthen the knowledge of this phenomenon.

It is widely recognized that experts and novices use qualitatively different cognitive processes and strategies for decision making. While the results of my research provide critical insight to avalanche experts, an area of equal importance is to study recreationists to discover the salient features and boundary conditions that inhere in their judgment and decision processes. Extensive NDM research reports that identifying the strategies used by experts to develop their decision making proficiency, and using that knowledge to design reflective practice learning strategies, can accelerate the development of decision skills in less-experienced decision-makers. While I have offered several recommendations through which recreational decision skills can be enhanced in consideration of the expert findings of my study, it is clear that what works for experts, versus what works for recreationists, is important and needs to be studied. Since a majority of the total number of avalanche fatalities in Canada have historically been recreationists, this knowledge is vital for effective recreational avalanche hazard communication, learning strategies, and a reduction in avalanche involvements.

My research, and recent initiatives in decision skills learning, emphasise the importance of building relevant experience and strong mental models as a base for sound decision-making. What kinds of experiences encourage the development of these mental models and how could this understanding be utilized to support sound avalanche judgment and decision skills?

I have suggested that avalanche decision makers evolve through a hierarchy of decision modes as they gain knowledge, experience, and detailed mental models of the avalanche domain. What are the emergent requirements for this adaptive performance and for evolution within the hierarchy of decision modes? How could this awareness be utilized to enhance decision skills learning in order to augment the development of this expertise? This topic deserves further study since it has strong implications for future learning strategies, and the enhancement of judgment and decision expertise.

As I stated in my literature review, there appears to be a lack of literature addressing learning styles and individual developmental differences in high-stakes decision-making. How do individual learning styles affect decision-making? Do personality characteristics and aptitudes contribute to the selection of decision modes and strategies? Interestingly, these are fundamental topics in learning science, therefore it seems plausible that they should have an impact upon decision making worth considering.

In addition, gender differences in judgment and decision making may offer some interesting insight, since I suspect that qualitative differences exist between males and females.

Finally, it is interesting to note that decision proficiency and quality seems to have been largely ignored in the avalanche domain. While an emphasis on debriefing close calls and accidents has been used effectively for future awareness, participants expressed the need to learn from decision success. Hence, what are the qualities of sound avalanche judgments and decisions? It seems reasonable that this should be a key focus to enable a strength-based approach to avalanche judgment and decision skills enhancement.

CHAPTER SIX –

LESSONS LEARNED

I. Research Project Lessons Learned

I.1. Conduct of the Research

The methods that I chose for this research were clearly the primary success of this action research project. I used two tools, a survey of critical decision incidents and key decision strategies, followed by two subsequent focus groups. Taking a NDM approach and capturing the most significant decision-making experiences of this group of avalanche experts using CTA and CDM enabled me to derive a deep and comprehensive understanding of the human realm of avalanche phenomena.

While I found that the first phase of the research (CIDS) provided a substantial and ample amount of descriptive data, the subsequent two focus groups added the opportunity to verify and further explore the themes that emerged. In essence, this was another complete cycle of this action research project. The focus groups actively engaged the avalanche experts in my study in discussing the complexities that inhere in professional avalanche decision-making, and formulating effective solutions to the problems they faced.

Participants expressed how much they enjoyed sharing in an open dialogue on this topic, and how they learned from each other through the sharing of experiences, thoughts and perspectives. While these sessions were three and a half hours in length, I sensed participants still had much to explore and learn from one another when we concluded. These focus groups reinforced my observations from the first phase of my research; that reflecting upon and articulating personal experiences is a very powerful learning tool for participants and for the researcher. A general conclusion from the experience of many researchers is that experts love to tell their stories, and some report that people learn more that way than through formal instruction (Hoffman et al., 1998, p. 271).

While conducting a two-phase study was logistically complex and very time consuming, the benefits lie in the depth of the discoveries that I have communicated. I suggest this approach was particularly effective because a lack of pertinent knowledge on avalanche expert's judgment and decision making existed prior to this research. Due to the exploratory nature of this research and the unintended findings, I found it was necessary to engage in lengthy periods of reflection, and a continual literature search in order to fully understand and accurately communicate the discoveries. In addition, I found the insight and comments offered by my two subject matter experts, Dr. Bruce Jamieson and John Tweedy, to be very helpful.

It is important to consider the time requirements involved in conducting and facilitating an effective action research project, in order to plan the project effectively. Avalanche professionals are busy people, and I conducted this research during the latter part of the summer when many were enjoying a well-deserved rest. However, I felt this was the best time to conduct the project, prior to the commencement of the winter season. I found this action research project required an extensive amount of correspondence and communication between each participant and myself, for example, engaging people in the research, asking subsequent probe questions following the receipt of most CIDS's, selecting and inviting participants to the focus groups, and verifying the results. Certainly I would anticipate and plan for this factor in future research.

I.2. Personal Lessons Learned

It is widely stated by social science researchers that the conduct of qualitative research often results in philosophical impact to the researcher, particularly as they closely study people and their experiences. I echo this notion. As I described in the introduction to this thesis, the topic of inquiry of my research was very close to me, and of significant interest and relevancy to my peers in the avalanche community. Thus, conducting the research and writing this thesis was, in itself, a phenomenological process for me. Understanding and representing the essence of the lived experiences of these avalanche experts resulted in profound learning and deep personal insight.

I was very honoured by the level of interest in my research, and the depth and honesty with which participants, who were also my peers, shared their experiences with me. The nature of my research required that participants commit a significant amount of time and focused thought in order to clearly decouple and describe their experiences. Some participants related to me that writing their CIDS was an intensely reflective and challenging experience for them. In addition, participating in the focus groups required a commitment of travel time, since participants were geographically spread across Western Canada. Consequently, I felt a deep sense of responsibility to analyze and represent their experiences in their entirety, hence, the length of this thesis.

As I read and analysed the CIDS's, I imagined myself in their situations and I reflected upon what cues I would have noticed, or how I would have reacted. Thus, I learned vicariously through the rich and provocative experiences of decision success and human error. Since their words were so meaningful to me as a researcher, I chose a narrative approach to communicate the findings with the purpose of offering a vivid explanation for this phenomenon that previously has not been well understood.

I found it interesting to note that recent research indicates that illustrative stories and simulations are especially effective at building relevant mental models and illuminating critical cues to enhance judgment and decision accuracy. As an avalanche professional and practitioner, I personally experienced a significant expansion of my mental model of the avalanche domain, an enhanced repertoire of critical cues, and a dramatic increase in my understanding of judgment and decision-making processes including the factors that influence them. This realization was particularly powerful as the season changed to winter, and I commenced work ski guiding and facilitating avalanche courses in the mountains.

Thus, experiencing the practical outcomes of this knowledge gives me confidence that the discoveries and recommendations of this action research project will resonate with other avalanche decision-makers, and offer the benefits of improved avalanche-related judgment and decision-making capacities.

REFERENCES

Adams, L. (2004). Supporting sound decisions: A professional perspective on recreational avalanche accident prevention in Canada. *Proceedings of the International Snow Science Workshop,* Jackson Hole. USA, 1-10.

Anderson, J.R. (1981). *Cognitive skills and their acquisition.* Hillsdale, New Jersey: Erlbaum.

Anderson, J.R. (1983). *The architecture of cognition.* Cambridge, MA: Harvard University Press

Anonymous (date unknown). In Marquardt, M. (1999). *Action learning in action: Transforming problems and people for world-class organizational leadership.* (p. 7). Palo Alto, California: Davies-Black Publishing.

Association of Canadian Mountain Guides (2003). *Terrain Guidelines*. Retrieved November 12, 2004 from: http://www.acmg.ca/pdf/ACMG%20Terrain%20Guidelines%20November%202003.pdf

Atkins, R. (2004). An avalanche characterization checklist for backcountry travel decisions. *Proceedings of the International Snow Science Workshop*. Jackson Hole, USA, 1 – 10.

Aven, T., & Kørte, J. (2003). On the use of risk and decision analysis to support decision-making. *Reliability engineering and System Safety, 79,* 289-299.

Baumann, M., Sniezek, J. A., & Buerkle, C. A. (2001). Self-evaluation, stress, and performance: A model of decision making under acute stress. In E. Salas & G. Klein, (Eds.). *Linking expertise and naturalistic decision making.* (pp. 139-158). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Beck, D.E. & Cohen, C. C. (1996). *Spiral dynamics: Mastering values, leadership and change.* Cambridge: Blackwell Publishers.

Birkeland, K.W., & Johnson, R.F. (1999). The stuffblock snow stability test: Comparability with the rutschblock, usefulness in different snow climates, and repeatability between observers. *Cold Regions Science and Technology, 30,* 115-123.

Block, P. (2000). *Flawless consulting: A guide to getting your expertise used (2nd Ed.).* San Francisco, CA: Jossey-Bass Pfeiffer.

Boyles, D. (1994). Considering hermeneutics and education: Hermes, teachers, and intellectualism. *Viewpoints, 120,* 1–18.

Brockett, R.G. (1994). Resistance to self-direction in adult learning: Myths and Misunderstandings. Overcoming Resistance to Self-Direction in Adult Learning. In R. Hiemstra & R.G. Brockett (Eds.), *New directions for adult and continuing education* (pp. 5-12). San Francisco: Jossey-Bass.

Brookfield, S., (1997). Assessing critical thinking. *New Directions for Adult and Continuing Education, 75,* 17 – 29.

Bruns, W. (1997). Snow science and safety for the mountain guide. *Proceedings of the International Snow Science Workshop,* Banff, Canada: Canadian Avalanche Association, 203-206.

Cannon-Bowers, J.A., and Salas, E. (2001). Reflections on shared cognition. *Journal of Organizational Behaviour, 22,* 195-202.

Canadian Avalanche Association (2002). *Observation guidelines and recording standards for weather, snowpack and avalanches.* Revelstoke, British Columbia.

Canadian Avalanche Association. (2003a). *Trends and patterns in avalanche accidents.* Retrieved: January 13, 2004 from http://www.avalanche.ca/accident/index.html

Canadian Avalanche Association. (2003b). Contributing factors to avalanche accidents.

From *Avalanche Accidents in Canada, 4. 1984-1996.* Retrieved: January 13, 2004 from http://www.avalanche.ca/accident/index.html

Canadian Mountain Holidays. (2004). *Mountain Operations Manual*. Banff, Alberta: Canadian Mountain Holidays.

Cannon-Bowers, J.A., & Salas, E. (2001). Reflections on shared cognition. *Journal of Organizational Behavior, 22,* 195-202.

Czarniawska, B. (1997). *A narrative approach to organization studies.* Thousand Oaks, California: Sage Publications.

Chartier, B. (2002). *Blueprints; Field guide for learning organization practitioners*. Victoria, B.C: Her majesty the queen in right of Canada.

Christensen-Szalanski, J.J.J. (1993). A comment on applying experimental findings of cognitive biases to naturalistic environments. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok, (Eds.). *Decision making in action: models and methods.* (pp. 252-264). New Jersey: Ablex Publishing.

Chi, M,.T. H., Glaser, R.E., & Rees, (1982). Expertise in problem solving. In R.S. Sternberg (Ed.) *Advances in the psychology of human intelligence, 1,* (pp. 1-75). Hillsdale, NJ: Erlbaum.

Cloutier, R., & Heshka, J., (2003). *Public avalanche safety review.* British Columbia: Ministry of Public Safety and Solicitor General.

Cohen, M. (1993). The naturalistic basis of decision biases. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok, (Eds.). *Decision making in action: models and methods.* (pp. 51-102). New Jersey: Ablex Publishing.

Cohen, M., Freeman, J., & Thompson, B. (1998). Critical thinking skills in tactical decision making: A model and a training method. In J. Cannon-Bowers and E. Salas (Eds.). *Making decisions under stress: Implications for individual and team training*. (pp.155-159). Washington, DC: APA Press.

Cohen, M., Freeman, J., & Wolf, S. (1996). Metarecognition in time-stressed decision making: Recognizing, critiquing, and correcting. *Human Factors, 38,* 206 – 219.

Coleman, C., (1993). The influence of mass media and interpersonal communication on societal and personal risk judgments. *Communication Research, 20,* 611-628.

Collbeck, S.C. (1987). A review of metamorphism and the classification of seasonal snow cover crystals. In B. Salm, and H. Gubler, (Eds.), *Avalanche formation, movement and effects, 162,* (pp. 3-33). International Association of Hydrological Sciences.

Cooke, N.J. (1994). Varieties of knowledge elicitation techniques. *International Journal of Human-Computer Studies, 41,* 801-849.

Covey, S. R. (1989). *The seven habits of highly effective people*. New York: Fireside.

Creswell, J. (1998). *Qualitative inquiry and research design; choosing among five traditions.* Thousand Oaks, California: Sage Publications Inc.

Cusins, P. (1996). Action learning revisited. In *Employee counseling today: The journal of workplace learning, 8,* (pp. 19–26). Bradford, England: Emerald Group Publishing.

Dick, B. (2000). *A beginners guide to action research*. Retrieved: February 13, 2004 From: http://www.scu.edu.au/schools/gcm/ar/arp/guide.html

Doud, R. (1999). *The hermeneutic struggle: a teaching method.* (ERIC Document Reproduction Service No. ED 347 075).

Dreyfus, H. (1997). Intuitive, deliberative, and calculative models of expert performance. In C. Zsambok, & G. Klein (Eds.). *Naturalistic decision-making.* (pp. 17-29).

Mahwah, New Jersey: Lawrence Erlbaum Associates.

Driskell, J.E. , & Johnston, J. H. (1998). Stress exposure training. In J. Cannon-Bowers and E. Salas (Eds.). *Making decisions under stress: Implications for individual and team training*. (pp.191-218). Washington, DC: APA Press.

Dunwoody, S., & Neuwirth, K. (1991). Coming to terms with the impact of communication on scientific and technological risk judgments. In l. Wilkins & P. Patterson (Eds.), *Risky business: Communicating issues of science, risk, and public policy*. (pp. 11-30). New York: Greenwood.

Einhorn, H. J., & Hogarth, R. M. (1981). Behavioral decision theory: Processes of judgment and choice. *Annual Review of Psychology, 32,* 53-88.

Endsley, M., (1997). The role of situation awareness in naturalistic decision making. In C. Zsambok, & G. Klein (Eds.). *Naturalistic decision-making.* (pp. 269 – 284). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Ericsson, K.A., & Charness, N. (1994). Expert performance: Its structure and acquisition. *American Psychologist, 49,* 725 – 747.

Ericsson, K.A., Krampe, R.T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100,* 363 – 406.

Etkin, D., Haque, E., Bellisoria, L., & Burton, I. (2004). *An assessment of natural hazards and disasters in Canada.* Ottawa: Environment Canada.

Fischoff, B. (1995). Risk perception and communication unplugged. *Risk Analysis, 12,* 127-135.

Flood, R. L. (1999). *Rethinking the fifth discipline: learning within the unknowable.* New York: Routledge.

Flynn, J., & MacGregor, D., (2003). Commentary on hormesis and public risk communication. *Human & experimental toxicology, 22, 31-34.*

Föhn, P.M.B. (1989). Snow cover stability tests and area variability of snow strength. *Proceedings of the International Snow Science Workshop* (pp. 262-273). Vancouver: Canadian Avalanche Association.

Fredston, J., & Fesler, D. (1994). *Snow sense.* Anchorage, Alaska: Alaska Mountain Safety Centre Inc.

Gaeth, G.J., & Shanteau, J., (1984). Reducing the influence of irrelevant information on experienced decision makers. *Organizational Behaviour and Human Performance, 33.* 263-282.

Gavelek , J,. & Raphael, T. E. (1985). Metacognition, instruction, and the role of questioning activities. In D. L. Forrest-Pressley, G.E. MacKinnon, & T.G. Waller (Eds.), *Metacognition, cognition, and human performance, 2,* (pp. 103-136). New York: Academic Press

Glanz, J. (1998) An introduction to action research: It's not all that complicated. In *Action research: an educational leader's guide to school improvement*. (pp. 1-34). Norwood, MA: Christopher-Gordon Publishers Inc.

Glaser, B. G., & Strauss, A.L. (1967). *The discovery of grounded theory: Strategies for qualitative research.* New York: Aldine de Gruyter.

Griffin, D. and Tversky, A. (1992). The weighing of evidence and the determinants of confidence. *Cognitive Psychology*. *24,* 411-435

Gottesman, L. (1996). *Hermeneutics: what is it? Is it critical?* (ERIC Document Reproduction Service No. ED399 846).

Gordon, S.E., & Gill, R.T. (1997). Cognitive task analysis. In C. Zsambok, & G. Klein (Eds.). *Naturalistic decision-making.* (pp. 131-140). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Gurabardhi, Z., Gutteling, J.M., & Kuttschreuter, M. (2004). The development of risk communication. *Science Communication,25,* 323-349.

Hein, P. & Leiss, W. (2003). *Parks Canada backcountry avalanche risk review.* British Columbia: Parks Canada.

Hoffman, R., Crandall, B., & Shadbolt, N.R. (1998). Use of the critical decision method to elicit expert knowledge: A case study in the methodology of cognitive task analysis. *Human Factors, 40,* 254 – 276.

Hönekopp, J., (2003). Precision probability information and prominence of outcomes. *Organizational Behavior and Human Decision Processes, 90,* 128-138.

Isaacs, W. (1999). *Dialogue and the art of thinking together: a pioneering approach to communicating in business and in life.* New York: Doubleday Books.

Jamieson, B. (1995). *Avalanche prediction for persistent snow slabs*. (pp. 275). (Doctoral dissertation, University of Calgary).

Jamieson, B. & Geldsetzer, T. (1996). *Avalanche accidents in Canada. Vol. 4., 1984 – 1996.* Revelstoke, BC: Canadian Avalanche Association.

Jannis, I.L., and Mann, L. (1977). *Decision Making*. New York: The Free Press.

Kahneman, D. (1991). Judgment and decision making: A personal view. *Psychological Science. 2,* 142-145.

Kahneman, D. (2003). A perspective on judgment and choice: mapping bounded rationality. *American Psychologist, 58,* 697-720.

Kahneman, D., Slovic, P., & Tversky, A. (Eds.) (1982). *Judgment under uncertainty: Heuristics and biases.* Cambridge, MA: Cambridge University Press.

Kalaidjieva, M.A., & Swanson, G.A. (2004). Intelligence and living systems: A decision-making perspective. *Systems Research and Behavioral Science, 21,* 147 – 172.

Karelitz, T., & Budescu, D.V. (2004). You say "probable" and I say "likely": Improving interpersonal communication with verbal probability phrases. *Journal of Experimental Psychology, 10,* 25-42.

Kemmis, S. & McTaggert, R. (1988). *The action research planner*. Victoria, Australia: Deakin University Press.

Kirby, S., & McKenna, K. (1989). *Experience, research and social change: Methods from the margins.* Toronto: Garamond Press.

Klein, G. (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok, (Eds.). *Decision making in action: models and methods.* (pp. 138-147). New Jersey: Ablex Publishing.

Klein, G. (1997). Developing expertise in decision-making. *Thinking and Reasoning*, *3,* 337-352.

Klein, G. (1998). *Sources of power: How people make decisions.* Cambridge, USA: The Massachusetts Institute of Technology Press.

Klein, G. (2003). *The power of intuition.* New York: Currency Books.

Klein, G., Calderwood, R, & Clinton-Cirocco, A. (1986). Rapid decision making on the fireground. *Proceedings of the 30th Annual Human Factors Society, 1,* (pp. 576 – 580). Santa Monica, California: Human Factors & Ergonomics Society.

Klein, G., Calderwood, R., & McGregor, D. (1989). Critical decision method for eliciting knowledge. *IEEE Transactions on Systems, Man, and Cybernetics, 19,* 462-471.

Klein, G., and Crandall, B. (1995). The role of mental simulation in naturalistic decision making. In. P. Hancock, J. Flach, J. Caird, & K. Vincente (Eds.). *Local applications of the ecological approach to human-machine systems,* (pp. 324 – 358). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Klein, G., & Militello, L. (2001). Some guidelines for conducting a cognitive task analysis. *Advances in Human Performance and Cognitive Engineering Research, 1,* 161 – 199.

Klein, G., & Militello, L. (in press). The knowledge audit as a method for cognitive task analysis. In H. Montgomery, R. Lipshitz & B. Brehmer (Eds.), *How professionals make decisions.* Mahwah, New Jersey: Lawrence Erlbaum Associates.

Klein, G., Orasanu, J., Calderwood, R., & Zsambok, C. (Eds.). (1993). *Decision making in action: models and methods.* New Jersey: Ablex Publishing.

Klein, G., & Thordsen, M. (1988). Use of progressive deepening in battle management. *Proceedings of the II Biennial DoD Psychology Conference.* Colorado Springs, CO.

Knowles, M. (1980). *The modern practice of adult education: Andragogy versus pedagogy*. Chicago: Follett.

Knowles, M. S., Holton III, E.F., & Swanson, R.A. (1998). A theory of adult learning: Andragogy. In *The adult learner: The definitive classic in adult education and human resource development (5th Edition),* (pp. 35-72). Woburn: Butterworth-Heinemann.

Kolb, D. (1984). *Experiential learning; experience as the source of learning and development.* New Jersey, USA: Prentice-Hall, Inc.

Kouzes, J., & Posner, B.Z. (1995). *The leadership challenge: How to keep getting extraordinary things done in organizations.* San Francisco: Jossey-Bass.

Krueger, R. (1994). *Focus groups; a practical guide for applied research*. Thousand Oaks, California: SAGE publications, Inc.

Kunreuther, H., Meyer, R., Zeckhauser, R., Slovic, P., Schwartz, B., Schade, C., et al., (2002). High stakes decision making: Normative, descriptive and prescriptive considerations. *Marketing Letters 13:3*, 259-268.

Larkin, P. & Pallister, A.E., (1976). Gaelic poetry for deaf seagulls: an essay on research funding. *Issues in Canadian Science Policy,* 2, 3-11.

Litt, M. D., (1988). Cognitive mediators of stressful experience: Self-efficacy and perceived control. *Cognitive Theory and Research, 12*. 241-260.

Lipshitz, R. (1993). Converging themes in the study of decision making in realistic settings. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok, (Eds.). *Decision making in action: models and methods.* (pp. 103-137). New Jersey: Ablex Publishing.

Lipshitz, R, & Strauss, O. (1997). Coping with Uncertainty: A naturalistic decision-making analysis. *Organizational Behavior and Human Decision Processes, 69,* 149-163.

Marsh, B. (2002). Heuristics as social tools. *New Ideas in Psychology, 20,* 49-57.

Marquardt, M. (1999). *Action learning in action: Transforming problems and people for world-class organizational leadership.* Palo Alto, California: Davies-Black Publishing.

Maturana, H. R. & Varela, F. J. (1980). *Autopoiesis and cognition: The realization of the living.* Dordrecht: D. Reidel.

Maule, J.A. (2001). Studying judgment: Some comments and suggestions for future research.

Thinking and Reasoning, 7, 91-102.

McCammon, I. (2004). Sex drugs and the white death. *Proceedings of the International Snow Science Workshop,* Jackson Hole, USA, 1-10.

McCammon, I. (2002). Evidence of heuristic traps in recreational avalanche accidents. *Proceedings of the International Snow Science Workshop,* Penticton, Canada, 1-8.

McCammon, I. (2000). The role of training in recreational avalanche accidents in the United States. *Proceedings of the International Snow Science Workshop*, USA, 31-39.

McClung, D.M. (1987). Mechanics of snow slab failure from a geotechnical perspective. *IASH Publication, 162*, 475-508.

McClung, D.M. (2002). The elements of applied avalanche forecasting: The human issues. *Natural Hazards 25*, 111 – 129.

McClung, D.M. & Schaerer, P. (1993). *The avalanche handbook*. Seattle, Washington: The Mountaineers Books.

Means, B., Salas, E., Crandall, B., & Jacobs, T.O. (1993). Training decision makers for the real world. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok, (Eds.). *Decision making in action: models and methods.* (pp. 306-327). New Jersey: Ablex Publishing.

Mellers, B.A., Schwartz, A., & Cooke, A.D.J. (1998). Judgment and decision making. *Annual Review of Psychology: 49,* 447-477.

Merriam, B. (Ed.). (2002). *Qualitative research in practice; examples for discussion and analysis.* San Francisco: Jossey-Bass.

Mills, S., (2002). Communicating snow risk management to Canada's youth. *Proceedings of the International Snow Science Workshop,* Penticton, Canada, 1-3.

Morse, J.M. (1994). *Critical issues in qualitative research methods*. Thousand Oaks, California: Sage Publications.

Morton-Cooper, A. (2000). Principles of action research design. In *Action research in health care*. Cambridge: Blackwell Science.

Murray, P. (1989). Poetic genius and its classical origin. In P. Murray (ED.), *Developing talent in young people.* (pp. 211-269). New York: Ballantine Books.

Orasanu, J., & Connolly, T. (2001). The reinvention of decision making. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok, (Eds.). *Decision making in action: models and methods.* (pp. 3-20). New Jersey: Ablex Publishing.

Orasanu, J., Martin, L. & Davison, J. (2001). Cognitive and contextual factors in aviation accidents: Decision errors. In E. Salas & G. Klein, (Eds.). *Linking expertise and naturalistic decision making.* (pp. 209-223). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Orasanu, J., & Salas, E. (1993). Team decision making in complex environments. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok, (Eds.). *Decision making in action: models and methods.* (pp. 327-345). New Jersey: Ablex Publishing.

O'Toole, J. (1996). *Leading change: the argument for values-based leadership*. New York: Ballantine Books.

Palys, T. (2003). *Research decisions: Quantitative and Qualitative Perspectives, (3rd. Ed).* Toronto: Harcourt Brace Jonanovich.

Patel, V. L., & Arocha, J. F. (2001). The nature of constraints on collaborative decision making in health care settings. In E. Salas & G. Klein, (Eds.). *Linking expertise and naturalistic decision making.* (pp. 383-406). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Phillips, J., Klein, G., & Sieck, W. (in press). Expertise in judgment and decision making: A case for training intuitive decision skills. In D.J. Koehler & N. Harvey (Eds.), *Blackwell handbook of judgment and decision making.* Mahwah, New Jersey: Lawrence Erlbaum Associates.

Piaget, J. (1952). *The origins of intelligence in children.* New York: International Universities Press.

Piaget, J. (1969). *Psychology of the child.* New York: Basic Books.

Pliske, R., McCloskey, M., & Klein, G. (2001). Decision skills training: Facilitating learning from experience. In E. Salas & G. Klein, (Eds.), (2001). *Linking expertise and naturalistic decision making.* Mahwah, New Jersey: Lawrence Erlbaum Associates.

Quinn, R. E. (1996). *Deep change: Discovering the leader within.* San Francisco: Jossey-Bass.

Rasmussen, J. (1993). Deciding and doing: decision making in natural contexts. In G. Klein, J. Orasanu, R. Calderwood & C. Zsambok (Eds.) Decision making in action: models and methods. (pp. 158-171). New Jersey: Ablex Publishing Corporation.

Reason, J. (1990). *Human Error.* New York: Cambridge University Press.

Riseman, C.K. (1993). *Narrative analysis*. Thousand Oaks, California: Sage Publications.

Royal Roads University. (2000). *Policy on integrity and misconduct in research and scholarship.* Retrieved March 3, 2004 from: http://www.royalroads.ca/Channels/research/ethical+reviews/integrity+and+misconduct.html

Russo, J.E., Schoemaker, P.J. & Hittleman, M. (2001). *Winning decisions.* New York: Doubleday.

Salas, E., & Klein, G. (Eds.). (2001). *Linking expertise and naturalistic decision making.* Mahwah, New Jersey: Lawrence Erlbaum Associates.

Schaerer, P.A. (1987). *Avalanche accidents in Canada III. A selection of case histories 1978 to 1984.* Ottawa: National Research Council of Canada. NRCC IRC 1468.

Schön, D. (1983). *The reflective practitioner: How professionals think in action.* London: Temple Smith.

Schön, D. (1987). *Educating the reflective practitioner: Toward a new design for teaching and learning.* San Francisco: Jossey-Bass.

Schweizer, J., & Jamieson, B.J. (2003). Snowpack properties for snow profile analysis. *Cold Regions Science and Technology, 37*, 233-241.

Schweizer, J., Jamieson, B.J., Schneebeli, M. (2003). Snow avalanche formation. *Reviews of Geophysics 41*, 10-16.

Selkirk College. (2003a). *Policy E10; Mission statement.* Retrieved February 27, 2004 from:http://admin.selkirk.bc.ca/board/old%20files/mission%20vision%20and%20value%20statements.pdf

Selkirk College. (2003b). *Policy E40; Outcomes.* Retrieved February 27, 2004 from: http://admin.selkirk.bc.ca/board/old%20files/outcome%20statements.pdf

Selkirk College. (2003c). *School of renewable resources strategic plan 2002/2003.* Castlegar, British Columbia: Selkirk College.

Senge, P. (1990). *The fifth discipline: The art and practice of the learning organization.* New York: Doubleday.

Serfaty, D., MacMillan, J., Entin, E.E., & Entin, E.B. (1997). The decision-making expertise of battle commanders. In C. Zsambok, & G. Klein (Eds.). *Naturalistic Decision-Making.* (pp. 233-246). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Sexton, J.B. (Ed.). (2004). *The better the team, the safer the world: Golden rules of group interaction in high risk environments.* Ladenburg: Gottlieb Daimler and Karl Benz Foundation, & Swiss Re Centre for Global Dialogue.

Shanteau, J. (1988). Psychological characteristics and strategies of expert decision makers. *Acta Psychologica, 68,* 203-215.

Shanteau, J. (1992). Competence in experts: the role of task characteristics. *Organizational Behaviour and Human Decision Processes, 53,* 252-296.

Simon, H.A., & Chase, W.G. (1973). Skill in chess. *American Scientist, 61,* 394 – 403.

Simon, H.A., (1955). A behaviour model of rational choice. *Quarterly Journal of Economics, 69.* 99-118.

Slovic, P. (2001). The risk game. *Journal of Hazardous Materials, 86,* 17-24.

Slovic, P. (1987). Perceptions of risk. *Science, 236,* 280-285.

Slovic, P., Fischoff, B., & Lichtenstein, S. (1978). Accident probabilities and seat belt usage: A psychological perspective. *Accident Analysis and Prevention, 10,* 281-285.

Slovic, P., Fischoff, B., & Lichtenstein, S. (1977). Behavioural decision theory. *Annual Review of Psychology, 28,* 1-39.

Sprafka, H., & Kranda, A. (2000). *Institutionalizing mentoring into police departments.*

Retrieved Nov 22, 2004 from: http://www.theiacp.org/documents/pdfs/Publications/BP-Mentoring.pdf

Stefanovic, I. L. (2003). The contribution of philosophy to hazards assessment and decision making. *Natural Hazards, 28,* 229-247.

Stethem, C.J. and Schaerer, P.A. (1979). *Avalanche accidents in Canada I: A selection of case histories of accidents 1955 to 1976.* Ottawa: National Research Council of Canada. NRCC DBR 834.

Stethem, C.J. and Schaerer, P.A. (1980). *Avalanche accidents in Canada II: A selection of case histories of accidents, 1943 to 1978.* Ottawa: National Research Council of Canada. NRCC DBR 926.

Stringer, E. (1999). *Action research: fifth edition*. California: Sage Publications, Inc.

Taylor, K., Marienau, C., & Fiddler, M. (2000). *Developing adult learners; strategies for teachers and trainers*. San Francisco, USA: Jossey-Bass Inc.

Tremper, B. (2001). *Staying alive in avalanche terrain*. Seattle, Washington: Mountaineers.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185,* 1124-1131.

Tyler, T. R. & Cook, F.L. (1984). The mass media and judgments of risk: Distinguishing impact on personal and societal level judgments. *Journal of Personality and Social Psychology, 47,* 693-708.

Van Herwijnen, A, & Jamieson, B. (2004). Fracture character in compression tests. *Proceedings of the International Snow Science Workshop,* Jackson Hole, USA, 1-10.

Van Manen, M. (1994). Hermeneutic phenomenological reflection. In *Researching lived experience*. London, Ontario: Althouse Press.

Van Manen, M. (1990). *Researching lived experience: human science for an action sensitive pedagogy*. Albany, NY: State University of New York Press.

Weinstein, N.D. (1987). Unrealistic optimism about susceptibility to health problems: Conclusions from a community-wide sample. *Journal of Behavioural Medicine, 10*, 481-500.

Wheatley. M., (1999). *Leadership and the new science: Discovering order in a chaotic world*. San Francisco: Berrett-Koehler Publishers.

Wilber, K., (2001). *A theory of everything. An integral vision for business, politics, science and spirituality.* California: Shambhala Publications.

Wilde, G. (2001). *Target risk 2: A new psychology of safety and health.* Toronto: PDE Publications.

Yates, J.F., (2001). "Outsider:" Impressions of naturalistic decision making. In E. Salas & G. Klein, (Eds.), (2001). *Linking expertise and naturalistic decision making*. (pp. 9-33). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Zeni, J. (1998). A guide to ethical issues & action research. *Educational action research. 6*, 9–19.

Zsambok, C. & Klein, G. (Eds.). (1997). *Naturalistic decision-making.* Mahwah, New Jersey: Lawrence Erlbaum Associates.

Zuber-Skerritt, O. (2002). The concept of action learning. *The Learning Organization, 9,* 114-124.

APPENDIX A

Phase One: Qualitative Semi-Structured Survey

A.1. Letter of Invitation and Informed Consent

Dear Canadian avalanche professional:

I invite you to be part of a human sciences avalanche research project that I am conducting as part of the requirement for a Master's Degree in Leadership and Training at Royal Roads University, in Victoria, B.C.

This segment of my research leads an inquiry into the human factors in decision-making processes in avalanche terrain. The purpose of the research is a scholarly inquiry to examine and identify the factors used by avalanche experts that enable sound avalanche decision-making, and explore how these findings can improve the decision practice of avalanche practitioners and recreationists. My thesis is that defining avalanche decision skills and providing learning tools to speed up the development of expertise can improve decision-making and reduce avalanche accidents. This research is supported by Selkirk College, the Canadian Avalanche Foundation, and the Social Sciences and Humanities Research Council of Canada.

You were chosen as a potential participant because you are a Canadian avalanche professional. The research is comprised of two stages and this letter is an invitation to join in the first stage.

Phase One: Questionnaire:

Participants will reflect upon their lived experience and respond by email, to the following two questions regarding their decision practice in avalanche terrain.

1. Describe your most significant avalanche decision-making experience, including how experience, knowledge, skills and human factors influenced your decision(s).
2. Describe the factors that enable you to make sound decisions when traveling in potential avalanche terrain.

The commitment required for recording your responses is approximately one hour. These responses will be categorized by themes and returned to you for review and further input. All documentation will be kept strictly confidential and anonymous in this first stage of the research. At no time will any specific comments be attributed to any individual unless your specific agreement, in writing or by email, has been obtained beforehand. The themes from stage one will form the topics of the second stage of the research, the focus group discussion sessions.

Phase Two: Focus Group:

18 participants will be invited from Phase One of the research to join one of two focus groups at either the International Snow Science Workshop in Jackson Hole on September 19th, or The Selkirk Geospatial Research Centre in Castlegar, BC on October 17th 2004 (based on participant convenience). These three-hour focus groups will be a "think tank" session where participants will examine the themes emerging from the first stage of the research and further the inquiry into decision-making processes and accident prevention. An honorarium to cover time and travel expenses is available to those focus group participants without institutional support.

The results of this study will be used solely for my research in avalanche decision-making and accident prevention. Results will be published in my thesis at Royal Roads University, in the National Library of Canada and in papers submitted to peer-reviewed journals and trade periodicals such as The Avalanche News and The Avalanche Review. In addition, the results will be presented at the Canadian Avalanche Association annual general meetings and at the International Snow Science Workshop. Research participants will receive a final copy of my results and links to the thesis and papers published. I will hold a debriefing session at the CAA AGM in May 2005.

Your participation in this research is important and will help generate key data that will enhance avalanche decision practice. If you do elect to take part in this research, you are free to withdraw at any time with no prejudice. Similarly if you choose not to take part, this information will also be held in confidence. Further information and my credentials with Royal Roads University can be established by telephoning XXXX, Organizational Leadership and Learning Division, Royal Roads University at XXXX, or XXXX, Selkirk College at XXXX.

Thank you for taking the time out of your busy day to read this correspondence. By returning your responses to the attached questionnaire by *September 3, 2004*, the individual gives free and informed consent to this project.

Sincerely,

Laura Adams
Graduate student at Royal Roads University, Victoria, BC

A.2. Survey Tool

Avalanche Decision Research

Conducted by Laura Adams, August 2004

Phase One: Electronic Survey

** Please return by September 3rd, 2004*

Please review the following questions and reflect upon your lived experiences as an avalanche practitioner and professional prior to recording your responses. Technical note: Select save-as to record your responses directly into your own word document. Please feel free to use as much space as you require to provide your answers to these questions.

Part I: Questions

1. Describe your most significant avalanche decision-making experience, including how experience, knowledge, skills and human factors influenced your decision(s).

2. Describe the factors that enable you to make sound decisions when traveling in potential avalanche terrain. (Feel free to use point form).

Part II: Demographics:

Please provide the following demographic information that will be used solely for purposes of describing in the final report, the composition of the group who completed the survey:

2.a. How many years of professional experience do you have working in the avalanche field?

1-4	
5-9	
10-14	
15-19	
20-24	
25-29	
30 and over	

2.b. Indicate your area(s) of involvement in the avalanche field. *Select all that apply to you.*

Mechanized ski guide	
Non-mechanized ski guide	
Ski area avalanche forecaster / technician	
Resource industry avalanche forecaster	
Snow avalanche educator	
Highways avalanche technician	
Park warden, public safety specialist	
Other (specify)	

2.c. Indicate the mountain range(s) of your current avalanche work.
Select all that apply to you.

North Coast	
South Coast	
North Columbia	
South Columbia	
North Rockies	
South Rockies	
Other (specify)	

2.d. What is the highest level of formal training you have achieved?

High school graduation	
Some college and / or university courses	
College diploma	
ACMG	
Bachelor's degree	
Masters degree	
Doctorate	
Other (specify)	

2.d. Indicate your gender and age.

Male		Age	20 - 29	
Female			30 - 39	
			40 - 49	
			50 - 59	
			60 - 69	

Part III: Focus Group

Please indicate your interest to participate in stage two of this research, the focus group. You will receive additional information regarding the structure of this session at the end of August.

Yes	
No	

If you answered yes, please indicate your preferred location.

ISSW, Jackson Hole, WY. Sept 19, 2004.	
Selkirk Geospatial Research Centre. Oct 17, 2004.	

Name and contact email address for future correspondence regarding the focus group and/or if you would like to receive further information about the results of this research project:

Thank you for your response. Please return by September 3rd, 2004 to Laura Adams XXXX

APPENDIX B

Phase Two: Avalanche Expert Focus Groups

B.1. Focus Group Invitation and Informed Consent

Avalanche Decision Research

September 8, 2004

Dear

I invite you to participate in an avalanche decision-making focus group at the International Snow Science Workshop in Jackson Hole, Wyoming on September 19, 2004. You were chosen as a potential participant because you are an avalanche expert who participated in the first phase of my research, and indicated an interest in participating in the second phase - focus group.

I am conducting this research as part of the requirements for a Master's Degree in Leadership and Training at Royal Roads University. This segment of my research furthers the inquiry into decision-making processes in avalanche terrain and effective accident prevention. The purpose of the research is an inquiry to examine and identify the factors that influence and enable sound avalanche decision-making in avalanche experts, and explores how these findings can improve the decision practice of avalanche practitioners and recreationalists. My thesis is defining avalanche decision skills and providing tools to speed up the development of expertise can improve decision-making and reduce avalanche accidents. This research is supported by the Canadian Avalanche Foundation, Selkirk College, and the Social Sciences and Humanities Research Council of Canada.

Phase Two: Focus Group:

A total of 18 avalanche experts are being invited from stage one of the research (questionnaire) to join one of two focus groups at either the International Snow Science Workshop in Jackson Hole on September 19th, or The Selkirk Geospatial Research Centre in Castlegar, BC on October 17th 2004. Each focus group will be a "think tank" session where 9 avalanche experts will discuss the themes emerging from the first stage of the research, and further the inquiry into avalanche decision-making and accident prevention.

* This focus group will be held at the International Snow Science Workshop in Jackson Hole, Wyoming on Tuesday, September 21, 2004 from 7:00 to 10:00 pm.

Please read the following information carefully and sign this document if you give your consent to participate in the study, which will use the following methods:

1. You will participate in a three-hour session with 8 other members of the avalanche experts' team. During the focus group, participants will discuss in further depth, the themes resulting from the first phase of the research. The focus group has two segments. The first part of the focus group will involve a discussion of the decision processes of avalanche experts and factors influencing decision-making. In the second part we will discuss factors enabling avalanche decision success and building and supporting decision expertise.
2. The focus group will be conducted in a room that is private and the discussion will be recorded through written notes and audiotape. A research assistant will

assist with the recording of written notes and operate the audiotape recorder. A qualified transcriptionist will subsequently transcribe all audiotapes.

You have the right to request that the recorder be turned off at any time during the discussion, or to request that any or all of your comments are removed from the data.

3. Due to the presence of other avalanche experts in the focus group, your comments will not be anonymous. However, I request that the content of the discussion remains within the confidence of the participants.

4. At no time in the research report/thesis will specific comments be attributed to any individual unless your specific agreement has been obtained beforehand.

You will be offered the opportunity to review and verify the themes resulting from this focus group session.

5. If you do elect to take part in this research, you are free to withdraw at any time with no prejudice.

The results of this study will be used solely for my research in avalanche decision-making and accident prevention. Results will be published in my thesis at Royal Roads University, in the National Library of Canada and in papers submitted to journals such as The Avalanche News and The Avalanche Review. In addition, the results will be presented at the Canadian Avalanche Association annual general meetings and at the International Snow Science Workshop. Research participants will receive a final copy of my results and links to the thesis and papers published. I will hold a debriefing session with participants at the Canadian Avalanche Association AGM in May 2005.

Your participation in this research is important and will help generate key data that has the potential to enhance avalanche decision practice and reduce avalanche accidents. An honorarium is available to focus group participants without institutional support. Please contact me for more information prior to the focus group session.

Your signature indicates that you understand to your satisfaction the nature of your participation in this research and that you agree to participate in the focus group session.

______________________________ __________________________
Research Participant Date signed

Please fee free to contact me at any time if you have further questions regarding this research.

Laura Adams
MALT candidate at Royal Roads University, Victoria, BC

B.2. Focus Group Agenda

Avalanche Decision Research

Phase Two – Focus Group

Conducted by Laura Adams, Fall 2004

Master of Arts in Leadership and Training, Royal Roads University, Victoria, BC

Location and Date:

Vertical Room at the Best Western Inn, Teton Village - September 21, 2004

6:30pm	Refreshments and informal review of first phase preliminary results
7:00 – 10:00 pm	Avalanche Experts Decision Making Focus Group

Objective and Format:

The focus group is designed as a "think tank" session where 9 avalanche experts will discuss, in further depth, the meta-themes that emerged from the first phase of this action research project, and further the inquiry into avalanche decision-making and accident prevention. To initiate the discussion in each part, meta-themes from phase one will be presented, including several anonymous, representative quotations. Participants will then be invited to discuss the topic in greater depth.

Focus Group Agenda and Questions

6:30	Opportunity to look at the preliminary results of phase one
7:00 – 7:15	Introduction and welcome.
7:15 – 8:00	The decision processes of avalanche experts.

What decision strategies and processes are used by avalanche experts when making field decisions?

8:00 – 8:30 Factors influencing decision making of avalanche experts.

What are the factors that influenced the decision making of avalanche experts (that participated in this research) that lead to close calls or avalanche accidents?

Break

8:45 – 9:15 Factors enabling sound avalanche decision-making.

What are the factors and conditions that enable avalanche expert decision success?

9:15 – 10:00 Building and supporting avalanche decision-making skills.

What strategies can support sound decision-making in avalanche terrain?

How can sound avalanche decision-making skills be developed?

10:00 Concluding remarks and refreshments

APPENDIX C

Avalanche Experts' Approach to Practice

Be organized.

Consider personal mental and physical state - mood, stress level, health, fatigue…

Think systemically – human, physical, and environmental.

Recognize and manage knowledge gaps.

Maintain an internal and external awareness.

Communicate to generate understanding with team members, clients, management.

Listen to and consider other perspectives.

Notice when communication is impaired.

Have faith in your decisions.

Pay attention when things are different.

Be aware of multiple indicators and trends of events when things are not going as expected.

Notice the influence of time pressure.

Respect avalanche phenomena.

Maintain a margin of safety that is bigger than what is thought to be needed.

Plan for the unexpected and be prepared for surprises.

Consider and manage variations in goals and objectives, knowledge and skills.

Consider varying levels of acceptable risk.

Avoid being influenced by ego, overconfidence, or higher risk tolerances of others.

Recognize and manage individual, team, client, organizational, socio-political pressures.

Be conscious of decision-making processes when the terrain is getting used up.