TERRAIN CLASSIFICATION OF NORWEGIAN SLAB AVALANCHE ACCIDENTS

Linda Hallandvik[1]*, Eivind Aadland[1] and Odd L. Vikene[1]

[1]Sogn & Fjordane University College, Sogndal, Norway

ABSTRACT: It is difficult to rely on snow conditions, weather and human factors when making judgements about avalanche risk because these variables are dynamic and complex; terrain, however, is more easily observed and interpreted. Therefore, this study aimed to investigate 1) the type of terrain in which historical fatal snow avalanche accidents in Norway have occurred using the Avalanche Terrain Exposure Scale (ATES), and 2) how to implicate ATES in avalanche education. The ATES classifies terrain as *simple* (Class 1), *challenging* (Class 2) and *complex* (Class 3). We investigated 30 fatal slab avalanche accidents in Norway over a 10-year period (2005-2014) involving 42 deaths. According to the ATES, 77% of the accidents occurred in complex terrain and 23% occurred in challenging terrain. Our results indicate that the ATES is a practical tool that may help recreationists with trip planning in the type of terrain that suits their level of experience and knowledge. This tool can be valuable to novices by helping them to acquire experience in recognizing relevant terrain features that might compromise their safety and interfere with their plans. Results in this study shows that most avalanche accidents occurred in complex terrain. Thus, for novices and advanced beginners, learning to use the ATES provides a sound basis for safe travel and gaining experience in avalanche terrain.

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KEYWORDS: Avalanche Terrain Exposure Scale (ATES), fatal avalanche accidents, outdoor recreation, practical implications, from novice to expert.

1. INTRODUCTION

Increased interest in winter backcountry recreation has resulted in increased exposure to avalanche terrain and a subsequent increase in avalanche accidents. In Norway, the accident rate has tripled over the last 10 years (Norwegian Geotechnical Institute, 2015). Similar trends have been observed in Canada and the European Alps (Colorado Avalanche Information Center, 2014; International Commission for Alpine Rescue, 2014).

Decision-making in avalanche terrain is complex and dynamic. When the environmental information upon which we base our assumptions is complex and incomplete, the relevant information may not be apparent, thus making sound judgments about avalanche risk difficult (Hogarth, 2001; Kahneman, 2011; Kahneman & Klein, 2009; Shanteau, 1992). Several studies have shown that accidents frequently occur under conditions where clear signs of danger are present (McCammon, 2004; McCammon & Hägeli, 2007; Tremper, 2008; Hallandvik, Vikene & Aadland, 2015). This suggests that many people may have an insufficient understanding of avalanche risk and thereby make poor decisions.

According to Fredston and Fesler (2011), in addition to the presence of people, there are three environmental factors that contribute to avalanche risk, which include the following: 1) *terrain,* 2) *weather* and 3) s*nowpack*. Of these three environmental avalanche risk factors, the terrain component is the easiest to evaluate as it is static and its interpretation is very straight-forward (Tremper, 2008; Fredston & Fesler, 2011), at least for those with some previous experience or when using a tool that clearly indicates the important terrain features associated with avalanche risk. Therefore, it may be appropriate to begin with the terrain component when assessing avalanche risk.

According to Statham, McMahon and Tomm (2006) and Fredston and Fesler (2011), terrain evaluation skills provide the most secure basis for decision-making in avalanche terrain and provide the best opportunity to base hazard evaluations upon a solid foundation of facts, rather than on assumptions, feelings, guesses, or fate.

* *Corresponding author address:*
Hallandvik L., Sogn & Fjordane University College, Sogndal, Norway; tel: 0047 57676187; fax: 0047 57676333; email: linda.hallandvik@hisf.no.

The Avalanche Terrain Exposure Scale (ATES) was developed by Parks Canada in response to a tragic avalanche accident in Glacier National Park, Montana on February 1, 2003, in which seven students died. The intention was to classify and map popular hiking backcountry routes for communication to the public. The ATES consists of one Public Communication Model and one Technical Model (Statham et al., 2006), each having a different level of detail. The Public Communication Model divides terrain into three classes (Statham et al., 2006; 493):

Class 1) *Simple,* which includes the following terrain criteria: exposure to low angle or primarily forested terrain, some forest openings that may represent the runout zones of infrequent avalanches, many options to reduce or eliminate exposure. No glacier travel.

Class 2) *Challenging*, which includes the following terrain criteria: exposure to well-defined avalanche paths, starting zones or terrain traps, options to reduce or eliminate exposure with careful route finding. Glacier travel is straightforward but crevasse hazards may exist.

Class 3) *Complex*, which includes the following terrain criteria: exposure to multiple overlapping avalanche paths or large expanses of steep, open terrain; multiple avalanche starting zones and terrain traps below; minimal options to reduce exposure. Complicated glacier travel with extensive crevasse bands or icefalls.

The Technical Model (Statham, et al., 2006; 493) is a tool that classifies all of the variables that constitute terrain exposure: slope angle, slope shape, forest density, terrain traps, avalanche frequency (events: years), start zone density, runout zone characteristics, interaction with avalanche paths, route options, exposure time and glaciation. The sum of these factors classifies the terrain according to the public communication model (simple, challenging or complex). Some features carry more weight than others.

A study by Gavaldà, Moner & Bacardit (2013), which analyzed 38 fatal avalanche accidents in the Aran Valley, Central Pyrenees showed that 71% of the accidents occurred in *complex* terrain and 29% occurred in *challenging* terrain. No accidents were reported in *simple* terrain. Their findings suggest that the ATES might be a valuable tool to include in the assessment of avalanche risk. Specifically, the tool could enable novices to recognize and avoid complex terrain and therefore improve judgements and make risks manageable. In addition, integrating and awareness of the ATES, the educator/skier could learn and encourage information on weather and snowpack.

Therefore, the aims of this study were two-fold. First, we examined the terrain classification for Norwegian fatal avalanche accidents from 2005/2006–2013/2014 using the ATES. Second, how to implicate ATES in avalanche education.

2. METHOD

Data were obtained from avalanche accident reports gathered by the Norwegian Geotechnical Institute (NGI). The accident reports are based on inspections of avalanche sites less than 24 hours after the accidents occurred and the observations of rescue personnel, police and eyewitnesses. Early reports (prior to 2005/2006) were variable in content and quality and lacked essential information. Since 2005/2006, the reports have been highly standardized and detailed. Therefore, we included accidents that occurred from 2005/2006 to the present (2013/2014). Three reports from the winter of 2013/2014 were not available at the time of analysis and were therefore not included in the present study. In addition to NGI reports, we used 1:50.000 topographic maps and Xgeo (2015) for calculation of the ATES.

2.1 <u>ATES-translated Technical Model</u>

The Norwegian environment has some differences from the Canadian environment. We have used the same descriptors as the ATES Technical Model (Statham et al., 2006; 493) in this study. However, The Norwegian Water Resources and Energy Directorate (NVE) have adapted the ATES to the Norwegian environment. The Norwegian model does not include "forest density" and "glaciation" because these factors are difficult to evaluate in Norway (Rustad, Lytskjold, Landrø, Peereboom, Statham & Engeset, 2014). Thus, "glaciation" is replaced by "other dangers" in the Norwegian model. "Other dangers" includes cornice fractures, slipping, falls and crevasses. In simple terrain, these dangers are not present; in challenging terrain they are present, but the dangers are clear; and in complex terrain the dangers are present but are unclear (Rustad et al., 2014). Moreover, “start zone density” and “runout zone characteristics” are merged into “runout and start zone characteristics” in the Norwegian model because these terms have a similar meaning. The Norwegian model was developed in collaboration with Statham, who developed the original model (Rustad et al., 2014). Last, “avalanche frequency" is not included in the present study because this information is not available for Norway. Based on the Norwegian model, the following information (fig. 1) was extracted and analyzed from the NGI database together with 1:50.000 topographic maps by using an inclination protractor and Xgeo (2015), a digital topographic map with terrain features such as steepness > 30° and < 30° and terrain below and above tree line.

	1 - Simple	**2 - Challenging**	**3 - Complex**
Slope angle	Angles generally < 30°	***Mostly low angles, isolated slopes > 30°***	***Variable, with large % > 35°***
Slope shape	Uniform	Some convexities	Convoluted
Terrain trap	Minimal, some creek slopes or cut banks	Some depressions, gullies and/or overhead avalanche terrain	***Many depressions, gullies, cliffs, hidden slopes above gullies, cornices***
Interaction with avalanche paths	Limited open terrain	Some but clear; single path or paths with separation	***More and disorganized; numerous and overlapping paths***
Runout and start zone density	Some well-defined areas. Smooth transitions, spread deposition	Steep transitions or depressions with deep deposition	Several concurrent avalanche paths, bordered deposition areas
Route options	Terrain allows multiple choices	A selection of choices of varying exposure; options to avoid avalanche paths	***Limited chances to reduce exposure; avoidance not possible***
Exposure time	None, or limited exposure crossing runouts only	***Isolated exposure to start zones and tracks***	***Frequent exposure to start zones and tracks***
Other dangers*	None	Exposed terrain, transparent	***Exposed terrain, unclear***

* Includes cornice fractures, slipping, falls and crevasses.

Fig. 1: ATES-translated Technical Model (Rustad et al., 2014; 17). Terrain that qualifies under ***italic and bold*** descriptors automatically defaults to that terrain class or a higher terrain class.

Terrain that qualifies under italic and bold descriptors automatically defaults to that terrain class or a higher terrain class. Non-italic and non-bold descriptors carry less weight and do not trigger a default category, but are considered in combination with the other factors. The sum of all factors defines the terrain classification.

To assess the reliability among raters, we randomly selected five accident reports that were examined by two different government avalanche experts. All of the raters extracted the identical information.

2.3 Statistical analyses

The results are reported as numbers (proportions) and range, median and interquartile range (IQR). Fig. 2 shows the distribution of terrain classifications (simple, challenging and complex) for the different ATES elements.

3. RESULTS

We examined 30 accident reports (91% of accidents) involving a total of 42 fatalities, of which 38 were men (age range 19-58 years, median 34 years, IQR 18 years) and 4 were women (age range 21-28, median 25 years, IQR 6 years). Of the included accidents, 20 (67%) involved skiers or snowboarders, 8 (27%) involved snowmobilers, 1 occurred while hunting, and 1 occurred while climbing. One accident (5 fatalities) occurred during a guided trip (involving skiers/snowboarders), whereas all other accidents occurred during private recreational trips.

Of the 30 accidents analyzed, 23 (77%) accidents occurred in complex terrain, whereas the remaining 7 (23%) accidents occurred in challenging terrain according to the ATES. The terrain elements most frequently classified as complex were exposure time (67%) and slope angle (60%), whereas very few accidents were classified as simple for any of these factors (fig. 2).

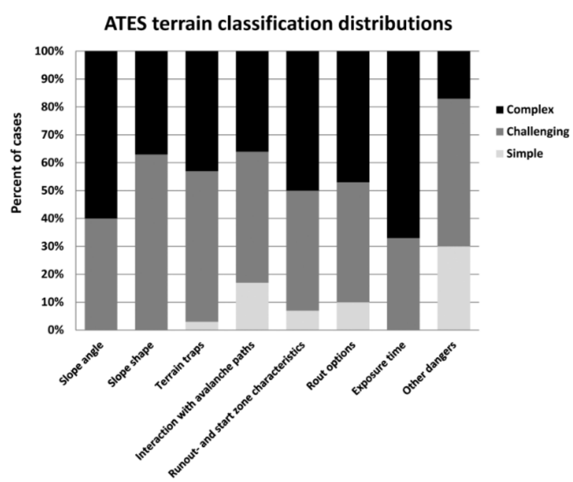

Fig. 2: The distribution of ATES terrain classifications (simple, challenging and complex) for the different ATES variables.

4. DISCUSSION

Decision-making in avalanche terrain is difficult because we lack important information from the environment regarding the present avalanche risk (Shanteau, 1992; Hogarth, 2001; Klein, 2011). However, most fatal avalanche accidents occur under conditions and in situations where clear signs of danger are present (McCammon, 2004; McCammon & Hägeli, 2007; Tremper, 2008; Hallandvik et al., 2015). Thus, decision-makers need simple tools or strategies to detect and evaluate the existing avalanche risk (Gigerenzer, 2007). Knowledge and awareness of the terrain classification (ATES) might be valuable for guiding our decisions and reducing uncertainty in complex situations. The present study showed that 77% of the accidents in Norway over a 9-year period occurred in *complex* terrain and 23% occurred in *challenging* terrain according to the ATES terrain classification. This result suggest that information regarding the terrain, as classified by ATES, together with knowledge and learning of weather, snowpack and typical human failure, in environment that allowed failure without fatal outcome, provide valid information about avalanche risk and provide novices with a simple basis for their decisions.

Our findings are very similar to those of Gavaldà et al. (2013), which showed that 71% of the accidents in the Pyrenes over a 25-year period occurred in *complex* terrain, while 29% occurred in *challenging* terrain. These findings indicate that terrain (as classified by the ATES) is an important factor to consider when evaluating avalanche risk. The benefit of increasing terrain awareness through ATES was demonstrated in a study by Salmon, Goode, Lenné, Finch and Cassell (2014), which showed that 50.2% of all accidents (private recreational or organized groups) occurred in "hazardous terrain" and therefore concluded that "… environmental hazards such as terrain should be considered more explicitly in planning and risk management …" (p. 119). The importance of terrain is consistent with other literature, as terrain is the foundation of avalanches and therefore should be the primary consideration when planning a trip (Fredston & Fesler, 2011; Tremper, 2008). Wagner and Hardesty (2014) have also stated that, "if you can't manage the snow, you have to manage terrain" (p. 15).

In our study, we also found that steepness and exposure time in avalanche terrain more often associated with accidents than other factors (exposure: 33% *challenging* terrain and 67% *complex* terrain; steepness: 40% *challenging* terrain and 60% *complex* terrain). These two variables are also the most heavily weighted factors in the ATES. Interestingly, exposure and steepness are also arguably the easiest factors to plan for by studying maps during route planning prior to trips. The Norwegian government has not classified and mapped popular hiking backcountry routes for communication to the public, but there have been pilot projects on such mapping using ATES in specific areas (Tromsø, Romsdalen and Hurrungane) (Rustad, et al., 2014). In other areas within Norway, recreationists must make use of ordinary topographic maps without direct terrain classification and/or use digital tools. Xgeo is a free database in Norway, providing topographic map information on terrain features such as steepness > 30° and < 30° and terrain below and above tree line, as well as regional avalanche danger ratings and snowpack conditions (Xgeo, 2015). Similar digital maps are available elsewhere; for example, in Canada (Ava Terra Services, 2015) and in the Swiss European Alps (WSL, 2015), although most are not available for free. Our findings, together with those of Gavalda et al. (2013), suggest that such tools might be a valuable resource for trip planning. Knowledge of steepness results in better calculations of runout-zones using an inclination protractor on planned trips. Both tools also help to evaluate route options, possible start zones for avalanches and exposure time. We believe that frequent use of ATES could be a good strategy to prevent future accidents. Knowledge and awareness on ATES combined with information regarding the weather and snowpack, may help the educator/skier to make robust decisions and remain safe in avalanche terrain.

A clear understanding of the terrain, combined with the existing danger rating and the weather forecast, provides recreationists with clear expectations about the existing avalanche risk. Still, evaluation of avalanche risk is not straightforward. After planning a trip at home, backcountry travelers must seek out additional information in the environment. They must consider terrain shape, terrain traps and other dangers that are not always visible on maps. According to Klein, Pliske, Crandall and Woods (2005), once recreationists detect a potential problem (i.e., are aware of the most important terrain features) in a specific situation, they can act in a variety of ways. They may seek more information, track the events more carefully, try to diagnose or identify the problem or/and raise the concern with others in the group. Once recreationists are aware of the situation, they must do further research. If they know the terrain classification, this knowledge should result in a thorough examination of whether it is safe to continue or whether it would be advisable to revise the goals and plans. Problem detection is about the recognition of discrepancies between what is observed and what is expected (Klein et al., 2005). If the recreationists are aware of terrain classification, they should search for further targeted information through key "cues" for decision-making in avalanche terrain. This suggestion is consistent with Klein (2011), who claims that proficiency development is the ability to recognize patterns and inconsistency in patterns. This recognition may result in improved “Situation Awareness” (SA) (Endsley, 1995; 1999; 2006). According to Endsley (2006), SA plays an important role in situations where there are many factors to track, and in which these factors may change quickly and interact in complex ways. Endsley (1995; 2006) divided the properties of SA into three levels: 1) the perception of elements in the current situation, 2) the comprehension of the current situation and, 3) the projection of future status. For novices, awareness of terrain complexity may stimulate the search for important elements in the current situation, and thus increase the understanding of a situation in terrain that allows for failure without fatal outcomes. Moreover, according to Tozer, Fazey & Fazey (2007), faster and more automatic intuitive decisions are made as a result of extensive deliberate practice, variation in the practice and reflection on experiences. Implementation of all summary factors in the ATES would deepen terrain classification and provide straightforward awareness of a planned route. Planning also plays a prominent role in managing our psychology and allows us to gain experience in a safe, low-stress situation. Information can be gathered by performing simulations of the trip and even by determining key decision points beforehand (Richardson, 2011). According to our results and the weighting of terrain features by the ATES, key points to consider should be steepness and exposure time in *complex* terrain.

To understand dynamically complex systems and make balanced, proficient judgments, individuals need to critically reflect on their experience and seek different perspectives (Fazey, Fazey, & Fazey, 2005). Although the literature describes different perspectives and approaches with respect to understanding decision-making, there seems to be general agreement that decision-making is a product of both conscious and instinctual processes (Schumann, Furman & Shooter, 2010; Furman, Shooter & Schumann, 2010). From this perspective decision-making is a dual process. Evans and Stanovich (2013) claim that the term “dual systems” is ambiguous as it can sometimes be synonymous with a two-minds hypothesis, but it has been used by other authors to convey little more than a distinction between two types of processing: system 1, which is intuitive and quick, and the more deliberate system 2, which is analytic and reflective but slow (Kahneman, 2003; 2011). This approach corresponds to Shooter and Furman (2011) who claim that “dual-process” in decision-making involves two perspectives: i) “a conscious, rational, controlled, deliberative process” and ii) an unconscious, automated, intuitive process. In our opinion, use of the ATES force us to use conscious, deliberate, analytical processes (Kahneman, 2003; 2011; Shooter & Furman, 2011). After developing more experience through extensive deliberate practice and reflection upon those experiences, recreationists may be able to make faster and more automatic intuitive decisions (Tozer et al., 2007; Kahneman, 2003; 2009; Shooter & Furman, 2011).

In addition to different perspectives on and approaches to decision-making processes related to dynamic and complex environments, we must consider the learning stage of the learner. According to Dreyfus and Dreyfus (1986) and their Five Stages Model of Skill Acquisition, we need to describe how use of the ATES may be reasonably implemented in the decision-making process. Their five-stage model describes how a learner develops from a detached and analytical rule-based stance toward the higher level of proficiency characterized by an immediate and intuitive situational stance.

Learners at the first three stages (Novice, Advanced Beginner and Competence) are characterized as analytic and ruled-based (Dreyfus & Dreyfus, 1986; Moe, 2004). The ATES as an analytic tool could help a Novice to deconstruct the task environment into context-free features that the beginner can recognize without a high level of skill. The first step for Novices should be to adopt a proactive approach to terrain awareness through trip planning. An Advanced Beginner is able to cope with real situations and develops an understanding of the relevant context through an understanding of the map or information received from the ATES, and comparing this information to the environment. This stage creates an awareness of the terrain from the planning and is used to address real situations: Is the planning suitable to the actual terrain situation? The decision is analytical and the commitment is detached (Conger, 2005). Through additional experience, the Competent learner would be able to adopt a perspective that then determines which elements of the situation or domain must be treated as important and which can be ignored (Dreyfus, 2004). At this stage, the learner develops the perspective to determine importance within the environmental context (Dreyfus & Dreyfus, 1986). If the decision-maker is aware of the importance of choosing *simple* terrain, they may learn more about environmental factors and human factors without fatal outcomes. In practice, this means that the decision-maker at the first three stages should learn about the terrain through studying maps and then challenge their perspectives in various contexts. After experience is gained from extensive deliberate practice, with variation and reflection on their experiences in *simple* terrain, the learner may be able to recognize which situations provide valid and true information.

At the fourth level, Proficiency, the decision-making process is changing; it has become a mixture of both an intuitive and analytic way of seeing the situation (Moe, 2004). The Proficient learner has learned to recognize the problem and develop an answer based on an assimilated set of salient experiences. The difference between the Proficient and Expert level is reasoning versus intuitively knowing. The Expert responds to specific situations in an intuitive way because they have experienced many similar situations before; "when things are proceeding normally, experts don't solve problems and don't make decisions; they do what normally works" (Dreyfus & Dreyfus, 1986, p. 30-31). However, when time permits or outcomes are critical, and when situations do not proceed normally, the Expert uses deliberate reasoning prior to acting (Klein, 2011). Klein (2011) claims that when analytical reasoning and intuition are in conflict, intuition should be suppressed. This is consistent with observations by Stewart-Patterson (2013), who found that when intuition and analysis clashed, the expert defaulted to a conservative option.

The present study, consistent with previous studies, shows that the first step in avalanche decision-making should be to consider the terrain complexity against the avalanche danger level to inform the decision-making process and prevent future avalanche accidents.

4.1 Strengths and Limitations

The strength of the present study is that we have included all avalanche accidents in Norway from the winter of 2005/2006 to 2013/2014 except for three accidents during the winter of 2013/2014 for which the accident reports were not published at the time of analysis. Thus, we have no selection bias in accidents, unlike McCammon and Haegeli's (2007) study, which was criticized by Uttl, Henry and Uttl (2008) and Uttl, McDouall, Mitchell & White (2012) for this reason. However, Norway is a small country; it has approximately 5 million inhabitants, and the absolute accident rate is low, leaving a relatively small number of accidents for analysis.

Our findings indicate that application of the ATES significantly reduce the risk of fatal slab avalanche accidents if choosing *simple* terrain. At the same time, we acknowledge that *simple* terrain may be perceived as overly conservative by many backcountry travelers, as it can severely restrict travel in *challenging* or *complex* terrain on days otherwise considered well-suited for exploring the backcountry. Nevertheless, we must accept that conservative decisions in avalanche terrain are required to prevent future accidents. Specially decision-makers at the first three stages of Skill Acquisition mentioned by Dreyfus and Dreyfus (1986).

5. CONCLUSION

Our results show that most fatal avalanche accidents in Norway over the last 9 years (2005-2014) took place in complex terrain. Learning and understanding ATES could help novices to develop expertise in decision-making skills by giving them the opportunity to perceive and understand the consequences of terrain choices against weather, snowpack and human failure. We recommend the inclusion of the ATES in outdoor learning situations to facilitate the development of sound judgement by focusing attention on important and valid information regarding avalanche risk.

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