

***Funding the Forecast: Comparing Approaches to
Avalanche Risk Management***

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Abstract

Winter backcountry recreation has grown dramatically in recent years. Despite this surge, annual avalanche fatalities in the US have remained stable for the last three decades. This juxtaposing trend is largely attributed to avalanche safety programs. The structure and stability of these programs directly shape their performance and effectiveness; structure encompasses operational architecture (staffing, governance, partner networks, and service dissemination), while stability refers to the financial mechanisms sustaining operations. When funding is unreliable, operations follow: staff positions go unfilled, forecast coverage shrinks, and public risk communication erodes, undermining a program's ability to reduce avalanche fatalities. Understanding how US avalanche programs are structured and funded, and how those models compare with peer countries, helps identify which models best support durable, effective public safety services.

This study is a comparative policy analysis examining avalanche programs in the US and peer countries across North America, Europe, and New Zealand. Using a literature review, expert informant surveys, semi-formal interviews, and comparative analysis of 12 programs across seven countries, the study evaluates differing organizational approaches to identify policy recommendations that could improve the long-term efficacy and stability of US avalanche programs.

Findings indicate that organizational structure explains how a program is funded and staffed, but does not reliably predict its effectiveness or funding stability. Instead, whether funding is legally protected—through legislated mandates or multi-year contracts—is the stronger predictor of program durability. Based on these and additional findings, this research recommends standardizing multi-year funding mechanisms, strengthening cohesion among US avalanche centers, preserving existing nonprofit partnerships, and adopting reach-based metrics alongside fatality data to more fully capture and translate program impact.

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Executive Summary

Introduction & Background

The February 2026 California avalanche that killed nine backcountry skiers was the deadliest avalanche in the country since the 1980s (Fuller & Cowan, 2026) and a stark reminder of the fatal risk avalanches pose. This tragic accident brought to light the importance of avalanche safety and warning efforts across the United States (US), placing US avalanche forecasting centers in the public eye at a time when nationwide winter backcountry recreation is at its peak (Valle et al., 2022; SIA, 2025). Despite significant growth in backcountry recreation, annual avalanche fatalities in the US have remained relatively stable over the last three decades, indicating that individual avalanche risks have been reduced (Birkeland et al., 2017). These juxtaposing trends do not exist in a vacuum; they span countries and continents (Dahl et al., 2026; Berlin et al., 2019; Neweduk & Haegeli, 2025), and this global pattern of avalanche risk reduction can be attributed to avalanche safety programs.

These programs reduce the risk of fatalities primarily through two mechanisms: forecasting services and educational programming (Greene et al., 2022; Fisher et al., 2021; McNeil et al., 2023). Because avalanche programs operate across a broad spectrum—from community-based nonprofits to national agencies—and each has developed in response to distinct geographic, institutional, and funding contexts, their structures and outputs vary considerably.

Most existing avalanche safety-focused studies concentrate on reducing public risk through improvements in forecasting techniques or educational programs (Greene et al., 2022; Hill, Wiesinger & Abromeit, 2004). However, one can surmise that the structure and stability of avalanche programs directly affect their performance and effectiveness in reducing risk. Structure encompasses a program's operational architecture, including staffing, governance, partner networks, and the dissemination of safety services. Stability refers to the financial mechanisms sustaining these operations. When funding is unreliable, operations follow: staff positions go unfilled, forecast coverage shrinks, and public risk communication erodes, ultimately undermining a program's ability to reduce the risk of avalanche fatalities.

The US has 29 distinct avalanche forecasting programs, which are largely decentralized and have a range of funding structures, including state-funded, fully nonprofit, and public-private partnerships supported in part by the US Forest Service and in part by a 'friends of' nonprofit group (NAC, 2025). In other countries, such as Canada and Switzerland, avalanche programs are much more centralized, clustered around one or two organizations, and predominantly funded by federal governments (Avalanche Canada, n.d.; Parks Canada, 2026; SLF, n.d.). Considering recent US Forest Service (USFS) budget cuts (USDA, 2025) and major organizational restructuring (USDA, 2026), US avalanche programs—half of which receive some funding from

the USFS—are in a precarious position. Would further centralization of the 29 programs under an entity such as the USFS provide increased funding, stability, and effectiveness, or does the current model allow greater freedom in funding streams and operational flexibility?

Understanding the structure and funding of US avalanche programs and how these designs compare with those of peer countries therefore helps identify which models best support durable, effective safety services. Thus, this study's comparative analysis examines avalanche programs across North America, Europe, and New Zealand to understand how program funding and organizational models differ among and within countries. What organizational traits relate to the financial stability, forecast consistency, and long-term durability of avalanche safety programs? Exploring these countries' differing organizational approaches will identify novel policy options that could improve the long-term efficacy and resilience of US avalanche forecasting services.

Methodology

This is a cross-sectional, comparative case study that integrates qualitative social science data with select quantitative elements to identify trends in how structural and funding models shape the stability and efficacy of avalanche safety programs. A case study approach allows for in-depth, multifaceted exploration of highly complex phenomena, which fits well for avalanche programs, as they vary widely in operational contexts and are inherently complex.

I collected data from 12 expert informants representing seven different countries' avalanche programs through in-depth surveys and semi-formal interviews. The study is led by surveys designed to elicit rich program descriptions through a combination of quantitative and open-ended qualitative questions. Interviews strengthened the design by providing data triangulation. Avalanche safety programs and affiliated expert informants from those programs were selected through purposive sampling to identify information-rich cases.

To represent each organizational type of avalanche center in the US, I selected one of each main type of center: the USFS-run national agency (NAC); a larger-scale public-private partnership with a closely integrated nonprofit arm and a USFS arm (NWAC); a smaller-scale public-private partnership with a distinct nonprofit 'friends of' group and USFS team (SAC); a fully state-run organization (CAIC); and a fully nonprofit-run organization (HPAC). In Canada, I studied the two primary existing programs—Avalanche Canada and Parks Canada—as these organizations represent a highly centralized model. Outside North America, I looked at a range of newly formed programs, such as NVE's Varsom program in Norway (established in 2013), and well-established programs, such as Switzerland's SLF program (responsible for avalanche warnings since 1945) (Varsom, n.d.; SLF, n.d.). I also selected this set of programs because they vary widely in structure and funding: Austria's program focuses on regional services; France's program operates as part of the country's national weather service; New Zealand's program has an advisory branch and a national nonprofit branch.

Overview of Findings

Six major themes were prominent in participants' responses: four related to program funding, one related to trade-offs in organizational structure, and another related to useful metrics to reflect program efficacy.

Themes

Theme 1: Organizational structure predicts trade-offs, not outcomes (see Table A)

Theme 2: Avalanche risk is funded as 'voluntary' recreational risk

Theme 3: Funding certainty, not amount, drives program stability (see Table B)

Theme 4: Funding concentration predicts funding concerns (see Table C, Figure A)

Theme 5: There are 3 key improvements programs would make if resources allowed

Improvement 1: Guaranteed, Multi-Year Funding Consistent Across Longer Time Spans

Improvement 2: Dedicated Non-Forecasting Staff

Improvement 3: Investment in Technical Improvements to Keep Up with Demand

Sub-Theme: Programs Stress the Importance of Collaboration with Other Countries

Theme 6: Reach is a compelling metric for measuring program efficacy

Across the 12 programs, organizational structure (federal, state, nonprofit, or hybrid public-private) explains how a program is funded and staffed but does not reliably predict its effectiveness or the stability of its funding. Program structure is not black and white; even more centralized national systems have multiple forecasting programs, varied funding across the country, and some operations housed within a broader agency. Annual budgets range from \$220,000 to over \$4 million, a spread that relates more closely with a country's size and population than with its organizational structure.

What does predict stability is whether funding is legally protected. Programs with a legislated mandate or multi-year funding contract reported more confidence in their financial futures than those relying on annual fundraising. Federal and state program types are funded almost entirely (80-100%) by government appropriations and endowments, giving them a consistent but sometimes politically exposed base. Nonprofit and hybrid programs procure funding from a fragmented mix of sources, including individual donations, corporate sponsorships, and foundation grants, which diversifies revenue but makes any given year harder to predict.

Effectiveness is more difficult to tie to any funding pattern, largely because avalanche fatality counts—a widely used efficacy metric—scale with population and terrain exposure rather than program quality. A program reporting lower fatalities may simply serve a user base that is less exposed to avalanche terrain and dangers. Reach-based metrics, such as a program's education course participants or a program's unique website users, emerged as a compelling proxy for program effort and public impact; one that is underused in funding conversations and advocacy efforts.

Table A: Trade-Offs for Each Avalanche Program

Program	Country	Label	Pros	Cons
Federal/ national agency				
Parks Canada	Canada	CAN 2	Legislated authority to manage land; stable, protected funding	Bureaucracy/ red tape; inability to be nimble; subject to changing federal politics/ priorities
National Avalanche Center	United States	USA 3	Tripod of experts; hub supporting regional centers	Bureaucracy; overburdened staff; interagency resource competition
Federal/ national agency + academic/ research institution				
Météo-France	France	FRA	Strong weather forecasting; dense data foundation	Coordinating 7 regions is hard; isolation effects; long staff shifts
WSL Institute for Snow & Avalanche Research	Switzerland	CHE	National consistency; strong regional/local network; proximity to research institute	Development resources compete with operational needs
State/ provincial agency				
Avalanche Warning Service Tyrol	Austria	AUT	Clear, legally defined mandate from provinces	Budget cuts (mismanagement during COVID-19 crisis)
Norwegian Water Resources & Energy Directorate	Norway	NOR	High quality/efficiency; full national coverage	Uncertain about having sufficient future funding, observations, and IT support
Colorado Avalanche Information Center	United States	USA 1	Efficient resource use; single govt group covers large area	Insufficient resources for forecast area's size and threat variability
Nonprofit organization				
Avalanche Canada	Canada	CAN 1	Centralization = cost savings, unified tech, easier govt relations, clear recognition as major avy program in country	Public perceives as govt entity (hurts donations); users recreate outside forecast zones; hard to be competitive with wages
Mountain Safety Council	New Zealand	NZL	Flexibility, adaptability, agility; evidence-based institution	Lack of qualified forecasters in rural regions; lack of data
Hatcher Pass Avalanche Center	United States	USA 2	Agile/ adaptable; sets own forecasting schedule/ staffing structure to meet local needs	100% dependent on charitable giving/ grants; hurts wages, retention, and growth
Hybrid: public-private partnership				
Northwest Avalanche Center	United States	USA 4	50-year USFS history; umbrella protection of federal workers issuing forecasts	USFS restructuring and funding shortfalls; federal govt chaos
Sawtooth Avalanche Center	United States	USA 5	Friends group offers flexibility; advocacy; more nimbleness in tech and purchasing than govt	Chaotic govt leadership; low awareness/ understanding of program structure; staff turnover

Table B: Comparison of Efficacy, Staffing, and Funding Stability Among Programs

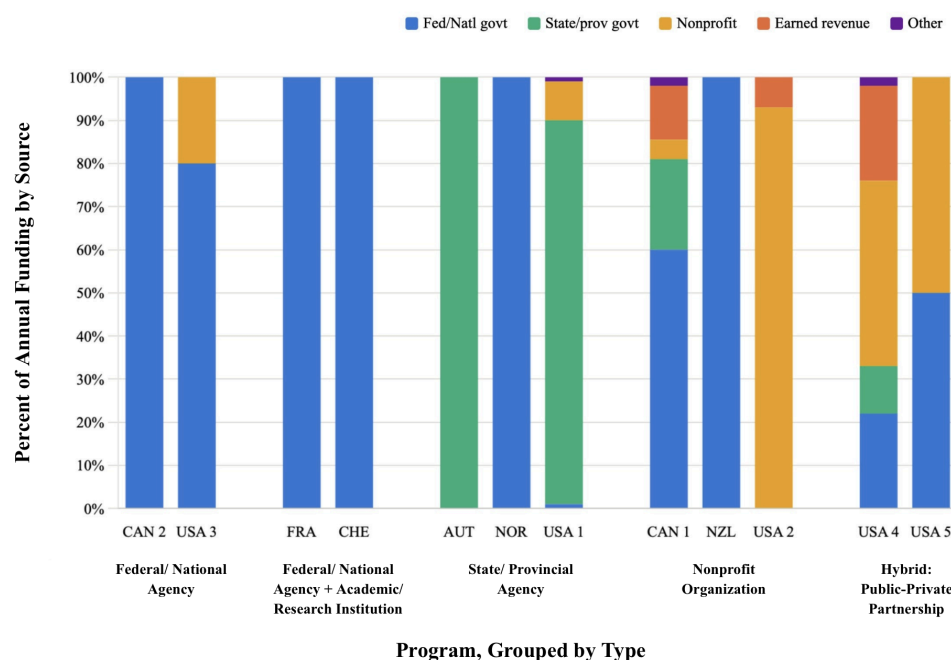
					Spread of Annual Revenue Sources				
Label	How effective is your org in reducing avalanche risk	Are staffing levels sufficient	How stable does funding feel over next 5-10 years	Total Annual Budget (USD)	Fed/ Natl Govt	State/ Prov Govt	Non-profit	Earned Rev	Other
Federal/ national agency									
CAN 2	Very effective	Yes	Very stable	Not available ¹	100%				
USA 3	Very effective	No	At risk	\$450,000	80%		20%		
Federal/ national agency + academic/ research institution									
FRA	Somewhat ineffective	Yes	Very stable	\$3,421,000	100%				
CHE	Unanswered	Somewhat	Very stable	Not available ²	100%				
State/ provincial agency									
AUT	Very effective	No	Somewhat stable	\$912,000		100%			
NOR	Very effective	No	Somewhat stable	\$3,060,000	100%				
USA 1	Very effective	No	Somewhat stable	\$3,700,000	1%	89%	9%		1%
Nonprofit organization									
CAN 1	Very effective	No	Uncertain	\$4,095,000	60%	21%	4.5%	12.5%	2%
NZL	Very effective	Yes	Somewhat stable	\$461,000	100%				
USA 2	Very effective	Yes	Somewhat stable	\$220,000			93%	7%	
Hybrid: public-private partnership									
USA 4	Somewhat effective	No	Uncertain	\$2,500,000	22%	11%	43%	22%	2%
USA 5	Somewhat effective	Somewhat	Somewhat stable	\$640,000	50%		50%		

¹ The budget for the avalanche program within Parks Canada was not available due to the complexity of the organization's large, multi-jurisdictional operations.

² The budget for the avalanche program at SLF was not disclosed by the participant.

Table C: Primary Funding Concerns by Organizations' Primary Funding Source

Primary Funding Source	Program	Primary Funding Concern
Federal/ national government	CAN 1	No guarantee of large government grants being renewed
	CAN 2	Not well financed for capital projects or growth; difficult to innovate
	USA 3	Erratic government environment
	FRA	None besides possible budget cuts to training, communication tools
	CHE	Federal cost-cutting measures
	NOR	Global military, political, and economic situation/ uncertainty; being prioritized in government budget will become harder
	NZL	None at this time; funding recently increased, locked in for 3 years
State/ provincial government	AUT	Keeping forecasters on staff; budget cuts on further development of digital tools
	USA 1	Severance Tax and Colorado Department of Transportation funding based on state budget fluctuations
Nonprofit	USA 2	Effect of increasing cost of living on charitable giving; state/ local government deficits affect grant availability
	USA 4	USFS budget and staffing cuts/ lack of support; macroeconomic headwinds impacting individual/ foundation giving
50/50 Split: Federal/ national government <i>and</i> nonprofit	USA 5	Uncertainty with federal appropriations/ budgets; nonprofit fundraising program vulnerable to economic downturn

**Figure A: Funding Sources by Program**

Recommendations

The recommendations detailed below aim to improve US avalanche safety programs. Through this research project, I sought to compare the structure and funding of US avalanche programs with those of peer countries, with the aim of identifying policy options to improve the long-term efficacy and resilience of US avalanche forecasting services. These options are outlined in the recommendations below.

Recommendation 1 - Standardize Multi-Year Funding Across the US

US avalanche safety programs should band together to pursue a three- to five- year legislated or contractually guaranteed funding stream (modeled on France/ Switzerland/ Parks Canada counterparts). They should do so through a reliable mechanism, but it is unclear whether that should be through a government entity such as the US Forest Service (USFS) or National Weather Service (NWS), or whether some form of private sector funding should facilitate this. A large percentage of funding should come from government sources due to 1) the high percentage of government ownership of backcountry lands in the US; 2) overlap in equipment, technology infrastructure, and staff that contribute to avalanche forecasts; 3) the usually greater stability that government funding represents in other countries; and 4) such forecasting and education centers should be seen as part of a general public good that governments should provide.

State governments could contribute funding through Departments of Transportation and/or Natural Resources, state park passes or other outdoor recreation pass revenue, or extraction or resource taxes. The federal government could contribute legislatively mandated funding through mechanisms such as the SHRED (Ski Hill Resources for Economic Development) Act, a proposed Bill with bipartisan support that could invest in public safety by enabling avalanche centers to retain a portion of the annual fees paid by ski areas operating within National Forest boundaries. As proposed in H.R. 1084, the SHRED Act would establish a Ski Area Free Retention Account to retain fees that ski areas pay to the Forest Service, using those fees to support a variety of recreation management and community needs, including avalanche information and education.

This recommendation is complex and requires additional research to understand which funding mechanisms and sources are most feasible and sustainable. The exact mix of funding is variable across US avalanche centers. Still, a coordinated effort to gain clarity and commitment to fund these centers over multi-year cycles is an important next step.

Recommendation 2 - Create Cohesion Among All US Avalanche Centers

In addition to the first recommendation, the National Avalanche Center (NAC) should continue as the central hub for the 14 US Forest Service-funded avalanche programs, but should also endeavor to encompass and lead all 29 US avalanche programs. While the NAC does not have an official mandate to serve avalanche centers not on Forest Service lands (as the organization is

housed under the USFS), it does provide support—particularly through the management of its centralized software system, the Avalanche Forecasting Platform (AFP), and its collaboration with the American Avalanche Association (A3)—to centralize the dissemination of avalanche information across all types of US avalanche centers. Due to limited funding, limited staffing, and chaos caused by recent USFS restructuring, the NAC is currently limited in its ability to support all 29 centers. The NAC should serve as a body that consolidates resources, facilitates collaboration, and advances US avalanche forecasting and safety services. However, further research is required to determine whether the NAC would be better suited as a federal entity under the USDA/ USFS (where the program currently resides), affiliated with a different governmental agency (such as the NWS), or operating as a nonprofit (501c3) entity funded by federal appropriations.

Recommendation 3 - Do Not Dissolve Existing Nonprofit Organizations

Existing nonprofit arms of avalanche programs in the US should remain intact to enable flexible advocacy efforts, community outreach, and additional fundraising to support technological and forecasting advancements. That said, avalanche programs should not have to rely on these nonprofits to remain operational (refer to Recommendation 1). To mitigate the sheer number of avalanche programs and affiliated nonprofits in the country, I do not recommend that centers currently without a nonprofit arm spend time and effort creating one.

Recommendation 4 - Adopt Reach-Based Metrics to Showcase Efficacy

US programs should adopt reach-based metrics (education participants, unique website users) alongside—not instead of—fatality data in program evaluations and advocacy efforts, given the consensus that fatalities alone underrepresent program effectiveness. Reach is a distinct metric that programs should utilize more frequently to explain the breadth of public safety work they conduct. Because it is difficult to support any single metric as a clear proxy for program effectiveness, there is a need to expand these metrics and demonstrate program effectiveness through a robust government review (similar to reviews conducted in Canada and New Zealand, as referenced in the Literature Review). Programs should also adopt reach-based metrics to showcase the amount of public infrastructure they help safeguard. Providing avalanche forecasts and other crucial weather data for transportation corridors, such as highways and mountain passes, reaches vast numbers of people and goes far beyond protecting backcountry recreationists.

Recommendation 5 - Collaborate on Public Communication & Advocacy

US programs should combine Recommendations 2 and 4 to strengthen inter-country collaboration when it comes to providing a compelling story to funders. By pooling resources and speaking with one voice, rather than many disparate ones, avalanche centers can maintain funding streams essential to their mission.

Chapter 1: Introduction

The February 2026 California avalanche that killed nine backcountry skiers was the deadliest avalanche in the country since the 1980s (Fuller & Cowan, 2026) and a stark reminder of the fatal risk avalanches pose. This historic accident brought to light the importance of avalanche safety and warning efforts across the United States (US), placing US avalanche forecasting centers in the public eye at a time when nationwide winter backcountry recreation is at its peak (Valle et al., 2022; SIA, 2025). Despite significant growth in backcountry recreation and notwithstanding this tragic accident, annual avalanche fatalities in the US have remained relatively stable over the last three decades, indicating that individual avalanche risks have been reduced (Birkeland et al., 2017). These juxtaposing trends do not exist in a vacuum; they span countries and continents (Dahl et al., 2026; Berlin et al., 2019; Neweduk & Haegeli, 2025), and this global pattern of avalanche risk reduction can be attributed to avalanche safety programs.

These programs reduce the risk of fatalities primarily through two mechanisms: forecasting services and educational programming (Greene et al., 2022; Fisher et al., 2021; McNeil et al., 2023). Beyond fatality reduction, these programs serve a broad array of public safety functions, including disseminating real-time hazard updates and avalanche warnings across transportation corridors and mountain ranges; supporting search and rescue operations; building community-level risk literacy; and improving scientific methods and technology to more accurately predict avalanche danger (Dahl et al., 2026; St. Clair & Haegeli, 2023). Because avalanche programs operate across a broad spectrum of scales—from community-based nonprofit organizations to national agencies—and each has developed in response to distinct geographic, institutional, and funding contexts, their structures and outputs vary considerably.

Given this complexity, questions about the efficacy of the avalanche safety program are not easy to answer. Reduced or stabilized avalanche fatalities offer one indicator of success, but this metric alone does not capture the full scope of what these programs provide to the general public (St. Clair & Haegeli, 2023). Limited literature exists on avalanche programs' efficacy in bolstering public safety (Dahl et al., 2026; St. Clair & Haegeli, 2023), and just a few select government agencies have conducted formal reviews on the impact of their national programs (Public Safety Canada, 2024; Norwegian Water Resources and Energy Directorate, 2014; New Zealand Search and Rescue Council, 2014). Overall, assessing and quantifying how much 'safety' a program provides is quite difficult and nuanced. Isolating program impact from confounding factors, such as changes in backcountry recreation and participation or weather patterns, makes causal attribution challenging.

Most existing avalanche safety-focused studies concentrate on reducing public risk through improvements in forecasting techniques or educational programs (Greene, Hendrikx & Johnson, 2022; Hill, Wiesinger & Abromeit, 2004). However, one can surmise that the structure and stability of avalanche programs directly affect their performance and effectiveness in reducing risk. Structure encompasses a program's operational architecture, including staffing, governance, partner networks, and the dissemination of safety services. Stability refers to the financial mechanisms sustaining these operations. When funding is unreliable, operations follow: staff positions go unfilled, forecast coverage shrinks, and public risk communication erodes, ultimately undermining a program's ability to reduce the risk of avalanche fatalities.

The US has an array of 29 distinct avalanche forecasting programs, which are largely decentralized and have a range of funding structures, including state government-funded, fully nonprofit, and public-private partnerships supported in part by the US Forest Service and in part

by a ‘friends of’ nonprofit group (National Avalanche Center, 2025). In many other countries, such as Canada and Switzerland, avalanche programs are much more centralized, clustered around one or two main organizations, and predominantly funded by their respective federal governments (Avalanche Canada, n.d.; Parks Canada, 2026; SLF, n.d.). France’s avalanche program takes this a step further, as it is housed within the national meteorological service, Météo-France (Dufour et al., 2024). In Austria and Norway, avalanche programs are run by provincial agencies, less centralized than Canada and Switzerland, but not as decentralized as the US model (Kriz, 2018; Varsom, n.d.). Considering recent US Forest Service (USFS) budget cuts (USDA, 2025) and major organizational restructuring (USDA, 2026), US avalanche programs—half of which receive some funding from the USFS—are in a precarious position. Would further centralization of the 29 programs under an entity such as the USFS provide increased funding, stability, and effectiveness, or does the current model allow greater freedom in funding streams and operational flexibility?

Understanding the structure and funding of US avalanche programs and how these designs compare with those of peer countries is essential for identifying which models best support durable, effective safety services. Without this comparative framework, policymakers and avalanche professionals lack the evidence needed to strengthen programs that bolster public safety. Therefore, this study’s comparative policy analysis examines avalanche programs in the US and peer countries across North America, Europe, and New Zealand to understand how program funding and organizational models differ among and within countries. What organizational traits relate to the financial stability, service consistency, and long-term durability of avalanche safety programs? Exploring these differing organizational approaches will yield recommendations to improve the efficacy and resilience of US avalanche programs.

Chapter 2: Literature Review & Background

2.1: Definitions

Term	Definition
Avalanche Safety Program	field and community-based programs that reduce public avalanche risk (National Avalanche Center [NAC], 2025)
Avalanche Terrain	anywhere an avalanche can start, run, or stop (Montana State University, 2024)
Backcountry	mountainous areas where the avalanche danger is not managed or reduced as it would be at a ski area or on a highway (Northwest Avalanche Center [NWAC], n.d.)

2.2: Backcountry Recreation Levels: Growth & Popularity

Those seeking nature-based wintertime activities, such as ski and snowboard touring, snowshoeing, ice climbing, snowmobiling, and mountaineering, often recreate in backcountry terrain. While “backcountry” has multiple nuanced definitions, for the purposes of this research, the term refers to mountainous terrain that, unlike ski resort terrain, is not patrolled for hazards (NWAC, n.d.). Over the last decade, winter backcountry recreation across the US has surged in popularity (Valle et al., 2022). The COVID-19 pandemic played a significant role in this growth, pushing many individuals outdoors and leading to ski resort closures, which subsequently prompted recreationists to shift from in-bounds skiing and snowboarding to backcountry recreation (Valle et al., 2022). Backcountry use numbers are unknown nationwide, but outdoor market surveys can provide some insight.

The Snowsports Industries of America (SIA) nationwide 2024-25 participation study found that 4.9 million people participated in snowshoeing, 2.5 million people participated in

alpine touring (also called backcountry skiing), and 2.2 million people participated in snowboard touring (also called splitboarding) during the 2024-25 winter (SIA, 2025). Alpine touring participation alone grew by 96.3% between winter 2020-21 and 2021-22.³ In addition, the US Bureau of Economic Analysis (BEA) data show that outdoor recreation accounted for 2.4% of the nation's current-dollar GDP in 2024 (696.7 billion USD) and 3.2% of US employment in 2024 (5.2 million jobs) (BEA, 2026).

Despite the growing popularity and numerous physical and mental health benefits of these activities, winter recreation in mountainous backcountry regions carries the inherent risk of being caught in an avalanche (Neweduk & Haegeli, 2025). Recreating in avalanche terrain can be fatal, and data on avalanche fatalities in the US dating back to the 1950s demonstrates that periods of increased winter backcountry engagement are associated with higher avalanche fatality rates (Birkeland et al., 2017). Avalanche fatalities increased sharply during the 1970s, when backcountry recreation increased notably (Birkeland et al., 2017).

According to the US Forest Service (USFS), recreation in designated US wilderness areas expanded rapidly in the 1960s and 70s, with visitor use increasing 15-fold between the late 1940s and 1972 (Lucas & Stankey, 1987). Historians note that the growth in backcountry recreational use coincided with several factors, including technological advancements in gear, improved training courses, and increased cultural interest (LeSourd, 2018). This outdoor recreation boom from the 1960s into the 1970s coincided with a drastic increase in avalanche deaths across the US; from 53 fatalities between 1960 and 1969 (an average of 5.3 deaths per year) to a staggering 120 fatalities between 1970 and 1979 (an average of 12 deaths per year) (Colorado Avalanche Information Center [CAIC], 2025). This dangerous period in US avalanche history led to the

³ The SIA (2025) study is not a random survey of all snowsports participants; it is a report based on nationwide data from individuals who attend snowsports expos or receive communications from SIA.

development of the first US avalanche centers in Colorado, Washington, and Utah in the 1970s (Birkeland et al., 2017).

Avalanche fatalities in the US continued to grow to a total of 220 in the 1990s (an average of 22 per year), leveling out to 256 fatalities in the 2010s (an average of 25.6 per year) (CAIC, 2025). Despite exponential growth in backcountry recreation, the number of avalanche fatalities in the US has remained stable over the last three decades (averaging 25 to 30 deaths per year since the 1990s, representing a lower per capita risk), largely due to avalanche warning and safety services (Birkeland et al., 2017). Recently, avalanche risks have been painfully brought into public awareness; nine skiers died in an avalanche in the mountains near Lake Tahoe on February 17, 2026, marking the deadliest avalanche accident in the US since 1981 (Fuller & Cowan, 2026). This accident drew national media attention, sparking widespread awareness of avalanche danger and conversations about the utility of avalanche warning services (Sierra Avalanche Center, 2026).

2.3: Avalanche Fatalities Contextualized Across the Globe

The concern around avalanche danger is not isolated to the US; countries across Europe and North America are also experiencing a rise in winter tourism and outdoor recreation, with recreationists venturing into mountainous terrain exposed to avalanche hazards (Dahl et al., 2026). A recent study reported that over 100 people across Europe and 40 across North America die in avalanches each year (Dahl et al., 2026). Population-wide surveys in Switzerland show that engagement in backcountry winter activities has more than doubled over the last 15 years (Neweduk & Haegeli, 2025). Even so, Switzerland's avalanche fatalities remain relatively low for the 2025-26 winter, with 18 fatalities in total between October 2025 and April 2026 (SLF,

2026). This number aligns with Swiss avalanche fatality trends over the last three decades: approximately 20 people die each year in avalanches across Switzerland (Berlin et al., 2019).

The Swiss Federal Institute for Snow and Avalanche Research (SLF) began collecting data on avalanche accidents in Switzerland in 1936 (Bettzieche, 2026). However, the winter of 1950-51, dubbed the “Winter of Terror,” marked the turning point that redefined the country’s commitment to protecting its alpine population from snow-related hazards (Bettzieche, 2026). The Winter of Terror saw over 1,000 avalanches kill 98 people, bury 234 people, kill 235 head of livestock, and destroy 1,500 buildings, with financial losses in the hundreds of millions of Swiss francs (adjusted for current inflation) (Bettzieche, 2026). This historic winter prompted investment by the Swiss federal government, increasing research and financial support for avalanche safety measures by the Swiss Meteorological Office and providing subsidies for avalanche protection through the Swiss Federal Institute for Forest, Snow, and Landscape Research (SLF, n.d.).

Similarly, Avalanche Canada emerged in 2004 in response to the winter of 2002-03, during which 29 people died in avalanches, including seven high schoolers (St. Clair & Haegeli, 2023). Avalanches kill more people in Canada annually than all other natural hazards combined (Public Safety Canada, 2024). Michel Trudeau, son of former Canadian Prime Minister Pierre Trudeau and brother of former Canadian Prime Minister Justin Trudeau, notably lost his life in an avalanche in 1998 (CBC News, 2018). Upon Michel’s passing, the Trudeau family played a significant role in advocating for avalanche safety across the country (CBC News, 2018).

Avalanche Canada faced considerable budget constraints in the 2010s as more Canadians explored the backcountry and the demand for services grew exponentially (CBC News, 2018). To support Avalanche Canada’s long-term sustainability and service expansion, the Government

of Canada announced a one-time endowment of 25 million CAD in its 2018 Fall Economic Statement (Public Safety Canada, 2024). Public Safety Canada allocated the endowment through a grant agreement with the Avalanche Canada Foundation to ensure the organization could “provide services to all areas at high-risk for avalanches across Canada” (Public Safety Canada, 2024).

The US, Switzerland, and Canada demonstrate that concern for avalanche risk is widespread and that support for avalanche safety programs amasses during periods of heightened backcountry use and increased avalanche fatalities. These countries also demonstrate that, despite recent spikes in backcountry use, avalanche fatality trends have been proportionally lower, presumably due to the efficacy of avalanche centers in educating and warning backcountry users about immediate threats (Birkeland et al., 2017).

2.4: How Avalanche Safety Programs Contribute to Risk Reduction

Countries around the world have dedicated avalanche safety programs that exist to reduce fatalities and other harmful impacts from avalanches. A vast number and variety of these programs exist, each with different strategies to help reduce risk for recreationists, travelers, and professionals who interact with avalanche terrain. These programs reduce risk through two primary mechanisms: forecasting services and education programming. The design of avalanche forecasts, bulletins, and warning services differs by country, but most programs present information in a structure known as the “information pyramid” (Fisher et al., 2021). The top of the pyramid describes the overall avalanche conditions; the next level provides more detailed information on the nature of the avalanche hazard; and the bottom level provides detailed overviews of existing weather conditions, relevant snowpack structures, and observations of

avalanche activity (Fisher et al., 2021). These avalanche forecasting services are the primary product of avalanche safety programs, synthesizing complex data to inform decision-making and reduce risk for those entering avalanche terrain (Fisher et al., 2021).

Education programs are another main avenue for avalanche safety programs to reduce risk in their respective communities. These programs vary by user type (snowmobiler, skier, snowboarder, snowshoer, climber), level of training (beginner, novice, professional), and format (online course, in-person workshop, multi-day exploration on the snow). Courses aimed at recreational travelers are the primary means of increasing knowledge of avalanche hazards and promoting safe backcountry behavior (McNeil et al., 2023). McNeil et al. (2023) found that participants in Recreational Level 1 Avalanche courses in the US reported an increase in perceived frequency of behaviors associated with safer winter backcountry travel after completing their courses. Greene et al. (2022) noted that many avalanche education courses are short intervention programs that disseminate knowledge, helping participants learn to interpret relevant avalanche information and make better choices in avalanche terrain. Greene et al. (2022) found positive effects on participants' risk perception, confidence, and decision-making regarding winter backcountry travel after completing an avalanche education course in Montana. Further research is needed to examine the extent to which these courses shape risk-taking propensity. However, an evaluation of educational programs is outside the scope of this study.

2.5: Difficulties Evaluating the Efficacy of Avalanche Safety Programs

It is unclear how differences in organization and funding may affect the effectiveness of avalanche safety programs. Some literature exists on cross-border exchange programs for avalanche forecasters, but it focuses on forecasting knowledge and techniques rather than on

organizational structures (Hill, Wiesinger & Abromeit, 2004). Frankenfield (1994) synthesized budgets from the Colorado, Northwest, Southwest Montana, and Utah avalanche centers in the mid-1990s to examine whether programs should diversify their funding sources and reduce their reliance on federal funding. The question of avalanche program structure and funding efficacy has been debated for decades but has received little formal analysis or comparison with peer countries.

This research gap is in part due to a lack of concrete metrics demonstrating the efficacy of avalanche programs in improving public safety. Dahl et al. (2026) explain how the combination of complex decision-making, a lack of regulations governing backcountry use, and activities with difficult-to-quantify risks hinders policymakers' ability to manage human safety in winter mountain recreation. Beyond fatality reduction, avalanche programs achieve success in reducing avalanche risk through perhaps less obvious ways, including delivering education and outreach programming, distributing mountain weather and snowpack data, providing field observations to the public and professional partners, and communicating real-time hazard warnings for both recreationists and those traveling through transportation corridors that traverse avalanche terrain (Dahl et al., 2026; St. Clair & Haegeli, 2023). Still, the avalanche safety community tends to focus on fatalities to communicate impact, even though fatalities constitute only a small subset of avalanche-related incidents. Accident statistics cannot serve as a complete measure of program success (St. Clair & Haegeli, 2023).

Understanding what success looks like for these avalanche programs requires first understanding the nature of avalanche risk itself—how that risk is measured, who bears it, and what it costs the public. Quantifying the risk of winter backcountry recreation is challenging, and avalanche safety professionals still lack standardized terminology to discuss risk consistently

across programs. Dahl et al. (2026) propose using micromorts—a one-in-a-million chance of sudden death—as a standardized measure of risk that shifts the conversation away from fatality counts toward a metric that accounts for exposure to the risk of dying in an avalanche. Data from Norway estimates the risk of backcountry recreation at approximately 11.6 micromorts, which exceeds the risk of driving 1,000 km in Norway (1.7 micromorts) or scuba diving (5 micromorts), but is less than the risk of giving birth in Norway (27 micromorts) (Dahl et al., 2026). This kind of comparative framework is useful because it contextualizes avalanche risk relative to other familiar activities, rather than relying solely on fatality counts, which may obscure the true scale of exposure to avalanche risk.

Measuring the amount of risk avalanches pose is only part of the larger picture. Quantifying the human and economic cost when that risk is realized is equally complex and important. Natural disaster datasets in the US tend to quantify the human impacts of disasters using a combination of economic measures (e.g., damage to insured goods) and natural units (e.g., number of lives lost) (Kharb et al., 2022). Transforming human losses into monetary terms is not straightforward, and placing a value on a life seems morally complex, but conveying the magnitude of loss in terms policymakers can act on is essential. In lieu of putting a price on human life, economists define the value of statistical life (VSL) as the “local trade-off between fatality risk and money” to represent how much people are collectively willing to pay for small reductions in their risks of dying (Kharb et al., 2022).

Government agencies such as the US Department of Health and Human Services (HHS), the Environmental Protection Agency (EPA), and the Federal Emergency Management Agency (FEMA) use VSL figures calculated by labor and health economists to evaluate cost-benefit analyses of health and safety regulations, and to estimate the potential economic toll of natural

disasters, including avalanches (FEMA, 2025; Kearsley, 2026; EPA, 2026). Figures vary slightly by department, but HHS lists the 2026 central US VSL estimate at \$14.1 million in constant 2025 dollars (Kearsley, 2026). This means, on average, if a new public safety regulation would cost \$1 billion to implement but would prevent 100 premature deaths, the regulatory benefits are valued at \$1.41 billion (100 x \$14.1 million), and the benefits outweigh the costs. Applied to avalanche forecasting, VSL provides a framework for articulating the economic case for investing in forecasting and education infrastructure, even when the number of lives “saved” in any given year is modest in absolute terms.

Measurements like micromorts and VSL offer important macro-level tools for contextualizing avalanche risk and its human costs. Still, they are not sufficient on their own to evaluate the efficacy of avalanche programs. Program-level evaluation requires more localized operational metrics that reflect not just outcomes but also reach. Avalanche safety course enrollment rates, website and app usage, field observation submissions, and social media engagement all provide insights into how effectively a program reaches the public it serves with vital safety messaging (Clair & Haegeli, 2023). Avalanche safety programs also have a broader reach on transportation corridors. Avalanches can pose threats to those traveling through mountainous areas on major highways, mountain passes, and railroads. Many avalanche programs face the challenging task of deciding whether to allow workers to close down major infrastructure for avalanche mitigation efforts and to advise the public to travel when avalanche conditions are considered safe (Glassett & Techel, 2014). Currently, cross-program and cross-country research on these reach metrics is not yet comprehensive enough to support a robust systematic framework for evaluating avalanche program performance. This absence

makes it difficult to identify what works, replicate successes, or make the case to funders and policymakers for sustained investment.

Several countries have begun to address this gap. Government agencies in New Zealand, Norway, and Canada commissioned or conducted formal reviews of their avalanche warning programs over the past 12 years, including, but not limited to, the Natural Hazards Commission Toka Tū Ake (2024), the New Zealand Search and Rescue Council (2014), the Norwegian Water Resources and Energy Directorate (2014), and Public Safety Canada (2024). These reviews reflect a growing recognition that program efficacy cannot be assumed and should be investigated. However, the US lacks a comprehensive evaluation report on its 29 regional avalanche forecasting programs. This research aims to provide a comparative analysis of avalanche safety program structures and funding models to inform policy changes that could strengthen the resilience of US programs and thereby reduce avalanche fatalities.

Chapter 3: Methodology

3.1: Researcher Positionality

The drive to conduct this research stems from my deep and personal interest in avalanche safety. As I conduct this study, I enter my fourth year working at the nonprofit arm of the Northwest Avalanche Center, based in Washington State. My duties as the Deputy Executive Director of the Northwest Avalanche Center have brought me face-to-face with frustrating funding challenges and anxieties around government partnerships. My profession, along with my lifelong hobby as a skier, has also provided me with the wonderful opportunity to meet passionate outdoor enthusiasts, guides, educators, scientists, and advocates who are all striving for a safer community and have the same goal: for themselves and their loved ones to make it back home from the mountains.

Therefore, it is inherent that I have a unique lens through which I view the avalanche safety world, and I cannot disregard my personal and professional background during the course of this project. However, throughout this study, I strive to remain objective and grounded in my participants' words and perspectives. I provide analysis and findings backed by evidence rather than my own experiences. Furthermore, I approach this topic with curiosity and my skills as a social scientist rather than a snow scientist. I hope to contribute to a vast, ongoing conversation about what avalanche programs worldwide can learn from one another, and how those lessons can translate into meaningful programmatic improvements and strengthened advocacy for the resources avalanche programs need to help every backcountry traveler move through the mountains more safely.

3.2: Research Design & Data Sources

This is a cross-sectional, comparative case study that integrates qualitative social science data with select quantitative elements to identify trends in how structural and funding models shape the stability and efficacy of avalanche safety programs. A case study approach allows for in-depth, multifaceted exploration of highly complex phenomena (Crowe et al., 2011), which is well suited to avalanche programs, as they vary widely across operational contexts and are inherently complex. The scale of this complexity is significant, as there are well over 100 avalanche programs operating in more than 20 countries worldwide, with 29 regional centers and one national center operating in the US alone, and an additional 29 warning services spread across 16 countries in Europe (United Nations Office for Disaster Risk Reduction, 2025).

To navigate this complexity, I collected data from 12 expert informants representing seven different countries' avalanche programs through in-depth surveys and semi-formal interviews. The study is led by the surveys, which are designed to elicit thick program descriptions by asking simple quantitative questions and open-ended qualitative questions. Interviews strengthened the design by providing data triangulation. A qualitative interview approach is conducive to eliciting detailed personal narratives, revealing nuanced program dynamics that are not visible in quantitative datasets (Ahmed, 2025). Collecting multiple sources of evidence from participants helps develop a more holistic picture of each country's program landscape (Crowe, 2011). Avalanche safety programs and affiliated expert informant participants from those programs were selected using purposive sampling. This sampling approach identified information-rich cases that could offer deep insights into each country's program models, maximizing depth of findings over complete representativeness (Ahmed, 2025). Avalanche

programs take many forms across the seven focal countries explored in this study: Austria, Canada, France, New Zealand, Norway, Switzerland, and the US.

3.3: Study Sample

The programs chosen for this study span a wide geographic range, including North America, Western Europe, Northern Europe, Central Europe, and Oceania. To represent each organizational type of avalanche center in the US, I looked at one of each main type of center: the USFS-run national agency (NAC); a larger-scale public-private partnership with a closely integrated nonprofit arm and a USFS arm (NWAC); a smaller-scale public-private partnership with a distinct nonprofit ‘friends of’ group and USFS team (SAC); a fully state-run organization (CAIC); and a fully nonprofit-run organization (HPAC). In Canada, I studied the two primary existing programs—Avalanche Canada and Parks Canada—as these organizations represent a highly centralized model.

Outside North America, I looked at a range of newly formed programs, such as NVE’s Varsom program in Norway (established in 2013), and well-established programs, such as Switzerland’s SLF program (responsible for avalanche warnings in Switzerland since 1945) (Varsom, n.d.; SLF, n.d.). I also selected this set of programs because they vary widely in structure and funding: Austria’s program focuses on regional services; France’s program operates as part of the country’s national weather service; New Zealand’s program has both an advisory branch and a national nonprofit branch. Thus, each program represented in this study has a unique structure and funding model that could lead to novel insights for the US.

A brief description of the study samples’ country-by-country avalanche safety landscapes is provided below, along with details of the study participants and their respective programs.

3.4: Overview of Avalanche Programs' Structures & Funding Mechanisms⁴

Austria

Austria's program comprises seven regional avalanche warning services (Tyrol, Vorarlberg, Salzburg, Styria, Lower Austria, Upper Austria, and Carinthia) that receive funding through their respective provincial governments (Kriz, 2018). LAWIS is Austria's public portal for sharing all avalanche incident data, weather station data, and avalanche forecasts. LAWIS collaborates with the University of Vienna to host data and resources for the seven Austrian avalanche warning services in a single location (Kriz, 2018). Provincial laws dictate the objectives of avalanche warning services, so each province has its own program, two of which subcontract forecasting to the national weather service, GeoSphere Austria (Kriz, 2018). Austria also has a system of avalanche commissions that locally assess whether certain emergency measures must be taken and then connect with local authorities to implement road closures, evaluations, or emergency responses. Ultimately, Austria's system is decentralized within the national government but is moving toward centralization within the country and with neighboring European countries (Kriz, 2018). For this study, I received information from an expert at Avalanche Warning Service Tyrol.

Canada

Canada's avalanche services primarily come from Avalanche Canada, a nonprofit organization funded primarily by an endowment from the Canadian government and provincial grants from British Columbia, Alberta, and the Yukon (Avalanche Canada, n.d.). Avalanche Canada has its own foundation, the Avalanche Canada Foundation, which raises a very small

⁴ Country descriptions were crafted from publicly available information from avalanche programs and other reputable websites as well as information provided in participant surveys and interviews.

portion of the organization's funding. Parks Canada, a federal agency that works closely with Avalanche Canada, produces public avalanche forecasts for all of Canada's national parks (Parks Canada, 2026). Avalanche forecasting is just one part of Parks Canada's responsibilities, as the agency is responsible for protecting and managing all national parks, national marine conservation areas, national historic sites, and more. They conduct fieldwork and write their own forecasts for the national parks, but deliver the information through Avalanche Canada's online platforms. Additionally, there is one separate forecasting center, called Avalanche Quebec, that covers a small territory in Quebec and acts as a sister organization to the other programs. However, for the vast majority of the country, Avalanche Canada and Parks Canada work together to provide the nation's avalanche safety resources, acting as complementary organizations that often share data and best practices. For this study, I received information from an expert at Avalanche Canada and an expert at Parks Canada.

France

Météo-France, a public administrative body under the Ministry of Ecological Transition and Territorial Cohesion, serves as France's official meteorological service provider and is the backbone of the French avalanche forecasting system (Dufour et al., 2024). Météo-France publishes daily avalanche bulletins in winter that integrate real-time snow and weather conditions for three main mountain regions in France: the Alps, the Pyrenees, and Corsica (Dufour et al., 2024). The service comprises seven regional forecasting centers, each with the same infrastructure, with approximately 50 forecasters working shifts during which they conduct both weather and avalanche forecasting. Mountain weather forecasts for beyond two days in advance and local avalanche advisories for certain infrastructure are not free of charge, and all

revenue earned for those monetized services funds the broader Météo-France institution. The French program also uses a complementary “Vigilance” information system within Météo-France’s infrastructure to provide crisis management and public warnings for natural hazards, including severe weather events and avalanches (Dufour et al., 2024). France’s avalanche safety programs are closely intertwined with the broader national meteorological system and are fully funded by the national government (Dufour et al., 2024). For this study, I received information from an expert at Météo-France.

New Zealand

New Zealand utilizes a two-pronged model: the New Zealand Avalanche Advisory (NZAA) provides avalanche forecasting for 13 zones across the country, and the Mountain Safety Council (MSC), a national non-profit with a government mandate to keep people safe in the outdoors, owns and manages NZAA (NZAA, n.d.). New Zealand’s program receives funding from the MSC through a mix of government sources, including the Department of Conservation (the equivalent to the US National Parks Service or Parks Canada), the New Zealand Search and Rescue Council within the Ministry of Transport, and local lottery grants (MSC, n.d.). Funding for the program recently increased and is secured for the next three years. In addition, no one in New Zealand lives in avalanche terrain, and there is only one public road with avalanche hazard. Therefore, the program’s focus is largely on avalanche safety for backcountry recreationists rather than protecting national infrastructure. For this study, I received information from an expert at MSC.

Norway

The Norwegian Avalanche Warning Service (NAWS) is a relatively young program, launched in 2013 to “avoid accidents and mitigate problems to roads, buildings, and infrastructure due to avalanches” (Varsom, n.d.). The Norwegian Water Resources and Energy Directorate (NVE) delivers the country’s avalanche warning services with support from the Norwegian Meteorological Institute (MET) and Norwegian Public Roads Administration (NPRA) (Varsom, n.d.). Together, the organizations conduct observations and engage in research, development, and education initiatives. Varsom, Norway’s national warning system for natural hazards, serves as the collaborative platform for the country’s avalanche, flood, and landslide warning services (Engeset, 2013). NVE is a provincial government entity that receives funding from the Ministry of Petroleum and Energy to manage natural hazards, and it funds NAWS through federal allocations, while collaborating closely with the Ministry of Transport and Communication on safety initiatives (Engeset, 2013). For this study, I received information from an expert at NVE.

Switzerland

Switzerland’s avalanche forecasting program, WSL Institute for Snow and Avalanche Research (SLF), formed as part of the Swiss Federal Institute for Forest, Snow and Landscape Research, and now receives the entirety of its funding from the ETH Domain, a network of Swiss federal scientific and technical institutions (SLF, n.d.). SLF’s unique blend of research and federal support enables the organization to move beyond avalanche forecasting services; SLF researches natural hazards, snow, permafrost, and mountain ecosystems to understand how they change and to develop strategies to mitigate the risks they pose (SLF, n.d.). The avalanche

warning service within SLF comprises 10 staff members who are involved in forecasting shift work. Additional operational tasks include maintaining the observer network, conducting training courses, and preparing accident and winter reports. One staff member is dedicated to applied research and two-thirds of the resources for SLF's avalanche forecasting program are allocated to software and product development. For this study, I received information from an expert at SLF.

United States (US)

The US has 29 forecasting programs that vary in structure: hybrid public-private partnerships (operating with a USFS arm and a nonprofit arm); some managed solely by the federal government through the USFS; some run solely by a nonprofit or community-run organization; and one state-run center (NAC, 2025). The US also has a USFS entity, the National Avalanche Center (NAC), which provides guidance, support, and training to the 14 USFS centers and programs on Forest Service lands, and more informally coordinates with the other 15 US avalanche centers (NAC, 2025). Some of the earliest avalanche centers in the US have been in operation for over 50 years. Some centers have emerged within just the past few years. Multiple contributory organizations in the avalanche safety landscape, notably the American Avalanche Association (A3) and the American Institute for Avalanche Research and Education (AIARE), serve as resources for avalanche professionals, provide avalanche education standards, and conduct avalanche-related research in the US. In all, there is a rich tapestry of diversely funded organizations in the US, with a wide variety of staff sizes, budget sizes, and forecast land area coverage. For this study, I received information from an expert at the Northwest Avalanche Center (NWAC) based in Washington, an expert at the Sawtooth Avalanche Center (SAC) based

in Idaho, an expert at the Colorado Avalanche Information Center (CAIC) based in Colorado, an expert from Hatcher Pass Avalanche Center (HPAC) based in Alaska, and an expert from the NAC.

Table 1: Participant Program Key

Type of Program	Program Affiliation	Country	Label
Federal/ national agency	Parks Canada	Canada	CAN 2
	National Avalanche Center (NAC)	United States	USA 3
Federal/ national agency + academic/ research institution	Météo-France	France	FRA
	WSL Institute for Snow & Avalanche Research (SLF)	Switzerland	CHE
State/ provincial agency	Avalanche Warning Service Tyrol (LWD Tyrol)	Austria	AUT
	Norwegian Water Resources & Energy Directorate (NVE)	Norway	NOR
	Colorado Avalanche Information Center (CAIC)	United States	USA 1
Nonprofit organization	Avalanche Canada	Canada	CAN 1
	Mountain Safety Council (MSC)	New Zealand	NZL
	Hatcher Pass Avalanche Center (HPAC)	United States	USA 2
Hybrid: public-private partnership	Northwest Avalanche Center (NWAC)	United States	USA 4
	Sawtooth Avalanche Center (SAC)	United States	USA 5

3.5: Participant Recruitment & Data Collection Protocol

Expert informant participants from each of the 12 programs range in expertise from Program Directors to Safety Specialists to Operations Managers to Lead Avalanche Forecasters. All participants have in-depth knowledge about their respective programs, particularly around organizational challenges, operational needs, and program strengths. I reached out to participants

from the 12 programs using my existing knowledge and my colleagues' knowledge of experts at each organization. This sample size is consistent with thematic qualitative analysis and sufficient to support thematic findings, ensuring data collection is manageable and yields meaningful insights (Ahmed, 2025).

I recruited one expert informant from each program between March and April and distributed a survey to all participants (see Appendix A). The survey comprised 10 sections and 47 questions, the majority of which were open-ended qualitative questions, with some Likert-scale questions, some quantitative questions asking for budget numbers or funding percentages, and some multiple-choice questions. The survey begins by asking about basic participant and organization background (such as “Is your organization best described as...” and “How is your avalanche forecasting system organized?”). The questions then delve into organizational structure and governance; funding model and financial stability; staffing and capacity; forecasting methodology and operations; observations and data inputs; education and outreach; forecast use and public engagement; outcomes, risk, and value; and reflections and future discussions. This last section asks very open-ended questions, such as, “What changes would most improve the effectiveness or sustainability of your organization?” and “Are there elements of other countries' avalanche programs that you see as particularly successful or worth adopting?”

In addition, I interviewed participants from each US and Canadian program via an hour-long Zoom call to discuss complex qualitative questions listed in my survey (see Appendix B). The five participants outside North America were unavailable or declined to be interviewed. With participant consent, I recorded and transcribed each interview, then collated the transcriptions with the corresponding survey responses for each participant. I followed up with

participants as needed if survey responses were vague or unclear. Each participant in this study is identified by a generic title and label to maintain the confidentiality of individuals' identities.

Ethical approval for this study was obtained through the University of Washington Institutional Review Board (IRB) prior to participant recruitment and data collection. All participants were verbally informed that participation is voluntary and that they may withdraw at any time without penalty, and their informed consent was documented via a signed consent form (see Appendix C). Participants were treated as expert informants, and any discussion of their responses avoided linking comments to individual names or exact job titles. I protected participants' confidentiality and anonymity by using coded program names rather than individual identifiers. All data related to this study were stored securely on password-protected devices and encrypted storage, with access limited to the researcher and faculty advisor. Audio recordings were also deleted following transcription and verification.

3.6: Methods for Analysis

The study design, data collection, data analysis, and writing stages happened iteratively and concurrently as the study evolved. The qualitative and quantitative analysis in the findings chapters is exploratory and descriptive, with codes and categories emerging from the survey and interview data rather than being predetermined. I used Braun and Clarke's six-phase thematic analysis framework (Ahmed et al., 2025): first familiarizing myself with the interview transcripts and survey data with several read-throughs and note-taking, then generating initial categories, searching for themes among expert informant responses, reviewing themes, defining and naming those themes, and writing my findings. I discussed preliminary themes emerging from each of the 10 survey sections with my advisor, Dr. Martha Groom. Vetting categories with the aid of an

additional researcher reduced my bias, allowed me to note themes I might otherwise miss, and ensured I did not overly focus on certain themes due to single-researcher bias (Ahmed et al., 2025).

I developed categories to code participant responses in a way that captured the variations within each avalanche program, described categories with definitions and examples from interview transcripts and survey responses, and created tables to display major similarities and differences between programs. I used bar graphs to display funding models visually, and selected quotations as appropriate to exemplify key themes. I also documented my interpretive decisions and engagement with participants' responses through rigorous note-taking and spreadsheet records to ensure credible and meaningful findings. Interpretation involved comparing and presenting themes in ways that align with my research question and capture the complexity of the data, ultimately providing connections and patterns that can be attributed to various aspects of avalanche program organizational models.

Table 2: Comparative Analysis Focuses

Survey Question	Survey Question	Category of Question	Similarities & Differences Examined Among Programs
5	Is your organization best described as (multiple choice)	Participant & organization background	What is the overarching organizational structure (non-profit, state/ provincial agency, federal/ national agency, academic or research institution, or hybrid model)?
7	Are forecasting operations housed within a broader agency (e.g., meteorological service, transportation agency, land management agency)? If yes, please describe	Organizational structure & governance	What do partnerships look like in each country with other professional and volunteer agencies?
8	Is your organization financially or operationally tied to Search and Rescue (SAR), road authorities, or emergency management agencies?		
10	What do you see as the primary strengths of your current organizational model?		Do certain strengths or challenges align among countries with similar organizational structures?
11	What organizational challenges do you face?		
12	Approximate annual operating budget (current year)	Funding model & financial stability	How do funding sources and total budgets align with the stability of funding over the next 5-10 years and is funding standardized across the country? And how do funding concerns compare among countries with similar organizational structures?
13	Approximate percentage breakdown of annual funding sources		
14	Is funding standardized across the country or does it vary regionally?		
16	How stable does your funding feel over the next 5-10 years?		
17	What are your primary funding concerns?		
19	Approximate number of paid staff (full-time equivalent)	Staffing & capacity	How do staffing levels and whether they meet current demand relate to budgets and funding sources? Do larger budgets/ more staff equate to a greater feeling of stability?
21	Are staffing levels sufficient to meet current demand? Why or why not?		
27	What technical or infrastructure limitations most affect your forecasting capability?	Forecasting methodology & operations	How do technical limitations relate to budgets, staffing, and organizational structure?

31	What types of avalanche education programs does your organization offer?	Education & outreach	How far do an organization's education programs reach in relation to budget, staffing, and organizational structure?
32	Approximate number of education programs held annually		
33	Approximate number of education participants per year		
37	Estimated number of unique users accessing avalanche forecasts per season via website, mobile apps, and other platforms	Forecast use & public engagement	How many people are these programs reaching through their online presence, relative to overall backcountry recreation use/ growth in the country? Which types of programs are reaching the most users?
38	How has backcountry recreation grown in your country in the last 10 years? And what metrics do you use to determine this growth (e.g., counting trailhead users, unique website users, etc)?		
40	What is the average number of avalanche fatalities in your country each year?	Outcomes, risk & value	How does a "traditional" efficacy metric like avalanche fatalities compare across countries? And how does this correlate to how well these programs view their efficacy?
41	How effective do you think your organization is in reducing public avalanche risk? (Likert scale: very effective, somewhat effective, somewhat ineffective, very ineffective)		
42	What is the approximate area of coverage of your organization's avalanche forecasting services (in sq km)		What does coverage look like per program? How much does this vary by country? Does this correlate with views on program efficacy or organizational strengths/challenges?
43	How do avalanche warning systems compare to other emergency warning systems in your country (e.g., floods, earthquakes) in terms of perceived value or funding priority?		Are other natural hazards perceived as more "dire/ important" to fund, and how might that affect funding for avalanche programs?
45	What changes would most improve the effectiveness or sustainability of your organization?	Reflections & future discussions	How do countries view one another's programs? Is there one program that is seen as a "model?" What do these experts really want in order to bolster efficacy for their programs? Is there a theme emerging among countries?
46	Are there elements of other countries' avalanche programs that you see as particularly successful or worth adopting?		

3.7: Limitations

A limited time frame for this project—about six months—meant limiting the avalanche programs included in this study. While I had over 20 countries with avalanche programs to choose from, I chose seven countries and 12 distinct programs within those countries. This sample size was still representative of a wide range of organizational structures and funding models. Should there be future research in this area, I suggest examining additional countries such as Italy, Germany, Sweden, and Japan.

Within the US, I examined five programs, each with distinct structures that capture five major organizational types present in the country (as listed in the Study Sample & Data Collection Protocol section). There are another 24 regional avalanche centers in the US, meaning certain programs' geographic particularities and nuanced characteristics are not present in this study. Moreover, many US avalanche centers have just one or two operational staff members who work part-time or seasonally, which complicates efforts to collect a larger data sample. The centers I did recruit for this project had the time and capacity to contribute to the study in a timely manner.

Finally, I could not interview study participants from Europe or New Zealand. The challenges presented by time zone differences and the unpredictability of seasonal outdoor worker schedules made it difficult to meet with these participants over Zoom. I did, however, collect survey responses from all of these participants, and mitigated the lack of interview data by following up on some of the open-ended survey responses via email for greater clarity or detail. European and New Zealand participants were quick to respond as follow-up questions arose.

Overall, this mixed-methods approach with an emphasis on qualitative data aims to provide a foundation for further research into how avalanche programs differ in structure and funding, so that countries and regions might learn from each other's successes and limitations. I followed this approach to provide a policy research perspective that US programs can use when administering advocacy work to bolster their programs' efficacy at a local, state, and federal level. The lack of qualitative data that US programs can rely on when describing the need for resources is apparent, which is why this research approach is important.

Chapter 4: Thematic Findings & Discussion

4.1: Overview of Findings

Organizational structure (federal, state, nonprofit, or hybrid public-private) explains how a program is funded and staffed, but it does not reliably predict the effectiveness of an avalanche program or the stability of its funding. What predicts these outcomes is whether funding is legally protected (ie: legislated mandate or multi-year funding contract) versus discretionary or fundraising-dependent. Program structure and governance are rarely black and white; even in countries where the avalanche forecasting system is a national organization structure, multiple forecasting programs exist, funding varies across the country, and some portion of forecasting operations is housed within a broader agency. Annual operating budgets also vary greatly, by more than a factor of 18 across programs (from \$220,000 to over \$4 million in USD). Budgets relate more closely to country size, population, and institutional scope than they relate to organizational structure. Within the US alone, budgets of those surveyed range from \$220,000 to \$3.7 million among regional centers (see Appendix D for a comprehensive data dashboard).

Perhaps the more productive way to think about these programs is in terms of the spread of their funding sources. Federal and state program types are funded almost entirely (80-100%) by government appropriations and endowments. In contrast, nonprofit and hybrid programs secure funding from a wider range of sources, including donations, corporate sponsorships, and earned revenue. In addition, reach metrics (ie: education program participants and unique website users) are helpful proxies for program success when coupled with avalanche fatalities, which scale with population and terrain exposure rather than avalanche program quality. Themes listed below surface and discuss the data supporting these findings.

4.2: Theme 1 - Organizational structure predicts trade-offs, not outcomes

According to Resource Dependency Theory, organizations are not self-sufficient and must acquire resources from their external environment, which creates power dynamics and external constraints (Pfeffer and Salancik, 1978). In their elaboration of this theory, Pfeffer and Salancik (1978) explained that organizations attempt to manage or avoid uncertainty by seeking to create more stable and predictable environments around themselves. Greater instability produces larger efforts to manage the environment, which often leads organizations to manage their interdependence through interorganizational coordination. Strategies to manage interdependence require interlocking activities with others, resulting in concentrated power. Pfeffer and Salancik (1978) surmise that if all organizations attempted to solve problems of uncertainty and instability by interlocking their behaviors with others, the result would be the creation of larger organizations operating in more regulated, politically controlled environments with tightly coordinated actions, and structures would become more centralized. Yet the trade-offs here are that an organization's larger size and increased commitment to its mission make it less able to adapt, and failures become more consequential.

These trade-offs are illustrated by the avalanche programs surveyed; each program model has a clear strength and a corresponding weakness. National programs have greater funding protection, but bureaucracy slows down innovation; state programs have high efficiency, but limited resources to cover large areas with vast differences in avalanche threats; research institution programs have dense information and consistency in forecasting quality, but compete for resources within their broader institutions; nonprofit programs have greater adaptability, but experience a range of funding instability; hybrid public-private programs have a mix of pros and cons from each of the aforementioned models. No single structure is clearly the 'best.'

Table 3: Organizational Trade-Offs for Each Avalanche Program

Program	Country	Label	Pros	Cons
Federal/ national agency				
Parks Canada	Canada	CAN 2	Legislated authority to manage land; stable, protected funding	Bureaucracy/ red tape; inability to be nimble; subject to changing federal politics/ priorities
National Avalanche Center	United States	USA 3	Tripod of experts; hub supporting regional centers	Bureaucracy; overburdened staff; interagency resource competition
Federal/ national agency + academic/ research institution				
Météo-France	France	FRA	Strong weather forecasting; dense data foundation	Coordinating 7 regions is hard; isolation effects; long staff shifts
WSL Institute for Snow & Avalanche Research	Switzerland	CHE	National consistency; strong regional/local network; proximity to research institute	Development resources compete with operational needs
State/ provincial agency				
Avalanche Warning Service Tyrol	Austria	AUT	Clear, legally defined mandate from provinces	Budget cuts (mismanagement during COVID-19 crisis)
Norwegian Water Resources & Energy Directorate	Norway	NOR	High quality/efficiency; full national coverage	Uncertain about having sufficient future funding, observations, and IT support
Colorado Avalanche Information Center	United States	USA 1	Efficient resource use; single govt group covers large area	Insufficient resources for forecast area's size and threat variability
Nonprofit organization				
Avalanche Canada	Canada	CAN 1	Centralization = cost savings, unified tech, easier govt relations, clear recognition as major avy program in country	Public perceives as govt entity (hurts donations); users recreate outside forecast zones; hard to be competitive with wages
Mountain Safety Council	New Zealand	NZL	Flexibility, adaptability, agility; evidence-based institution	Lack of qualified forecasters in rural regions; lack of data
Hatcher Pass Avalanche Center	United States	USA 2	Agile/ adaptable; sets own forecasting schedule/ staffing structure to meet local needs	100% dependent on charitable giving/ grants; hurts wages, retention, and growth
Hybrid: public-private partnership				
Northwest Avalanche Center	United States	USA 4	50-year USFS history; umbrella protection of federal workers issuing forecasts	USFS restructuring and funding shortfalls; federal govt chaos
Sawtooth Avalanche Center	United States	USA 5	Friends group offers flexibility; advocacy; more nimbleness in tech and purchasing than govt	Chaotic govt leadership; low awareness/ understanding of program structure; staff turnover

Strengths of federal/ national programs (CAN 2, USA 3, FRA, CHE), encompassing programs that are also academic/ research institutions, include CAN 2's broad legislated authority to manage the land within park boundaries; federal funding that is relatively stable; and high professional employment standards for Visitor Safety staff.

"We manage everything, and the interesting thing about the park system is everything inside the circle, the park boundary, is our responsibility. So we have in our agency everything from first responders to highways. We maintain the highway system; we look after the wildlife, you know, we do everything, and we have the authority to do that, and it's been almost like we're the landowner, right, but we're the land manager on behalf of Canadians. So in some ways I think that's a real strength for us, because it means that we also have a legislative responsibility to deliver search and rescue inside our parks. We cannot *not* do that. And so part of that is the prevention work of the avalanche bulletin. So [the bulletin] won't get taken away, because we're required to do that as a part of occupiers' liability in various legislative tools in Canada. We have to produce an avalanche or some version of warnings and search and rescue inside our park boundaries. So, in terms of our funding, that's good for us, because they can't just pull our funding and say, 'Okay, no more avalanche bulletins.' They can't do that in the national park." —CAN 2

In addition, CHE cited strengths lie in the *"national consistency in avalanche warning system; fewer staff required than, for example, under a cantonal regulation (service provided 7 days a week); maintenance of a close network with regional and local players as well as associations (users of the avalanche warning service); and proximity to research within a research institute is advantageous for development and implementation into application and education."* FRA emphasized their main strength is *"having weather forecasting competence and dense information as a solid basis to start avalanche forecasting."* Meanwhile, USA 3 cited their role as a source of support and expertise for regional centers in the US as a strength of

being a national program, saying *“every [regional] center is able to operate and respond to their unique snowpack and community needs.”*

Despite these strengths, national programs experience significant challenges, including slow bureaucratic processes, overburdened staff, and competition for resources among departments in these large national agencies. CAN 2 explained their frustrations:

"Okay, we're the government, and no matter how hard I try and how hard we try to move things here, there's a million government processes in place, red tape, and you know all the usual stuff, which, and you know, we have to do everything in two languages, which is challenging. Whereas Avalanche Canada, you know, they're a not-for-profit, they're nimble, they're fast, so it's really easy for us to partner with them, and they deliver a lot of this stuff, and we can just benefit from it. Might take us twice as long to do something, and it's not going to be as good as the way [Avalanche Canada] can do things these days." —CAN 2

FRA referenced difficulties around the coordination of seven centers that share the same IT infrastructures, observation networks, etc, stating, *“Those centers have 50 forecasters in total who do long hours on shifts (12 or more) and work in isolated places; as a result, difficult it is to train together; hard to communicate for coordination purposes, and isolation creates island effects among staff.”* CHE maintained that *“resources for implementation and development compete with the resources of operational operations.”*

State/ provincial programs (AUT, NOR, USA 1) identified efficiency and a clear mission as program strengths. NOR boasted *“high quality, high efficiency, and national coverage,”* USA 1 listed *“efficient and effective use of resources and single government group covering multiple avalanche safety applications over a large area with vast differences in avalanche threat,”* and AUT appreciated the clear-cut aspect of its program duties, stating *“provincial laws fix the objectives we have to cover.”* Alongside the efficiencies mentioned, these state programs come

up against a variety of challenges. USA 1 has limited resources to cover services for a large area with vast differences in avalanche threat; NOR is concerned about sufficient funding, observations, and IT support in the future; AUT battles budget cuts due to mismanagement of the COVID-19 crisis.

Nonprofit programs surveyed (CAN 1, USA 2, NZL) deviate from one another in their strengths. NZL and USA 2 noted flexibility, adaptability, and agility as strengths. USA 2's program is *"able to define their own forecasting schedule and staffing structure to best meet the needs of a particular season and rapidly growing user base."* CAN 1, a primarily government-funded nonprofit (like NZL), named centralization as a strength of their program.

"Well, I think a lot of the resources are in one place, so you know, there's one CEO for the whole country, essentially, as opposed to there's probably 23 EDs in the States and 23 boards and 23, you know, and then there's a bunch of not-for-profits, etc. So I think there's cost savings because we all work for the same cause. And so I think when we decided to build our own forecasting software and system, there weren't like 16 different options. It was okay, let's do one. Instead of everybody spending money on their own, the funding comes to us, and we built a capacity. So we have an IT team of five full-time people. Those are year-round full-time, and it's a million-dollar department for us, but we've been able to build things—incredible tools. But in terms of public safety, it's a lot easier to deal with the government, because it's not like 23 different people talking to 23 different, you know, governments. So that's another strength. I think the recognition is easier. Like Avalanche Canada is recognized as, you know, there's nobody else, so there's not a lot of confusion, there's a lot of clarity." —CAN 1

Meanwhile, nonprofits face donor fatigue, staff retention challenges, and public confusion about who funds their program, all amid increasing demand for their products and services. CAN 1 explained:

"People go to different places where they didn't go before; they go further, they access different things, especially in Canada, you know, with snowmobiling and with climate change. Some areas, which used to have more snow, have less snow, so they go to different places where we don't necessarily have a forecast, or we don't have a field team. One of the challenges is a large percentage of users think we're a government department, so they're like, 'Why would I give to the government? I don't want to give to the government.' Well, we're not government; we do get government funding, but we are not government employees or government departments or anything like that." —CAN 1

USA 2 said it is *"challenging to raise 100% of our operating funds through charitable giving and grants without any program-driven revenue"* and this *"has impacts on our ability to offer competitive wages and benefits, retain quality staff, and plan future growth."* NZL is challenged by funding windows no greater than 3 years and a lack of qualified forecasters in some rural regions.

Hybrid programs (USA 4, USA 5) have the best and worst of both worlds. They have a unique blend of the flexibility and adaptability of their nonprofit branch and legitimacy from their US Forest Service branch. USA 4 mentioned a *"50-year history of having its program in the USDA/ USFS and umbrella protection of federal workers issuing public safety forecasts."* USA 5 remarked:

"The federal-private partnership creates flexibility, advocacy opportunities, financial support and stability, and nimbleness that the federal government does not have. Specifically, 1) the technology and communication platforms would not function as well if owned/ operated/ maintained by the government, 2) purchasing and strategic planning is much simpler outside the federal government, and 3) the financial and organizational stability of the Friends group acts as a smoothing mechanism during times that the government is more chaotic." —USA 5

On the flip side—similar to national programs—hybrid programs fight bureaucracy and whiplash from changing political administrations. USA 4 highlighted recent “*Forest Service restructuring, a lack of funding within the agency, and overall US federal government chaos*” as a major challenge. USA 5 also observed challenges with the changing, chaotic government structures:

“Changing and at times chaotic government structures and leadership (mid and upper level) create inefficiencies, increased workloads, and stress for avalanche center directors. A marginal understanding and awareness of the Forest Service avalanche program exists at the national level. Government wages in expensive mountain towns (Sun Valley, Jackson, etc) have not come close to keeping up with the cost of living or private industry wage increases over the past 10+ years, resulting in better paid opportunities in the private sector (ski area forecasting, non-avalanche jobs) than in the public sector (Forest Service avalanche forecasters); construction laborers and many fast-food employees earn more than entry level avalanche forecasters. As a result, the quantity and overall quality/ previous experience of applicants for forecasting positions is decreasing while the turnover rate increases.” —USA 5

Programs tend to blame their organization type for problems that are instead related to funding certainty versus operational autonomy. Nonprofits and grant/ endowment-dependent programs (CAN 1, USA 2) are nimbler but struggle with issues like increasing user demand and employee retention because they lack legislated, stable funding that is certain to be renewed. Most federal or state programs (CAN 2, NOR, AUT) have steadier funding but are slowed by bureaucracy and political volatility that are not necessarily fixed by a budget increase. No specific structure gets both stability and autonomy; each trades one problem for another.

4.3: Theme 2 - Avalanche risk is funded as a ‘voluntary’ recreational risk

Across all 12 programs, avalanche risk is funded as a ‘voluntary’ recreational risk rather than a public hazard like floods or earthquakes. This framing, more than the structure or performance of avalanche safety programs, appears to play a role in setting the ceiling on funding priority across every country studied. Across the US, regional avalanche centers see stark differences between the public’s and the government’s perception of avalanche risks and how important it is to fund safety efforts. While public support seems high, government support for these programs is described as “unpredictable” and “low-priority” compared to other natural disasters.

USA 5 surmised that the public’s perceived value of avalanche centers in the US is “*very high,*” stating, “*I think people assume their taxes cover the entire cost of the warning programs.*” While this may be part of the public’s perception, as described in the literature above, this is not the case for programs across the states. USA 2, on the other hand, stated: “*[Avalanche centers are] not considered as high priority as other emergency warnings. Alaska has a state statute to develop and implement a statewide avalanche warning system, but it has never been fully staffed or funded.*” When describing how avalanche warning systems compare to other emergency warning systems in their country in terms of perceived value or funding priority, USA 1 relayed:

“The perceived value of these systems differs based on who is being protected and why. Floods and earthquakes, for example, are ‘involuntary’ risks that threaten critical infrastructure, cities, and the economy. This gives them high political priority. Avalanches are often viewed as a ‘voluntary’ risk taken by backcountry recreators, which can lead to lower priority in general public safety budgets. While flood warnings protect billions in real estate, avalanche centers protect transportation corridors and the outdoor industry. State Departments of Transportation are

often big financial backers because a single highway closure due to an unpredicted slide can cost millions in lost commerce. The ‘output’ of these systems is also fundamentally different.

Earthquake warnings (seconds-to-minutes) and flood or hurricane warnings (hours-to-days) are designed to trigger immediate evacuation or ‘drop, cover, hold on.’ Avalanche warnings are primarily educational.

“The North American Public Avalanche Danger Scale is designed to help users make their own decisions. The system's value is measured by its ability to change human behavior rather than just provide a siren. Avalanche centers fall into the lower part of the hierarchy of emergency management. They provide high-value, life-saving data for a fraction of the cost of other systems, but because their primary audience is a specific niche of backcountry users rather than the general urban population, they rarely see the ‘priority’ status afforded to broad-scale natural disasters. Avalanche warning systems in the United States operate under a very different funding and priority model than major emergency systems like those for floods, earthquakes, or hurricanes. Systems like the USGS Earthquake Hazards Program or NOAA’s National Weather Service receive significantly more federal funding than avalanche centers, which rely on a patchwork of public and private support, including small Forest Service grants, state DOT funds, and reliance on 501(c)(3) non-profit Friends groups.” —USA 1

USA 4 expressed similar frustration that avalanche centers in the United States fall into a lower tier of emergency management priority in the country:

“We are connected to the NWS (National Weather Service) early warning system for avalanche warnings, but overall, avalanche warning systems are dwarfed by other systems in scope and budgets. I think the public, if I had to answer this question, I think the public perceives [our avalanche center] as very valuable; the people that use us, the people that give us membership, highly valuable. I think it's insane the amount of money we spend on, say, volcano warning systems and tsunami warning systems, and then, if you look at, like, nationally, the US federal

government spends about three million dollars on the public forecasting system, like funding priority seems really amiss in the US. Otherwise we wouldn't be in the system, the world that we're in right now. I think in the US, it's like, yeah, there's 25 people killed a year, you know, and that value of statistical life is like nine or 10 million dollars. You know, what is that 25 times? That's a quarter of a billion dollars in economic loss through fatal accidents. Yeah, and you compare it to all these other warning systems that we have—earthquakes, floods, tsunamis, volcanoes—it's all natural disaster. There's a huge, like, lightning thunderstorm warning system that we have in the US; tornadoes, the hurricane program for the Atlantic Seaboard, and the federal government's only giving three million dollars to public avalanche forecasting." —USA 4

In Canada, the government's perceived value of avalanche programs fluctuates with perceptions of the country's greatest needs. CAN 1 explained how being successful can lead to less perceived importance, which is why it is necessary to constantly advocate for avalanche programs and improve systems to remain relevant and successful in hazard mitigation:

"It depends on the season, so we've had quite a few bad wildfire seasons, you know, similar to in the States, so a lot of the focus shifts on those needs, and avalanches are not a big deal. I think being successful works against us, which is terrible to say, but you know, the better we are at what we're doing and the less accidents we see, the less perceived importance we have. We've had in BC big flood events, big fires, and so I think that's where the attention goes. That's why we try to stay connected with, especially at high level, like ministers, and to make sure they understand what we're doing and why we're successful, and how the funding helps, et cetera, to keep their attention, because otherwise we'll get lost in all the other bad things going on in the world, but we're also looking at their systems to improve ours. I know we were looking at how the hurricane center might warn people about different hazards and how they do it and why they do it. So we've looked at that, and we even went to Boulder two years ago to NOAA, and we met with those people to see how they do that with weather and how they use AI and automation. So I think

where the future is going for us is using more and more tools and going towards more automation, not of the forecast, but of a lot of the data, and sourcing the data." —CAN 1

CAN 2 expanded on the challenge of keeping funding strong for avalanche programs in Canada, communicating that government officials tend to find greater worth in avalanche programs when avalanche risks threaten public infrastructure:

"Avalanche warnings appear to have more importance than other natural hazards in relation to their actual impact. Avalanches are a media fascination and get outsized attention in the media. But keeping funding going for Avalanche Canada is always an issue. One possible reason is that the other natural hazards have a greater impact on infrastructure and economics, while avalanche fatalities are typically related to voluntary risk-taking by adults with less economic impact on the country. So when it comes to media, the attention is outsized, but when it comes to funding avalanche forecasting outside of Parks Canada, the attention is less.

"If they close the road for a long period of time, particularly an important one, then [officials] care. Because there's money on the table, right? So we still work pretty closely with the Meteorological Service, who is constantly being told by their executive not to get too involved with avalanches, because they feel avalanches are outside their mandate. But all the weather staff I speak to always want to know how much our highways matter to us. That's what their management listens to, is economic impacts from highway closures. You know, if you get one consenting adult killed in an avalanche while ski touring on the weekend, I mean, that's sad, but [officials] don't care as much. That's not a big impact, but you drop some economics on there, and that's where the impact lies." —CAN 2

CAN 2 went on to describe how those engaging with avalanche risks recreationally, rather than via public infrastructure like highways, are often perceived as reckless and putting themselves in harm's way, leading some people to believe that avalanche programs are perpetuating reckless behavior that could be avoided.

"You know, I work in search and rescue, and so it's very common when I meet people, one of them will say to me, 'Wow, you work in search and rescue, that's interesting. You must meet a lot of idiots.' I get people saying it all the time, as if to say that everybody who gets rescued is an idiot, and I just push back hard on that. You know, it's not like that. The vast majority of people that I rescue are just like you and me. They're normal people trying to have a normal day, and then somebody broke their leg, or they slipped on a rock, or fell off a boulder, you know, they're not doing anything wrong, things happen. But there's a perception in society that everybody's an idiot, so let's not fund them, and I have a feeling that comes right through with respect to public avalanche programs, because it's largely for a recreational community." —CAN 2

The participant from NZL noted similar sentiments to the US and Canada, finding that other natural hazards impact everyday life for more people in New Zealand:

"I would imagine the comparative value is a lot less simply due to the number of fatalities, and the greater risk to life, posed by earthquakes, floods and other natural hazard events. New Zealand has suffered in recent years from some catastrophic natural events, such as the Christchurch Earthquakes and recent major flooding events. Comparatively, avalanches only pose a danger for those who go into the backcountry, whereas floods, earthquakes, tsunamis and extreme weather events impact everyday life for many more people." —NZL

Conversely, European participants surveyed (CHE, FRA, AUT, NOR) see the perceived value of avalanche warning services as slightly higher in their countries, due in part to winter tourism. NOR noted the perceived value is *"comparable to flood and landslide forecasting, but more valued by recreationalists"* and AUT remarked, *"I have the feeling that avalanche warning is perceived as a fundamental part of winter backcountry recreation, which in turn is a large part of winter tourism. Tourism in general drives about 40% of the economy in Tyrol. So I think the perceived value is higher than for other comparable services."*

4.4: Theme 3 - Funding certainty, not amount, drives program stability

Programs with a legislated mandate or institutional home (FRA, CHE, CAN 2) reported the most funding stability at any budget size; programs heavily dependent on government endowments and appropriations (USA 3, CAN 1), along with one program with mixed funding sources (USA 4), reported the least funding stability, even with moderate-to-large annual budgets (see Table 4). Even the most stable programs (FRA, CHE, CAN 2) still described the same unmet need: no protected funding for capital investment or technological innovation.

Furthermore, being sufficiently staffed and feeling confident about the stability and efficacy of one's program are not correlated. Some programs that answered 'yes' to being sufficiently staffed still flagged funding stability over the next five to ten years as 'somewhat stable' (USA 2 and NZL) or structural inefficiency (FRA) as an issue, showing that staffing sufficiency alone is an incomplete success metric. Whereas all three state agencies (AUT, NOR, USA 1) flagged funding stability as 'somewhat stable' and organizational efficacy as 'very effective,' but answered 'no' to the question of whether staffing levels are sufficient. Therefore, having enough staff is not a prerequisite for organizational efficacy or stability. In fact, half of programs surveyed (USA 3, AUT, NOR, USA 1, CAN 1, and USA 4) said staffing was insufficient to meet current demand, and another two programs (CHE, USA 5) said staffing is only 'somewhat' sufficient to meet current demand. This insufficiency cuts across every organizational model (see Table 4).

These findings align with Pfeffer and Salancik's theory that resource (or funding) certainty and concentration are most important for organizational longevity—more so than formal structure, mission, staffing, or other factors. Organizational choices about how to manage funding certainty have trade-offs, so there can never be a single 'best' organization or structure

since the organizational environments vary over time and by location. Stability correlates less with how much staff and money a program has and more with the degree to which a program's funding is legally protected. Legislated responsibilities and multi-year national contracts buy peace of mind even for programs with moderately sized budgets, while endowment- and appropriation-dependent programs feel exposed even with larger budgets. Programs with a legislated mandate or a stable institutional home (FRA with France's Météo-France, CHE with Switzerland's federal research institute, and CAN 2 with Parks Canada and its legal responsibilities to national parks) reported feeling the most funding stability.

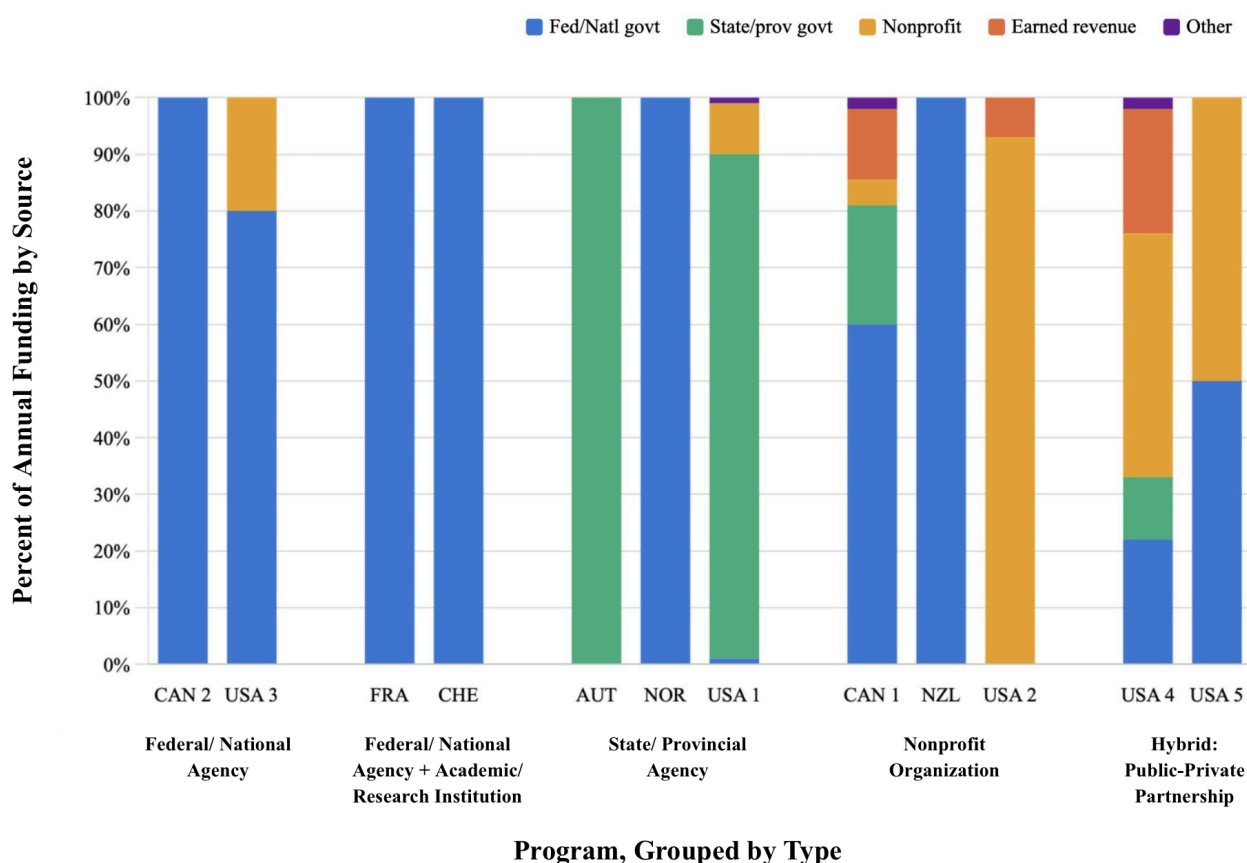


Figure 1: Funding Sources by Program

Table 4: Comparison of Efficacy, Staffing, and Funding Stability Among Programs

					Spread of Annual Revenue Sources				
Label	How effective is your org in reducing avalanche risk	Are staffing levels sufficient	How stable does funding feel over next 5-10 years	Total Annual Budget (USD)	Fed/ Natl Govt	State/ Prov Govt	Non-profit	Earned Rev	Other
Federal/ national agency									
CAN 2	Very effective	Yes	Very stable	Not available ⁵	100%				
USA 3	Very effective	No	At risk	\$450,000	80%		20%		
Federal/ national agency + academic/ research institution									
FRA	Somewhat ineffective	Yes	Very stable	\$3,421,000	100%				
CHE	Unanswered	Somewhat	Very stable	Not available ⁶	100%				
State/ provincial agency									
AUT	Very effective	No	Somewhat stable	\$912,000		100%			
NOR	Very effective	No	Somewhat stable	\$3,060,000	100%				
USA 1	Very effective	No	Somewhat stable	\$3,700,000	1%	89%	9%		1%
Nonprofit organization									
CAN 1	Very effective	No	Uncertain	\$4,095,000	60%	21%	4.5%	12.5%	2%
NZL	Very effective	Yes	Somewhat stable	\$461,000	100%				
USA 2	Very effective	Yes	Somewhat stable	\$220,000			93%	7%	
Hybrid: public-private partnership									
USA 4	Somewhat effective	No	Uncertain	\$2,500,000	22%	11%	43%	22%	2%
USA 5	Somewhat effective	Somewhat	Somewhat stable	\$640,000	50%		50%		

⁵ The budget for the avalanche program within Parks Canada was not available due to the complexity of the organization's large, multi-jurisdictional operations.

⁶ The budget for the avalanche program at SLF was not disclosed by the participant.

4.5: Theme 4 - Funding concentration predicts funding concerns

Eight of the respondents (CAN 1, USA 3, CHE, NOR, USA 1, USA 2, USA 4, and USA 5) named the stability of their primary revenue source as the greatest risk to their program's stability. Whichever revenue source a program relies on most heavily (federal endowments or charitable giving) is the source the avalanche program identifies as its top risk to stability. FRA did not have many funding concerns, stating their only worry was, *"We may face budget cuts that can affect training and communication tools, such as development of website/ mobile apps for efficient client communication."* CAN 2 said their program's *"annual level is steady, but we are not well financed for capital projects or growth, so it is difficult to innovate."*

Notably, programs dependent on discretionary or short-cycle funding (USA 3 and CAN 1) feel the least stable when it comes to funding. USA 3 listed the *"erratic government environment"* as their main funding concern. CAN 1 said, *"We have a couple of large funding grants that will be depleted and no guarantees of being renewed. Most of our other government funding is on three- to four-year agreements with no guarantees of being renewed."*

Hybrid programs dependent on both federal funds and nonprofit fundraising (USA 4 and USA 5) also report anxieties around funding stability. When asked about primary funding concerns, USA 5 mentioned:

"[There is] uncertainty with federal appropriations and budgets on a year-to-year basis due to shifting priorities, budget deficits, congressional spats, and local or regional level 'bad players' who control our budget. The Friends fundraising program is vulnerable to a significant economic downturn, and we're overdue for a lengthy recession." —USA 5

Table 5: Primary Funding Concerns by Organizations' Primary Funding Source

Primary Funding Source	Program	Primary Funding Concern	Funding Standardization in Country
Federal/ national government	CAN 1	No guarantee of large government grants being renewed	Varies
	CAN 2	Not well financed for capital projects or growth; difficult to innovate	Varies
	USA 3	Erratic government environment	Varies
	FRA	None besides possible budget cuts to training and communication tools	Standardized
	CHE	Federal cost-cutting measures	Standardized
	NOR	Global military, political, and economic situation/ uncertainty; being prioritized in government budget will become harder	Standardized
	NZL	None at this time; funding recently increased, locked in for next three years	Standardized
State/ provincial government	AUT	Keeping forecasters on staff; budget cuts on further development of digital tools	Varies
	USA 1	Severance Tax and Colorado Department of Transportation funding based on state budget fluctuations	Varies
Nonprofit	USA 2	Effect of increasing cost of living on charitable giving; state/ local government deficits affect grant availability	Varies
	USA 4	USFS budget and staffing cuts/ lack of support; macroeconomic headwinds impacting individual/ foundation giving	Varies
50/50 Split: Federal/ national government and nonprofit	USA 5	Uncertainty with federal appropriations/ budgets; nonprofit fundraising program vulnerable to economic downturn	Varies

4.6: Theme 5 - Key improvements programs would make if resources allowed

Across every organizational structure type, programs converge on the same three wishlist items: guaranteed, multi-year funding that is consistent across longer time spans; dedicated non-forecasting staff (IT, administrative, and fundraising) so forecasters can focus on one role instead of many; and investment in more advanced predictive snowpack modeling and other technical improvements to keep up with the demands of winter backcountry users. Six of the 12 programs also mentioned that cross-country learning and collaboration are vital for program advancement.

Improvement 1: Guaranteed, Multi-Year Funding Consistent Across Longer Time Spans

Seven programs wish for guaranteed, multi-year funding to focus on avalanche safety work instead of spending so much time securing funding for avalanche safety work. USA 3 explained:

"I mean, obviously I support what we've been talking about with guaranteed funding, and just let us get on with our job rather than spending all our time fighting for survival. That would be the biggest change. I mean, Canada's program got a massive endowment. They were pretty much going to be dead in the water, and it just saved them, and now they're this really strong force in the industry. So ideally it would be that sort of situation, but it does make you wonder, would we just be better—since we're 50% funded privately anyway—would we just be better, like trying to form this gigantic nonprofit? I don't know, that's not my area of expertise, but if this is the way it's going to be in the future, I don't know, I think it should be funded. It's a public safety thing; I think it does have a role in the government, but, like, for all of last year, we were one of the few programs that was actually even like getting anything done." —USA 3

USA 3 went on to suggest there should be a guaranteed, consistent mechanism of funding for US avalanche centers, because regional centers tied to the Forest Service receive inconsistent funding from the government agency:

"There's this SHRED Act, so the ski areas pay like something incredible, like \$14 million or it might be more than that, might be \$40 million in permitting and administration fees to the Forest Service annually, and there's an act that's been kind of dead in the water with all this government stuff that was in there as a provision to fund directly fund the avalanche centers. Because some centers are really well supported at the regional level, but then we have other avalanche centers that get the allocated funding, and it goes to the district ranger in some places, and then they say, 'Well, we need more money for trails,' so they take the money and give it to trails. So there's no guarantee the money that's allocated to them actually makes it to them. And so we're working hard on that, and that's where the AFP (Avalanche Forecasting Platform) and a national level of collaboration will really help us to get our own secure funding stream. Five million [USD] would be the minimum to run the centers, really, and continue to grow the program at a reasonable rate; 10 [million USD] we'd be able to really do some work. I do think the place is in the government for these programs, but I just... it just blows my mind sometimes. I'm like, should we be in the Forest Service? Is there a better agency for us to be paired with, you know? And is that why we're not getting the support?" —USA 3

NZL deeply appreciates this type of multi-year, solidified funding:

"Funding beyond the current three-year cycle would be ideal, but that also comes with risks. Three years allows us to make a case for increased funding reasonably frequently. While a longer-term funding window would be nice to have for long-term certainty, it does not provide the same opportunity to account for rapid inflation and other factors. We do not have funding concerns beyond our current period." —NZL

CAN 2 stressed the importance of having the resources to work year-round:

"One important thing in terms of policy that is worth noting is if you're going to produce avalanche forecasting systems—most managers who don't follow snow avalanches don't even think about avalanches until October—but if you're someone who's working on avalanche systems, you've got to be building that stuff in the summer. Like, you know, my friend put it best. He said, 'If you want to produce a Christmas album, you've got to record it in the summer.'" —CAN 2

Improvement 2: Dedicated Non-Forecasting Staff

Forecasters are vital to issuing accurate, timely avalanche and mountain weather forecasts. However, these forecasters often have to take on multiple roles due to a lack of funding. Some forecasters may take on roles in IT, fundraising, communications, or office administration, and struggle to focus on forecasting excellence while juggling these roles. Conversely, some avalanche programs run into a shortage of qualified forecasters because there is a small hiring pool for those with technical forecasting expertise who are also able to live in more expensive mountain towns. Eight programs would find it advantageous to separate job duties more and have dedicated non-forecasting staff. CAN 2 mention these limitations affect their forecasting capabilities:

"[We have] minimal to no staff available to us with skills to set up and manage databases, and to use the data towards building better forecasting products. Our operations are heavy on field/ operational skills, and we have an absence of database/ technical/ scientific staff. We also have no dedicated administrative staff, which leaves all the program administration to the program managers who are also forecasters with an operational focus. Currently, we're focused on keeping up with operational tasks, and strategic planning is absent. In addition to being operationally robust, organizations require strategic planning, funding, and admin staff." —CAN 2

USA 3 had a similar limitation, having to find staff with a unique, varied skillset:

"Obviously technology is constantly evolving, and it's really expensive, so the major challenge is if you're strong in one skill set, you may not be strong in the other. And it's sort of a unicorn position, where there's only a few folks out there that can do it. Because you need a vision of the future, you need technological expertise, and then you need forecasting expertise to really understand the whole problem. So the challenges then are being able to keep up with how technology is changing, how the public is using the technology, which is constantly evolving, and then tying that in with all the social science on how we best communicate with folks." —USA 3

FRA is lacking *"IT know-how and capacities to provide efficient forecasting tools (visualization of model output and efficient forecast editing tools) as well as modern communication outlets for our products."* FRA elaborated on what would help improve operations:

"Rethinking the way our institution, and avalanche forecasting therein, is organized. Including clear roles for the different entities (head of avalanche forecasting, head of forecasting centers, forecaster); clear top-down hierarchy (this is how Météo-France is actually organized at all levels); or transverse teams with only one head (not typical for Météo-France). Centralize into two or three forecasting centers (the human exchange is so important as we are still doing so much human expertise); organize two- to three-day field work campaigns from these centers. Centralize development (web, data services, communication) to keep a closer tie to the forecasting needs. Introduce compulsory and regular training and exchange for all personnel, ideally a lot of continued on-the-job training." —FRA

Improvement 3: Investment in Technical Improvements to Keep Up with Demand

Ten programs want increased investment in technological advancements in avalanche and weather forecasting. As winter backcountry use increases, avalanche programs must keep up with increased public safety demands. Technology is rapidly evolving, particularly in the use of

artificial intelligence (AI), and avalanche prediction models must keep pace. USA 1 underscored this need, also touching on how having dedicated non-forecast staff ties into the ability to innovate:

“Avalanche forecasters would benefit greatly from a numerical avalanche prediction model.

Progress is being made towards this end, but an operational model is still in the mid- to long-range future. Once a model is operational, calibrating and validating such a model presents an additional challenge. Improved avalanche detection is needed for this last step, involving advancements in quantifying avalanche activity in real time through satellite imagery, AI applications, and other technology. Improvements in numerical snowpack modeling, remote sensing, public data collection and sharing, public risk communication. One of the things that I think is really a challenge for us, and is probably going to be, you know, more and more of a challenge moving forward. It's not just us, I think, you know, the European centers have dealt with it as well. It's that we're not that good at building the staff that can do both of those things; they're really good at doing field operations or they're really good at the technical side. Finding the people that can do both is, they're out there for sure, but it's not a realistic personnel model, because there's just not training programs for that. And so, if I was given, you know, even another half a million dollars, employing the whole staff year-round would be great, but the skill set of the staff is not conducive to year-round work.” —USA 1

USA 4 brought up a similar sentiment, saying, *“We would like to more rapidly incorporate new technologies and forecasting changes into our products. It's been ten years since we changed the avalanche forecast layout.”* USA 5 expressed wanting a system like Norway’s Regobs or Canada’s SNOWPACK modeling dashboard, elaborating:

“Our goal is to provide actionable information for users to make the best decisions possible. Each user decides how much risk they are willing to accept, and our products help them choose terrain that matches their desired risk.” —USA 5

AUT wished for more personnel and a fixed amount of the budget for software and model development. CHE wanted a better understanding of how users apply information from the avalanche bulletin, more support from snowpack and meteorological models, and effective tools for analyzing model output. NOR also stressed the importance of improving the forecasting process coupled with recruiting dedicated staff members:

“AI and modeling could improve the forecasting process and the forecasts. More actionable products for the users, taking into account terrain, competence, and user applications, could make the forecasts more useful. Sustainability is related to having trust with our users, being the primary source of information, and increasingly documenting the cost-benefit aspects of forecasting. Furthermore, sustainability is linked to keeping and recruiting competent, innovative, and dedicated staff.” —NOR

Sub-Theme: Importance of Collaboration with Other Countries

Interest in cross-border learning is high, but the mechanism for it is informal (via personal relationships, occasional visits, and the biennial International Snow Science Workshop) rather than structured. This high appetite for cross-border knowledge sharing, paired with little infrastructure for actually sharing lessons, is an area for improvement.

USA 1 recounted their relationship with various European programs, and recommended the US look toward France as a potential model for national centralization of its programs:

“Beyond our close collaboration with Canada, I mean, we've had a really long, you know, stemming again, like what we talked about from the 60s, we've had a very long collaboration with the Swiss. There's great things that they've done, whether you want to adopt it wholesale or not, I don't know, but there's definitely some great things that have been done there. The Norwegians are a really interesting model, because they're not an old program, right? Even though they're 10

years old at this point, they went from kind of zero to 60 and have built a really interesting program and done a lot of innovation there, so I think that that's a really good place to look. The French are again a really interesting model, especially if what you want to do is run a national program, because it's essentially the National Weather Service that's doing it. Météo-France does the weather forecasting and avalanche forecasting. There's, you know, some great capabilities that come out of that, and some big liabilities, and they've also been doing it for a long time, so they have an interesting perspective, I think. But if the US was going to sit down and be like, 'Hey, we want 100% coverage of avalanche forecasting for the US,' I think you have to do it in some similar way." —USA 1

CAN 2 also praised other countries' work:

"I'm always paying close attention to the Swiss research work, as it is very good. I dream of the Swiss research component. Avalanche detection systems being developed in other countries. Avalanche control methods being developed in other countries. There are many advancements happening in this industry in different countries that are valuable and worth tracking. I mean, the Swiss have the observer network, and the Norwegians have an observer network, which is pretty good. Also, I think it works pretty well, but so do we. And our observer network is highly trained professionals all over the place, so we have a very high-level observer network." —CAN 2

NOR added, *"We collaborate with and get inspired by many other programs, in Europe, Canada, and the US. All of this is very important to us."* NZL's program adopted recommendations from other countries' experts:

"[We] regularly reflect on our system and processes, and look to other countries for things we can adopt. We've visited Canada and USA several times in the last five years to explore these partnerships further, and are in regular contact with Avalanche Canada, Parks Canada, and the CAIC [Colorado Avalanche Information Center]. We've had two external reviews conducted by two experts from North America, and in both cases we've adopted numerous recommendations.

Most recently, we have incorporated the Confidence Statements into the NZAA forecasts, modeled off Avalanche Canada.” —NZL

FRA valued learning from other countries, but lamented the lack of exchange among decision-making entities at European programs:

“Each and every operation has strong points that others can learn from. However, there is limited exchange between European countries at the level of the decision-making entities in the organizations. Often, forecasters or the staff responsible for the avalanche forecasting program know these points, but as the forecasting program is in most cases embedded in a larger (state-owned) administrative structure, the room for maneuvering is limited.” —FRA

4.7: Theme 6 - Reach is a compelling metric for measuring program efficacy

Reach, including education program participants and unique website users, is a more compelling proxy metric for measuring program efficacy than fatality count alone. Reach, whether through online resources or in-person courses, is the core mechanism by which avalanche programs help the public adjust their behavior around avalanche risk. With each awareness and skills class taken and each view of an avalanche forecast, these programs are reaching the public with unique safety resources.

Every avalanche program offers a variety of educational courses. Public short-form awareness sessions and professional training are nearly universal. Only a handful of programs offer longer-form, field-based recreational courses and 'other' formats. What varies between programs is how many people these courses serve. The number of programs held annually ranges from 2 (USA 3) to over 200 (CAN 1), and the number of annual education participants ranges from 120 (USA 3) to 25,000 (CAN 1). These numbers appear to correlate to a program's staffing

and budget capacity, and are not related to whether the organization is a nonprofit or a federal agency. Additionally, greater numbers of education participants do not necessarily correlate directly with greater program effectiveness, but these figures do tell a rich story of how many people find these public safety services valuable.

Table 6: Number of Annual Education Programs and Participants per Organization

			Types of avalanche education programs your organization offers				
Program	Number of education programs held annually	Number of education participants per year	Public awareness: short form, classroom environment	Recreational user courses: long form, field-based learning	Professional training	School or youth programs	Other
AUT	5	500	X		X	X	
CAN 1	200+	25,000	X	X		X	
CAN 2	3	400	X				
FRA	10	1,000	X		X	X	
NZL	104	540	X				X ⁷
NOR	50	5,000			X		X ⁸
CHE	8	240			X		
USA 1	100	3,000	X		X	X	
USA 2	15	1,000	X			X	
USA 3	2	120			X		X ⁹
USA 4	200	4,500	X			X	
USA 5	35	1,400	X	X	X	X	X ¹⁰

⁷ NZL does not deliver training themselves; they provide course curriculum and have agreements with training providers to deliver them

⁸ 'Other' includes open seminars in November and webinars for local stakeholders

⁹ 'Other' includes web-based tutorials for recreational users

¹⁰ 'Other' includes advanced recreational presentations/ events, rescue and transceiver training

Furthermore, annual unique website users range from under 20,000 (USA 2) to five million (AUT), a gap driven as much by population, tourism volume, and land area served as by program capacity. This makes raw user counts a weak stand-alone metric for cross-country comparison of a program's 'success' in reaching the public. However, these are strong indicators of how many people in a given region rely on the forecasts, data, and educational materials on these programs' websites.

Table 7: Number of Unique Online Users Accessing Avalanche Forecasts Per Season

Participant	Number of Seasonal Unique Website Users	Number of Seasonal Unique Mobile App Users	Total Number of Seasonal Unique Online Platform Users
AUT	5,000,000	N/A	5,000,000
CAN 1	245,000	36,000	281,000
CAN 2 ¹¹	245,000	36,000	281,000
FRA	3,120,000	Not quantified ¹²	3,120,000
NZL ¹³	58,600	N/A	58,600
NOR	850,000 ¹⁴	20,000	872,000
CHE ¹⁵	Not quantified	Not quantified	Not quantified
USA 1	350,000	30,000	380,000
USA 2	18,000	900	18,900
USA 3 ¹⁶	2,500,000	N/A	2,500,000
USA 4	750,000	32,000	782,000
USA 5	27,200	1,200	28,400

¹¹ Avalanche Canada and Parks Canada share a website and app platform, and therefore share usage numbers

¹² Participant did not have access to this data; forecasts and weather data are available on multiple apps and websites

¹³ The only other method to obtain the NZAA forecasts are via two approved NZ weather providers: MetService and NIWA, both of whom use APIs to display a small widget showing the danger levels. Participant cannot obtain metrics for these.

¹⁴ Figure reflects total visitors this season but logging tools do not track uniqueness of visitors over more than a day

¹⁵ Participant did not have access to this data; forecasts and weather data are hosted on multiple platforms

¹⁶ Users pass through the National Avalanche Center website to access national information and find regional avalanche center websites and forecasts

Describing and measuring program success is not straightforward because the baseline of winter backcountry use per capita does not exist. The lack of metrics on how backcountry use has grown and evolved hampers avalanche programs' ability to appeal to government entities or other funders, as they cannot quantify their impact in reducing avalanche risk or increasing public safety. Not a single program surveyed had quantifiable metrics to cite when referencing growth in winter backcountry usage. Instead, programs provided anecdotal evidence and exponential estimates of the growth they have witnessed. Website use, education course registrations, backcountry gear sales, snowmobile registrations, and visitor numbers to state or national parks are some of the common proxies. Across every program, participants explicitly said this data gap actively hurts their ability to argue for more funding. USA 5 expressed this sentiment:

“We think [backcountry recreation] has increased geometrically. This is based on anecdotal evidence—vehicles at trailheads, the amount of tracks/ traffic in the backcountry—and some ‘hard’ numbers—website use, avalanche class students, local retail sales and rental of backcountry equipment. However, the ‘hard numbers’ cannot be 100% correlated to use. For example, the website and social media numbers appear to correlate better with snowfall/ large storms, elevated danger, and weekends/ holidays, and seasonal use totals are higher in big snow years.” —USA 5

USA 5 went on to compare increased use to the static annual fatality rates in the US:

"Through Covid, it was, you know, use was skyrocketing, and there was no way to come up with a coherent argument against that. And the fatality rate stayed static. So that's the best way we can show that what we're doing works, is that despite, you know, whether you want to say that use doubled, tripled, quadrupled, or is 10x, it's something in that order of two to 10 times compared to what it was in 1995, and the fatality rate has stayed static. So the fatalities have stayed static, the rate has significantly decreased, and you know, you can't attribute that entirely to the avalanche

forecasting program, but a significant part of it, I think, you can attribute to what avalanche centers are doing with education, outreach, and forecasting." —USA 5

CAN 1 joked that they would go to great lengths to have the answer on usage metrics:

"If you ever get the miracle answer on metrics, you know, we'll do whatever we need to get it from you, but it's very challenging here. There's, you know, parking lots are full, and it's crowded in some places, just the same as in the States. So we know that there's a tenfold increase in the last 10-15 years of users. We have a lot of anecdotal data from even Parks Canada or Alberta Parks, where on Avalanche Awareness Day weekend 10 years ago there were like 50 cars in the parking lot, and now there's 500 cars, and they're parked all along the highway. But they're not official, it's not empirical data, so that's one of the challenges." —CAN 1

NZL believes that backcountry recreation has grown in New Zealand in the last 10 years, but has no way of measuring it:

"Currently New Zealand does not have a robust scientific mechanism for measuring this. We've recently had 'mountaineering' added as an activity to our national sport and recreation participation research, and we hope this will give us some insights in 2027. Otherwise, anecdotal evidence from backcountry retailers and general industry sentiment suggests there has been growth." —NZL

USA 1 noted a spike in backcountry recreation correlated to the COVID pandemic, but has a hard time turning the story around rising backcountry use and their program's successes into a compelling narrative for funders:

"At this time there's no systematic way to look at backcountry user growth. The other thing that is complicated is that a lot of the stuff that we do, we're very proud of, but when you compare things number to number to other state government programs it's just not that compelling, you know? Like the Know Before You Go awareness program—at the height of that collaboration with the Utah Center, I think that we reached like 15,000 to 17,000 students in a year, and I was super proud of it. And I was in some meeting with a bunch of different departments talking about education programs and school kids, and I trotted it out, and they all looked at me like I was

insane. Because it's such a drop in the bucket compared to the other programs that, you know, if you're talking about teaching kids about forest fires, or teaching kids about stranger danger, or public health. There's a little bit of an infamous day where I had a meeting with one of the previous governors and was talking about our support for avalanche workers, so it was really like a workplace safety discussion that we were having. And in the middle of it, he stopped me and he's like, 'Do you know how many people die in swimming pools every year in this state?' And so he was really unimpressed with the numbers. There's more people that die in avalanches in Colorado than any other state over the long term—not every year, but most years. But when you look at that compared to other public safety programs, it's not that many people." —USA 1

Table 8: Average Annual Avalanche Fatalities by Country and Program Forecasting Area

Participant	Approx Area of Forecasting Coverage (Sq Km)	Country	Average Annual Fatalities in Country
AUT	12,000 km ²	Austria	20
CAN 1	368,000 km ²	Canada	11
CAN 2	23,000 km ²		
FRA	360,000km ²	France	31
NZL	20,000 km ²	New Zealand	1
NOR	200,000 km ²	Norway	7
CHE	28,000 km ²	Switzerland	21
USA 1	80,000 km ²	United States	27
USA 2	90 km ²		
USA 3	218,000 km ² ¹⁷		
USA 4	39,000 km ²		
USA 5	10,000 km ²		

¹⁷ USA 3 (National Avalanche Center) does not issue forecasting, but rather acts as a national support organization for a large portion of US avalanche centers. Therefore, forecasting coverage area here encompasses the total area that all 29 US avalanche centers cover with forecasting services. This gives a more robust picture of the national avalanche forecast coverage for the US.

Chapter 5: Recommendations

The recommendations detailed below aim to improve US avalanche safety programs. Through this research project, I sought to compare the structure and funding of US avalanche programs with those of peer countries, with the aim of identifying policy options to improve the long-term efficacy and resilience of US avalanche forecasting services. These options are outlined in the recommendations below.

5.1: Recommendation 1 - Standardize Multi-Year Funding Across the US

US avalanche safety programs should band together to pursue a three- to five- year legislated or contractually guaranteed funding stream (modeled on France/ Switzerland/ Parks Canada counterparts). They should do so through a reliable mechanism, but it is unclear whether that should be through a government entity such as the US Forest Service (USFS) or National Weather Service (NWS), or whether some form of private sector funding should facilitate this. A large percentage of funding should come from government sources due to 1) the high percentage of government ownership of backcountry lands in the US; 2) overlap in equipment, technology infrastructure, and staff that contribute to avalanche forecasts; 3) the usually greater stability that government funding represents in other countries; and 4) such forecasting and education centers should be seen as part of a general public good that governments should provide.

State governments could contribute funding through Departments of Transportation and/or Natural Resources, state park passes or other outdoor recreation pass revenue, or extraction or resource taxes. The federal government could contribute legislatively mandated funding through mechanisms such as the SHRED (Ski Hill Resources for Economic

Development) Act, a proposed Bill with bipartisan support that could invest in public safety by enabling avalanche centers to retain a portion of the annual fees paid by ski areas operating within National Forest boundaries. As proposed in H.R. 1084, the SHRED Act would establish a Ski Area Free Retention Account to retain fees that ski areas pay to the Forest Service, using those fees to support a variety of recreation management and community needs, including avalanche information and education.

This recommendation is complex and requires additional research to understand which funding mechanisms and sources are most feasible and sustainable. The exact mix of funding is variable across US avalanche centers. Still, a coordinated effort to gain clarity and commitment to fund these centers over multi-year cycles is an important next step.

5.2: Recommendation 2 - Create Cohesion Among All US Avalanche Centers

In addition to the first recommendation, the National Avalanche Center (NAC) should continue as the central hub for the 14 US Forest Service-funded avalanche programs, but should also endeavor to encompass and lead all 29 US avalanche programs. While the NAC does not have an official mandate to serve avalanche centers not on Forest Service lands (as the organization is housed under the USFS), it does provide support—particularly through the management of its centralized software system, the Avalanche Forecasting Platform (AFP), and its collaboration with the American Avalanche Association (A3)—to centralize the dissemination of avalanche information across all types of US avalanche centers. Due to limited funding, limited staffing, and chaos caused by recent USFS restructuring, the NAC is currently limited in its abilities to support all 29 centers. The NAC should serve as a body that consolidates resources, facilitates collaboration, and advances US avalanche forecasting and safety services.

However, further research is required to determine whether the NAC would be better suited as a federal entity under the USDA/ USFS (where the program currently resides), affiliated with a different governmental agency (such as the NWS), or operating as a nonprofit (501c3) entity funded by federal appropriations.

5.3: Recommendation 3 - Do Not Dissolve Existing Nonprofit Organizations

Existing nonprofit arms of avalanche programs in the US should remain intact to enable flexible advocacy efforts, community outreach, and additional fundraising to support technological and forecasting advancements. That said, avalanche programs should not have to rely on these nonprofits to remain operational (refer to Recommendation 1). To mitigate the sheer number of avalanche programs and affiliated nonprofits in the country, I do not recommend that centers currently without a nonprofit arm spend time and effort creating one.

5.4: Recommendation 4 - Adopt Reach-Based Metrics to Showcase Efficacy

US programs should adopt reach-based metrics (education participants, unique website users) alongside—not instead of—fatality data in program evaluations and advocacy efforts, given the consensus that fatalities alone underrepresent program effectiveness. Reach is a distinct metric that programs should utilize more frequently to explain the breadth of public safety work they conduct. Because it is difficult to support any single metric as a clear proxy for program effectiveness, there is a need to expand these metrics and demonstrate program effectiveness through a robust government review (similar to reviews conducted in Canada and New Zealand, as referenced in the Literature Review). Programs should also adopt reach-based metrics to showcase the amount of public infrastructure they help safeguard. Providing avalanche forecasts

and other crucial weather data for transportation corridors, such as highways and mountain passes, reaches vast numbers of people and goes far beyond protecting backcountry recreationists.

5.5: Recommendation 5 - Collaborate on Public Communication & Advocacy

US programs should combine Recommendations 2 and 4 to strengthen inter-country collaboration when it comes to providing a compelling story to funders. By pooling resources and speaking with one voice, rather than many disparate ones, avalanche centers can maintain funding streams essential to their mission.

Chapter 6: Conclusion

This study set out to identify what organizational traits relate to financial stability, forecast consistency, and long-term durability across avalanche safety programs to inform improvements to US programs. The answer does not lie in the program structure itself, as all organization types—federal, state, nonprofit, and hybrid—produce programs that can be either durable or unstable. Research results point to legally protected, multi-year funding as an organizational trait that correlates most closely to greater program stability. Furthermore, organizational structure or type is rarely clear-cut across these programs; even nationally organized forecasting systems contain multiple programs and regional funding variations. Budget size is also a complex variable, as national programs’ annual budgets range from a couple hundred thousand USD to several million USD. These budgets track more closely to land area and institutional scope than they do to governance models. Funding composition paints a clearer picture when drawing lessons from these avalanche programs. Federal and state programs receive 80-100% of their funding from government sources, providing forecast consistency but limited flexibility. In contrast, nonprofit and hybrid programs stitch together individual donations, corporate sponsorships, grants, and government funding, trading consistency and stability for adaptability.

Regardless of structure or funding, stabilizing avalanche fatality trends alone do not provide a robust understanding of how these programs are reducing public avalanche risk. Reach metrics such as the number of educational programs and participants, the volume of online traffic on websites and apps, and the land area covered by avalanche forecasts tell a richer story of a program’s effectiveness, particularly when coupled with fatality statistics.

These findings translate directly into the five recommendations above. Because guaranteed funding, not structure, drives stability, Recommendation 1 targets legislated or contractually guaranteed funding streams. Since centralization alone did not predict greater stability and durability among the participants surveyed, Recommendation 2 treats consolidation under the NAC as a coordination and consensus-building block, not the guaranteed solution to the US' instability problems. Recommendation 3 preserves the flexibility that nonprofit programs offer, but acts as a supplement rather than a foundation for US avalanche programs. Recommendation 4 provides examples of metrics that programs can lean into when securing guaranteed, multi-year funding, and offers an additional suggestion to expand such metrics through an official government review of nationwide avalanche programs. Finally, because comparative data showed that funding concerns map to whichever revenue source a program depends on most, Recommendation 5 focuses on pooling the resources of the existing 29 US programs into one coordinated effort to attract long-term, reliable funding. These recommendations are meant to complement one another and work in tandem to create a stronger, more effective ecosystem of avalanche safety organizations in the US.

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References

- Ahmed, S.K. (2025). Sample size for saturation in qualitative research: Debates, definitions, and strategies. *Journal of Medicine, Surgery, and Public Health*, 5.
<https://www.sciencedirect.com/science/article/pii/S2949916X24001245?via%3Dihub>
- Ahmed, S.K., Mohammed, R.A., Nashwan, A.J., Ibrahim, R.H., Abdalla, A.Q., Ameen, B.M., Khdhir, R.M. (2025). *Journal of Medicine, Surgery, and Public Health*, 6.
<https://www.sciencedirect.com/science/article/pii/S2949916X25000222#sec0005>
- Avalanche Canada. (n.d.). *About - Avalanche Canada: The Home of Public Avalanche Safety in Canada*. Retrieved April 22, 2026. <https://avalanche.ca/about>
- Berline, C., Techel, F., Moor, B.K., Zwahlen, M., Hasler, R.M. (2019). Snow avalanche deaths in Switzerland from 1995 to 2014—Results of a nationwide linkage study. *PLoS ONE* 14(12). <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0225735>
- Bettzieche, J. (2026, January 20). *The avalanche winter of 1951: a disaster unfolds*.
<https://www.slf.ch/en/news/the-avalanche-winter-of-1951-a-disaster-unfolds/>
- Birkeland, K.W., Greene, E.M. & Logan, S. (2017). In response to avalanche fatalities in the United States by Jekich et al. *Wilderness & Environmental Medicine*, 28(4), 380–382.
<https://journals.sagepub.com/doi/10.1016/j.wem.2017.06.009>
- Bureau of Economic Analysis. (2026, March 5). *Outdoor recreation economic statistics, U.S. and states, 2024* [News release]. U.S. Department of Commerce.

<https://www.bea.gov/news/2026/outdoor-recreation-economic-statistics-us-and-states-2024>

4

CBC News (2018, November 22). *Avalanche Canada gets \$25M boost from Ottawa after years of financial struggle*.

<https://www.cbc.ca/news/canada/british-columbia/avalanche-canada-25m-boost-ottawa-1.4915864>

Colorado Avalanche Information Center. (2025). *Accident statistics and reporting*. Retrieved April 22, 2026. <https://avalanche.state.co.us/accidents/statistics-and-reporting>

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., Sheikh, A. (2011). The case study approach. *BMC Medical Research Methodology*, 11(100).

<https://link.springer.com/article/10.1186/1471-2288-11-100#article-info>

Dahl, T., Dassler, T., Fjellaksel, R., Hetland, A., Pfuhl, G., Street, K., Toft, H.B., Schulze, C. (2026). It's fun ... until it isn't: Boosting and nudging for safer decisions in hazardous backcountry winter mountains. *Journal of Outdoor Recreation and Tourism*, 53.

<https://www.sciencedirect.com/science/article/pii/S2213078025001422>

Dufour, A., Coléou, C., Retuer, B., Viallon-Galinier, L., Gilet-Chaulet, B., Hamelin, O. & Trajan, A. (2024). Avalanche Warnings: The main information channels in France, with a focus on “Vigilance,” a mature crisis communication tool. *Proceedings of the 2024 International Snow Science Workshop*, 1684–1691.

https://arc.lib.montana.edu/snow-science/objects/ISSW2024_P12.10.pdf

Engeset, R.V. (2013). National Avalanche Warning Service for Norway - established 2013.

Proceedings of the 2013 International Snow Science Workshop, 1–19.

https://arc.lib.montana.edu/snow-science/objects/ISSW13_paper_P1-19.pdf

Federal Emergency Management Agency. (2025). *National Risk Index data: Methodology and Hazards Overview*. U.S. Department of Homeland Security.

https://www.fema.gov/sites/default/files/documents/fema_national-risk-index_methodology-hazards-overview.pdf

Fisher, K.C., Haegeli, P. & Mair, P. (2021). Impact of information presentation on interpretability of spatial hazard information: lessons from a study in avalanche safety. *NHESS*, 21, 3219–3242. <https://nhess.copernicus.org/articles/21/3219/2021/>

Frankenfield, J. (1994). Building community support and diversifying funding for backcountry avalanche forecasting. *Proceedings of the 1994 International Snow Science Workshop*, 488–493. <https://arc.lib.montana.edu/snow-science/objects/issw-1994-488-493.pdf>

Fuller, T. & Cowan, J. (2026, February 19). *After Avalanche Warnings, a Sierra Nevada Tragedy*. The New York Times.

<https://www.nytimes.com/2026/02/19/us/avalanche-lake-tahoe-deaths.html>

Glassett, T. & Techel, F. (2014). Avalanche Accidents Involving People Along Transportation Corridors and the Implications for Avalanche Operations. *Proceedings of the 2014 International Snow Science Workshop*, 343–350.

https://arc.lib.montana.edu/snow-science/objects/ISSW14_paper_O14.02.pdf

- Greene, K., Hendrikx, J. & Johnson, J. (2022). The Impact of Avalanche Education on Risk Perception, Confidence, and Decision-Making Among Backcountry Skiers. *Leisure Sciences*, 47(1), 113–133.
<https://www.tandfonline.com/doi/full/10.1080/01490400.2022.2062075#d1e193>
- Hill, M., Wiesinger, T., & Abromeit, D. (2004). Avalanche Forecaster Exchange Program U.S. – Switzerland. *Proceedings of the 2004 International Snow Science Workshop*, 172–176.
<https://arc.lib.montana.edu/snow-science/objects/issw-2004-172-176.pdf>
- Kearsley, A. (2026). *HHS standard values for regulatory analysis, 2026*. Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services.
<https://aspe.hhs.gov/sites/default/files/documents/2d83af5823915d81871334ee08ad03d9/Standard-RIA-Values-2026.pdf>
- Kharb, A., Bhandari, S., Moitinho de Almeida, M., Castro Delgado, R., Arcos González, P., & Tubeuf, S. (2022). Valuing human impact of natural disasters: A review of methods. *International Journal of Environmental Research and Public Health*, 19(18), 11486.
<https://doi.org/10.3390/ijerph191811486>
- Kriz, K., Nairz, P., & Zenkl, G. (2018). LAWIS – A collaborative data communication portal for avalanche risk management and prevention. *Proceedings of the 2018 International Snow Science Workshop*.
<https://cartography.univie.ac.at/lehre/hgex/media/2018-09-P18.2-ISSW-LAWIS.pdf>
- LeSourd, P. (2018, May 1). The Northwest’s Influence on the Growth of Wilderness Recreation. *History Link*. <https://www.historylink.org/file/20551>

Logan, H. (2014). *A review of the New Zealand avalanche hazard advisory and information service.*

<https://www.nzsar.govt.nz/assets/Downloadable-Files/Avalanche-Advisory-Report-Oct-2014.pdf>

Lucas, R.C. & Stankey, G.H. (1987). Shifting Trends in Wilderness Recreational Use.

Intermountain Research Station, US Department of Agriculture.

<https://www.umn.edu/media/leopold/pubs/205.pdf>

McNeil, K.R., Morgan, J.A., Riggs Meder, L.Y., & Walker, E.R. (2023). Understanding backcountry behaviors after participation in a recreational avalanche course. *Proceedings of the 2018 International Snow Science Workshop*, 1112–1119.

https://arc.lib.montana.edu/snow-science/objects/ISSW2023_O12.01.pdf

Montana State University. (2024). Avalanche safety: What to know before you go. *Lives and Landscapes*, Winter 2024. Montana State University Extension.

https://www.montana.edu/extension/lila_extn/avalanchesafety.html

Mountain Safety Council New Zealand. (n.d.). *About Us*. Retrieved April 22, 2026.

<https://www.mountainsafety.org.nz/about-us>

National Avalanche Center. (June 2025). *USDA Forest Service Avalanche Centers.*

<https://avalanche.org/wp-content/uploads/2025/06/NAC-USDA-Forest-Service-Avalanche-Centers.pdf>

Natural Hazards Commission Toka Tū Ake. (2024). *Funding and risk management statement for Natural Hazards Commission Toka Tū Ake*. New Zealand Treasury.

<https://www.treasury.govt.nz/sites/default/files/2024-08/funding-risk-management-statement-natural-hazards-commission.pdf>

New Zealand Avalanche Advisory. (n.d.). *About Us*. Retrieved April 22, 2026.

<https://www.avalanche.net.nz/about-us>

Neweduk, A. & Haegeli, P. (2025). Exploring motivations of winter backcountry recreationists in support of avalanche risk communication. *Journal of Outdoor Recreation and Tourism*, 52. <https://www.sciencedirect.com/science/article/pii/S2213078025000386>

Northwest Avalanche Center. (n.d.). *What is the Backcountry*. Retrieved May 11, 2026.

<https://nwac.us/what-is-the-backcountry/>

Parks Canada. (2026, March 25). *Parks Canada avalanche information*. Retrieved April 22, 2026. <https://parks.canada.ca/pn-np/mtn/securiteenmontagne-mountainsafety/avalanche>

Pfeffer, J. & Salancik, G.R. (1978). The Design & Management of Externally Controlled Organizations. In J. Greenman & R.E. Beach (Eds.), *The External Control of Organizations: A Resource Dependence Perspective* (pp. 257-287). Harper & Row.

Public Safety Canada. (2024). *Evaluation of Public Safety's support to Avalanche Canada's long-term sustainability and expansion of services*. <https://www.publicsafety.gc.ca/cnt/rsrscs/pblctns/vltn-vlnch-cnd/vltn-vlnch-cnd-en.pdf>

Sierra Avalanche Center. (2026, February 17). *Avalanche Forecast Archive*.

<https://www.sierraavalanchecenter.org/forecasts/avalanche/central-sierra-nevada#/forecast/1/180664>

SLF. (n.d.). *About the SLF-Portrait-History*. Retrieved April 22, 2026.

<https://www.slf.ch/en/about-the-slf/portrait/history-1/>

SLF. (2026). *Fatal avalanche accidents in the hydrological year 2025/26*. Retrieved April 22, 2026.

<https://www.slf.ch/en/avalanches/avalanches-and-avalanche-accidents/fatal-avalanche-accidents-in-current-year/>

Snowsports Industries America. (2025). *Snowsports Industries America 2024-25 Participation Study*.

St. Clair, A. & Haegeli, P. (2023). Toward improved effectiveness of public avalanche safety services: A framework for asking constructive questions. *Avalanche Research Program, Simon Fraser University*.

https://sfuarp.ca/wp-content/uploads/2023/09/2023_StClairHaegeli_Evaluation.pdf

Statham, G. (2014). *Norwegian Avalanche Warning Service Program Review* (Report No. 80).

https://publikasjoner.nve.no/rapport/2014/rapport2014_80.pdf

United Nations Office for Disaster Risk Reduction. (2025). *UNDRR–ISC Hazard Information Profiles – 2025 Update: MH0801 Avalanche*. <https://www.undrr.org/terms/hips/MH0801>

US Department of Agriculture, Forest Service. (2025). *FY 2026 Budget Justification*.

<https://www.fs.usda.gov/sites/default/files/fs-fy26-congressional-budget-justification.pdf>

US Department of Agriculture, Forest Service. (2026). *Forest Service Reorganization*.

<https://www.fs.usda.gov/about-agency/reorganization>

US Environmental Protection Agency. (2026, January 26). *Mortality risk valuation*.

<https://www.epa.gov/environmental-economics/mortality-risk-valuation>

Valle, E.A., Cobourn, A.P., Trivitt, S.J.H., Hendrikx, J., Johnson, J.D. & Fiore, D.C. (2022).

Perceptions Among Backcountry Skiers During the COVID-19 Pandemic: Avalanche

Safety and Backcountry Habits of New and Established Skiers. *Wilderness Environ Med*.

33(4), 429–436. <https://pmc.ncbi.nlm.nih.gov/articles/PMC9561445/>

Varsom. (n.d.). *About the Norwegian Avalanche Warning Service*. Retrieved April 22, 2026.

<https://www.varsom.no/en/avalanches/avalanche-warnings/about-the-norwegian-avalanche-warning-service/>

Appendix A: Survey Questions

Funding the Forecasting: Comparative Approaches to Avalanche Risk Management - Survey Questions

This study examines how avalanche forecasting operations are organized, funded, staffed, and utilized across different countries. The survey focuses on institutional structure, funding stability, forecasting practices, education programs, and public use of avalanche information.

Format

- Participants receive this questionnaire and should prepare as many written responses as possible in advance of a verbal interview
- Responses not prepared in writing will be discussed verbally during a 60-minute Zoom call (if participant availability allows)
- Not all questions must be answered if information is unavailable or is not applicable

Section 1: Participant & Organization Background

1. **Country of organization:**
2. **Name of avalanche center/ organization:**
3. **Participant role/ title:**
4. **Years in current role:**
5. **Is your organization best described as (select all that apply):**
 - ☐ Non-profit
 - ☐ State/ provincial agency
 - ☐ Federal/ national agency
 - ☐ Academic or research institution
 - ☐ Hybrid model (please describe):
 - ☐ Other (please describe):
6. **How is your avalanche forecasting system organized?**
 - ☐ National organization
 - ☐ Umbrella organization with regional branches
 - ☐ Multiple independent organizations
 - ☐ Other (please explain):

Section 2: Organizational Structure & Governance

7. Are forecasting operations housed within a broader agency (e.g., meteorological service, transportation agency, land management agency)? If yes, please describe that relationship.
8. Is your organization financially or operationally tied to Search and Rescue (SAR), road authorities, or emergency management agencies? If yes, please describe the relationship(s).
9. Does your data directly trigger road closures, evacuations, or emergency responses? If yes, please explain.
10. What do you see as the primary strengths of your current organizational model?
11. What organizational challenges do you face?

Section 3: Funding Model & Financial Stability

12. Approximate annual operating budget (current year):
 - Approximate annual operating budget 10 years ago (if available):
13. Approximate percentage breakdown of annual funding sources:
 - Federal/ national government: %
 - State/ provincial government: %
 - Non-profit or charitable organizations: %
 - Corporate sponsorships/ donations: %
 - Individual donations/ memberships: %
 - Earned revenue (fees, education services, training, workshops, etc): %
 - Other: % Please specify:

14. Is funding standardized across the country or does it vary regionally?

- ☐ Standardized
- ☐ Varies Regionally
- ☐ Other (please describe):

15. Does your organization charge for any products or services? Check all that apply

- ☐ Forecast access
- ☐ Education programs
- ☐ Professional training
- ☐ Data services
- ☐ Other (please describe):

16. How stable does your funding feel over the next 5-10 years?

- ☐ Very stable
- ☐ Somewhat stable
- ☐ Uncertain
- ☐ At risk

17. What are your primary funding concerns?

18. How do you explore or secure new funding sources?

Section 4: Staffing & Capacity

19. Approximate number of paid staff (full-time equivalent):

- Forecasters:
- Educators:
- Observers (professional):
- Fundraising/ development staff:
- Administrative staff:
- Research staff:
- Other (technology, communications, etc):

20. How many volunteer hours does your organization utilize annually?
21. Are staffing levels sufficient to meet current demand? Why or why not?

Section 5: Forecasting Methodology & Operations

22. Which avalanche danger scale(s) does your organization use?
- ☐ North American Danger Scale
 - ☐ European Avalanche Danger Scale (EAWS)
 - ☐ Other:
23. How frequently are avalanche forecasts published or updated?
- ☐ Multiple times per day
 - ☐ Daily
 - ☐ Weekly
 - ☐ Other:
24. What danger level/ other requirements are necessary for your organization to issue a special avalanche warning or statement to the public?
25. How many weather or snow stations does your organization:
- Directly manage?
 - Rely on third-party organizations?
26. Is your organization part of a unified digital platform (e.g., NAC AFP, Varsom, etc.)? If so, which one?
27. What technical or infrastructure limitations most affect your forecasting capability?

Section 6: Observations & Data Inputs

28. Approximate number of observations collected annually:
- Public observations:
 - Professional observations:

29. **Who are the primary contributors of professional observations?** (e.g., ski patrol, DOTs, guides, military, researchers)

30. **How important are public observations to your forecasting process?**

- ☐ Very important
- ☐ Somewhat important
- ☐ Neutral
- ☐ Unimportant

Section 7: Education & Outreach

31. **What types of avalanche education programs does your organization offer?** Check all that apply.

- ☐ Public awareness: short-form (1-2 hours), classroom learning environment
- ☐ Recreational user courses: long-form (half day to multi-day), field-based learning
- ☐ Professional training
- ☐ School or youth programs
- ☐ Other:

32. **Approximate number of education programs held annually:**

33. **Approximate number of education participants per year:**

34. **Describe the general makeup of your education participants** (e.g., beginner, intermediate, advanced backcountry recreationists; user type; youth vs adult):

35. **What percentage of your organization's education programs are:**

- Free: %
- Paid: %

36. **How important is education to your organization's mission compared to forecasting?**

Section 8: Forecast Use & Public Engagement

37. **Estimated number of unique users accessing avalanche forecasts per season via:**
- Website:
 - Mobile apps:
 - Other platforms:
38. **How has backcountry recreation grown in your country in the last 10 years?** And what metrics do you use to determine this growth (e.g., counting trailhead users, unique website users, etc)?
39. **Has your organization conducted surveys or studies on public understanding of avalanche bulletins, icons, or terminology?** If yes, what were the key findings?

Section 9: Outcomes, Risk, and Value

40. **What is the average number of avalanche fatalities in your country each year?**
41. **How effective do you think your organization is in reducing public avalanche risk?**
- ☐ Very effective
 - ☐ Somewhat effective
 - ☐ Somewhat ineffective
 - ☐ Very ineffective
42. **What is the approximate area of coverage of your organization's avalanche forecasting services** (in square miles or square kilometers):
43. **How do avalanche warning systems compare to other emergency warning systems in your country** (e.g., floods, earthquakes) in terms of perceived value or funding priority?
44. **What do you believe are the most valuable activities your organization performs?** (e.g., forecasting, education, infrastructure protection, cultural impact, etc.)

Section 10: Reflections & Future Directions

45. What changes would most improve the effectiveness or sustainability of your organization?
46. Are there elements of other countries' avalanche programs that you see as particularly successful or worth adopting?
47. Is there anything else you feel is critical to understanding your avalanche forecasting system/ organization that is not covered here?

Appendix B: Interview Questions

1. Can you please provide context around your program's history, organizational structure, and main funding mechanisms?
2. Survey Question #10: What do you see as the primary strengths of your current organizational model?
3. Survey Question #11: What organizational challenges do you face?
4. Survey Question #17: What are your primary funding concerns?
5. Survey Question #20: Are staffing levels sufficient to meet demand? Why or why not?
6. Survey Question #27: What technical or infrastructure limitations most affect your forecasting capabilities?
7. Survey Question #38: How has backcountry recreation grown in your country in the last 10 years?
8. Survey Question 39: Has your organization conducted surveys or studies on public understanding of avalanche bulletins, icons, or terminology? What were the key findings?
9. Survey Question 43: How do avalanche warning systems compare to other emergency warning systems in your country (e.g., floods, earthquakes) in terms of perceived value or funding priority?
10. Survey Question 45: What changes would most improve the effectiveness or sustainability of your organization?
11. Survey Question 46: Are there elements of other countries' avalanche programs that you see as particularly successful or worth adopting?
12. Survey Question 47: Is there anything else you feel is critical to understanding your avalanche forecasting system/ organization that was not already covered?

Appendix C: Consent Form

W INFORMATION ABOUT A UNIVERSITY OF WASHINGTON RESEARCH STUDY

Title of Study: Funding the Forecast: Comparative Approaches to Avalanche Risk Management

Principal Investigator: Liz Daniel

Department: Masters in Policy Studies, School of Interdisciplinary Arts & Sciences

Phone Number: 208-250-5452

Email Address: emdaniel@uw.edu

What is this study about?

I am conducting this study to understand how avalanche forecasting centers in the U.S. and peer countries are structured and funded. Your professional expertise will help me identify policy recommendations that may improve the effectiveness, efficiency, and long-term stability of U.S. avalanche centers. You have been invited because of your role or experience in avalanche safety, forecasting, or related work.

What will you be asked to do?

If you decide to participate, you will be asked to:

- Take part in a **one-time interview** lasting approximately **60-90 minutes**, conducted via phone or video call
- Take part in one to two **30-60 minute follow-up calls** if further information is requested
- Answer questions and provide data about your professional experience, organizational context, and perspectives on governance, funding, and operations of avalanche forecasting centers
- You may skip any question or stop the interview at any time
- With your permission, the interview will be **audio-recorded for accuracy**

Procedures

Procedure	Description
Interview scheduling	Participant & researcher coordinate a time for a 60-90 minute interview
Interview	Researcher asks about your professional experience and organizational practices
Optional audio recording	Researcher may record the interview; recording will be stored securely and destroyed after the project
Optional follow-up	Researcher may request one to two 30-60 minute follow-up calls to gather additional information

Why might you want, or not want, to participate?

Possible Benefits:

- Contribute to research that may inform policy improvements for avalanche safety in US
- Share your professional expertise with a graduate-level research project, which may also inform other professionals in the field

Possible Risks or Discomforts:

- Anticipated risks are minimal and low probability but may include professional concerns
- Questions may involve professional opinions, which you can choose not to answer
- Participation requires time

How will we protect the information you provide?

Your confidentiality is protected. Your name and other identifiable information will be stored separately from the study data. Access to your identifying information will be limited to the study's research team, which includes the Principal Investigator and affiliated University of Washington faculty advisor. Audio recordings and notes will be stored securely and accessible only to the research team. All recordings, notes, and identifying data will be destroyed after the project is completed. The published results of this

study will not use your name. You may be referred to by generic role or organization only (e.g., “Avalanche Center Director”).

What if you want to stop being in this study, or if the researcher decides you should no longer participate?

Being in this study is voluntary. This means that you can refuse to sign up. It also means that if you do sign up, you can decide to stop participating in interviews at any time without penalty.

Other information about this study

A copy of the consent form will be emailed to you at an email address that you provide. It will be a “PDF” document. Most computers already have PDF viewer software installed, which will allow you to open, read, or print the consent form. If you would prefer to receive a paper copy of the consent form at no cost to you, please contact the researcher listed in this consent form.

A PDF copy of the final capstone project will be shared with you at the close of the study should you request to view the final product. Possible future uses of this study include peer-reviewed academic publications, conference presentations, and reports intended to inform public safety agencies, avalanche centers, and related nonprofit organizations.

What can you do if you want more information?

Talk to the study team. Please ask any questions you may have, even about things that are not in this document. It is our responsibility to give you the information you need to make a decision and to give you time to think about whether or not you want to sign up.

Talk to someone else. If you want to talk about the study with someone who is not part of the study team, talk about your rights as a research participant, or to report problems or complaints about the study, contact the UW Human Subjects Division.

Study Team	Principal Investigator: Liz Daniel, 208-250-5452, emdaniel@uw.edu Faculty Advisor: Martha Groom, 425-352-5410, groom@uw.edu
UW Human Subjects Division	206-543-0098 hsdinfo@uw.edu

Consent presenter statement

By printing my name on this form, I am attesting that I have provided the participant with information about this study. The participant has been given sufficient time to consider participation and I have answered any questions they had. The participant indicated that they understand the nature of the study, including risks and benefits of participating.

Printed name of study staff obtaining consent: _____

Date: _____

Participant's statement

By signing this consent form, I confirm that the study has been explained to me and I volunteer to participate in the research. I have had a chance to ask questions. If I have questions later about the research or feel I have been harmed by participating in the study, I can contact a member of the research team or the UW Human Subjects Division using the information listed above. I will receive a copy of this consent form.

Printed name of participant: _____

Signature of participant: _____

Date: _____

Appendix D: Data Dashboard

	Federal/ national agency		Federal/ national agency + research institution		State/ provincial agency			Nonprofit organization			Hybrid: public-private partnership	
Program Label	CAN 2	USA 3	FRA	CHE	AUT	NOR	USA 1	CAN 1	NZL	USA 2	USA 4	USA 5
Program / Agency	Parks Canada	National Avalanche Center (NAC)	Météo-France	WSL Institute for Snow & Avalanche Research (SLF)	Avalanche Warning Service Tyrol (LWD Tyrol)	Norwegian Water Resources & Energy Directorate (NVE)	Colorado Avalanche Information Center (CAIC)	Avalanche Canada	Mountain Safety Council (MSC)	Hatcher Pass Avalanche Center (HPAC)	Northwest Avalanche Center (NWAC)	Sawtooth Avalanche Center (SAC)
Forecasting System Org Structure	National organization	Multiple independent organizations	National organization + Umbrella organization with regional branches	National organization	Multiple independent organizations	National organization	Umbrella organization with regional branches	National organization	National organization	Multiple independent organizations	Multiple independent organizations	Multiple independent organizations
Forecasting Ops Housed Within Broader Agency	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	Yes	Yes
Funding Standardization in Country	Varies	Varies	Standardized	Standardized	Varies	Standardized	Varies	Varies	Standardized	Varies	Varies	Varies
How Effective Is Org In Reducing Avalanche Risk	Very effective	Very effective	Somewhat ineffective	Unanswered	Very effective	Very effective	Very effective	Very effective	Very effective	Very effective	Somewhat effective	Somewhat effective
Total Annual Budget (USD)	Not available	\$450,000	\$3,421,000	Not available	\$912,000	\$3,060,000	\$3,700,000	\$4,095,000	\$461,000	\$220,000	\$2,500,000	\$640,000
Total Staff (FTE)	40	3	89	214	7	27	47	31	9	4	18	5

	Federal/ national agency		Federal/ national agency + research institution		State/ provincial agency			Nonprofit organization			Hybrid: public-private partnership	
Program Label	CAN 2	USA 3	FRA	CHE	AUT	NOR	USA 1	CAN 1	NZL	USA 2	USA 4	USA 5
Staffing Levels Sufficient	Yes	No	Yes	Somewhat	No	No	No	No	Yes	Yes	No	Somewhat
Coverage Area (km2)	23,000	218,000	360,000	28,000	12,000	200,000	80,000	368,000	20,000	90	39,000	10,000
Avg Annual Fatalities in Country	11	27	31	21	20	7	27	11	1	27	27	27
Unique Online Users per Season	281,000	2,500,000	3,120,000	Not available	5,000,000	870,000	380,000	281,000	58,600	18,900	782,000	28,400
Education Participants per Year	400	120	1,000	240	500	5,000	3,000	25,000	540	1,000	4,500	1,400
How stable does funding feel over next 5-10 years	Very stable	At risk	Very stable	Very stable	Somewhat stable	Somewhat stable	Somewhat stable	Uncertain	Somewhat stable	Somewhat stable	Uncertain	Somewhat stable
Spread of Annual Revenue Sources												
Fed/ Natl Govt	100%	80%	100%	100%		100%	1%	60%	100%		22%	50%
State/ Prov Govt					100%		89%	21%			11%	
Nonprofit		20%					9%	4.5%		93%	43%	50%
Earned Rev								12.5%		7%	22%	
Other							1%	2%			2%	