TOWARD IMPROVED EFFECTIVENESS OF PUBLIC AVALANCHE SAFETY SERVICES: A FRAMEWORK FOR ASKING CONSTRUCTIVE QUESTIONS

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ABSTRACT: Making decisions about how to design, revise, or discontinue public avalanche safety products and programs is not a simple or straightforward task. However, there are currently no systematic approaches supporting these decisions, and existing performance measures (e.g., fatality counts) fall short in helping service providers meaningfully understand what works well, in what circumstances and why, and importantly, how interventions can be improved. Our aim is to contribute to this gap by developing an approach that supports public avalanche safety decision-making in more constructive ways.

In this paper, we share our preliminary findings from a literature review that explored relevant existing approaches and frameworks in other disciplines with similar challenges to ours, including risk governance, public health, natural hazards risk communication, resource and environmental management and policy studies. What emerges is a systems thinking perspective, which prompts a comprehensive and detailed look at the systems' principal components, interactions, and defining characteristics. The resulting characterization of the public avalanche safety system sets the stage for better understanding how the system works and how interventions could be improved. Embedding this systems thinking perspective within a practical planning model like the PRECEDE-PROCEED model from public health has great promise for making informed decisions about how to further improve avalanche safety. This work provides a useful starting point for developing a new approach to intervention planning and evaluation.

KEYWORDS: Risk governance, program development, program evaluation, systems thinking.

1. INDUSTRY NEED

Public avalanche safety agencies, such as avalanche warning services and education providers, are faced with a continuously growing demand for avalanche safety products and services from an increasingly diverse audience. To make meaningful decisions about how to best meet this demand, it is critical for program managers to have a good understanding of which programs and services work well, how they could be improved to be more effective, and what other initiatives may need to be developed to address gaps in existing programming. However, despite the fundamental nature of these questions, assessing the effectiveness of avalanche safety programs in a meaningful way has been challenging.

Tracking fatalities numbers has been a cornerstone of our industry, and insights from accidents have provided critical catalysts and valuable guidance for setting up avalanche safety products and services. In Canada, for example, the 2003 fatal avalanche accident in Connaught Creek that killed seven high school students resulted in the creation of Avalanche Canada, the Avalanche Terrain Exposure Scale, the Avaluator, and other developments that have strongly shaped how avalanche hazard is communicated to the public in Canada (O'Goman et al., 2003; Bhudak Consultants, 2003). However, relying mainly on fatality numbers to drive avalanche safety program decisions has serious limitations.

It is well known that fatal accidents represent only a limited sample of situations in which members of the public make unsafe decisions in the backcountry. Combined with the lack of comprehensive exposure data and the sparse and inconsistent reporting of non-fatal incidents, accident statistics are simply unable to provide a meaningful picture of the existing challenges. Fatal accidents are also "too distant" from individual programs and services to provide directly actionable product-specific guidance in support of prevention. Finally, relying on accident insight also inherently creates a "reactive system" that responds to problems only after they have emerged.

There are other performance measures to gauge the reach and popularity of existing programs and services (e.g., statistics on website traffic, social media engagement or student numbers), and

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there is an emerging body of research explicitly examining the effectiveness of existing products or components thereof (Fisher et al., 2022; McNeil et al., 2023; St. Clair et al., 2021). But this research is not comprehensive enough yet to provide high-level guidance. Hence, managers of avalanche safety agencies are currently mainly left to their own devices for making strategic decisions about what programs to advance, change, or remove.

For these reasons, we believe that the avalanche safety community needs an alternative approach for assessing the effectiveness of public avalanche safety services and supporting programming decisions in more meaningful ways.

2. PROPOSED APPROACH

Luckily, we do not need to reinvent the wheel. We have explored existing concepts and perspectives across other disciplines with similar challenges to ours, including risk governance, public health, natural hazards risk communication, resource and environmental management and policy studies. While these fields have developed conceptual frameworks that provide systematic approaches to program development and evaluation, the uniqueness of the public avalanche safety context prevents their direct application.

The following sections provide a summary of our current thinking. To set the stage, we first describe how the avalanche safety situation is different from other public safety contexts. We then introduce the two main components of our proposed approach to facilitating informed decisions for program development and evaluation: a) planning models from public health as the overarching road maps, and b) a systems approach for meaningfully and comprehensively describing and characterizing the different components of the avalanche safety system and their interactions.

2.1 Public avalanche safety context

The public avalanche safety context has a few unique characteristics that make it distinctly different from public health and other natural hazards management contexts (e.g., earthquakes, landslides, hurricanes).

First, the nature of avalanche hazard is spatially localized at a slope or feature scale, may not be obvious to the observer, and can range from rapid to slow onset (e.g., storm snow versus deep persistent slab instabilities) (Statham et al., 2018).

Additionally, members of the public traveling in the backcountry expose themselves to avalanche hazard voluntarily and often repeatedly given that the activities can be particularly rewarding to physical and mental wellbeing (Lackey et al. 2021; Thomsen et al, 2018). Also, users' exposure patterns can differ based on their frequency of travel, terrain preferences, motivations, and activity type (Neweduk and Haegeli, in prep).

Avalanche risk management is a learned behavior, and the backcountry community varies widely when it comes to their knowledge, skills, and experience, as well as both their need and desire for support with avalanche risk management. Yet, despite repeated exposure, backcountry users seldom receive corrective feedback from the hazard environment in response to their risk management decisions, and social learning often takes precedence.

Finally, service providers are limited in how they can effectively intervene. The backcountry operates as a free choice environment (Falk, 2005), where the responsibility for avalanche risk management rests on the individual. As a result, products and programs require voluntary uptake, and a realistic objective for public avalanche safety interventions is to inform backcountry users' risk management decisions to the extent that it is feasible within the specific context.

2.2 High-level planning models

Various planning models have been developed in public health that structure the process of designing, implementing, and evaluating public health promotion efforts with an evidence-based approach.

A particularly useful, widely used, and easy-to-follow example is the PRECEDE-PROCEED planning model (Crosby and Noar, 2011), which consists of two main phases. The PRECEDE phase provides structured guidance for understanding the factors influencing a health issue, identifying its determinants, and assessing the needs and preferences of the target population. This phase involves assessing social, behavioral, and environmental factors. The PROCEED phase involves planning, implementing, and evaluating interventions based on the insights gained in the PRECEDE phase. It emphasizes designing strategies to address the identified determinants of the health issue. Overall, the PRECEDE-PROCEED model provides a structured approach to designing effective health interventions by considering both the behavioral and environmental factors that influence health outcomes.

While planning models like the PRECEDE-PROCEED provide effective high-level roadmaps for developing programs that are transferable to the avalanche community, the devil is in the detail.

2.3 Systems thinking

To meaningfully apply this model in the avalanche context, we need to be able to describe the avalanche safety system with all its components and relationships in a comprehensive way. This is the foundation for systematically identifying problems and

challenges and meaningfully developing insightful performance measures that can guide development.

Inspired by the ideas of social-ecological systems theory (Bronfenbrenner, 1992), we are taking a systems-based approach to describing and characterizing the avalanche safety system. A systems thinking perspective is a holistic approach that views phenomena as interconnected and interdependent systems, rather than isolated components (Bronfenbrenner, 1992; Cabrera et al., 2008). It examines how an element within a system, be it biological, social, or organizational, interacts and influences other elements. Systems thinking acknowledges that a problem space is multifaceted, complex, and dynamic, and interactions can occur at different levels and scales.

Principal components of the system

The first step in a systems approach is to define and characterize the principal components of the system. In the case of public avalanche safety, the three principal components of the system are:

- Avalanche hazard,
- People/Communities, and
- Services

For each of these three components, we can identify traits that influence how they interact with the other components of the system. While the conceptual model of avalanche hazard (Statham et al., 2018) provides the language for describing the hazard, meaningful characteristics for describing people or communities include activity type, risk propensity, risk perception, motivation, residency and cultural identity. All of these characteristics can give insight into people's attitudes towards avalanche hazard and services. Similarly, relevant characteristics for services and their delivery include capacity, timelines, budgets, jurisdictions, values, and underlying assumptions.

Interactions

In addition to the components themselves, the interactions between them are key for understanding the system. For public avalanche safety, the key interactions are the following relationships between:

- People traveling in the backcountry with avalanche hazard,
- Avalanche hazard and services, and
- Services and people traveling in the backcountry.

Similar to the characterization of the components, we can identify key qualities for each of these interactions or relationships that describe their nature. To meaningfully characterize the interaction of people traveling in the backcountry encountering avalanche hazard, for example, it is important to account for their avalanche risk management experiences, terrain exposure preferences and frequency, and group decision making processes and dynamics (Neweduk and Haegeli, in prep; Zweifel et al., 2016). Similarly, it is important to consider the accuracy, validity, and reliability of the hazard information for describing how a product "interacts" (i.e., represents) the hazard. Finally, there is a set of meaningful descriptors for describing interaction between people and services, which include the product or program's availability, accessibility, inclusivity, relevancy, comprehensibility, and applicability as well as the trust and self-efficacy of the target audience relating to the product (Fisher et al., 2022; Lundgren and McMakin, 2018; St. Clair et al., 2021).

While the above lists of qualities for describing the nature of the principal components and their interactions is not complete, we hope that the examples highlight the capacity of the systems approach to comprehensively characterize the avalanche safety system.

3. APPLICATION EXAMPLE

The practical value of the systems perspective described above is the probing questions it provides for characterizing the interactions between people, avalanche hazard, and services in a systematic, comprehensive but solution-oriented way.

To illustrate the framework in practice, we explain how the systems perspective can inform the development of a new avalanche safety service for entry-level snowshoers. In this case, the framework generates questions, such as:

- How are entry-level snowshoers characterized at a community level (e.g., culture, motivations, risk perception)? (Community component)
- Does the community have a distinguishable exposure pattern, terrain preference, decision-making process, or group dynamic when traveling in the backcountry? (Community-hazard interaction)
- How does the entry-level snowshoer community engage with existing services in their trip planning and field-based decision making? (Community-service-hazard interaction)
- How have service providers engaged with this community in product development and implementation? (Service-community interaction)
- How are the products that entry-level users utilize challenged by avalanche hazard accuracy, validity, and reliability? (Service-community-hazard interaction)

We hope that the snowshoe example provides a first impression of how the systems perspective can be applied in practice starting from a community. However, explorations can also be started from other

components of the system. For example, one might explore the interactions around an existing service, like special public avalanche warnings, and examine if and how it reaches the intended audiences. Another possibility is to start from a particular hazard situation (e.g., deep persistent slab avalanche problems or atmospheric river events) and explore which members of the public interact with the hazard, how existing services are able to capture and communicate the condition, and how the affected members of the public access, understand, and use the provided information.

It is also important to point out that our approach is flexible and scalable since the probing questions are generic and can be applied at various scales. Hence, the framework is equally suited for exploring the effectiveness of an international standard like the avalanche danger scale or a local avalanche awareness event.

4. CONCLUSION

Making decisions about public avalanche safety is not a simple or straightforward task, and existing performance measures (e.g., fatality rates) fall short in helping service providers understand what works well, in what circumstances and why, and, most importantly, how products or programs can be improved. Our aim is to contribute to this gap by developing an approach that supports public avalanche safety decision-making in more constructive ways. To do this, we conducted a review of relevant literature in search of contextualized guidance for organizing a structured approach to decision making.

A foundational element that emerged from public health and resource management and policy research is systems thinking, which prompts a comprehensive look at a systems' principal components, interactions, and key characteristics. While program managers have based strategic decisions and program development on some of the components or characteristics present in the system, having a structured approach that prompts practitioners or researchers to think about all the different components and their interactions will ensure a more holistic approach to planning. Embedding this systems thinking perspective within a practical planning model like the PRECED-PROCEED model from public health has great promise for making informed decisions about how to further improve avalanche safety. Importantly, this approach does not have to be cumbersome. Regardless of the scope of the intervention, the framework provides a useful perspective and starting point due to the universality and scalability embedded in the system.

Further developing and testing this approach is a critical first step. We invite the community to engage with us as we look to develop case studies and move forward with this work.

ACKNOWLEDGEMENT

We are grateful to the Coast Salish peoples on whose traditional and unceded territories Simon Fraser University and our research program resides.

We would like to extend our gratitude to all members of the SFU Avalanche Research Program as well as Kelly McNeil and many other academic and practitioner colleagues who have constructively contributed to our thinking on risk governance approaches for public avalanche safety.

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