

INVESTIGATING SYSTEMS, NOT PEOPLE: LEARNING FROM INCIDENTS IN MOUNTAIN SAFETY PROFESSIONS

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ABSTRACT:

Over the last twenty years, several innovative new incident investigation methods have been developed to assist organizations with taking a systemic view into contributing factors to accidents. These vary in practicality for mountain safety environments where techniques need to be: relatively easy to learn, efficient, and produce meaningful insights that can improve safety performance. This paper reviews the need for systemic accident investigation methods for avalanche involvements, provides a brief overview analyzing the existing methods, outlines a case study of translating and applying a method used in another domain, and offers recommendations for future research and development in this area.

KEYWORDS: learning from incidents, accidents, investigations, organizational learning, skills development.

1. INTRODUCTION

There were deep gouges in the dirt where the gravel had been scattered leading up to the overturned vehicle, with wheels pointing up to the sky. Looking over the scene, the supervisor shook his head and said, "This is clearly a case of complacency and carelessness. It's pure human error."

One of the authors had worked with the foreman for over 5 years and disagreed. They were anything but careless or complacent. So how could two people view the same event and see the same facts, yet still come to such different conclusions?

Patient safety researchers studying medical error in the late nineties identified what they called the first stories and second stories of accidents (Cook, Woods, & Miller, 1997). The first story represented a very surface account of what happened. It focused on how a person made an error that was seen as the primary cause of the accident, was heavily influenced by hindsight bias, and saw the decisions and actions as "obvious" mistakes that stemmed from willful disregard of rules, incompetence, or negligence. The outcomes of investigations followed the pattern of "shame, blame, and retrain" recommending disciplinary actions, retraining, or tightening up procedures and rules. And yet, many organizations felt incident investigations, and their follow-up activities, did little to help understand how failures occurred in ways that could aid in prevention.

In contrast, the second story took a systemic view that looked not just at the minutes and hours preceding an accident, but at how deeper organizational patterns of pressures, constraints, tradeoffs, and goal conflicts, as well as tool and technology design, shaped the conditions that heavily influenced worker decisions and actions. Organizational patterns – like pressure on an avalanche control team to keep a road open to the mining operation during periods of heavy snowfall- or system behavior – like a tendency for "dawn patrol" backcountry users to disregard requests to stay out of terrain where control work needs to take place - created additional difficulties, effort, and workarounds that workers need to navigate in everyday operations. These factors, along with less tangible aspects of the work environment – such as time pressure, uncertainty, and stress – had to be considered when assessing why a worker's action or decision made sense to them at the time. The outcomes of a systemic investigation focused less on an individual's observed behavior or perceived motivations, and more on identifying and addressing the controllable influences of the factors, fixing latent issues (problems that have been present for years or decades), and supporting human capacity to adapt and adjust to less than perfect work conditions. In other words, the outcomes of the investigation aimed to be useful design guidance to engineer resilient systems that could withstand a variety of unexpected events without collapsing or forcing workers into impossible-to-handle situations.

Accidents, paradoxically, are not the best time to learn about how an organization operates. After all,

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no one would suggest trying to understand successful marriages by studying divorces. And yet, following an unintended event, most organizations end up spending substantial resources to repair or replace broken equipment, care for injured workers, or, even more tragically, to respond to the regulatory and legal reactions that follow fatalities in the workplace. Of course, these are important considerations following an accident, but they are insufficient to understand the underlying dynamics that drive behavior and decisions. Instead of initiating reactive and narrowly focused investigations, we propose practical methods for surfacing the sometimes-hidden technical, organizational, and industry factors that influence why someone did, or didn't, act in a certain way at a certain moment. There is a need to integrate these philosophies into practical, workable solutions for mountain safety operations.

2. BACKGROUND

Significant advancements in accident investigations have taken place within the safety science community over the last 25 years. The changes focus on: cultivating a better understanding of the sources of human error to see attributions of errors as “the starting point of an investigation not the end” (Dekker, 2006), identifying the latent and systemic contributors to accidents (Dabkowski et al, 2025), making visible the complex interactions between components that create unintended consequences (Thomas & Malmquist, 2017), highlighting the role of management and distant parties in influencing decision making (Yule, 2003), and strategies to build high-performance learning cultures (Hess, 2014).

These concepts have been integrated into different techniques for conducting systemic incident reviews and learning from incidents such as: Casual Analysis based on Systems Theory (Leveson, 2019); Functional Resonance Accident Method (Hollnagel, 2012); Human Factors Analysis Classification System (Shappell & Wiegmann, 2000); AcciMap (Rasmussen, 1997) & the recent entry AgileMap (Pieper, 2026); Systemic Contributors Adaptations Diagramming (Walker et al., 2016), the Learning Review (U.S. Department of Agriculture Forest Service, 2017); and the Howie Guide (Maguire et al., 2021). Many of these have been used to analyze large-scale, catastrophic events such a nuclear power meltdown, a commercial airliner crash, a near drowning event in space operations, as well as less public but still impactful events within a variety of domains. Of these, several have powerful characteristics highly relevant to mountain safety operations. For example, emphasizing a focus on narrative building over highly technical (and often unreadable) language in accident reports, a practice which have been well established in high-risk, high-consequence work settings such as wildland firefighting (U.S. Department of Agriculture Forest Service, 2017), healthcare (Kwok et al., 2021), and software engineering (Maguire et al., 2021). Others (CAST, FRAM, SCAD, AcciMap & AgileMap) use graphical representations in the analysis or the communication of findings to trace and show the complexity and interactive nature of failures. Several have also aimed to make the process accessible to practitioners (the Howie Guide, AgileMap, and SCAD).

A systems-oriented, complexity-informed investigation represents a concerted effort to move away from investigating individual actions and move towards understanding how work typically gets done. This includes: the workarounds and adaptations that occur when rules don't fit the situation faced; equipment doesn't work as intended; someone calls in sick and you are running short-staffed; or any number of other ways conditions are different than expected when the day started. Increasingly, a key focus is to avoid reports that get filed but not read and instead aim to facilitate a collaborative discussion designed to bring together multiple parties, representing diverse perspectives from across the organization that typically do not interact, but whose work influences each other. Integrating diverse perspectives is necessary to improve understanding of how different parts of the business work together to strengthen communication and coordination across roles and levels within an organization. Improved communication and coordination can mean relevant information is shared in a timely fashion, with less confusion, and different departments are better able to anticipate how a seemingly insignificant event might cascade to cause a larger issue. A lift operator who notices oil unexpectedly dripping from the terminal might notify not only the maintenance staff but also ticket sales, so guests can be proactively encouraged to choose a different lift – potentially minimizing the scale of a response should the issue be found to be serious.

Maintaining a coherent and integrated “big picture” perspective on changing risks is critical for safe operations. Without it, perception of risk is fragmented, and the organization may operate with an extensive safety margin representing potentially inefficient operations. Or, insufficient safety margin where it is taking on more risk than intended. Consolidation of information and perspectives is vital. Consider the parable of the blind men and the elephant, where each man is touching a different part of the animal. The one touching the trunk says, “an elephant is a snake”, the one touching the leg says, “an elephant is a tree”, the one touching the ear will think “an elephant is a fan” and the one touching the tail thinks

“an elephant is a rope”. None of these perspectives are wrong, but only by sharing and integrating the multiple, diverse perspectives will the group be able to fully understand what the complete elephant is like.

A challenge in risk management in distributed operations like ski resorts or guiding terrain is maintaining a coherent understanding of the “whole elephant.” Therefore, coordination and communication across departments is key (Watts, 1996; Olson & Olson, 2009). This is especially true in dynamic situations where uncertainty may be high (Watts-Perotti & Woods, 2007). These environments require near-continuous coordination to integrate different perspectives as conditions are changing quickly (Klein et al., 2006; Maguire, 2020). Therefore, a key attribute of learning from incidents is to focus on local rationality (Simon, 1957) - or what made sense to people at the time. This shifts the focus away from external and retrospective behavior or motivational interpretations of actions and decisions. It instead redirects the focus to the mental models of those involved, which allows for more specific understanding of the nature of potential human performance issues.

Post-incident reviews focused on cognition that surface how mental models were different across those involved and highlight things like:

- where information asymmetries exist (whereby some parties have information about changing events while others don't or receive it too late to act upon),
- where knowledge gaps or inaccuracies may be present (if an individual misunderstood or did not recognize the importance of specific information or events), or
- where gaps in tools or technologies can limit sensemaking in real time (such as radio dead zones that limit the sharing of critical or time-sensitive instructions).

This allows greater specificity in the resultant corrective actions – another source of costly organizational attention and effort spent on safety. While training workers or development of new or more thorough procedures may still be an outcome from a systemic review, they are less generalized (refresher training on explosives handling, for example) and more pointed in their purpose (hands-on demonstrations by experienced coworkers and practice with throwing charges from different locations, for example), increasing the benefits of the effort expended to improve safety.

In this way, a systems-oriented review aims to create a feedback loop on how work is getting done, not how it is supposed to be done (Hollnagel, 2017). This gap is well established in the literature (Dekker, 2006; Catchpole and Jeffcott, 2016; Hollnagel & Clay-Williams, 2022) and, while it may seem an alarming admission of rule-breaking, it instead represents the reality that, because the world is always changing and organizations rarely operate in fully optimal conditions, plans change. Improved learning about how and why planned work changes and what workers do to adapt deals with the world as it is, not how it could be in some envisioned other state. Being able to talk about these changes and adaptations, instead of hiding them, means companies can consider with greater clarity whether their rules, procedures, staffing, workload, and available support are sufficient and appropriate.

2.1 What do we mean by learning?

Post-incident learning activities target two aspects of learning: individual and organizational.

Individual learning is aimed at facilitating the ongoing process of refining, correcting, and updating knowledge. All mental models are partial and incomplete, and our knowledge can be flawed or outdated (Woods et al., 2010; Maguire et al., 2023). As new advances are made in snow science and new technologies are introduced, new knowledge and practices emerge. In addition, conditions can change minute-to-minute, hour-to-hour in the mountains, so maintaining a current mental model of the conditions is required. Therefore, continuous learning and perspective-sharing is required to accurately interpret and respond to hazards in the work environment. In this way, learning prepares individuals to be able to adapt or respond differently than the plan expected as conditions change. Learning together as a team establishes and maintains common ground (Klein et al., 2006) about the current state of an event, the nature of the hazards faced, and the expected goals and priorities, helping the team better anticipate others' expected decisions and actions and smoothly adapt together.

Organizational learning is aimed at maintaining a shared and current knowledge of how work is carried out by different roles, at different levels. A post-incident review provides a forum for eliciting the influences of often-hidden factors established and controlled by the organization. This includes factors like how teams are resourced and structured, how performance is incentivized, how mistakes are interpreted and responded to, and how workers are expected to handle increasing time pressure, budget cuts,

staffing shortages, and other factors that influence the range of possibilities for action available. Other hidden organizational factors relate to cultural values or expectations. Learning at the organizational level provides concrete data about operations that can be used to change rules or procedures, staffing levels or tasks, and identify gaps in hand-offs or needed coordination. It directly connects the sometimes distant and hidden contributing factors to the observable actions and behaviors in an event.

2.2 *Why is it hard to learn from avalanche accidents?*

With so much activity already dedicated to post-incident reviews, why aren't we learning more? Four factors can impede even the best efforts. They are: 1) a punitive culture, 2) fear of negative perception by others, 3) lack of time and resources, and 4) limited data collection and analysis.

2.2.1 *Punitive culture*

Historically, accident investigations have aimed to find the "root cause" of an event. Investigators have a mindset that people are prone to making mistakes, so they look at what decisions and actions were made immediately before the event to find the "human error" or "bad apple" that broke an otherwise safe system. People who made these decisions or actions are then blamed for the event, shamed for their choices, and either retrained or fired.

This punitive culture fails threefold. First, focusing on fault and error typically ignores the underlying issues in a system, degrading the learning that can occur from that event. Another person who finds themselves in a similar situation will have to manage the same pressures from leadership, constraints from the environment, and risk to their safety or reputation. Firing one person doesn't mitigate those issues.

Second, a punitive culture incentivizes individuals to bury near-misses or "mistakes" out of fear they will be blamed and punished. This handicaps proactive learning. Near-misses are a prime opportunity for learning because they highlight vulnerabilities and pressures in the system without the stigma of a negative outcome.

Third, a punitive culture is difficult to rectify. Long-term learning requires trust by staff that they won't be punished for sharing their story. When organizations try to move away from 'blaming, shaming, and retraining' it takes significant time and effort to build trust in the new, non-punitive culture.

2.2.2 *Fear of negative perception*

Even when an organization develops a non-punitive culture, people may still be afraid to share their stories out of fear that they look incompetent to their peers. Like the fear of being fired, a fear of looking incompetent shuts down proactive and vicarious learning (Maguire et al, 2026).

Vicarious learning (drawing lessons from others' experiences) also happens at the organizational level. When a company shares an accident or near-miss event that happened in their operations, other organizations can learn from it. However, fear of legal repercussions or impacts on public reputation can discourage voluntary sharing and vicarious learning opportunities that may help the industry improve.

2.2.3 *Lack of time and resources*

Learning from incidents takes time - going to the site of the accident, testing the snowpack, interviewing participants, analyzing the data, synthesizing lessons learned, and compiling all the information for private or public consumption. Time spent investigating takes away from the ongoing daily tasks and other priorities. Organizations must prioritize which incidents to invest in and how much time to dedicate.

Hastily conducted investigations can erode trust. If people see that their stories are not handled with care and respect, they will be less likely to share them in the future. A successful learning program requires a genuine commitment of time, resources, and intention toward transparency.

2.2.4 *Limits of Data Collection & Analysis*

In addition to time, learning from incidents requires expertise with data collection and analysis. Early in the organization's journey, it's difficult to know what data to collect and how to turn that data into practical, actionable lessons. Investigators must learn where to look and how to interpret the ambiguous, disparate data available. Without training or practical guides on the process, muddling through this process can be frustrating and time-consuming. Investigators can start to feel like the results don't justify the effort and pull back to the minimum-required collection and analysis to satisfy regulations or leadership.

2.3 *What resources are currently available to aid practitioners?*

There are a variety of established and emerging systemic accident analysis techniques that exist in academic literature and industry. Table 1 summarizes a selection of these with the goal or value they intend to provide, and the challenges for use in mountain safety operations. Most of these techniques are time-intensive, require significant training before they can be used effectively, and/or may produce artifacts (e.g., diagrams) that can only be understood by the creators. The diagramming and elicitation techniques that are less time-consuming to produce often have limited instructions for practitioners and are difficult to translate into practical lessons.

Table 1: Examples of Existing Systemic Analysis Techniques

Name	Source	Description	Challenges for practitioners
Causal Analysis based on System Theory (CAST)	Leveson, 2019	- An analysis and modeling technique - Focus: Describing accidents as a dynamic control problem rather than a single, root failure	- Time intensive - Requires significant training - Difficult to share results with others - Difficult to translate into practical lessons
Functional Resonance Analysis Method (FRAM)	Hollnagel, 2012	- An analysis and diagramming technique - Focus: Describing the variability in everyday work and how that variability contributes to success and unexpected outcomes	- Time intensive - Requires significant training - Difficult to share results with others - Difficult to translate into practical lessons
Human Factors Analysis and Classification System (HFACS)	Shappell & Wiegmann, 2000	- An analysis framework based on James Reason's Swiss Cheese description of accident causation (Reason, 1990) - Focus: Identifying and classifying underlying active and latent failures at multiple levels of the organization	- Focuses more on classification than connection of contributors - Time intensive - Requires significant training - Difficult to share results with others - Difficult to translate into practical lessons
AcciMap & AgileMap	Rasmussen, 1997	- A multi-layered diagram technique - Focus 1: Creating a visual map of the contributing factors to an adverse event - Focus 2: Showing interactions across a socio-technical system	- Difficult to share results with others - Difficult to translate into practical lessons - Limited practical instruction for practitioners
	Pieper, 2026	- An adaptation of the AcciMap diagram technique - Focus: Creating a series of AcciMap diagrams to make the results more digestible for readers	- Offers a promising improvement for practical application - Does not provide a process for implementation for practitioners
Systemic Contributors Adaptations Diagramming (SCAD)	Walker et al, 2016	- An elicitation, analysis, and diagramming technique - Focus 1: Connecting frontline actions and adaptations to the high-level systemic pressures - Focus 2: Creating a visual map of action, adaptations, and pressures over time	- Difficult to share results with others - Difficult to translate into practical lessons - Limited practical instruction for practitioners
The Learning Review	U.S. Dept of Agriculture Forest Service, 2017	- An alternative to traditional incident investigations - Focus: Centers on constructing a narrative that captures complexity	- Time intensive - Lessons learned are difficult to interpret and does not lead to systemic improvements
The How We Got Here Guide	Maguire et al., 2021	- An incident investigation guide aimed at software engineering teams - Focus: Provide practical instructions for learning from incidents in software development and other knowledge-work domains.	- Created for a software audience, requiring translation for other domains - Limited instructions on conducting analysis

3. AN APPLIED CASE STUDY

In February 2023, during an advanced industry training course, one of the lead instructors suffered a medical event and passed away. The event was deeply felt by the close-knit organization delivering the training. One of the authors, who was working within the organization, wanted to conduct a post-incident review to provide an analysis of the response efforts and allow team members to process the event. He (investigator 1) reached out to another of this paper's authors (investigator 2), who provided him with the "Howie guide", a resource developed for another industry to outline the process of reconstructing

the timeline of events that led up to and immediately following the incident. In other words, to answer the question of “How we got here” to be able to analyze the organizational preparedness, the handling of the incident by various parties, the processes and resources that were available that helped, and the ones they wished they had. They wanted to learn what the real needs of the organization were in light of this event and whether they could accomplish that with how they were resourced and staffed.

The Howie Guide consists of: some background context on systemic investigations; advice on selecting the investigator and the types of events to investigate; information to collect to orient to the incident; suggestions for who to interview and how to interview them; methods for verifying the data and perspectives you collected are accurate; information on how to prepare for and facilitate an incident review meeting; and how to write up and distribute the findings. The guide provides step-by-step instructions and templates but expects the process to be flexibly applied according to available time and the expected amount of learning. While written for a software engineering audience, the process is applicable more broadly and similarly focuses on the cognitive and systemic factors at play in an event.

After reading the guide, Investigator 1 translated the interview questions provided in the Howie guide to fit the context of the training course and the mountain setting. The two investigators reconvened to discuss them and the strategies for the interviews themselves.

Interviews are a key part of information gathering within the process and approaching interviewees after an incident can be a delicate matter. It is important to state the intention up front that the purpose of the conversation is not to find blame but rather to hear the story from their perspective. This can help set people at ease and results in a more productive conversation where the interviewer and interviewee are working together to reconstruct the bigger picture by integrating what they heard, saw, thought, and felt into the stories collected from others, comparing and contrasting views to understand how the incident played out in real time. The interviews were conducted after the season ended and over the course of several months to accommodate participant schedules and other work demands. Following the interviews, the two investigators reconvened to discuss the findings and the themes that were emerging.

The process of analyzing incident data can be challenging – information comes in different forms, to varying degrees of reliability, and serves different purposes. In addition, large amounts of qualitative data from interviews can be hard to manage. Investigator 1 created a table to collate perspectives, creating a compact method for himself to review the relevant data and identify patterns and themes. Through email and phone calls, they interpreted the findings and implications to the organization and created a plan for the facilitation of a group discussion of the results. Investigator 1 then facilitated the review meeting, prompting participants to discuss different aspects and themes. Feedback from the session was very positive, with participants describing how well he had handled a difficult topic, providing a holistic and integrated synthesis that aligned instructor trainers and staff to determine and implement simple and powerful changes to their practices and procedures.

4. OUTCOMES

With a proof-of-concept established and a clear need within the mountain safety community for practical guidance on handling both the interpersonal and technical aspects of incident reviews, the authors of this paper began revising and expanding the Howie guide. Over the next two years, we conducted an analysis of existing systemic methods, with an emphasis on those that supported graphical representations of the events and emphasized interactive discussion over written reports that may not be read by the intended audience. The guide was then revised and piloted within outdoor recreation settings and adjusted to better account for the nature of mountain operations, the likely time available for post-incident activities, and the settings in which the interviews may take place. In addition, further guidance has been created to help assist investigators with analyzing the data and identifying appropriate corrective actions. The guide is freely available for download, and several public avalanche centers, ski resorts, and outdoor recreation facilities have adopted the process. We propose an addition to the corpus of existing methods: The Howie Learning Review (Maguire & Reynolds, 2026).

Table 2: The Howie Learning Review

Name	Source	Description	Challenges for practitioners
The Howie Learning Review	Maguire & Reynolds (2026)	- Incorporates elements from modern investigation techniques while emphasizing practical application - A practice guide for mountain safety professionals and operations	- Handling experiences of participants needs both empathy & logic - Managing sensitive subjects & potential conflict in real time

5. FUTURE WORK

In our opinion, the best investigation protocol for the mountain safety community has several characteristics:

1. It will get consistently used. It is lightweight but valuable enough to merit the time and effort invested.
2. It handles the stories of those involved with due care and high accuracy – protecting privacy while producing detailed descriptions of what made sense to them so that others may learn
3. It meets the needs of the organization for company and regulatory requirements, so it does not produce extra work and provides high value insights that improve safety and risk management.

Our vision for the mountain safety community is to develop a culture of learning where individuals feel committed to openly sharing incidents and near misses and safe enough to do so amongst their peers, organizations similarly provide details of their incidents and responses so that other organizations may learn from their insights and innovations.

In other words, they do not “compete on safety,” and findings that can improve operational performance in other organizations are seen as important to share. And finally, for the industry itself to set a standard for investing in learning from incidents by making it standard practice to allocate sufficient time and resources to understanding the sources of failure within mountain operations. In time, perhaps we will begin to move towards learning not just from failures, but from successes to amplify efforts to continuously share the knowledge, skills, and expertise within the community.

6. CONCLUSION

The mountains are a dynamic and potentially dangerous place where, despite careful planning and diligence, avalanche involvements happen. Safety sciences have produced important advances in the processes used to investigate, analyze, and represent complex, challenging incidents. But many of these processes require extensive training, time, and methods that are not always practical in mountain operations. Through a process of iterating on established practices from other domains and translating them for the operational realities of this environment, we present an investigation guide to aid operations in learning from their incidents.

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