A NEW, GUIDE-FOCUSED APPROACH FOR CHARACTERIZING SKIING TERRAIN TO FACILITATE RISK MANAGEMENT DECISIONS AND RESEARCH

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ABSTRACT: Perception of terrain characteristics is fundamental to risk and hazard management for professional guides in mechanized skiing operations. Existing terrain studies in avalanche safety research have primarily focused on identifying the hazard potential (e.g., identification of start zones) based on easily measurable physical characteristics (e.g., incline, aspect). However, terrain choices in mechanized skiing depend on a much broader set of factors, including operational benefits and barriers for accessing the terrain. In this paper, we present a new, guide-focused approach for characterizing ski runs to facilitate risk management decisions in mechanized backcountry skiing operations, which gathers objective and subjective assessments with respect to access, skiing experience, operational usability, hazard potential and mitigation practices. We explore the value of the proposed system at two mechanized skiing operations in Canada. The resulting terrain framework captures the existing terrain knowledge of a guiding team and offers a valuable resource for training of new guides, continuous mentorship, land management, and daily operational decision-making. The presented terrain characterization approach represents a crucial step for studying guides' terrain choices, extracting their decision rules, and developing meaningful decision aids that can help them make effective terrain choices more efficiently.

To be presented at the International Snow Science Workshop in Innsbruck, Austria, from October 7-12, 2018.

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KEYWORDS: Avalanche terrain, terrain characterization, ski guiding, avalanche risk management.

1. INTRODUCTION

In the backcountry, the physical risk from avalanches is managed by choosing terrain that avoids unnecessarily high exposure to the existing avalanche hazard. These decisions require a good understanding of the current hazard conditions and an accurate perception of the terrain characteristics one may encounter during backcountry travel. Traditionally, avalanche safety research has primarily focused on improving our understanding of the hazard and describing it in a way that supports informed decision-making, however the terrain component of the risk management process has not received the same attention. While there has been considerable research on identifying avalanche release areas from physical terrain characteristics (see, e.g., Bühler et al., 2013; Veitinger et al., 2016), research focusing on a more inclusive picture of all terrain factors pertaining to backcountry risk management is missing.

Mechanized ski guiding operations (i.e., helicopter and cat ski operations) have a tremendous amount of expertise in evaluating avalanche hazard and selecting optimal terrain for their needs. Decades of practical experience have resulted in sophisticated operating procedures and rich community knowledge regarding what type of terrain is appropriate in different types of conditions. However, this expertise is primarily stored as tacit knowledge within the community, which makes is difficult to access, evaluate systematically, and use to improve operating procedures. Since the misapplication of terrain is considered one of the key issues of professional guiding (Guyn, 2016), it deserves further examination.

To address these issues, various recent studies have focused on extracting professionals' terrain and risk management expertise in a systematic way. Initial research in this area used online surveys to examine stated terrain preferences of backcountry users in hypothetical decision situations (e.g., Haegeli et al., 2010). More recently, however, research has focused on capturing and examining revealed terrain preferences in professional guides and the causes behind their inclinations. Hendrikx et al. (2016) monitored guides' terrain choices using GPS trackers and examined differences in incline, elevation, and aspect of skied runs during different hazard conditions. Also using GPS tracking data, Thumlert and Haegeli (2018) extracted terrain factors influencing route selection under certain avalanche hazard conditions and used this information to generate avalanche condition-dependent maps that visualize acceptable terrain choices. Sterchi et al. (2016) used hazard assessments from daily run list

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records to investigate patterns in run list codings and define terrain categories that are linked to particular types of avalanche conditions.

All of these studies describe terrain exclusively with physical terrain characteristics (e.g., incline, aspect, convexities, forest density) that are well-established in the avalanche risk management literature (e.g., McClung and Schaerer, 2006; Tremper, 2008) and supported by the existing research on avalanche release areas (Bühler et al., 2013; Veitinger et al., 2016). An additional reason for the prevalent use of these terrain parameters is the fact that they can be easily extracted from publicly available geospatial databases and digital elevation models (DEMs). However, there is much more to terrain assessment and terrain-use than physical terrain features, and there is much more to guiding than just avalanche risk management.

The objective of professional guiding is to maximize the quality of the guest experience while operating within an appropriate safety margin (ACMG, 1999). Hence, a guide's choice to ski a particular run reflects a balance between the factors that make it desirable for skiing and the factors that contribute to the associated avalanche hazard. To illustrate this balance, McClung (2002) introduced the concept of the operational risk band (ORB), which states that the risk associated with providing guests with a high-quality skiing experience needs to stay between two limits: excessive conservatism (i.e., too little risk) will result in missed skiing opportunities, while too much risk will lead to serious accidents.

Over time, guides also develop a comprehensive understanding of their terrain and how to use it most efficiently to achieve their objective. Access, relative position of ski runs, and ease of guiding each play a critical role in terrain selection when guides strategize their day.

Since terrain choices manifest from *all* influencing factors present when decisions are made, a more insightful description of terrain is required to properly identify insightful patterns in revealed terrain preferences, confidently isolate the effect of avalanche hazard on decisions, and develop meaningful decision aids. This objective of this study was to develop a comprehensive framework for describing the nature of skiing terrain that captures the expert terrain knowledge in a meaningful way, supports operational decision making and provides the foundation for future research on terrain selection.

2. CONTEXT

It is critical to examine revealed terrain preference observations within their full context to accomplish a meaningful analysis. The general daily procedure for terrain selection in mechanized skiing operations begins with the assessment of the day's expected avalanche hazard conditions. Based on this forecast, the team evaluates their list of established ski runs for the first time in the day and discusses which are appropriate for guiding under the expected conditions. The resulting consensus-based "run list" governs subsequent terrain decisions in the field by eliminating certain runs from "today's menu." Once in the field, the guide of the first group serviced by a helicopter (known as the lead guide) chooses suitable ski runs from the list of open runs to provide an attractive skiing program based on hazard considerations, guest ability, snow quality, number of groups, operational efficiency, and many other factors (Israelson, 2015). The guides of individual groups are then responsible for establishing the appropriate ski line for the group within the run and making smaller-scale terrain choices while skiing.

All terrain choices in mechanized skiing are high-stakes decisions upon which the lives of guides and guests critically depend. These decisions are made in a complex, fast-paced environment with considerable uncertainty. This uncertainty includes both unpredictability inherent to the natural system and limited knowledge from imperfect information (CAA, 2016). Research in cognitive science (e.g., Kahneman, 2011; Klein, 2003; Todd et al., 2012) and reflections from avalanche experts (e.g., Adams, 2005; Atkins, 2014; Kay, 2016; McCammon, 2001; McClung, 2002) both highlight that decision-making in such an environment is heavily influenced by subconscious pattern-recognition that stems from extensive practical experience. While the analytical and more "rational" decision processes are important, the backcountry system is just too complex, fast-paced, and uncertain to routinely depend on them. Instead, decisions in these environments rely heavily on intuition, perception, and cumulative personal experience. Hence, a better understanding of guides' personal perception of terrain is crucial for understanding their terrain choices and variations among them.

3. FRAMEWORK FOR AN INSIGHTFUL TERRAIN CHARACTERIZATION

We developed a comprehensive website that allows interested operations and guides to characterize their skiing terrain in detail (avterrain.avalancheresearch.ca). Fundamentally, factors influencing guides' terrain selection can be grouped into three main categories: **Barriers** describe potential obstacles what prevent guides from accessing a run; **Benefits** explain what might motivate guides to go to a run; and **Hazards** describe

what type of hazards guides have to manage when guiding guests on the run.

To define the specific aspects of barriers, benefits and hazards for individual runs in detail, we structured our run characterization framework around five main topics: access, skiing experience, usability, hazard potential, and mitigation. **Access** represents the barrier dimension; it describes how easy or challenging it is to physically get to a run based on flight economics, the required weather conditions for safe access, the quality of visual references at the landing and pick-up, and any additional flight hazards. The benefits dimension is captured by: **Skiing experience**, which describes the nature and quality of the skiing guests will encounter on a run, and **Usability**, which describes the factors affecting the way a run can be used advantageously by guides. These usability factors include the number of fresh tracks a run can support, whether a run has any particular operational role (e.g., destination run, jump run), and whether environmental conditions (e.g., freezing levels) and/or other backcountry users might prevent the use of a run. The hazard dimension is split into hazard potential and mitigation. **Hazard potential** describes the terrain features and typical snowpack characteristics that contribute to the severity of avalanche hazard on a run. It also describes other non-avalanche-related risks that may exist. **Mitigation** captures options to control hazard on a run or describe features that help reduce it. This includes information on suitable guiding procedures (e.g., weak layer management through skier traffic) or natural processes (e.g., slopes that commonly self-stabilize).

The run characterization uses a range of question types to capture relevant information from a variety of perspectives. Most questions seek to capture guides' personal terrain perceptions, since this is the lens through which all their information is processed (e.g., type of skiing terrain, special skiing experiences for guests, steepness, etc.). Other questions ask guides to assess run characteristics based on their integrated personal perspectives. Examples include "overall friendliness" with respect to hazards, and "overall guide-ability" of a run. Also included are questions that aim to capture guides' experience with a run and historical information on incidents. Since basic terrain characterizations (e.g., incline distributions, elevation of landings and pickup) can easily be extracted from DEMs, they are generally not included in the website. However, our characterization includes a few factual questions about information that is otherwise difficult to access (e.g., conflicts that may exist with other backcountry user groups, cumulative number of fresh tracks a run can accommodate).

To ensure the framework captures terrain perceptions in the most meaningful and decision-relevant way, the survey utilizes existing terrain terminology (e.g., "jump run") and concepts (e.g., "friendliness") commonly used in the mechanized skiing community, such that they are properly integrated into the questions and response categories. Instead of aiming for a complete characterization that includes every potential benefit and hazard of a run, the objective of our framework is to highlight decision-relevant standout features of runs that distinguish them from others. Hence, classification categories are designed to be informative for guiding instead of following existing scientific definitions. Slope incline, for example, is divided into three basic categories including gentle (typically not steep enough to produce significant avalanches), moderately steep (sufficiently steep to produce significant avalanches under specific conditions), and steep (sufficiently steep to produce significant avalanches under typical conditions).

4. BENEFITS OF FRAMEWORK

Our website allows interested operations and guides to develop concise, but rich ski run descriptions that contain essential information for guiding (Fig. 1). We believe that our approach offers numerous benefits for participating guides, operations, the mechanized skiing industry as a whole, and research.

4.1 Guides and operations

Guiding teams can use our website as a central repository for their operational terrain expertise. Guides who have worked with the website have stated that it provides a unique opportunity to reflect on the skiing terrain of their operation and their personal terrain preferences. The collected information offers a valuable resource for the instruction and mentorship of novice guides, and it provides a platform for the members of a guiding team to compare their perceptions and reconcile any differences that may emerge. This introspection can aid and facilitate deeper learning. Visualizations of the information collected on our website (Fig. 2) and integration with existing operational recordkeeping systems can lead to powerful support tools for operational decision-making.

The information collected on our website is also useful for business and land-management decisions by providing insight on individual runs, such as skier capacity and quality of skiing experience (Fig. 2), as well as more large-scale data on typical terrain-use patterns. This information can help operations better understand and communicate the way specific runs are used and how certain parts of the tenure region are vital to operation under particular circumstances.

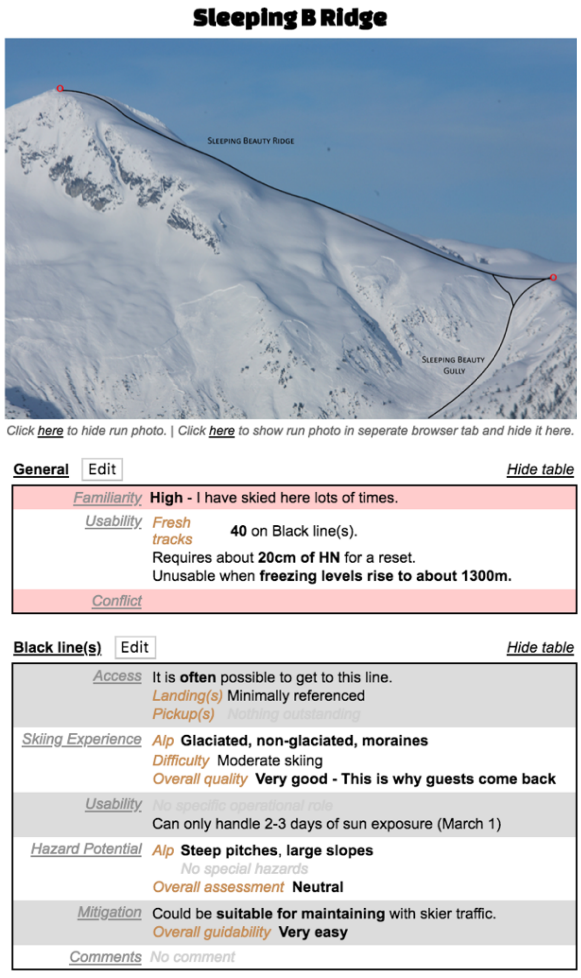

Fig. 1: Screenshot of run photo and run summary generated from survey questions for Sleeping Beauty Ridge (Northern Escape Heli Skiing).

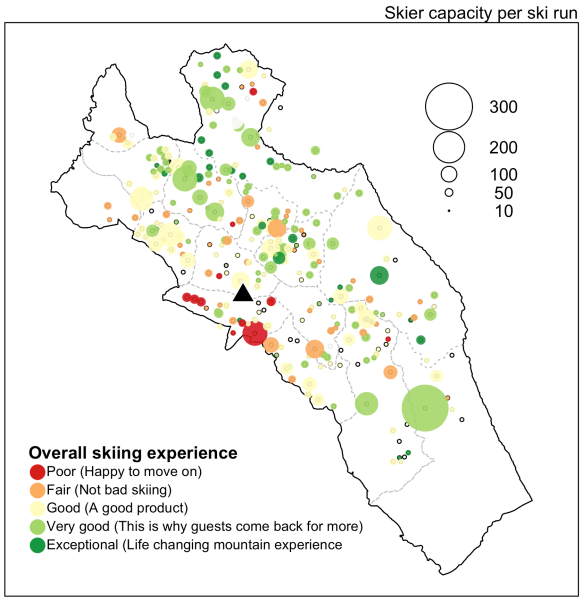

Fig. 2: Skiing experience and skier capacity at individual runs within the CMH Galena tenure region.

4.2 *Mechanized skiing community*

Our critical review of how guides communicate about avalanche terrain has allowed us to draft more formal definitions for the existing terminology and organize it in a structured framework focused on decision-making and backcountry avalanche risk management. Even though the framework does not introduce any new terms to describe the nature of ski runs, having explicit definitions and a more formal framework will enhance the community's ability to effectively communicate information on terrain characteristics and terrain choices. Ongoing efforts by the subscribers of InfoEx—the daily information exchange among avalanche safety operations in Canada (www.avalancheassociation.ca/page/InfoEx)—to find a better way to exchange information on terrain choices clearly highlight this need of the community.

A successful example of a comparable assessment and communication framework that is grounded in operational practice is the Conceptual Model of Avalanche Hazard (CMAH) (Statham et al., 2018). The CMAH provides a formal structure for avalanche hazard assessments and defines the associated terminology. Initially introduced in 2010, the CMAH has been widely adopted in the professional avalanche community in Canada and is an essential part of operational practice and formal avalanche safety training. Similar to the CMAH, the framework presented in this paper aims to provide a structured foundation for describing avalanche terrain in a decision-focused way.

4.3 *Research on risk management*

The present framework has direct benefits for research on avalanche risk management by offering a more comprehensive terrain characterization that goes beyond the inert physical parameters of terrain and the focus on hazard alone. This information is critical for explaining patterns that emerge from revealed terrain preferences in a meaningful matter. An example of applying such a comprehensive terrain characterization is the research by Sterchi and Haegeli (in review), who developed an approach for deriving operation-specific terrain classes from run list ratings. Ultimately, a better understanding of the nuances of skiing terrain is critical for developing evidence-based decision aids for both professional guides and amateur recreationists.

5. CURRENT APPLICATION

To test the framework presented in this paper, we are currently collaborating with two commercial helicopter skiing operations in British Columbia: Northern Escape Helicopters in Terrace, and

Selkirk Tangiers Heli Skiing in Revelstoke. At each operation, we are collecting complete characterizations of a select number of runs from multiple guides with varying backgrounds and experience levels. While the primary objective of this project is to explore the variability in terrain perception within guiding teams, the results will also help to further strengthen the characterization framework.

6. CONCLUSION

We presented a new conceptual framework for describing the key features of backcountry terrain, with a particular focus on use in mechanized skiing areas. The framework formalizes the existing terrain characterization terminology currently used by guides. It comprehensively incorporates the barriers, benefits, and hazard features of terrain in a meaningful way, and it reduces the complexities of terrain description into five categories: access, skiing experience, usability, hazard potential, and mitigation. The resulting information has the potential to aid learning and mentorship in guiding teams, assist operational business management decisions, and consider aspects of the decision-making process that have not yet been targeted in avalanche research.

ACKNOWLEDGEMENT

This study is funded by Mitacs in collaboration with HeliCat Canada. The avalanche research program at Simon Fraser University is supported by Canada's Natural Science and Engineering Research Council (NSERC), CP Rail, HeliCat Canada, the Canadian Avalanche Association, Mike Wiegele Helicopter Skiing, Avalanche Canada and Avalanche Canada Foundation.

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