UiT THE ARCTIC UNIVERSITY OF NORWAY

CARE Center for Avalanche Research and Education

UiT NORGES ARKTISKE UNIVERSITET

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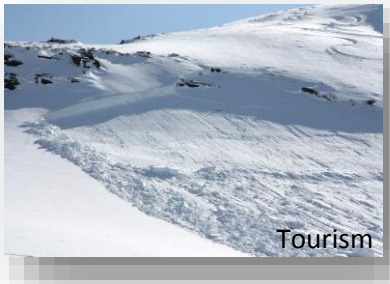
CARE Science Programme 2015-2020

Leading research to improve decision-making in risky environments, with a vision of zero avalanche victims.



UiT The Arctic University of Norway is establishing the Center for Avalanche Research and Education (CARE) during the period 2015-2017. The main objective for the Center is to provide new knowledge about the human factor in avalanche terrain and improve education to prevent loss of lives due to avalanches. Our approach is based on multi-disciplinary collaboration between the faculties, as well as relevant Norwegian and international stakeholders. We aim at being relevant in the daily life of individuals, companies and organisations – thus promoting economic, cultural and social development in the north through knowledge and human capital.

1. Relevance

Snow avalanches (referred to as avalanches in this plan) pose a major threat to our society. In Norway, 228 people (5.4 per year) died from avalanches between 1973 and 2015. Recreationists in avalanche terrain (e.g., skiers, snowboarder, snowshoers and snowmobilers) constitute the majority of avalanche victims (81 %). However, many serious accidents have also occurred on roads and railways (11 %) or in buildings (9 %). Recent winters cast tragic statistics and memories: On 19 December 2015, a massive avalanche hit 11 houses on Svalbard. 24 people were captured by the snow and 2 died. On 2 March 2015, 11 people were caught in their cars by an avalanche on E39. In 2014, a group of 4 skiers were caught and killed on 14 April and on 19 March 2012 another party of 5 lost their lives in the white death.

58 people died from avalanches in Norway during the 7 year from 2009 to 2015, on average 8.3 persons per year. 91 % were recreationists, 7 % in houses and 2 % on roads. A lion part of the fatalities occurred in North-Norway: 21 in Troms, 8 in Nordland, 4 in Finnmark and 4 at Svalbard.

All of these fatalities are immensely tragic. However, avalanches do not only pose threats to lives. Another devastating effect of avalanches is the disruption of modern infrastructure: in Norway, it is not uncommon that avalanches take out power lines and transformation stations. Avalanches close down hundreds of roads and causes cancellation of trains each winter. The effect is isolation of communities and possibly unacceptable risk to the users of transport network. The scale of the problem in Norway, and North-Norway in particular, is illustrated in *figure 1*.

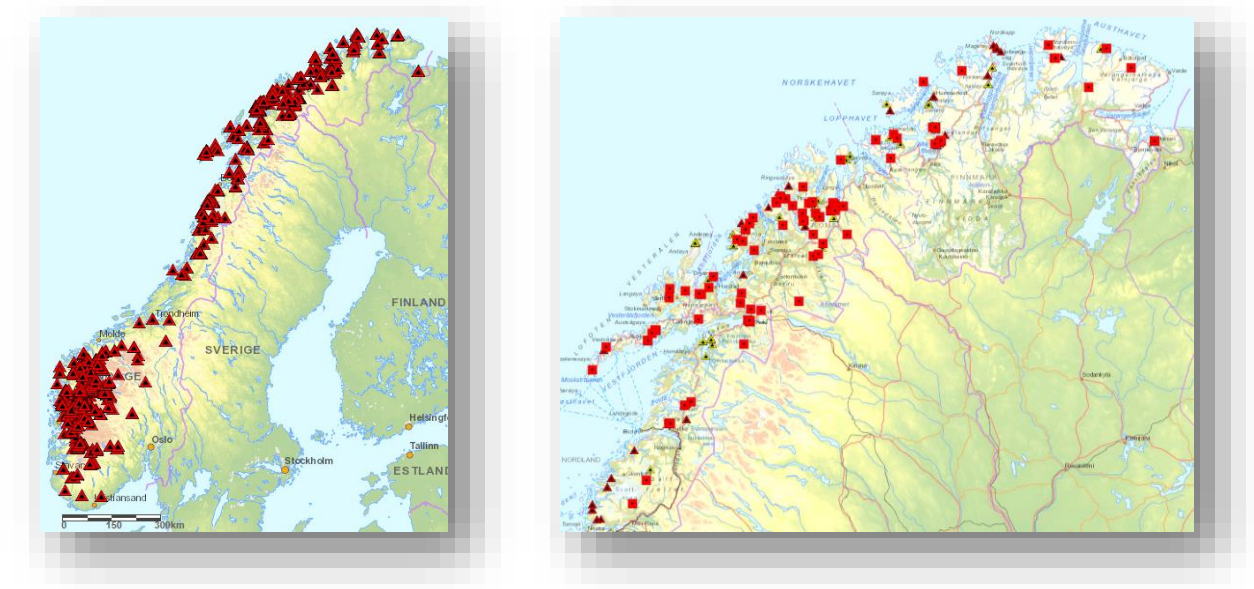


Figure 1. Maps showing the scale and distribution of the avalanche problem in Norway. Left: Map of roads closed due to avalanches on roads 2010-2015. Right: Roads closed to avalanches (red triangles), avalanche danger (yellow triangles) and events of avalanches with accidents or incidents (red squares). Data: www.xgeo.no.

Backcountry recreationists and tourists are most exposed to the risk of avalanches. During the past decade, backcountry recreation and nature-based tourism has increased exponentially in many places around the world[1]. The increased use of more complex avalanche terrain further away from roads and at all seasons, is associated with a number of challenges for society: the increased number of users implies that skiers and snowmobilers have a greater need for planning skills, experience and competence; tour operators need higher standards of competence and contingency planning;

[1] The Swiss Alpine Club (SAC) estimates that the number of ski tours and free riders in the Swiss Alps has quadrupled during the past 30 years.

finally, professional and volunteer rescue operators have to deal with more operations in challenging, remote and complex terrain with avalanche hazards.

In Norway, the region of Troms has the highest avalanche accident rate. However, for all of the arctic regions (Troms, Nordland, Finnmark and Svalbard) avalanches pose significant problems for roads, buildings and power supplies. The Arctic region is sparsely populated and subject to rapid climate change in combination with increasing volumes of nature-based tourism. Sparsely populated as it is, observing the present and predicting future changes are more challenging than in many other places – both in terms of climate effects and human behaviour.

The aim of the CARE Science Programme is to generate new knowledge and to educate scientists and professionals. It is our hope and belief that CARE research will make Norway in general, and Northern-Norway in particular, better prepared in terms of better knowledge and management strategies, and therefore more able to avoid avalanche accidents and damages.

Research on avalanches and decision-making is highly relevant, as

- The UiT campuses are unique sites for research and education, situated in avalanche terrain, with large volumes of nature-based tourism, avalanche-exposed roads, buildings and infrastructure and significant climatic variation
- Knowledge-based decision-making need to be improved in order to have a safe society and reduce the risk from avalanches.

Many roads are closed by avalanches hitting the roads – could better criteria for closing and opening roads save lives and provide more predictable transport? Could better education and knowledge improve the safety in guiding, or for other professionals operating in avalanche terrain? A number of sectors have employees working in avalanche terrain, thus workers safety is also an important area of concern. A common standard for professional avalanche education is lacking in Norway, although several organisations have established courses covering most of their needs.

2. Research questions, background and approach

2.1 Objectives

The main objective is to

> Improve decision-making in risky environments, with the vision to have an active society with zero avalanche victims.

The secondary objectives are to

1. Review current methods, including human behaviour, decision criteria, safety technology and geoscientific knowledge.
2. Hypothesize and test innovative improvements, including technology developments and eliminating fatal flaws.
3. Creatively engage with practitioners, in order to capture relevant ideas and turn new knowledge into action

The research should be relevant to Norway, where socio-cultural changes and changes in behaviour, climate, economy and technology may influence decision-making policies in the future. The value of nature-based physical, socio-psychological, and cultural activities should underpin the research, In other words, the research should stimulate active use of nature rather than scare people away from using it. The studies will be in the context of public safety, tourism, transportation, civil protection, acute medicine, rescue and so on.

2.2 Background and status of knowledge.

> "The literature and basic research shows avalanche accidents are not a terrain, weather, or snowpack problem; avalanche accidents are a human problem"
>
> *(Atkins, 2000, p. 47)*

Three factors are needed to produce an avalanche; 1) steep terrain, 2) snow of a certain quality and 3) a triggering factor. In Norway, with rugged terrain and costal climate, the two first factors are given. Triggering factors can be changes in weather like increasing temperatures, wind or sun, or a human being, on foot, on skis, on snowboard or on a snow mobile.

Natural hazards have traditionally been seen as biological and geological phenomena. Historically, avalanche research has therefore focused on the physical understanding of such hazards to better predict catastrophic events and improve the ability to manage and control such hazards through technical means (Haegeli, Haider, Longland, & Beardmore, 2009); (Haque & Etkin, 2006). In Norway, the Norwegian government for a long time focused primarily on safety measures and prevention strategies such as building avalanche protection along exposed infrastructure like roads and buildings (Regjeringen.no, 2016). However, although such actions effectively prevent avalanches at these specific locations, the large majority of avalanche fatalities (91%) occur in the outback away from roads and settlements (see *table 1*). The overrepresentation of backcountry recreationists in *table 1* is a sign of an on-going trend. Winter backcountry recreation activities in avalanche terrain have steadily increased in popularity over the past few decades. Technical advances in skiing equipment and snowmobile gear allow a greater number of people to venture farther into the backcountry. The combination of challenging terrain, rapidly changing environmental conditions and remote locations make the winter backcountry a hazardous place where perceptual errors and even minor decision mistakes can have serious consequences. Accordingly, in nine out of ten fatal avalanches the triggering factor are the victims themselves, or somebody in their party (Brattlien, 2013; Tremper, 2011).

Table 1. Avalanche fatalities in Norway 2010-2015

Category	Number of victims	Percent of victims
Ski	34	65%
Snow mobile	10	19%
On foot /climbing	4	7%
Car / House	5	9%
Total	53	100%

Since the large majority of accidents happen after people voluntarily expose them self to avalanche hazards and eventually trigger fatal avalanches, a better understanding of the decision process in avalanche terrain is crucial for the success of safety initiatives.

In other words, observations of human error have made judgment and decision-making key to understand why people die in avalanches. Over the last two decades, there has therefore been a paradigm shift towards a more comprehensive human environment perspective that integrates societal and human aspects into the assessment and effort to reduce the impact of natural hazards. Several important scientific contributions have been made (e.g., McCammon, 2002; McCammon, 2004) and more promising research is underway (Hendrikx & Johnson, 2014). However, the field of research on decision making in relation to natural hazards is a discipline still in its infancy.

In Norway, 2010 marks a shift in the history of avalanche prevention, in terms of the development of a National Avalanche Warning Service at varsom.no. Previous research on risk taking in avalanche terrain (Furman, Shooter, & Schumann, 2010) show that backcountry recreationists state

avalanche danger forecasts as the most important source of information for choosing where and when to go in the backcountry. The first Norwegian public avalanche forecasts were launched in January 2013 (Engeset, 2013) on www.varsom.no, accompanied by the introduction of the Avalanche school and a number of outreach activities targeting public information on avalanches, avalanche danger and how to avoid getting hit and hurt by avalanches.

The CARE science programme seeks to deepen and expand this historical shift in terms of generating new knowledge concerning the mechanisms behind decision processes in avalanche prone terrain and concerning how these decisions can be improved so that people can recreate more safely in the backcountry.

Decision making in avalanche terrain

Decision making in avalanche terrain is complex, multifaceted and influenced by a large number of factors. Traditionally, such decision-making has been viewed as rational and analytic, where all relevant information is reviewed in detail, and all alternatives are weighed according to their pros and cons (McClung, 2002a, 2002b). This type of decision-making demands a high level of expertise and effort. However, such level of expertise demands extensive education and take years of practice. In addition, the snow pack varies extensively rendering it is impossible to take all factors into account, even for experts.

Several decision-making aids have been developed to facilitate this process and reduce the probability of human errors. The most well-known is probably the 3x3 Munter method (Munter, 1991). Studies show that decision aids of this type can improve the quality of decisions for non-experts. The avaluator card was developed in Canada. This card is a decision-making aid that includes checklists and helps the users apply the information given in the avalanche forecast to the specific terrain they are travelling in. In Norway, the Norwegian Water Resources and Energy Directorate have developed the avalanche card ("skredkortet") available on www.varsom.no, which also includes advice and points to consider as individuals and groups.

However, even though people may be well educated in assessing avalanche danger, and even with the use of decision aids of the type described above, research show that human decision-making in avalanche terrain is greatly biased by factors, which have nothing to do with avalanche danger. The most well-known biases in avalanche decision making are the heuristic traps.

Heuristic Traps

Heuristics are simple and efficient rules of thumb used to form judgments and make decisions. These mental shortcuts usually involve focusing on one aspect of a complex problem and ignoring others, or exchanging a complex question with a simpler one (Tversky & Kahneman, 1974). This strategy works well in most cases, but can in some cases lead to deviation from rational choices and probability, which can be a major hazard in avalanche terrain. Previous research has identified six heuristics that impact decision-making in avalanche terrain. These are scarcity (whether the slope was tracked or untracked), familiarity (whether the terrain is known or unknown), expert halo (presence of a recognizable leader in the group), acceptance (the desire to get noticed and respected), social facilitation (presence of another group) and consistency (commitment to a goal) (McCammon, 2002; Schumann, Furman, & Shooter, 2010a). Several of these heuristics contribute in changing the perception of risk, thus reducing the level of fear and increasing the level of experienced safety.

In accordance with the findings of McCammon (2002) and Schumann, Furman, and Shooter (2010b), research at UiT The Arctic University of Norway (Berget, 2012) find that the size of the group and familiarity with the specific mountain decrease the level of fear and increase the level of experienced safety. In addition, Berget (2012) also find that equipment like avalanche beacons and avalanche airbags are associated with an increased perception of safety. The latter is consistent with risk homoeostasis: even though such may increase survival probability if an avalanche is released,

they may also cause greater risk acceptance.

Cultural issues and tradition - rational plans, irrational participants?

The mainstream approach within recreational avalanche accident prevention has been enlightening the public using a universal approach based on a mutual understanding of snow and avalanche science. This common understanding has been presented through avalanche literature and courses, and has led to the development of multiple universal and domestic planning tools the past decades. Therefore, snow should be universally white in the world of skiing. What about cultural bias and tradition influencing risk management and decision-making within recreational backcountry skiing?

Perhaps different cultures with their national ski and mountaineering heritages give the white snow crucial colours we haven't mapped within avalanche risk acceptance and management? Observing another culture and tradition as an outsider gives insights the locals normally can't see, since they are likely to be blinded and restrained by their own traditions and habits. Since we import and export avalanche accidents to each other, this is an issue that should be of crucial interest domestic and internationally,

Today there is an emerging understanding that the rational approaches and decision making tools developed the past decades, might not be used among ordinary people as intended (Zweifel, 2015). We have plenty of rational planning tools. Despite that, we have many "irrational" practitioners that are making crucial mistakes.

Therefore, in depth understanding of "What people really do – or not do – and why", should be an upcoming focus area to better understand the minds we are targeting. Different levels of cultural bias may be influencing our risk management and decision-making.

> "*When we see that decision making in avalanche terrain is very complex, it is hard to gain detailed enough data from online studies. Probably qualitative methods from social science can give better results in the future"*
>
> *(Zweifel, Techel, & Björk, 2012)*

Cognitions, Emotions and Risk Perception

Emotions hold the potential to affect decision-making under risk and risk taking behaviour in several ways (see e.g., Slovic, Finucane, Peters, & MacGregor, 2004). According to Oatley (2009), the experience of affect, in terms of strong emotions such as fear, activate predefined "checklists" and prime people for a set of actions. The feeling of fear, evoked from a threatening situation, sets up the cognitive system to confront the danger. More specifically, fear evokes a state of alarm in the human body. This means that our cognitive system treats everything except actions targeting the immediate danger as inferior. As a consequence, all on-going action is terminated and focus is instead directed at the source of the danger while the individual prepare for and execute appropriate counter action. For athletes practicing extreme sports, fear is an important emotion and its function is embraced. This is neatly spelled out by one of the informants in Brymer and Schweitzer (2013) study

> *"I think fear is probably the most important single facet in survival. Yeah I think it's a good healthy emotion, fear. People are afraid of fear [but] fear is what keeps you alive, it's your fear that stops you from standing right on the very edge; fear is the most important thing in survival; the most important thing."*
>
> *(Participant D, Brymer and Schweitzer (2013))*

The emotion of fear is usually tied to the challenge the participants set out to master. In mountaineering, lead climbing is often described as mentally challenging and fear provoking. The lead climber ascends with rope passing through intermittent anchors. An increasing distance between the climber and the anchor below will increase the length of a potential fall and similarly increase the potential for injury. The resulting feeling of fear motivates the lead climber to put in

another anchor. In BASE jumping the participants are afraid of hitting the wall during the jump or for a mal function of the parachute. These scenarios are also the most probable way to be killed during such activities.

In skiing, the source of danger is not necessarily tied to the challenge the participants set out to master. Even though skiing and snowboarding, just as climbing and mountaineering, are associated with dangers in terms of the risk of falling off cliffs, these activities can be potentially lethal even when the skiing conditions in themselves are not challenging (for example large amounts of fresh snow on a smooth 35° slope). In fact, difficult conditions for skiing (ice, frequent rocks above the surface and tight couloir) may in some cases be relatively safer in terms of avalanches. Therefore, fear provoked by challenging skiing conditions will not help the participants focus on the real danger, but rather reduce the level of challenge tied to skiing.

In contrast, recreation in avalanche terrain may well be associated with *positive* emotions that hamper decision-making capability. Avalanches are a high consequence/low probability event. Research in psychology suggest that the way people make decisions in the face of a hazard has as much to do with their perception of the risk as it has to do with probabilities, and that such perceptions depend on affect. Just like fear diverts focus towards the source of danger, affect, in terms of positive emotions, may divert focus from objective but less obvious dangers (see e.g., Ariely & Loewenstein, 2006; Loewenstein, Weber, Hsee, & Welch, 2001; Slovic et al., 2004; Slovic, Finucane, Peters, & MacGregor, 2007) Ariely and Loewenstein (2006) show that individuals that experience a positive physical arousal are more inclined to both take higher risks and to break social norms to get what they want and Slovic et al. (2004, 2007) show that induced positive affect is associated with a lower level of perceived risk. Indeed, Slovic et al. (2007) goes as far as claiming that there is an affect heuristic. Taken to the setting of recreation in avalanche terrain, these findings points to the possibility that states of positive affect, for example induced by nice weather, nice snow and nice people, may hamper proper risk evaluations. To the best of our knowledge, no research on the effects of positive affect on risk taking behaviour in avalanche terrain is currently available.

Humans' limited cognitive capabilities also create problems that are not directly linked to emotions. Most people are relatively poor at evaluating objective probabilities. Calculating likelihoods is often a complex task that requires a substantial amount of both information and energy. In order to reduce complexity, Tversky and Kahneman (1974) show that people often rely on a set of heuristic principles. These heuristics can be quite useful, but they may also lead to severe and systematic errors. A recent study by Hohle and Teigen (2015) supports this notion. In the study, individuals' perception of risk of landslides in Norway were analysed in an experimental setting. The results of the study suggest that the trend in danger level may be as important as the absolute level of danger for risk perception: using variations in trend for a 5-level danger scale for landslides, Hohle and Teigen found that a change from green (low) to yellow (moderate) was associated with a significantly higher level of worry than a change from orange (considerable) to yellow. As mentioned above, Furman et al. (2010) show that avalanche forecasts are important decision aids for backcountry recreationists. The research by Hohle and Teigen (2015) points to the importance of evaluating how such forecasts are used and understood and how trends in avalanche danger affects perceived risk of an avalanche occurring.

The low probability/high consequence characteristic of avalanches also contributes to other challenges for adequate decision-making. If the probability of triggering one avalanche in one specific slope is 1/20, this means that an individual can ski the slope 19 times without triggering an avalanche, just to trigger it on the 20th run. Such lack of specific feedback creates a difficult learning environment, as the fact that no avalanche occurred is often taken as a sign of good judgment when it in reality may have been a strike of luck.

Group processes

A final feature worth mentioning is group processes. Research in psychology suggests that humans' sense of self-worth is closely linked to our perception of how well we do in the eyes of others (Baumeister & Leary, 1995; Baumeister & Twenge, 2003)[2], but that this link is more closely related to subjective evaluations of others beliefs than objective facts (e.g., Shrauger & Schoeneman, 1979). Our self-esteem further appears to be more closely related to our performance relative to other group members than it is to the absolute level of the performance (Festinger, 1954; Rivis & Sheeran, 2003; Tesser, 1988; White, Smith, Terry, Greenslade, & McKimmie, 2009)[3] In other words, self-esteem largely seems to depend on relative social status.

Research in economics on consumption that promotes social status shows that such behaviour is associated with negative side effects (so called negative externalities. see e.g., Blanchflower & Oswald, 2004; Clark & Senik, 2010; Johansson- Stenman, Carlsson, & Daruvala, 2002; Luttmer, 2004)[4] Such negative side effects arise because the increment in consumption made to gain social status by one individual is a social cost to the individual who gets pushed down the social ladder. Being pushed down the social ladder, in turn, creates incentives to act to restore social status, and this spurs consumption by others. In other words, social comparisons are associated with a risk of racing to the top.

In relation to risk, social comparisons may create incentives to engage in more risky activities if other members of the social group value such activities (e.g., Loewenstein, 1999). Previous research provides suggestive evidence that this is the case for a number of risky activities such as e.g., smoking, alcohol- and drug use, sun tanning etc. (e.g., Aloise-Young, Hennigan, & Graham, 1996; Fischer, Greitemeyer, Kastenmüller, Vogrincic, & Sauer, 2011; Leary, Tchividijian, & Kraxberger, 1994; Miller-Johnson et al., 2003). However, to the best of our knowledge, no one has to date analysed the effect of social comparisons in relation to risk taking behaviour in avalanche terrain.

The social nature of humans further holds the potential to affect behaviour in terms of conformity to group norms and obedience to authorities. The famous Milgram studies showed that a very high percentage of normal people were prepared to obey an authority, albeit unwillingly, even if apparently causing serious injury and distress to a third person (Milgram, 1963). On going research at UiT (Hetland & Finne, manusricpt in preparation) have demonstrated that the quality of communication within a group is a better predictor than experience and education for levelling the perceived risk with the avalanche forecast. However, this research is just scraping the surface of the ocean of possible group factors contributing in the decision-making process. Zweifel (2015) recently concluded that albeit group dynamics affects avalanche safety, research in this field is surprisingly sparse.

Education and learning

Ignoring or not recognizing obvious alarm signs in the weather, snowpack or terrain for avalanches is dominant reason (up to 2/3 of all accidents in the US) for avalanche accidents, (Tremper, 2011). This is pointing to that avalanche awareness is still important to raise by good courses and education. There are many courses addressed to skiers who aim to increase their knowledge and their skills to avoid avalanche. It will be of great interest to look further on education, learning-methods and learning paradigms when it comes to preventive avalanche training.

On going research at UiT indicates that approaches to learning well known in the subject of friluftsliv, which also lends to the tradition of experiential learning may have a good learning effect

[2] According to Baumester and Twenge (2003), this close link has its base in the fact that we, at least historically, were completely dependent on the social group for survival and reproduction.
[3] Especially for activities that are highly valued within the social group.
[4] Veblen, as early as 1899 noticed that individuals not only derive utility from their absolute level of consumption, but also from how this level compares to the level of consumption by referent others. Duesenberry developed the first economic model on the subject in 1949.

in field- based learning situation such as nature-based adventure tourism (Andersen & Rolland, 2016). In their work "Naturguiding – profesjonalisering eller kommersialisering av friluftslivskompetanse" (Natureguiding – professionalization or commercialization of the competence in friluftsliv), Andersen and Rolland (2016) argue that an integration of perspectives and methods from friluftsliv (Faarlund, 1973), tourism (Gelter, 2008) and pedagogics (Zoglowek & Rolland, 2007) may work very well together to achieve learning in nature-based tourism. They base their theoretical analysis on the importance of the experiences people get by staying outside in the natural environment. An important point is that it is crucial to achieve learning that the guests get the possibility to get conscious about, to reflect upon and to discuss their experiences. Therefore, it will be relevant to further investigate the possible importance and potential of this understanding of learning when it comes to preventive avalanche training. This will include research on classical didactic categories like what do we do, why do we do it and how do we work to get the best practice? In addition, the question of what is the role of people's own experience in these matters, is of relevance.

Tourism and guiding

Risk management are important factors within the field of nature-based tourism. Successful development of adventure-based tourism requires that the level of safety and quality are high. There is a need for identifying a minimum standard in the industry, and developing an organisation and national certification system for companies operating in this field in Norway.

There are already activities on this, where UiT together with about 8 companies has a pilot for developing a common risk-based quality system, based on common knowledge and best practice. The system will prevent accidents and provide standard preventive measures.

Climate

The avalanche conditions rely largely to the meteorological conditions during each winter. Over decades, zones of different snow climate may be identified on a regional scale or stratified by different elevation zones. The snow climate is changing, and with current projections for climate change, large changes are likely in North-Norway. With average temperature increase of 4-8 degrees Celsius over the next 100 years or so, the snow line will be much higher and the snow season will be much shorter (Hanssen-Bauer et al., 2009). It is not hard to imagine that the consequences will be large to snow-based activities and risks, and research on this topic is important in order to exploit the opportunities and mitigate the adverse effects.

Snow climate is also important to decision-making. Different types of snow climates, has different challenges. Persistent weak layers is a typical avalanche problem of dry and cold continental snow packs, whereas transient avalanche problems, such as new snow, are more common in maritime snow packs. In maritime snow packs, weak layers are frequently destructed by rain and snow melt. Differences are also found in common transient problems related to wind-transported snow, due to differences such as air and snow moisture. In a changing world, with both increased travelling between climate zones (for example foreign tourist visiting Norway) and climate zones changing due to climate change, an increasing number of people have to manage avalanche problems they are not familiar with. Avalanche problems and the management of these differ from Hemsedal to Sogn, from the Alps to Troms. How familiarity and management of avalanche problems varies in time and space is a matter we know too little about. Decision-making approaches and habits developed in Austria may not automatically be applicable in Lyngen, as the dynamics of the snow and avalanche problems differ and the interplay of ocean, snow, weather, terrain and snow is different. Also the effects of terrain and vegetation may be different, or the behavioural patterns of people may be different in different climates.

Medicine

To be added.

Geology

The geoscientific part of CARE focuses on variations in snow avalanche activity and processes in time and space under a changing climate. There is scientific consensus that terrain and climate are the all-dominant factors that humans have to deal with in practice in order to avoid exposure to snow avalanches There is scientific consensus that terrain is the all-dominant factor that humans have to deal with in practice in order to avoid exposure to snow avalanches (Jamieson & Schweizer, 2000; Schweizer & Reuter, 2013). The Department of Geology deals with the study of terrain and brings the tools to trace former snow avalanche deposits. The geological snow avalanche record is a natural extension of the written avalanche record and we are able to study snow avalanches during former warmer climate periods that also have seen changes in precipitation amounts and patterns. This is important because in northern Norway we might expect more than 40% more precipitation in the future (Hanssen-Bauer et al., 2009).

In the spatial domain, we focus on mapping the distribution and extent of snow avalanches. Evidence of past snow avalanche activity is obtained through geomorphological mapping of avalanche tracks in forests and of landforms such as avalanche boulder tongues (Corner, 1980). Methods relevant for geomorphological mapping and sedimentary studies of past snow avalanche activity are already used at the Department of Geology, to resolve stability, hazard and risk mitigation related to landslide in bedrock in Troms. Such studies include mapping of surface morphology and internal structure of unstable source areas, controlling factors for displacement and stability (snowmelt, temperature, precipitation, water pressure, permafrost etc.), in order to discuss initiation, deformation and movement processes (gravity, fall-out, sliding) for various types of rock slope failures. The Department of Geology has a strong research relation with NORUT and NVE applying advanced monitoring technology and data analysis of avalanche movement patterns, providing an excellent framework for extended avalanche studies.

The sedimentary and geomorphological record contain information about snow avalanche activity (Johnson & Smith, 2010). This is because snow avalanches also transport sediments that eventually get deposited in the geological record. Lake sediment cores, for instance, might provide a record of past snow avalanche activity provided that the lakes receive characteristic avalanche sediments (Nesje, Bakke, Dahl, Lie, & Bøe, 2007; Vasskog et al., 2011). This means that we are well prepared to join and complement the rest of the CARE team that focuses on more recent snow avalanches.

Information and communication technology

Development of ICT may be the one single driver with the highest potential to change the decision-making process – in terms of information availability, quality and abundance, in terms of machine learning substituting or enhancing human decision making, and in terms of analysis of knowledge and behavioural patterns. Research on numerical prediction systems, big data machine learning, multi-parameter networked sensors, virtual reality visualisation and interaction, etc could dramatically change the way decisions are made in the near future. Understanding the potential in the interaction between the human, the society and technology is highly valuable in terms of rendering better services and mitigating security threats. The rate of innovation in IT is high, and the potential impact on industry and public service may be very beneficial.

Technology

Skiing has seen a technological revolution over the past decade, especially with regards to equipment in the ski touring segment. Safety equipment has improved and become more widely used. Skis, boots and bindings have become very lightweight and versatile, creating a large increase in the use of avalanche terrain throughout the entire season and far away from motorized access routes and lifts.

Personal equipment typically includes receivers, probes and spades. Airbags are also becoming increasingly popular. Airbag backpacks blow up and airbag, which increase the probability of

staying on top of an avalanche rather than being buried. Receivers, probes and spades are used for companion rescue, which is very important, as most avalanche burials are fatal if not excavated within 15 minutes.

Search and rescue is a time demanding process, and time is very critical. UiT is in 2016 establishing an engineering study on drone technology. Drones can be used with receivers, radars or other sensors to locate people in avalanches or assess the danger of new avalanches to the rescue teams. The technology is being developed by UiT in close cooperation with NORUT and local rescue organisations, hospital and the police.

New sensors, and lighter sensors, may make drone technology very efficient for search and rescue, for example by using snow radars for detection of buried people, vehicles or snow properties. New light sensors may also be used mounted on skis to map unfavourable snow properties, such as weak layers, and used with information technology software on the smart phone. Data from weather and avalanche forecasting may be analysed and presented in real time to the skier together with personal movement and terrain data, and data from smart sensors measuring snow and weather conditions in real time. This demand collaboration between disciplines: electronics, cybernetics, glaciology, meteorology, physics, psychology, media-user interaction design, etc.

Economics

From an economic perspective, research on risk-taking behaviour in avalanche terrain and prevention of accidents is interesting for several reasons. One such reason is that, even if the exposure to avalanche risk is optimal from a private perspective it is unlikely to be socially optimal. According to economic theory, rational individuals maximize utility by adjusting their behaviour such that the expected marginal cost is equal to the expected marginal benefit of the action. In terms of avalanches, the expected marginal cost is related to the risk of being injured or killed in an avalanche and the marginal benefit is the utility from skiing the desired slope. In order for have an efficient level of risk taking on a societal level the social marginal benefit should similarly be equal to the social marginal cost. If the social and private marginal cost coincides, the market outcome is efficient. However, when it comes to risk taking behaviour in avalanche terrain, the social marginal cost is likely to be substantially higher than the private marginal cost: avalanches may capture other parties far away from the trigger point or destroy forests and infrastructure on their way down the mountain. If health care is publicly funded, treatment of avalanche-induced injuries and costs related to sick leave are further only partly paid by the victim.

Taken together, this implies that even if the risk that backcountry (or side-country) recreationists are exposed to is rationally chosen and therefore privately optimal, the degree of risk taking is likely too high from society's perspective. Market failures of this type usually call for some form of intervention to increase efficiency. Some research has been done on the effectiveness on different types of interventions for improved avalanche safety (see e.g., McCammon, 2004). However, much more research is needed to fully evaluate the potential benefits and costs of such interventions.

2.3 Approaches, hypotheses and choice of method

There are a number of relevant research questions and hypotheses to be addressed in research projects, PhD-, Master- and Bachelor-studies, as well as topics in courses:

- **Avalanche forecasting**: Is the message in the avalanche forecast understood? Does it trigger changed behaviour, making travelling in avalanche terrain less accident-prone? Is information or attitudes most important? What are the effects of rule-based versus process-based methods? Is communication means, such as symbols, text, maps, well understood? How does the trend in avalanche danger affect risk perception? Are important users groups left out? Is avalanche forecasting efficient? How can new technologies be developed and used?

- **Risk exposure**: What is the temporal development of exposure time, as opposed to accident rates? What are the cultural and social changes over time, and what are the drivers of change? What are the effects of different risk management methods during the past generations? What risk awareness and risk acceptance patterns are being used in different parts of Norway, and how do these compare to those used in other countries (considering recreation, residential areas and roads)? How does social interaction and social aspirations affect risk exposure? How does the experience of physical arousal due to positive emotions affect risk-taking behaviour?
- **Recreational decision-making**: What are the different single-slope decision rules? What are their uncertainty and biases? What is missing to significantly improve safety? What is the reason why danger level 2 and 3 accidents flourish, and which management strategies could change these statistics for the good? What are the effects of education and experience? What are effects of group dynamics? Which is the decision-making of snowmobilers? What are the effects of cultural background to risk management?
- **Local governance and infrastructure**: Risk awareness, preparedness and decision-making in municipalities, transport authorities, ski resorts, energy companies: What are common and best practices concerning avalanche residential avalanche safety in Norwegian municipalities with avalanche problems? And with regards to roads? What are acceptable risk levels? How could snowmobile tracks be planned and managed? How large variations are there? Is the scope of avalanche-exposed residential areas known to local authorities and populations? Are risk mitigation and preparedness according to acceptable standards? What are common practices in comparable countries, such as in the Alps, Iceland or North America? Are worst-case scenarios considered? How can new technologies be developed and used?
- **Tourism**: Do companies have avalanche safety systems in place? Are different types of guides providing equal safety? Is required planning information provided by the authorities and industry organisations? What about new activities, such as catskiing, heliskiing, etc?
- **Education**: Do courses and training improve safety? What is the role of experience and attitudes? Are course-delivered behaviour reducing the chance of accidents? Are the messages clear? Is terrain, snow, weather or human factor under-addressed in courses in Norway? How can new information technologies be developed and used?
- **Rescue**: Is rescue training effective? Are rescue personnel operating within acceptable tolerances? Is rescue capacity proportionally distributed? Are volunteer rescue operations suitable for future needs? How can new technologies be developed and used? Could acute medical treatment be improved in order to reduce negative consequences?
- **Workers safety**: Are avalanche professions subject to acceptable standards? Are avalanche-exposed workers getting adequate training and practice?
- **Economics**: What are the economic obstacles to better avalanche safety? What are the cost-benefits of preventive measures and preparedness, such as forecasting, education, planning and active control? Which incentives may reduce accidents?

The programme will liaise with leading national and international partners in order to bring in best practices and state-of-the-art knowledge. It will couple students and supervisors from different disciplines in projects in order to examine all relevant factors to decision-making from a multi-disciplinary perspective.

The programme will apply well-established scientific methods. Students and researchers will have background from an array of sciences (natural, social, economics, psychology, etc) with the theme

"avalanches" as the glue in between. This will be an unprecedented opportunity to share knowledge between communities and apply methods in new ways – thus stimulating innovation.

3. Research plan

3.1 Management

The management of CARE is divided into two branches, research and outreach. The research is lead by Audun Hetland (associate professor) and Rune Engeset (associate professor II), Bjørn Michaelsen (lector II) on the basis of this scientific programme. The outreach is lead by project manager Espen Nordahl based on the project plan for the establishment of the Center.

The management of CARE reports to a steering committee, lead by Carsten Rolland (Head of Department of Sport Sciences, UiT). The other members are Sigmund Andersen (Department of Sport Sciences, UiT), Bjørn Michaelsen (lector II), Audun Hetland (Department of Psychology, UiT), Matthias Forwick (Head of Department for Geology, UiT), Yngve Birkelund (Head of Department of Engineering and Safety, UiT), Markus Landrø (NVE) and Rune Engeset (NVE and Department of Sport Sciences, UiT).

All research and studies related to avalanches may be part the Center. In fact, the prime concern of the Center is to stimulate students to choose avalanche-related subjects for their studies and research, rather than to establish a stand-alone study programme or research. A mobility programme is planned for exchange of students and scientists between institutes internally and with external institutions.

The Center will establish and maintain a list of thesis supervisors with expertise and areas of interest, in order to manage and coordinate students, courses and research. A list of external supervisors will also be maintained, in order to achieve mobility and collaboration with other scientists and practitioners with international standing.

The programme will work towards incentives for collaboration and counteract administrative constraints which may potentially limit creativity and effectiveness, in order to stimulate cross-disciplinary research and education. This will be addressed at the Faculty and Departmental management levels. The Center will not be established as a standalone unit, but integrated in existing administrative lines. Thus students and research at the Center will not be in competition with other activities at the Departments, but rather viewed as a resource for getting even more interesting and important problems solved at the university. Furthermore, rather than creating an "avalanche-degree" programme, the Center will provide avalanche-related courses, supervision and research to other Bachelor, Master and PhD programmes. In this manner, the Center will contribute to specialists in psychology, medicine, tourism, engineering, geosciences, economics, etc with a strong avalanche-related know how, rather than discharging a lag renumber of avalanche specialists to a limited avalanche employment market.

3.2 Funding

The core funding has up until now been provided by UiTs strategic funds. The CARE programme aims to be funded by a combination of UiT budgets and external grants.

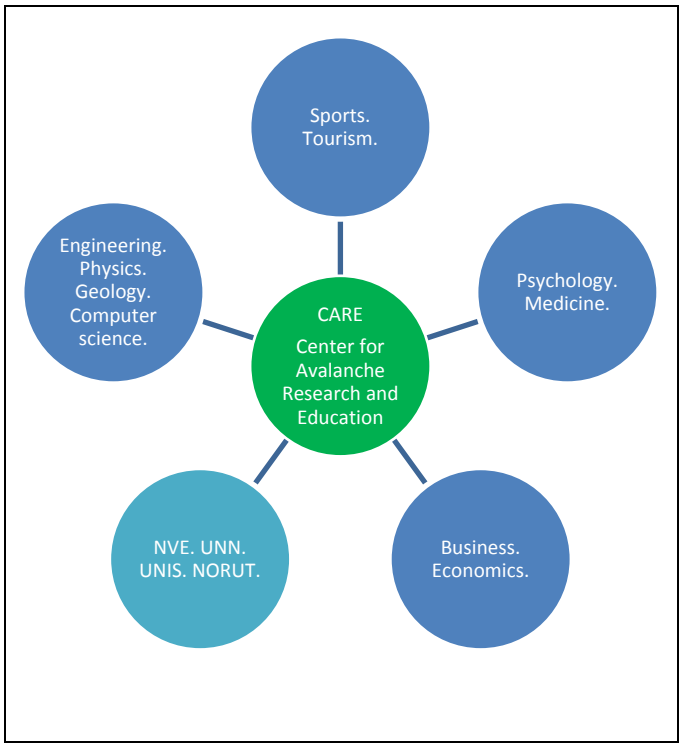
3.3 Cooperation

The CARE programme is a multi disciplinary cross faculty and cross-institutional research programme, which aims at developing new knowledge about the human factor in avalanche terrain.

CARE will engage a stakeholder forum, in order to ensure societal influence and relevance. The stakeholders will raise key questions and knowledge gaps, as well as give feedback on the

significance of the research and education at CARE. The staff at CARE will report to the Head of Institute, Carsten Rolland. He will also see to that a collaborative environment is maintained, including other institutes, faculties and institutions national and international.

The following faculties, institutes and partners are involved in the Center (some more, some less):



Faculty of Sports, Tourism and Social Work:

- Department of Sport Sciences
- Department of Tourism and Northern Studies

Faculty of Health Sciences:

- Department of Psychology
- Department of Medicine

Faculty of Science and Technology:

- Department of Engineering and Safety
- Department of Physics and Technology
- Department of Geology
- Department of Computer Science

Faculty of Biosciences, Fisheries and Economics:

- School of Business and Economics

UiT partners (**partnership to be determined*):

- NVE – The Norwegian Water Resources and Energy Directorate
- *UNN* – The University Hospital North-Norway*
- *UNIS* – The University Center in Svalbard*
- *NORUT* – Northern Research Institute*

4. Key perspectives and compliance with strategic documents

4.1 Compliance with strategic documents

The aim of UiT The Arctic University of Norway is to help in promote economic, cultural and social development in the north through building knowledge and human capital. Avalanches are a matter of life and death for recreation and nature-based winter culture, tourism, transport, energy, communication etc in this part of the world, where steep terrain, people and snow makes a deadly mix during the long winter season. CARE is relevant to UIT areas of priorities:

- Energy, climate, society and environment research – contribute to understand societal transformation, adaption and challenges as a consequence of changes in climate, environment and natural hazards;
- Technology research – develop technologies for risk management, e.g. instruments and methods for measuring snow and avalanches from satellites, air and ground, information technology for data gathering, dissemination and communication of avalanche danger and managing risk, using internet technology and apps for studying decision-making or crowd-sourcing and sharing observations and advice;
- Health, welfare and quality of life – support knowledge-based education, recreation and tourism as a means of increasing nature-based activities that promote physical and mental health, e.g. studying effects of preventive measure to avoid accidents, effectiveness and commitment of local authorities in preventing accidents and damages to buildings, roads and infrastructure, effectiveness and risk in rescue operations and medical treatment after avalanche accidents;

- Community development and democratization – reducing accident rates by providing better decision-making strategies and understanding of risk behaviour, e.g. enhancing citizens participation in avalanche warning services and their ability and motivation to influence their development, study the effects of culture and ethics on changing behaviour and use of avalanche terrain; and
- Sustainable use of resources – strengthening the cultural and knowledge framework for increasing the volume of sustainable nature-based tourism without having more accidents.

The programme is relevant to the Faculty' strategic area *Community development and democratization*, as it aims to increase public safety by creating new knowledge on safe travelling in avalanche terrain. The strategy of the Institute of sports science has as a research goal to be practical, nationally leading and internationally relevant. Knowledge on safety and travelling in avalanche terrain is essential for the education of arctic nature-based guides at the Institute. The institute' strategy points out that the Avalanche Science Center will be a regional Center of gravity with respect to avalanche safety.

4.2 Relevance and benefit to society

The CARE science programme is highly relevant to the society, as it is located in a region with an extensive multi-sectorial avalanche problem. It is relevant to UiT, which recently lost a student in an avalanche accident. UiT is located in the heart of avalanche terrain with easy access to study sites, with literally thousands of avalanche paths in its vicinity, a large tourism sector and an active recreational sector on and off campus. UiT has six campuses, all in the vicinity of avalanche terrain: Tromsø, Alta, Hammerfest, Harstad, Kirkenes and Narvik. Cross- and multi-disciplinary collaboration is in high demand today. In response to this, CARE based its science programme on collaboration between humanities, social sciences, natural sciences and education in sports and tourism. We bring together knowledge and perspectives from sports sciences, psychology, medicine, geology, meteorology, technology, risk management and pedagogy.

Better decision-making is the key to success towards the vision of zero fatalities. The understanding of the physics of snow and avalanches is fairly well developed, while the knowledge of human behaviour and decision-making with respect to uncertainty and social influence is limited. Thus, implementation of the CARE Science Programme is critical.

Avalanche-related decision-making has an inherent element of risk and uncertainty, thus the outcome of research on this topic may be very useful to a number of other disciplines, such as other natural hazards, economics, climate adaption, etc. CARE is well suited for synergies between disciplines, due to its multi-disciplinary structure.

4.3 Ethical perspectives

The reference for the discussion of ethical concerns is the guidelines of the National Committees for Research Ethics (www.etikkom.no). In general, this research project is expected not to violate any research ethics and does not go against the norms and values of the community. However, studies including people in hazardous environment raise some ethical concerns. A major focus in the CARE programme is that none of the research activities shall lead people to expose themselves to a greater level of risk than they would if they did not participate in the study.

The participants in these studies will be volunteers from a healthy adult population and they will be fully informed about the purpose and content of the different studies. Participants will be asked to give an informed consent to participate. There will be no deception in any of the studies and participants are free to quit the studies at any time.

However, some of the research methods might include film of faces, pictures, Facebook updates or other information that might disclose the identity of the participants. In these cases, the relevant

CARE research project will seek an approval from Norwegian Social Science Data Service (NDS). The data gathered from such studies will be archived after advice from NSD and in line with the UiTs guideline in this matter.

5. Dissemination and communication of results

5.1 Dissemination and communication

The Center will establish a web site and blog for communicating its vision, mission, projects, activities, personnel (direct and affiliated), partners, student opportunities, lessons learned and publications.

The programme plan to disseminate results to a stakeholder forum and by:

- Publication of scientific papers
- Presentations at scientific and practitioners conferences
- Articles and interviews to newspapers, TV and radio, forsking.no
- Popular science outreach
- Blog with Norwegian summary from a selection of relevant papers, presentations and films from other corners of the world
- Open evening classes

Communication with users is planned through:

- Identification of relevant stakeholders, grouping, prioritization, establishment of a stakeholder forum
- Developing a process of involvement, prior, during and after projects
- Using the Center' web site and blog

Seminars are planned for:

- Top level scientists and practitioners from different disciplines
- Students and employees from different institutes
- Open evening seminars with presentations on a monthly basis

6. Implementation plan, first phase: 2015-2017

The plan for the implementation of this strategy has four lines of actions: 1. Submitting proposals for PhD-projects and scientific positions at UiT, 2. Developing new avalanche-related courses and integrating avalanche-related studies into existing programmes, 3. Integrating existing and initiating new research in Center, and 4. Involving external scientists in the Center's future activities.

6.1 Research plan, proposals and staff

The following activities are planned:

- Science programme developed (by 1 Jun'16)
- Road map for avalanche-related education developed (by 1 Jun'16)
- Proposals submitted
  - PhD on decision making – Strategic prioritised funds (sub. Feb'16, no grant)

  - *PhD on decision making in avalanche terrain – IRS Faculty funds (awarded Mar'16, student starting Jan'17)*
  - PhD on single slope decision making – matching of Health Faculty funds and NVE funds (in process, planned for Apr'17)
  - OFFPHD PhD on road safety and/or rescue (open)
  - NÆRPhD on tourism and guiding (open)
  - PhD on psychology and decision making – Health Faculty funds (tbd'16/17)
  - PhD on risk management and preparedness/rescue – NT Faculty funds (tbd'16/17)
  - PhD on decision taking and risk management on snow mobile (FeFO check call)
  - PhD on rescue and acute medicine – Health Science Faculty funds (tbd'16/17)
  - Projects funded by RCN, regional funds (e.g. RDA) and EU – Relevant calls (tbd)
  - UiT Strategic thematic project (include 3 faculties or more, 3 PhD's, strategic importance) – UiT funds (prepare for May '17)
- Research employees at UiT involved
  - Bjørn Michaelsen, associate lector II
  - Rune Engeset, associate professor II
  - Audun Hetland, associate professor
  - Andrea Mannberg, associate professor
  - Many others will be added to this list

The Center aims at including all students, employees and projects, which are related to avalanches in one-way or another.

Candidates to positions funded through the Center will be recruited in an open and competitive process. The Center will search for additional funding, when approached by potential PhD-candidates already have secured most of their funding.

6.2 Education

CARE courses aims at contributing to other bachelor and master degree programmes with courses on human factors in avalanche terrain. This will be a multi-disciplinary education which combines a theoretical and "hands on" approach to the field of human factors. These educations will be based on psychology but also include courses in outdoor education, geology, technology and geography/metrology. Students in will take part in the ongoing research and work closely with the CARE research group throughout their degree. Two courses will address the human factors in avalanche terrain both theoretically and through practical, in the field lectures. The goal is that all students that study avalanche relevant studies (like geology, technology, geography etc.) can complement their studies with courses specifically covering the human factor.

The following two courses are aimed to start spring 2017:

- PSY 2028 Human Factors in Avalanche Terrain 10 ECTS
- PSY 3028 Decision Making in Avalanche Terrain 10 ECTS

The following two courses will be considered to be starting up in autumn 2017:

- Avalanche observations for professionals 10 ECTS
- Avalanche forecasting and risk management for professionals 10 ECTS

A separate bachelor and master programme related to avalanches and decision making will be considered in due course. Also a PhD-level course will be considered.

Finally, the CARE programme seeks to offer similar courses that can complimentary in teacher's education. In addition to the human factor such courses will include hands on avalanche courses, as well as basic geology and metrology.

The avalanche specific courses will be taught by CARE scientists and practitioners. The other courses will be part of the already established study portfolio at UiT. Some of the lectures that are most relevant for the general public will be taught as open evening classes. Previous experience has shown that there is a tremendous interest in avalanche related classes in Tromsø. The previous avalanche seminar at UiT arranged by "Fjellsportgruppa" had about 1100 participants registered. Unfortunately, the largest auditorium at UiT only seats 550 and this was filled to the brim.

In order to reach new students, a Massive Open Online Course (MOOC) will be considered established. The MOOC will give an introduction to avalanches, snow, terrain, meteorology, forecasting and human decision making in avalanche terrain. Other initiatives, such as White Risk (www.whiterisk.ch) or www.snøskredskolen.no, will also be considered as sources or platforms for courses.

It will also be considered to initiate a Norwegian Avalanche Association, where the Center could take a leading or secretary role. The Center should also consider developing and coordinating Norwegian guidelines or standards for avalanche-related education for professionals and recreationalists.

6.3 Research

The following initial activities are planned:

- Cultural aspects versus rational decisions in avalanche terrain (Bjørn Michaelsen)
- New method for risk management at danger level 2 in the backcountry (Bjørn Michaelsen)
- Decision-making in avalanche terrain (Audun Hetland)
- Risks and avalanche safety in tourism and guiding (Sigmund Andersen)
- Single slope evaluation (Markus Landrø)
- Workers safety (Markus Landrø)
- Effects of avalanche forecasting (Rune Engeset)
- Social aspirations and risk-taking behaviour (Andrea Mannberg)
- Affect and risk-taking behaviour (Andrea Mannberg and Audun Hetland)
- Trend effects in risk perception of avalanche forecasts (Andrea Mannberg and Audun Hetland)

Preliminary results were presented at ISSW'16.

6.4 Collaboration

In order to ensure high quality and world-class research, the Center will establish close relationships with external scientists and science groups, with the aim to have common projects, external supervision of students and options for two-way exchange of students and scientists.

The Center aims at collaborating with other scientists and practitioners. These include scientists on avalanche and earth observation at NORUT, acute medicine and rescue at UNN, snow and safety at UNIS, as well as scientists at Montana State University, SLF, Simon Fraser University, Umeå University, and more. The Center will also collaborate closely with governmental and commercial partners with avalanche-related challenges and/or competence, such as the Norwegian Public Roads Administration (NPRA).

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Revisions

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- Version 1.0 (2016-06-20): First official version, approved by the Steering Committee on 15 June.
- Version 1.1 (2016-11-05): Minor revisions, and change of name from ASC to CARE.


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