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Assessment of Avalanche Mitigation Planning for Developed Areas in the Rocky Mountain's of Colorado

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ASSESSMENT OF AVALANCHE MITIGATION PLANNING FOR DEVELOPED AREAS IN THE ROCKY MOUNTAIN'S OF COLORADO

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ABSTRACT

Colorado communities and located within the Rocky Mountains are at risk from avalanche events that have the potential to damage property, infrastructure, and threaten human-life. This vulnerability to avalanche events can be decreased and managed with the development of well-crafted hazard mitigation plans. While research, both current and historic, has found that mitigation plans or plan components addressing particular hazard types often have a number of weaknesses (e.g., within the factual base, goals and objectives, policies, tools, and strategies, coordination, and implementation elements), thus far no studies have been conducted to determine how local jurisdictions have included avalanche hazard mitigation into their hazard planning frameworks. The purpose of this study is to explore the quality of avalanche hazard mitigation plans from 24 jurisdictions in the Rocky Mountains of Colorado and Juneau Alaska. Much of Juneau has been developed in what are now known to be avalanche slide paths. Juneau's updated hazard mitigation plan has what many might consider to be the most comprehensive treatment of avalanche hazards in the United States. In an effort to assess the current preparedness level of these jurisdictions, local hazard mitigation plans were assessed using a scoring protocol adapted from protocols employed by other investigators and consisting of five main components and 30 indicators. Juneau's hazard mitigation plan achieved the highest quality score, but was not included in further analysis. The results of this study indicate that on average, the sampled avalanche hazard mitigation plans are in need of improvement. The average plan score is 19.7 out of a possible 50 points. The most notable weakness with the mitigation plans overall were found to be within the Policies, Tools, and Strategies component, while the Factual Base component was found to be the most solid component. Only one sampled county (Costilla) made no mention of avalanche hazards in its plan. Examination of the data for patterns revealed that avalanche plan quality is likely not influenced by the presence or absence of ski resorts within the area. However, it does appear the avalanche plan quality may be influenced by the number of avalanche-related fatalities that have occurred over the past 50 years. Recommendations for improving the quality of future avalanche hazard mitigation plans are provided.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PROBLEM STATEMENT

Snow avalanches are a notable type of natural hazard that occurs in mountainous areas throughout the world. The United States alone experiences up to 10,000 potentially damaging avalanches per year (Smith 2001). Avalanche events have the potential to inflict large-scale impacts to infrastructure such as buildings, roads and railways. Though only about 1 percent of these annual events cause damage to property or impose human harm and or loss of human life, a considerable threat still remains.

Natural hazard mitigation strategies in the form of hazard mitigation plans (HMP) have been developed in an effort to reduce, and possibly eliminate, the long-term risk to human-life and property from natural disaster events such as avalanches (Burby et al. 1999; Cutter 2001; Randolph 2004; Schwab, Brower, and Eschelbac 2007; Schwab 2010) . Natural hazard mitigation is an important policy issue from a local, regional, and national point of view because of the ever increasing monetary damages resulting from natural disaster events (Godschalk, Brower, and Beatley 1989; Godschalk et al. 1999). Though the occurrence of natural hazard events cannot be completely averted, the impacts inflicted on populations and property can be reduced through proactive measures outlined within a HMP (Burby et al. 1999; Burby et al. 2000; Cutter et al. 2003; Frazier et al. 2013; Godschalk et al. 1999)

In the United States, natural hazard mitigation policy is established under the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Public Law 93-288) and the amended Disaster Mitigation Act of 2000 (DMA). Under this legislation, state, local, and tribal governments are required to develop a hazard mitigation plan as a condition for receiving certain types of non-emergency disaster assistance, including funding for mitigation projects.

Natural hazard research has expanded over the past 30 years. In particular, many peer-reviewed articles that address the evaluation of HMP quality have been published (Table 1); a large portion of the literature has focused on the evaluation of HMP quality at the state level (Berke, Smith, and Lyles 2012; Godschalk et al. 1999), and recently, more studies have emphasized assessment of local HMPs (Burby et al. 1999; Burby et al. 2000; Brody 2003; Frazier et al. 2013; Lyles, Burke, and Smith 2012). However, there is limited research in the evaluation of mitigation strategies for specific hazards within a HMP. Srivastava and Laurian (2006) proposed a methodology to assess flood, fire, and drought mitigation within six Arizona counties. Fu et al. (2013) empirically examined drought hazard mitigation within a number of state-level HMPs. Tang et al. (2008) evaluated tsunami planning on the U.S. Pacific coast. However, no study thus far has conducted an assessment on avalanche hazard planning at the local level within the U.S.

In the final week of February 2014, Missoula experienced its second avalanche on Mount Jumbo resulting in a fatality and damaged property. According to the Mount Jumbo Avalanche Accident report, the avalanche was unintentionally triggered by a snowboarder recreating in an out-of-bounds designated area. During the week leading up to the event, Missoula had experienced near record snowfall amounts, and a combination of several additional inches of snow and high winds from the east loaded ravines and formed sensitive wind slabs on the mountain. Once triggered, the avalanche traveled down the western facing slope of Mount Jumbo towards the lower Rattlesnake neighborhood. At the base of the mountain two children were caught, carried, and buried in the slide. The slide also destroyed an adjacent home containing two residents. Both were buried by snow and debris. All were rescued and transported to the hospital, with one dying from traumatic injuries (Karkanen 2014).

Table 1. Plan Quality Evaluation Publications to Date

Investigators	Topic	Setting[a]	Number of Plans	Intercoder Reliability[b]
Berke 1994	Natural hazards	NZ	8	PA
Berke and French 1994	Natural hazards	US	139	PA
Burby and Dalton 1994	Natural hazards	US	140	U
Berke et al. 1996	Natural hazards	US	139	A
Berke, Dixon, and Ericksen 1997	Natural hazards	US, NZ	23	U
Burby and May et al. 1997	Natural hazards	US	180	U
Deyle and Smith 1998	Coastal management	US	18	U
Berke et al. 1999	Environmental management	NZ	50	PA
Godschalk et al. 1999	Natural hazards	US	40	S
Berke and Manta-Conroy 2000	Sustainable development	US	30	PA
Berke et al. 2002	Human rights	NZ	34	PA
Nelson and French 2002	Natural hazards	US	19	U
Brody 2003a	Natural hazards	US	60	U
Brody 2003b	Ecosystem management	US	30	U
Brody, Highfield, and Carrasco 2004	Ecosystem management	US	45	PA
Davis 2004	Coastal management	US	15	U
Manta-Conroy and Berke 2004	Sustainable development	US	42	PA
Norton 2005a	Coastal management	US	40	N
Norton 2005b	Growth management	US	40	U
Brody, Carrasco, and Highfield 2006	Sprawl	US	46	PA
Srivastava and Laurian 2006	Natural hazards	US	6	U
Edwards and Haines 2007	Smart growth	US	30	PA
Hoch 2007	Affordable housing	US	36	N
Termorthuizen, Opdam, and van den Brink 2007	Ecosystem management	HO	38	U
Evans-Cowley and Gough 2008	Environmental protection	US	9	A
Norton 2008	Development management	US	29	A
Tang 2008	Coastal management	US	46	U
Wheeler 2008	Climate change	US	64	U
Evans-Cowley and Gough 2009	New urbanism	US	9	PA
Tang and Brody 2009	Environmental protection	US	40	N
Bassett and Shandas 2010	Climate change	US	20	K
Jones et al. 2010	Pedestrian safety	US	46	A
Kang, Peacock, and Husein 2010	Natural hazards	US	12	U
Tang et al. 2010	Climate change	US	40	U
Aytur et al. 2011	Physical activity	US	41	U
Hamin 2011	Climate change	US, AU, CA, UK	7	A
Bunnell and Jepson 2011	Persuasiveness	US	40	A
Olonilua and Ibitayo 2011	Natural hazards	US	202	U
Preston, Westaway, and Yuen 2011	Climate change	US, AU, UK	57	N
Tang et al. 2011	Coastal management	US	53	PA
Baker et al. 2012	Climate change	AU	7	U
Evenson et al. 2012	Physical activity	US	46	U
Berke, Smith, and Lyles 2012	Natural hazards	US	30	PA
Horney et al. 2012	Natural hazards	US	57	PA
Stone, Vargo, and Habeeb 2012	Climate change	US	50	U
Berke et al. 2013	Watershed protection	US	9	PA
Bayntham and Stevens 2013	Climate change	CA	25	PA

[a]US = United States AU = Australia CA = Canada HO = Holland NZ = New Zealand UK = United Kingdom.
[b]PA = reported percent agreement as measure of intercoder reliability; K = reported Kappa as measure of intercoder reliability; A = all plans were coded by at least two coders, but did not assess intercoder reliability; S = some plans were coded by at least two coders, but did not assess intercoder reliability; N = no plans were coded by at lea two coders; U = unclear whether any plans were coded by at least two coders.

Source: Stevens, Lyles, and Berke (2014)

Currently Missoula County's Pre-Disaster Hazard Mitigation Plan (2011) does not address avalanche hazards. This current plan was in effect at the time of the avalanche. The omission of avalanche hazards within the HMP leads to questions such as:

- How common is it for counties in mountainous areas to not address avalanches in their HMPs?
- Where avalanches are addressed, what constitutes "best practice" with regard to avalanche hazard mitigation?

Sources have indicated that the state of Colorado experiences the highest frequency of avalanches within the United States. Therefore, this research will focus on assessing avalanche hazard mitigation planning at the local level within developed areas of Colorado's Rocky Mountains.

RESEARCH QUESTIONS

The proposed investigation will address the following questions:

1. To what extent are counties within Colorado's Rocky Mountain region including avalanches as a hazard type within their HMPs?

2. Historically, what is the frequency and magnitude of avalanche events in these counties if any?

3. How comprehensive are these HMPs regarding avalanche hazard mitigation?

4. Are there specific HMPs that seem to represent "best practice" for avalanche hazard mitigation?

BACKGROUND

Introduction

The Rocky Mountains have experienced accelerating pressures from rapid development over the past 50 years. According to Hobbs et al. (2002), between 1950 and 2000 the five fastest-growing states within the U.S. were Nevada, Arizona, Florida, Alaska and Colorado (Figure 1). Colorado has experienced tremendous growth within its mountainous areas due in part to the expansion of the recreation industry and the continuous construction of new homes. Mountain counties such as Summit, Eagle, Grand, Gunnison, Park, and Pitkin are well known for exceptional winter recreation opportunities (especially downhill skiing) and have seen a continual growth of population and development (Figure 2). Growth in these areas is estimated to increase

Stunning views and a plethora of recreational opportunities make Colorado's mountainous areas appealing to visitors and amenity migrants alike. The allure of the Rocky Mountains has resulted in a population surge which has placed large numbers of people with little to no mountain experience in high mountain terrain (McClung and Schaerer 2006).
The rugged and complex terrain of the Rocky Mountains is a limiting factor in the amount of land suitable for the development of resorts, homes, and condominiums. However, a combination of speculation, ignorance, and the high speed of development has resulted in the erection of homes, businesses, and public works within areas that are subject to a variety of natural hazards such as avalanche, landslide, flood, and rock fall (Ives et al. 2010).

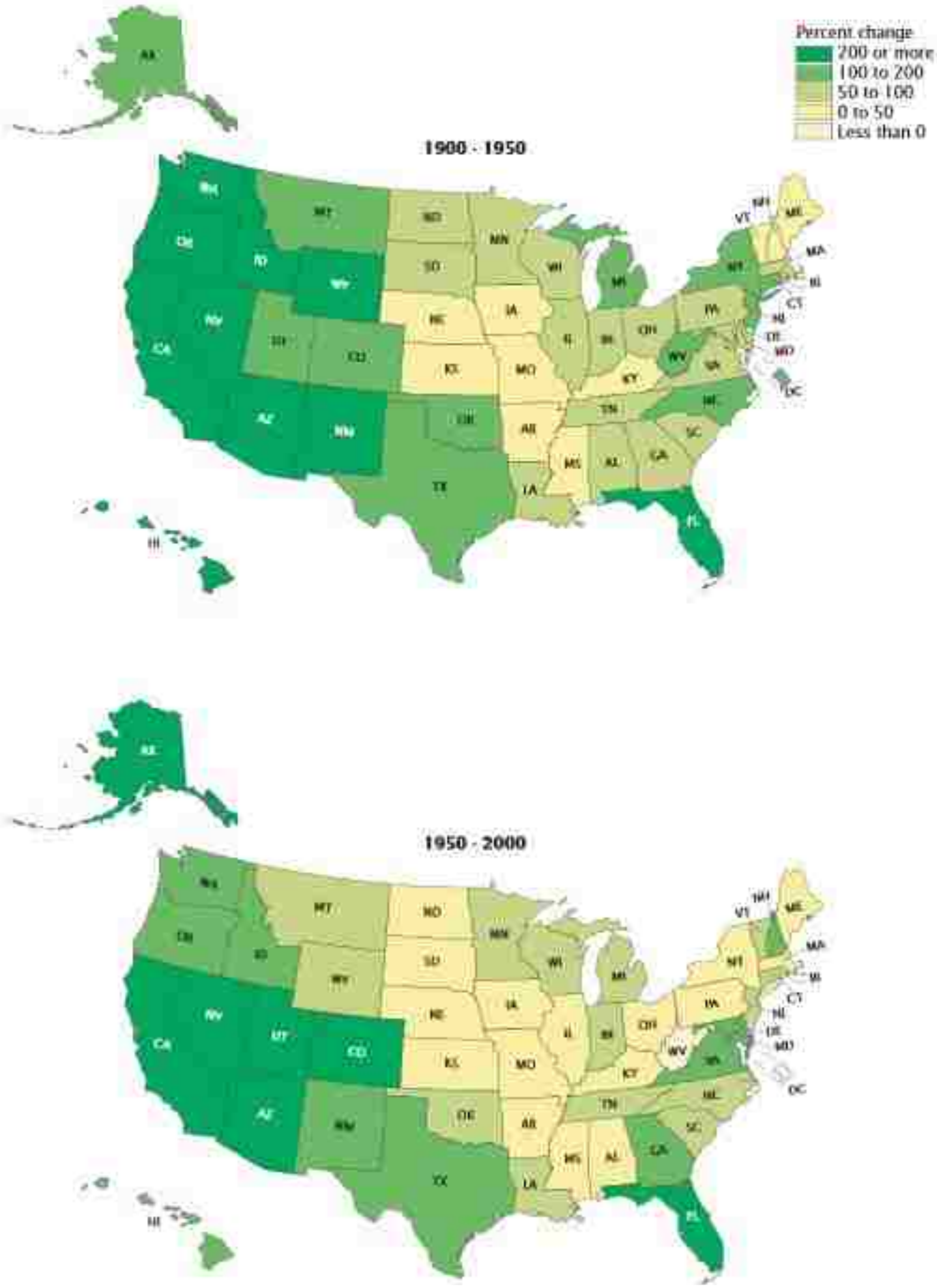


Figure 1. Percent Change in Total Population by State 1900-2000 (Source: U.S Census Bureau 2010)

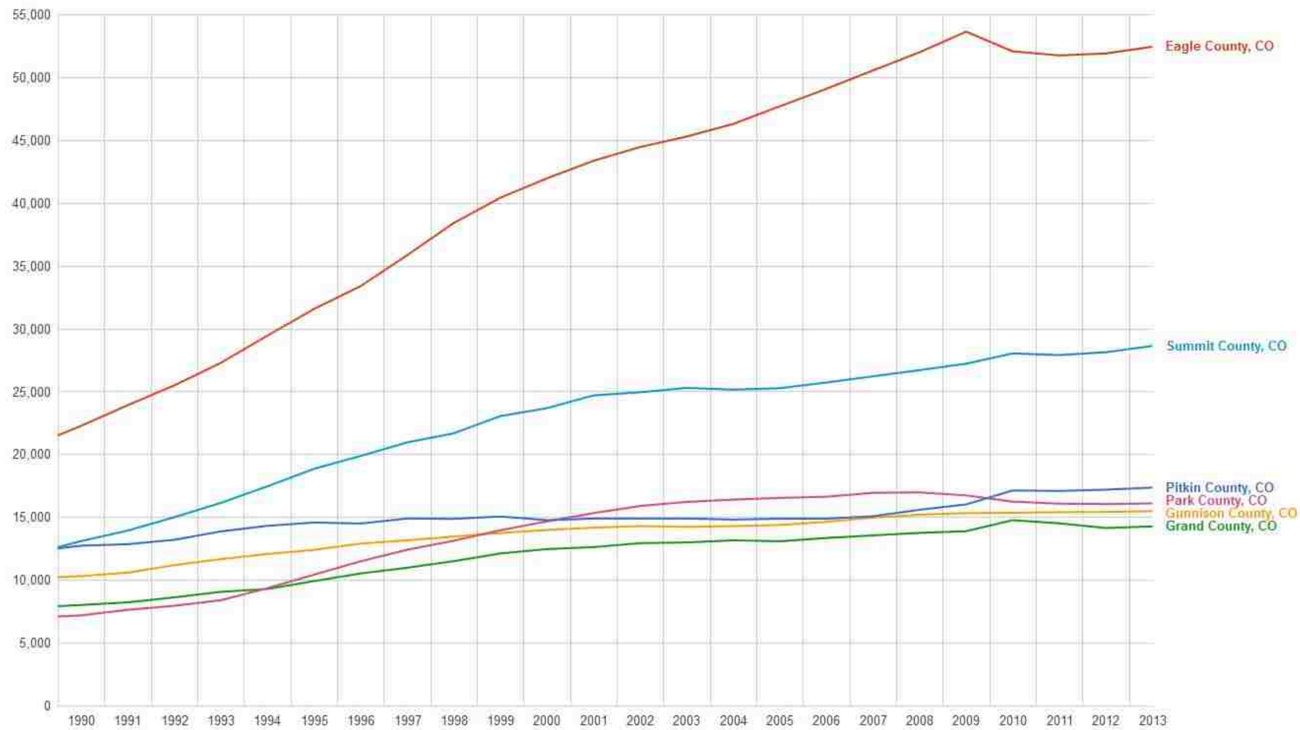


Figure 2. Mountainous Colorado County Population Growth 1990-2013 (Source: U.S. Census Bureau 2013)

Hazards

Within hazards research literature, the terms hazard, risk and disaster are used interchangeably, although they do have different meanings (Cutter 2001; Mileti 1999). Randolph (2004) defines a hazard as: "the inherent danger associated with a potential problem such as an earthquake or avalanche." He continues saying, "the danger includes regional susceptibility, as well as the relative hazard of specific areas within that region. Cutter (2001) provides a much broader definition saying that: "hazards are merely a threat to people and the things that they value." Cutter (2001) also indicates that hazards will arise due to interactions between civil, natural, and technological systems. Traditionally each hazard has been classified by its causal agent, meaning, that tornadoes and floods would be classified as natural hazards, a plane crash would be a technological hazard, and a terrorist attack would be considered a civil hazard. This classification method has been demoted within the research community due to the complexity of origin that hazards encompass (Cutter 2001)

The concept of risk encompasses the combination of a hazard, the exposure of a population to that hazard, and the vulnerability (how unprotected) the population is from the hazard. Risk is best defined as: “the probable degree of injury and damage likely to occur from the exposure of people and property to the hazard of a specific time period” (Randolph 2004). Therefore, the element of risk is generated within the overlap of a hazard, exposure to the hazard and a vulnerability to damage (Figure 3). Hazards emanate from interactions between natural, social, and technological systems (Cutter 2001).

Figure 3. Risk Component Venn-Diagram (Source: Randolph 2004)

Natural Hazards

During an extensive period of time in human history hazards (environmental hazards in particular) were widely considered to be "Acts of God" for the purposes of punishing humans for their acts of insubordination (Smith 2001). This historic way of thinking wrongly suggests that humans play no role in the creation of hazards and therefore have no power to prevent or mitigate their impact. In actuality, humans play a significant role in hazards with respect to their creation of hazards, exposure, and vulnerability (Cutter 1996; Cutter et al. 2003; Randolph 2004; Smith 2001).

A widely accepted definition of natural hazards is: elements of the physical environment that are harmful to humans and caused by forces that are considered to be exogenous. These natural events often refer to atmospheric, geologic, hydrologic, and seismic phenomena that affect humans and their property (Table 2).

Over the past three decades, the United States has experienced an increase in the damages caused by natural hazards. This increase is due in part the U.S. becoming more vulnerable to natural hazards as population and development continue to expand into natural hazard prone areas (van der Wink et al. 1998).

Natural Disasters

Natural disasters are characterized as extreme forces that impact exposed people, infrastructure, and property. Hurricanes, earthquakes, tsunami, tornadoes, floods, drought, and substantial mass movements such as landslides and avalanches are all examples of potential natural disasters. Each disaster type, with respect to the magnitude and

Table 2. Natural Hazard Phenomenon Examples (Adapted From: Schwab, Eschelbach, and Brower 2007)

Natural Hazard Phenomena Examples		
Atmospheric		Tornado
		Hurricane
		Hailstorm
		Lightning
Hydrologic		Flooding
		Desertification
		Drought
		Wildfire
Geologic		Landslide
		Rock falls
		Debris Avalanche
Seismic		Fault
		Earthquake
		Tsunami
Extraterrestrial		Meteorite
		Space Junk
		Comet

frequency of occurrence, can inflict catastrophic results both during and in the aftermath of given events.

It is important to recognize that the natural hazards mentioned previously are only classified as "disasters" when their presence directly or indirectly results in hardship for humans. By definition, a natural disaster is a naturally occurring phenomenon that affects developed areas, threatens life, and damages property. Antithetically speaking, when a natural hazard transpires within an area that lacks the presence of human beings, no disaster occurs (Godschalk et al. 1999).

Hazard Mitigation Planning

Communities are often exposed to a range of natural hazards. As a protective measure, communities must identify and prioritize mitigation strategies for specific hazards. Within the context of hazards, mitigation is any activity that prevents a disaster, reduces the likelihood of a disaster occurring, or reduces the impact of a disaster (Schwab, Brower, and Eschelbac 2007). Hazard mitigation planning is a preemptive measure utilized with the intention of reducing or eliminating long-term risk to property and people from hazards and their potential negative effects (Burby et al. 1999; Burby et al. 2000; Cutter et al. 2003; Frazier et al. 2013; Godschalk et al. 1999).

Within the United States of America, hazard mitigation is the mainstay approach employed by the Federal Emergency Management Agency (FEMA) with the goal of reducing the nation's vulnerability to disasters stemming from natural hazards (Godschalk 2003). The Federal Emergency Management Agency defines hazard mitigation planning as the process that state, local, and tribal governments should use to identify risks and vulnerabilities associated with natural disasters. Once hazards and risks are identified, long-term strategies for protecting people and property in future hazard events are developed. This detailed process results in a mitigation plan that offers a strategy for breaking the cycle of disaster damage, reconstruction, and repeated damage, and a framework for developing feasible and cost-effective mitigation projects (Figure 4). Under the Disaster Mitigation Act of 2000 (Public Law 106-390), state, local and tribal governments are required to develop HMPs as a condition for receiving certain types of non-emergency disaster assistance. Once the HMPs have been approved and implemented, state, local, and tribal governments gain eligibility for pre- and post-disaster federal mitigation

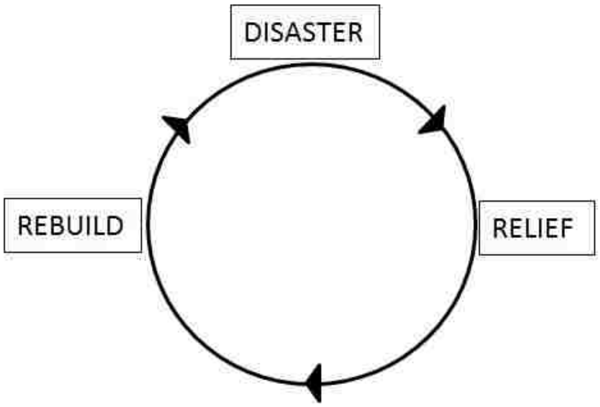


Figure 4. Disaster, Relief, Rebuild Cycle (Source: Randolph 2004)

funding (Berke, Smith, and Lyles 2012). These funds may then be put towards anything from structural reinforcement projects to the development of community based hazard education programs.

According to Godschalk, Brower, and Beatley (1989), there are four stages of disaster response: mitigation, preparedness, response and recovery. Of these four stages, mitigation is the only stage that occurs well in advance of the disaster event, while all other stages are initiated just before or after the event (Figure 5). Preparedness includes short-term activities such as last minute property protection applications and evacuation of residents upon receiving the disaster warning. Response is also structured by short-term activities including search and rescue missions and debris clearance which are completed immediately following the conclusion of the disaster event. Recovery is the final disaster response and is composed of the renovation of damaged structures to restore traditional community operations.

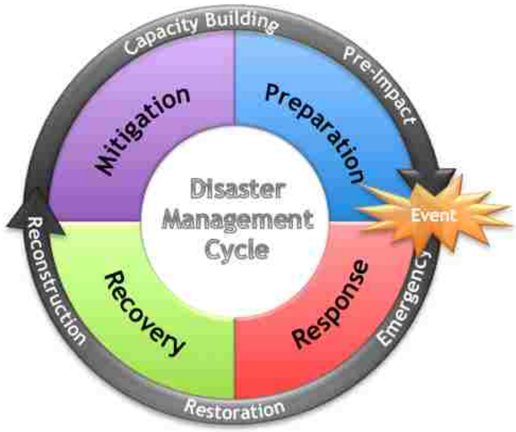


Figure 5. Disaster Management Cycle (Accessed from: http://mjcetenvsci.blogspot.com 2012)

The mitigation planning process promoted by FEMA creates a framework for governments to reduce the negative impacts associated with future disasters. Successful mitigation planning entails the inclusion of the following elements:

- Public Involvement- Planning creates a way to solicit and consider input from diverse interests. The involvement of stakeholders is imperative for gaining community support for the plan.
- Risk Assessment- Natural hazards and risks are identified based on a history of occurrence, generate an estimate of potential losses of life and property, and project the potential frequency and magnitude of disasters.
- Mitigation Strategy- Communities generate mitigation objectives and goals based on the risk assessment as part of a strategy for minimizing disaster impact. These mitigation efforts have been concluded to be cost-effective, environmentally sound, and technically feasible.

Completed mitigation strategies/plans identify specified targets for a mitigation action. The type of action is dependent upon whether the target is structural (buildings) or non-structural (land-use). Godschalk et al. (1999) lists the following actions traditionally initiated for the purposes of hazard mitigation:

- Strengthening buildings and infrastructure exposed to hazards by means of updated construction practices, engineering practices, and building codes with the purpose of increasing damage resistance and structural resiliency.
- Preserving protective features of the natural environment such as wetlands, forests, sand dunes, vegetated areas, and other ecological elements that can help to lessen hazard impacts.
- Creating visual representations such as hazard maps in order to direct new development away from known hazard areas through land use plans and regulations.

Assessment of Hazards

The process of understanding the hazards that communities may encounter, and how these hazards can impact people and property is known as a risk assessment (Cutter 2001; Schwab, Brower, and Eschelbac 2007). According to Kates and Kasperson (1983) and Randolph (2004),a risk assessment is comprised of three steps:

1. Hazard identification: describes hazards and reviews historic events to reveal areas of interest. It also reviews existing and future developments.

2. Hazard exposure and vulnerability assessment: combines data from hazard identification with inventory of population and property that is exposed to hazard, predicting how a hazard will impact humans and property

3. Risk analysis: estimates the potential damage, loss of life, and costs associated with a hazard

While similar, Schwab, Brower, and Eschelbac (2007) provides a more detailed assessment consisting of six steps. These steps are said to be universally applicable when addressing different hazards and the included elements are based on the risk assessment procedure as outlined by FEMA. During all risk assessments, historical records are reviewed in order for the community to have a better grasp on the previous hazard events with respect to their magnitude, frequency, and location.

A vital component to the risk assessment is the completion of a detailed vulnerability assessment (Cutter 2001). During the vulnerability assessment, communities will inventory their residents and all buildings and structures within their boundaries. Key community assets such as landmarks, historical buildings, transportation networks, and public utilities are also identified during this process. The completed inventory allows the community to estimate potential losses (financial and human life) in the event of a particular disaster. This data can then be projected to account for future losses based on current growth patterns. The findings of the vulnerability assessment provide communities with a sophisticated tool for prioritizing potential hazards (Cutter 1996; Cutter 2001; Schwab, Brower, and Eschelbac 2007)

Capability assessments provide information about a community's ability to carry out proposed mitigation actions (Schwab, Brower, and Eschelbac 2007). This type of assessment serves to identify the strengths and weaknesses of different branches and departments of government within a community. It also scrutinizes existing laws, policies, and programs for their contributions and detractions during the current state of risk and vulnerability in the community. It is critical that the capability assessment results clarify all resources and strategies available for hazard mitigation (Schwab, Brower, and Eschelbac 2007).

Stafford Act of 1988

The Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) of 1988 (Public Law 100-707) regulates how the United States government has traditionally responded to domestic disasters. The Stafford Act is an amended version of the Disaster Relief Act of 1974 (Public Law 93-288), passed by President Richard Nixon. This federal law provides legal authority for the federal government to provide assistance to states in times of declared disasters and emergencies. It also authorizes the President of the United States to declare a major disaster or state of emergency in response to an incident of disaster, or a threatened disaster, that inundates the response capabilities of state and local governments. Under the Stafford Act, a presidential declaration facilitates access to disaster relief assistance and funds that are allotted by Congress.

The Stafford Act was the first legislation that focused on all four disaster management phases and also established the current Individual and Public Assistance Programs as well as the Hazard Mitigation Grant Program (HMGP)(Schwab 2010). To be eligible for the HMGP, states were required to prepare hazard mitigation plans. States were able to prepare plans before a disaster or immediately after in an effort to reduce the likelihood of a repeated event in the future (Federal Emergency Agency 2004). In order for an affected area to receive federal assistance, the governor of that state must first respond to the event by executing the state's emergency response plan, prior to filing a request for a presidential declaration. The magnitude of the event must be in exceedance of the state's resources in order for supplemental federal assistance to be granted.

The Stafford Act covers any natural catastrophe of sufficient magnitude to warrant aid in order to alleviate loss of life, structural damage, or hardship generated from the event. Assistance provided by the Stafford act can take the form of grants, direct federal aid, reimbursement for expenditures, or technical support. The Stafford Act authorizes three categories of assistance in time of need including:

- Hazard Mitigation Assistance- provides grants to governments with the goal of implementation of long-term mitigation measures in an area prone to disaster.
- Individual Assistance- provides financial assistance to individuals for disaster related necessities.
- Public Assistance- provides aid to applicants in need of assistance for hardships incurred from disaster.

Disaster Mitigation Act of 2000

The Stafford Act was last amended on October 30, 2000 and was renamed the Disaster Mitigation Act (DMA). This legislation is focused primarily on controlling and streamlining the administration of federal disaster relief and mitigation programs, and emphasizes pre-disaster mitigation planning as an effort to reduce losses incurred from disaster events. The DMA promotes sustainability as a strategy for disaster resilience and rewards local and state pre-disaster planning. The DMA is also intended to facilitate cooperation between local and state governments to enhance communication of needs for mitigation (Schwab, Brower, and Eschelbac 2007).

The DMA requires that local governments develop and implement a FEMA approved mitigation plan in order to be eligible for pre-and post-disaster project grants. This added requirement promotes proactive rather than reactive mitigation efforts. Prepared plans must identify all hazards that pose a threat to the community and include a detailed risk analysis for each hazard (Federal Emergency Agency 2004). In the event that a disaster occurs that was overlooked in the HMP, the community affected would not be eligible for aid.

Avalanches

An avalanche is a large mass of snow, ice, earth, rock, and other debris that travels in a swift motion down a mountainside or precipice (McClung and Schaerer 2006; Schweizer 2003; Tremper 2008;). Avalanche events are common natural occurrences each year in mountainous areas throughout the world. Snow avalanches can be classified within a category of mountain-slope hazards that include: rock avalanches, rock fall, landslides, debris torrents and ice avalanches (McClung and Schaerer 2006) . Avalanche events are not easily predictable and often produce devastating results depending on the size of the slide, type of avalanche, the composition and consistency of the material in the avalanche, the force and velocity of the flow, and the avalanche path.

The initiation and release of avalanches depend on many different coupled parameters (Bühler et al. 2013). Schweizer (2003) classifies these parameters into three groups:

- Terrain Parameters- slope, exposure, curvature, roughness, and vegetative cover;
- Meteorological Parameters- temperature, wind direction, wind speed, humidity, and precipitation;

- Snowpack Parameters- the existence of weak layers, the bonding between layers, free water content, and grain size/grain form.

Additionally, there is the action of triggering the avalanche. An avalanche can be triggered or initiated by additional loading and movement caused by humans or other organisms, as well as natural occurrences such seismic events, additional fresh snow loading, or abrupt warming (McClung and Schaerer 2006).

Avalanche Types

Avalanches are most commonly classified as either slab or loose-snow slides. Both types of avalanches can occur with either wet or dry snow conditions. Within the northern hemisphere, slopes with a North to East aspect (0°-90°) are prone to dry-snow avalanche while slopes with a South to West aspect (180°-270°) are prone to wet-snow avalanche (Tremper 2008; McClung and Schaerer 2006).

Slab avalanches are considered to be the most dangerous type of avalanche, characterized by the breakaway of a mass of cohesive snow which then travels down the mountainside (Figure 6). The occurrence of a slab avalanche is the direct result of the presence of structural weaknesses within interfacing layers of the snowpack. The weakness exists when snow is not well bonded to the underlying layer or when a relatively strong layer of snow overlaps a less stable layer.

Loose snow avalanches, sometimes called point releases, generally occur when a small amount of incohesive snow slips and causes more incohesive snow to travel downhill (Figure 7) Loose avalanches occur frequently as modest sloughs, which remove excess snow on the upper layer. However, they can be large and destructive from their start at a point or over a small area where the steepness of the slope permits a gravitational force that eclipses the snow's ability to cling together.

Three other types of avalanches have been described in McClung and Schaerer (2006) and Tremper (2008) including:

- Slush Avalanche- occurs when overlying snowpack releases water, pressure will begin to increase between snow and rock. Eventually water pressure exceeds the limits of the bond and slushy snow runs downhill.
- Cornice Collapse- a cornice is an overhanging snow mass formed by wind blowing snow over a ridge crest. The breakaway of this mass serves as a trigger for avalanche formation, provided the snowpack exhibits avalanche prone characteristics.
- Ice Fall- occurs when broken glacier ice and do not require typical snow avalanche factors.

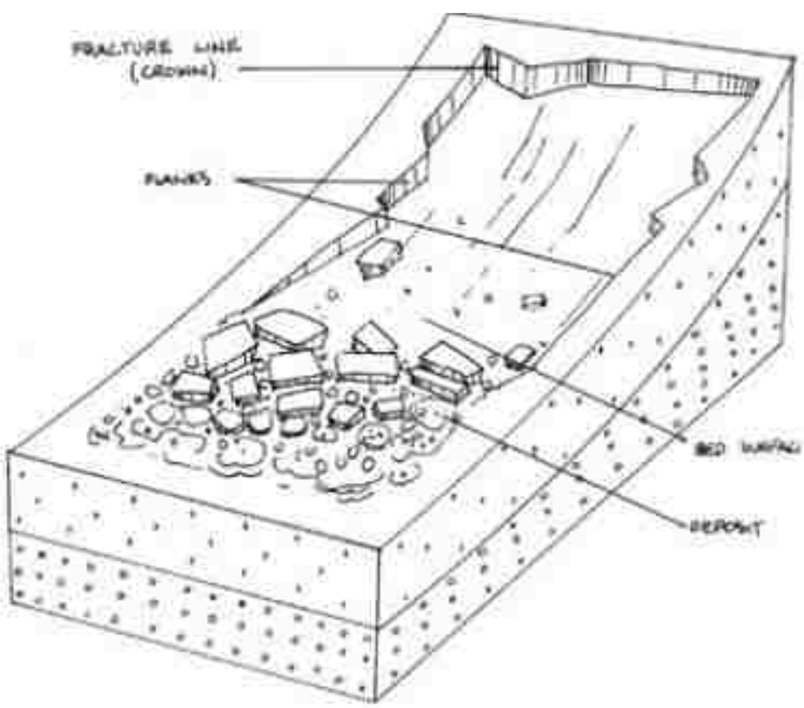


Figure 6. Slab Avalanche (Source: Canadian Avalanche Association 2012)

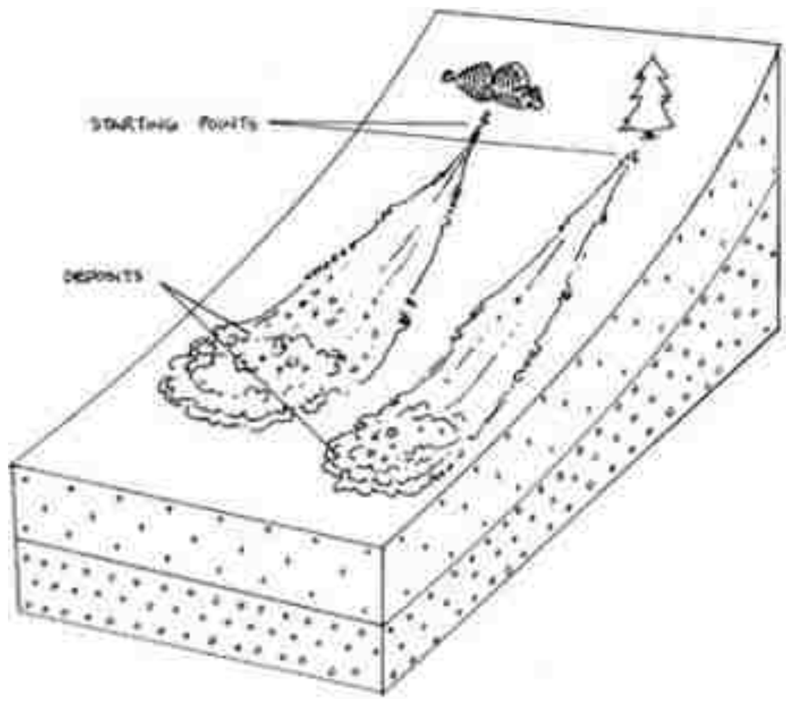


Figure 7. Loose Avalanche (Source: Canadian Avalanche Association 2012)

Avalanche Terrain Factors

There are several terrain factors that influence avalanche events, with regard to their magnitude and frequency, such as weather, slope, angle, slope aspect, slope shape, vegetation cover and elevation (McClung and Schaerer 2006; Schweizer 2003; Tremper 2008). Terrain with slope angles greater than 25 degrees and less than 60 degrees are considered optimum for avalanche events. Though avalanches can occur outside of the 25-60 degree range they are much less common. Snowpack generally remains stationary on slopes less than 25 degrees, while slopes greater than 70 degrees do not yield a sufficient accumulation of snow.

Slope aspect, which describes the direction a slope faces with respect to exposure to the wind and sun, plays a profound role in the creation of avalanche conditions. The aspect of a slope will dictate the depth of snow, temperature, and moisture characteristics of a snowpack.

The influence that aspect has on the promotion of avalanche conditions is greatest at mid-latitudes between 30-55 degrees (National Avalanche Center 2014). McClung and Schaerer (2006) and Tremper (2008) specifically identify the following slope orientations to be among the most dangerous during winter:

- Leeward Slopes or wind-loaded;
- Leeward slopes under cornice roofs;
- North-Facing slopes due to snowpack instability;
- South-Facing slopes due to direct exposure to sunlight.

Avalanche Path

Local terrain features dictate an avalanche's path. Avalanche paths are comprised of three identifiable parts: the starting or initiation zone, the tract, and the run-out zone (Figure 8). The starting zone is where the snow initially breaks free and begins sliding. Generally it is near the top of a mountain where slopes range between 25 and 60 degrees. The track is the path that the avalanche flows as it descends down the mountainside. The track can have milder slopes, however this is where the speed and volume of the avalanche is maximized. The run-out zone is where the avalanche slows down, resulting in snow and debris deposition (Tremper 2008).

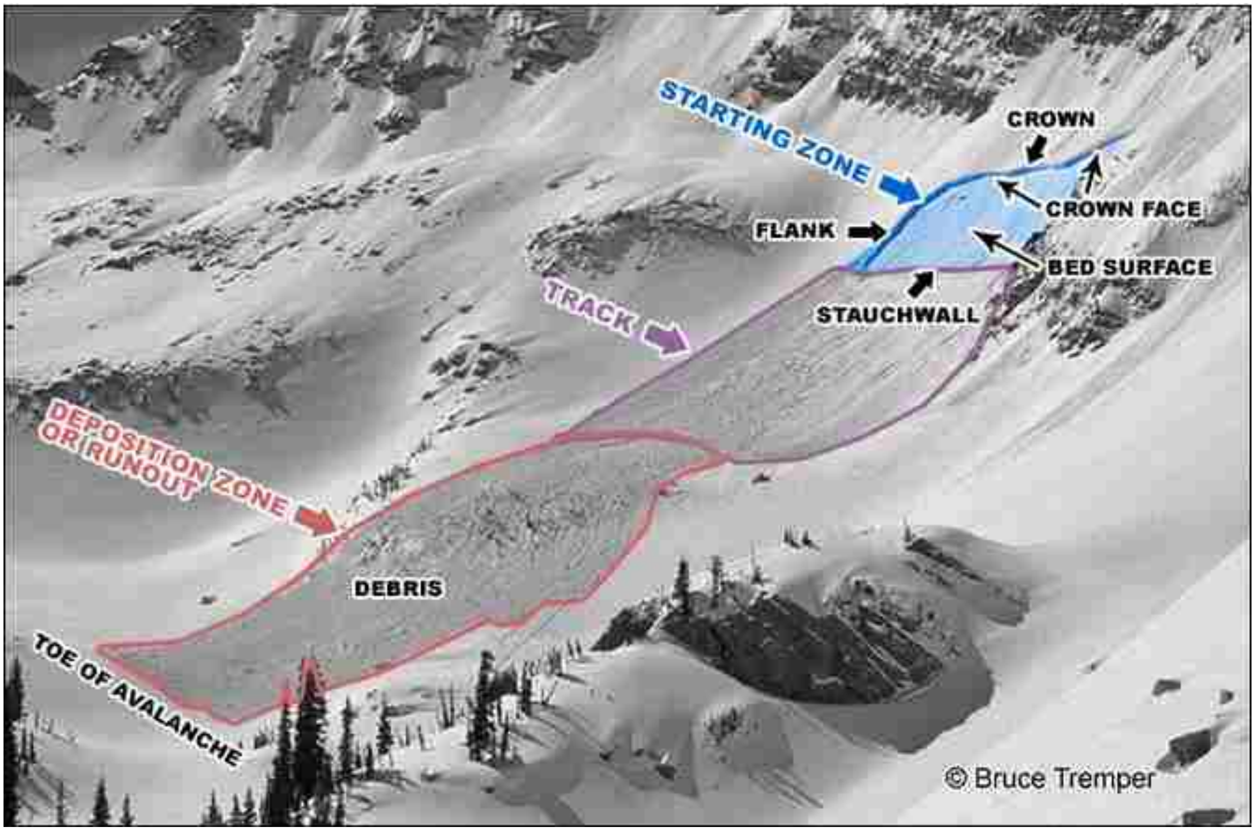


Figure 8. Avalanche Path (Source: Tremper 2008)

Avalanche Mitigation Strategies and Protective Measures

Within the United States there have been a total of 997 fatalities due to avalanche since 1950. The state of Colorado accounts for roughly 27% of these, and leads virtually every category in avalanche events (Figure 9). The Colorado Avalanche Information Center (CAIC) keeps track of avalanche events and avalanche-related fatalities within the United States. According to the CAIC, the majority of fatalities in the U.S. occur between the months of January and March. A significant number of deaths have also occurred in the later spring months of May and June (CAIC, 2015)

Within the realm of hazard mitigation planning, mitigation measures are implemented in an attempt to reduce losses of life and damages resulting from avalanches. Six general categories have been identified within the literature (Höller 2007; McClung and Schaerer 2006; Tremper 2008; Voight et al. 1990). These include:

- Avalanche retardant structures;
- Initiation of controlled avalanches;
- Zoning restrictions;
- Corridor management;
- Avalanche forecasting and monitoring systems;
- Avalanche education training and awareness.

Juneau Alaska Avalanche Mitigation

The city of Juneau Alaska, located on the coast of Alaska approximately 770 miles northwest of Vancouver, British Columbia, is situated in a mountainous area that is prone to avalanches. Much of Juneau has been developed in what are now known to be avalanche slide paths. According to Juneau's updated 2009 HMP, at least 72 buildings within a 10-mile radius of downtown have been damaged or destroyed by avalanches in the past century. Juneau's updated HMP has what many might consider to be the most comprehensive treatment of avalanche hazards in the United States. For instance, the city of Juneau contracted avalanche specialists from Switzerland's WSL Institute for Snow and Research to complete an avalanche mitigation study on known slide paths. This detailed study includes computer modeling simulations that can predict the force in pressure that slides can emit on structures. The results of these simulations can then be used for new construction permitting standards as well as updated zoning (Juneau HMP 2009).

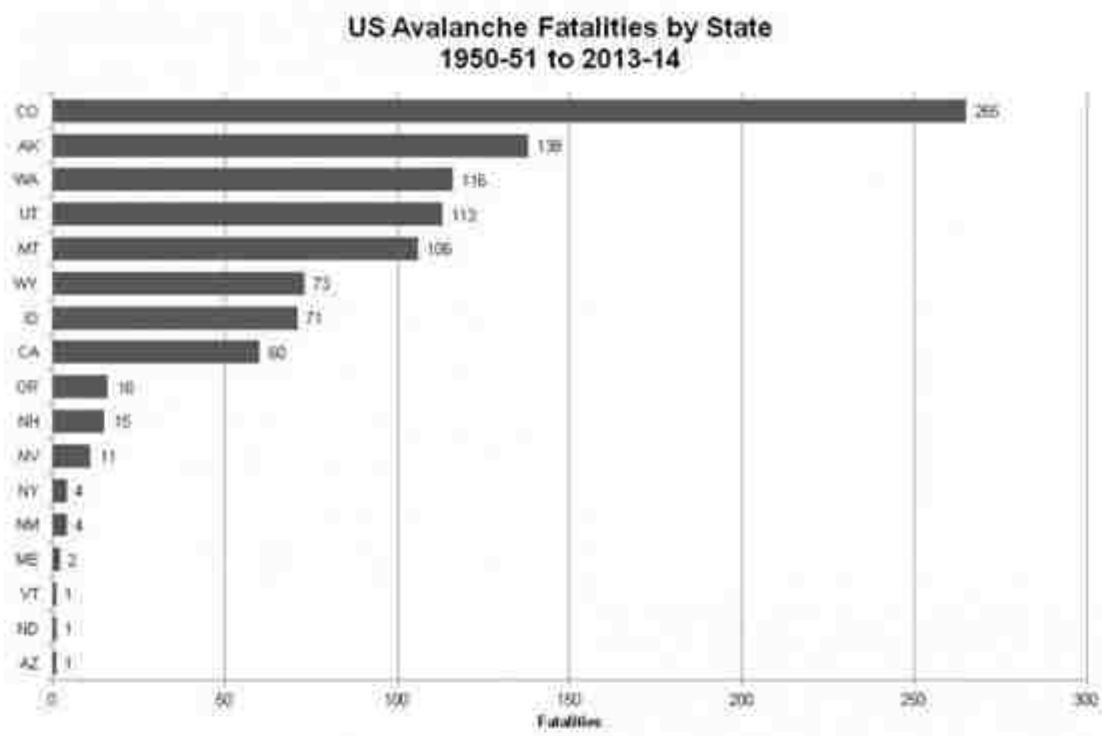


Figure 9.U.S. State Avalanche Fatalities (Source: Colorado Avalanche Information Center 2014)

RESEARCH DESIGN AND METHODS

Sample and Data Collection

The initial phase of this investigation was comprised of the process of identifying regions and counties within the Rocky Mountains of Colorado that could be at risk from avalanche events.Avalanche statistics reported by the CAIC indicated that the highest frequency of avalanches within the United States has historically occurred within this area of interest. All mountain regions, counties, and communities were included within this initial area of interest.

Upon further investigation, it was determined that regions, counties, and communites found within the CAIC's 10 avalanche forecasting zones would be the best suited for sampling due to the already ongoing avalanche monitoring practices. These avalanche forecasting zones are comprised of well-known ski desinations such as Vail, Summit, Pitkin, Grand Mesa, and

Steamboat as well as the larger mountain ranges including: the Sangre de Cristo, Sawatch, and San Juan Mountains (Figure 10). A total of 38 counties encompass one or multiple CAIC avalanche forecasting zones.

The second phase of the data collection consisted of the retrieval of current FEMA approved HMPs via internet download from the Colorado Division of Homeland Security and Emergency Management (CDHSEM) website (http://www.dhsem.state.co.us). Hazard mitigation plans not available on the CDHSEM website were downloaded from the county's website or obtained via written/email request. It is important to note that not all counties within the study area posessed a current and approved HMP during the collection phase of this reseach (Figure 11). Therefore, it was not possible to obtain HMPs from all mountainous Colorado counties. County HMPs that were previously FEMA approved but had expired were not considered for this study because only current and approved HMPs provide eligibility for federal assistance in the event of a large magnitude urban-avalanche. The HMPs aquired for assessment included those of the following counties: Alamosa, Archuleta, Boulder, Conejos, Costilla, Denver Regional, Eagle, Fremont, Grand, Gunnison, Hindsdale, Huerfano, La Plata, Lake, Larimer, Mineral, Ouray, Park, Pitkin, Rio Grande, Routt, Saguache, San Miguel, Summit, and Juneau Alaska.

Content Evaluation Procedure

The content evaluation procedure adopted for this study was informed by general criteria for plan assessement suggestions provided by Baur (1997). These suggestions, provided in a paper published in the planning profession's flagship publication *Journal of the American Planning Association*, include:

- Adequacy of content
- Adequacy of scope
- Approach, data, and methodology
- Quality of communication to public
- Guidance for implementation

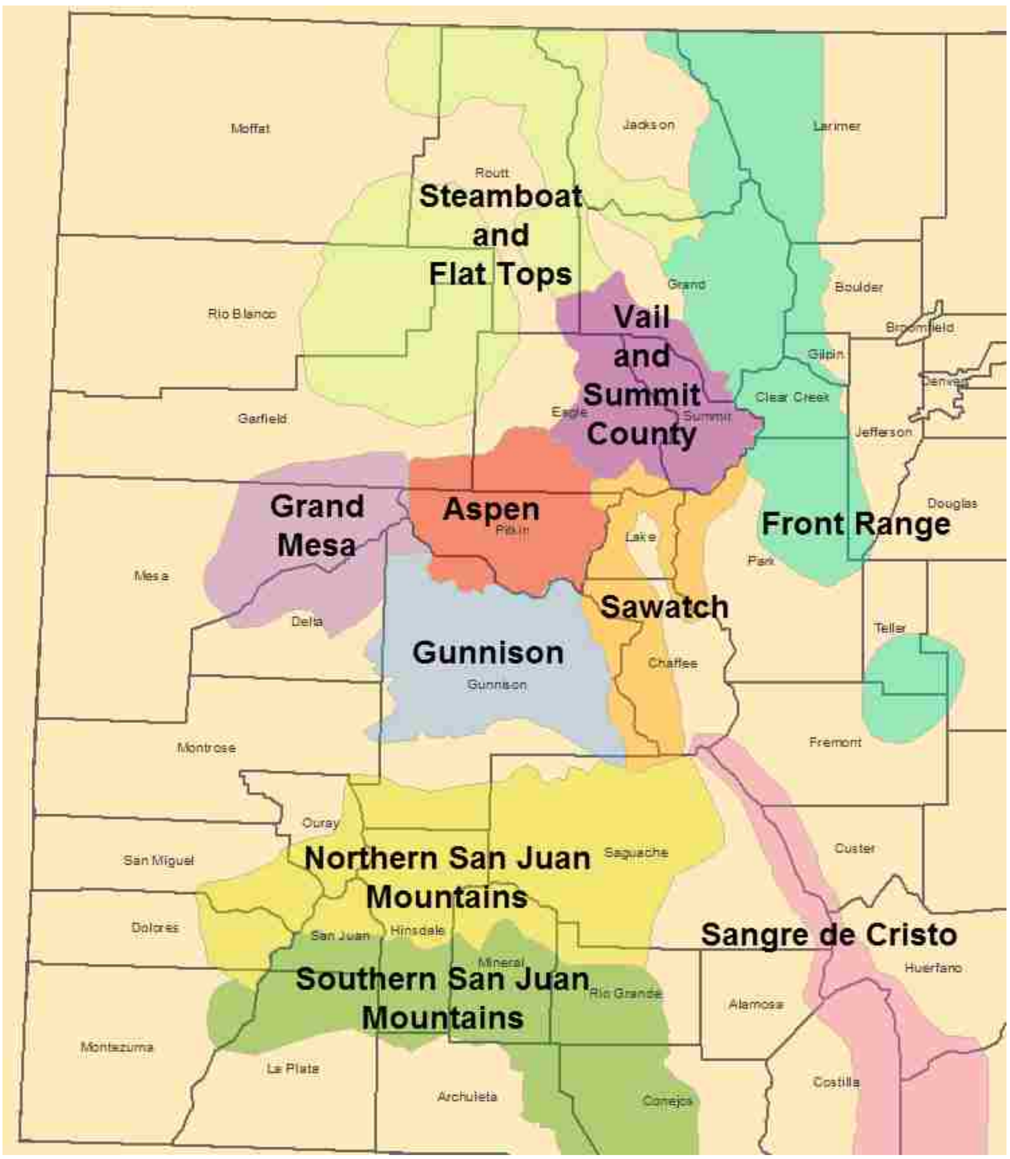
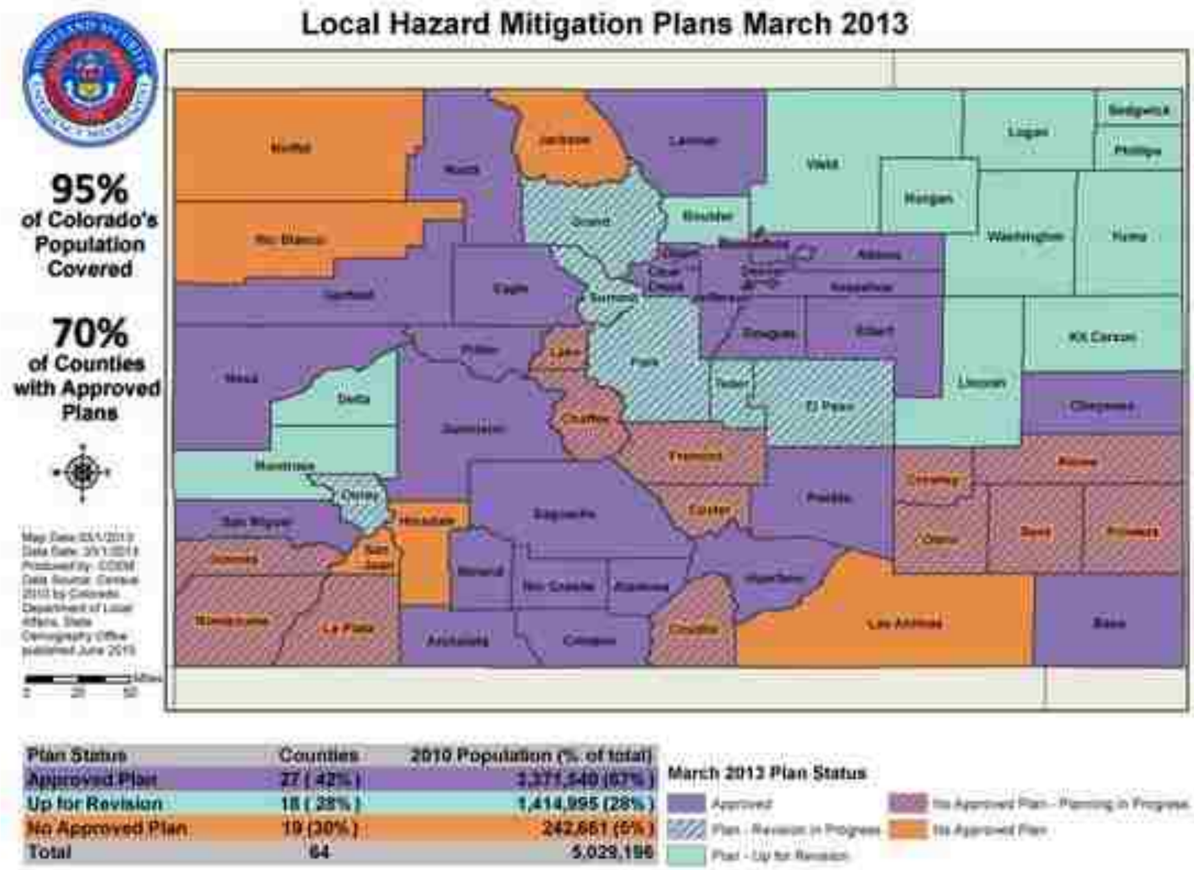


Figure 10. Avalanche Forecasting Zones (Source: Colorado Avalanche Information Center 2015)

Additional criteria for plan evaluation provided by other studies were also employed. Talen (1996) focused on methods for evaluating plan quality based on the implementation success of plans. Kaiser and Davies (1999) targeted the conceptual dimensions of plans that define their quality through goals, policies, and fact bases within their proposed model of plan evaluation. Hopkins (2001) recommends evaluating plans based on their relevance to meeting the needs of local situations



Plan Status	Counties	2010 Population (% of total)
Approved Plan	27 (42%)	3,371,540 (67%)
Up for Revision	18 (28%)	1,414,995 (28%)
No Approved Plan	19 (30%)	242,661 (5%)
Total	64	5,029,196

Figure 11. (Source: Colorado Division of Homeland Security & Emergency Management 2013)

The most commonly utilized recommendation within the HMP evaluation literature is the use of multiple coders in order to attempt to minimize bias. Unlike these previous HMP content evaluations such as Lyles, Burke, and Smith (2012), who utilized seven different scorers while conducting content evaluation on local mitigation plans, only one scorer was possible in this analysis.

A total of 24 HMPs from counties in Colorado and the HMP from Juneau Alaska were independently analyzed for content pertaining to the mitigation of potential avalanche events and scored based on the avalanche specific mitigation planning components and indicators outlined within the adapted scoring protocol tool described in the next section. Each HMP analyzed varied in its layout, organization of information, and use of terminonlogy, requiring careful interpretation in order to confidently assign scores. For instance, one county's HMP may label its avalanche education program as "avalanche outreach," while another may call this "avalanche awareness."

Avalanche Mitigation Scoring Protocol

An adapted version of the Tang et al. (2008) tsunami hazard mitigation scoring protocol was developed and tailored to assess avalanche mitigation plan quality. Like the model protocol, the adapted scoring protocol employed here includes a total of 30 indicators organized within 5 components (Tang et al. referred to these as "categories") the components are: Factual Basis, Goals and Objectives, Policies, Tools, and Strategies, Coordination, and Implementation. The Factual Basis component identifies existing local conditions, recognizes the risk of avalanches, maps areas prone to avalanches, and analyzes historic avalanche events. The Goals and Objectives component identifies the practices employed in order to protect the population, reduce the amount of damage to buildings and infrastructure, minimize socioeconomic impacts, and preserve the natural environment. The Policies, Tools, and Strategies component identifies governmental policies such as land-use permits, zoning, and building codes which prevent new construction in areas prone to avalanche. Additionally, this component focuses heavily on avalanche response and awareness through the implementation of avalanche education programs, guidance for tourists, and the posting of avalanche warning signs. The Coordination component identifies systemic cooperation between multiple government agencies, neighboring jurisdictions, and outside organizations like the CAIC, which specialize in avalanche monitoring. The Implementation component identifies the assignment of tasks to specific agencies, both governmental and non-governmental. This component also identifies a timetable for the completion of the assigned tasks. Finally, this component includes a framework which evaluates the perfomance of the plan and what improvements are necessary for future revisions and plan development.

Though many of the indicators from the Tang et al. (2008) scoring protocol were replicated within the avalanche scoring protocol used here, the avalanche scoring protocol differed from the prototype in several ways. For instance, the Tang et al. (2008) scoring protocol contains a total of 37 indicators distributed within 5 components. Seven indicators from the original 37 were excluded from the avalanche mitigation scoring protocol due to the dissimilar nature of tsunami and avalanche events. For instance, Tang et al. (2008) used a “Emergency Evacuation System” indicator within the policies, tools, and strategies category. This indicator does not translate to the nature of avalanche events. Additionally, the wording of many of the indicators used was altered in order to better address the specifics regarding avalanche hazard mitigation. For example, the Tang et al. (2008) tsunami protocol included indicators such as “Tsunami Risk Identification and Probability Estimation,” “Records of Historical Tsunami Experiences,” and “Delineation of Tsunami Risk Areas.” Indicators similar to these three examples, which are easily converted to focus on avalanche events, were altered and included within the adapted scoring protocol. Furthermore, categories that were deemed to be universal across all hazard mitigation such as “Goals and Objectives,” which contain generalized indicators such as “Protect Safety of Population,” and “Reduce Property Damage” were replicated directly into the avalanche mitigation scoring protocol. The complete avalanche mitigation scoring protocol is available in Table 3.

Upon completion of individual HMP content evaluation, scoring proceeded by measuring each indicator on a 0 to 2 ordinal scale. A score of “0”was assigned when the indicator was not identified or mentioned, a score of “1” was assigned when an indicator was mentioned or suggested but lacks detail. A common example of an indicator being mentioned but lacking detail would be an HMP indicating that there have been historic avalanche events within the jursdiction, however there is no further mention of location, date, or damage caused by the events. Finally a score of “2” was issued when the indicator was fully detailed or identified as mandatory within the plan. The overall score of avalanche HMP quality was then calculated with an equation utilized previously by Berke et al. (1996) and Tang et al. (2008). Four steps were completed in order to determine the final quality score:

1. Scores for all indicators within each of outlined components were summed.
2. The sum of these scores were then divided by the total possible score within each component in order to normalize the results.
3. The result of the previous step was then multiplied by 10 in order to place the plan component on a scale of 0 to 10 by utilizing the following equation:

$$APC_j = \frac{10}{2m_j}\sum_{i=1}^{m_j} I_i$$

where **APC*j*** (Avalanche Plan Component j) is equal to the quality of the *j*th plan component ranging from 0 to 10;

m*j* is equal to the number of indicators within the *j*th plan category;

I*i* represents the indicator's score ranging from 0 to 2;

4. Scores for all components were summed. The maximum score possible for each county/community's avalanche mitigation quality is 50. This is accomplished using the following equation:

$$APQ = \sum_{j=1}^{5} APC_j$$

APQ = total scores (Avalanche Plan Quality) of a whole plan ranging from 0-50.

Table 3. Scoring Protocol (Source: Adapted From: Brody (2003) and Tang et al. (2008)

Avalanche Hazard Mitigation Plan Coding Protocol		
Component	**Indicators**	**Score**
Factual Basis	Avalanche risk identification and probability estimation	
	Regional/local topographic settings	
	Records of historical avalanche events	
	Delineation of avalanche risk areas	
	Avalanche maps	
	Vulnerable populations	
	Vulnerable infrastructure and facilities	
Goals and Objectives	Protect safety of population	
	Reduce property damage	
	Minimize socioeconomic impacts from avalanche	
	Preserve the natural and built environment	
Policies, tools, and strategies	Land use permits	
	Indicative avalanche hazard zonation	
	Building code controls	
	Organizational avalanche response procedure	
	Avalanche monitoring and warning system	
	Environmental hazard review for avalanche	
	Volunteer/community groups for avalanche	
	Initiate and encourage avalanche insurance	
	Avalanche education program	
	Avalanche guidance for tourists and visitors	
	Posting of avalanche danger signs	
	Effective accessibility, notification, and dissemination for info	
Coordination	Coordinate with neighboring/state/federal agencies	
	Coordinate avalanche monitoring, warning and response	
	Link science, technology, and policy	
Implementation	Designation of responsibility	
	Clear timetable for implementation	
	Necessary technical assistance	
	Identify reliable financial support	

Analytical Procedure

Following the scoring of the HMPs, plans were ranked and examined for consistency with respect to content and also for unique information that can serve to help identify best practices in mitigation planning for avalanches. A mean was calculated from the total scores of all sampled HMPs in order to evaluate avalanche mitigation planning comprehensiveness and quality across this population. Individual component mean scores were also calculated in order to identify the strengths and weaknesses of the sampled avalanche mitigation plans.

Additionally, analysis was performed that focused on HMP comprehensiveness in relation to the presence or absence of downhill skiing resorts and historic avalanche fatality statistics. Originally, the intention was to also compare avalanche mitigation plan quality over time. However, historically approved HMPs for all sampled counties of differing dates of approval were not readily available. Therefore, the analysis could not be properly conducted.

In order to address the assumption that counties where downhill ski resorts are present are more likely to have better quality avalanche HMPs, the mean score for counties containing downhill ski resorts were calculated and compared to mean score for counties with no presence of downhill ski resorts; this comparison was a simple descriptive one rather than a statistical test of similarity, such as a T test, owing to the very small number of observations.

In order to address the assumption that counties that have historically had a higher number of deaths attributed to avalanche events would be more likely to have better quality avalanche mitigation planning within their HMP, the mean score for counties that have experienced 10 or more avalanche related deaths was calculated and compared to the mean score for counties that have experienced 0 to 9 avalanche related deaths. Historic avalanche related fatality statistics in Colorado counties from 1950-2012 can be found in Figure 12.

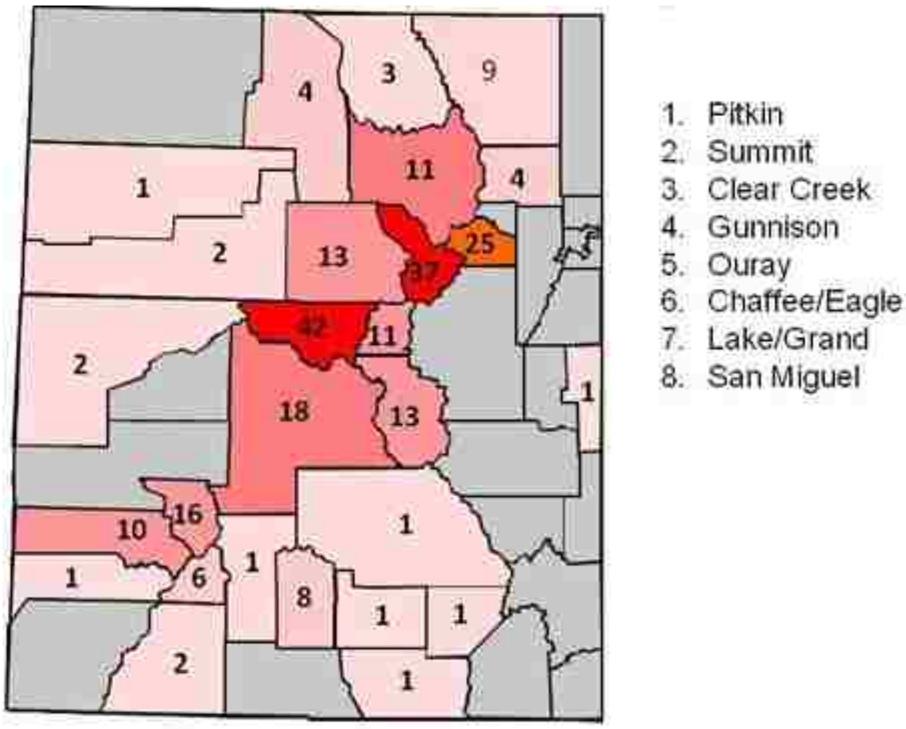


Figure 12. Colorado Avalanche Fatalities by County 1950-2011. Note, county rankings are indicated at right. (Source: Colorado Avalanche Information Center 2012)

RESULTS

Overall Avalanche Mitigation Planning Scores

The fact that nearly all sampled county HMPs identify avalanche as a potential hazard indicates that local government officials and planners are taking avalanche events seriously. Only one county (Costilla County) neglected to include avalanche as a hazard within its HMP. The results of the avalanche hazard mitigation assessments for counties in Colorado and, Juneau Alaska, are presented in Table 4 (specific county results are included in the Appendix). Figure 13 presents the final scores within a map for geographic reference. It is important to note that the Denver Regional HMP encompasses the counties of Adams, Arapahoe, Broomfield, Denver, Clear Creek, Douglas, and Gilpin Again, the 30 indicators categorized within five components were scored on a 0 to 2 ordinal scale. Indicators were scored based on their inclusion and the level of detail presented within the sampled mitigation plan.

Table 4. Overall Avalanche Hazard Mitigation Plan Quality Scores

Hazard Mitigation Plan	Overall Quality Score
Juneau Alaska	34.2
Pitkin County	30.1
Lake County	29.6
Gunnison County	28.3
Larimer County	28.0
Ouray County	27.5
Mineral County	21.4
San Miguel County	21.0
Eagle County	21.0
Saguache County	20.7
Archuleta County	20.5
Rio Grand County	19.9
Hindsdale County	19.6
Summit County	19.6
Denver Regional	19.5
Alamosa County	17.3
Conejos County	17.3
Grand County	15.4
Fremont County	14.3
Routt County	12.3
La Plata County	10.8
Boulder County	10.5
Huerfano County	9.6
Park County	5.5
Costilla County	0.0

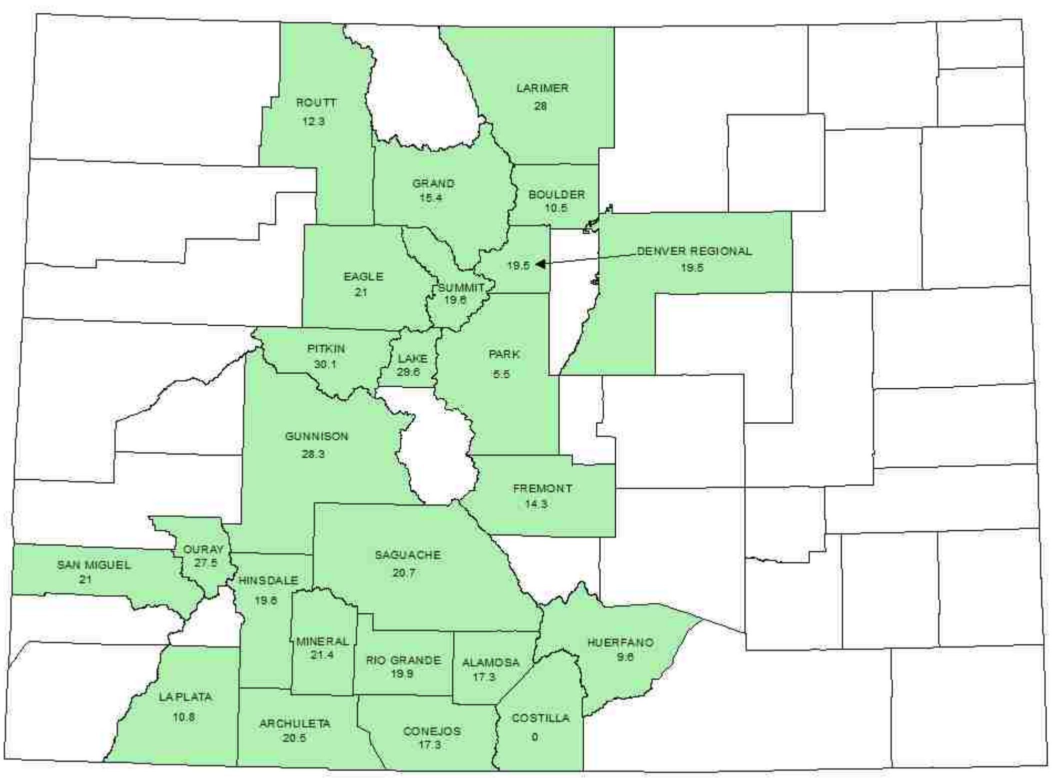


Figure 13. Overall Avalanche Hazard Mitigation Planning Scores Map

The results obtained are consistent with previous studies that found hazard specific mitigation plans to be insufficient on average (Tang et al. 2008, Fu et al. 2013). Costilla County was excluded from further analysis as it did not address avalanches as a potential hazard within its HMP. Means, maxima, minima, and ranges were determined for overall and component scores corresponding to the remaining pool of all other sampled HMPs. Juneau Alaska's scores were also excluded from the calculations of overall mean, max, min and range in order to present only data derived from Colorado counties.

The mean score of 23 Colorado county avalanche mitigation plans was 19.1 out of a possible 50 (39% of the total possible score), and their quality ranged from a low of 5.5 (11% of total possible score) to a score of 30.1 (60.2 % of total possible score). Overall, Juneau Alaska was found to have the most comprehensive avalanche HMP with the highest score of 34.2 among all sampled HMPs, while the lowest score (not including Costilla County) was Park County (overall score of 5.5).

Avalanche Mitigation Protocol Component Scores

Table 5 shows the individual component scores for each HMP as well as the mean results for each component (the counties are listed in the same order as Table 4, from highest overall score to lowest). The maximum score for each component was a score of 10. Overall the component with the highest mean score for all sampled HMPs was the Factual Base component. This component had an overall mean score of 6.7 out of a possible 10. The minimum score was 2.1 (Huerfano and Park counties) and the maximum score was 10, (Lake, Gunnison, and Ouray counties).This resulted in a range of 7.9 over all sampled HMPs.

Table 5. Scoring Protocol Overall Component Scores

Hazard Mitigation Plan	Factual Base Score	Goals and Objectives Score	Policies,Tools, and Strategies	Coordination	Implementation
Pitkin County	7.1	5.0	2.9	5	10
Lake County	10.0	5.0	3.3	5.0	6.3
Gunnison County	10.0	5.0	5.8	5.0	2.5
Larimer County	5.7	3.8	3.8	5.0	3.8
Ouray County	10.0	3.8	3.3	6.7	3.8
Mineral County	9.3	3.8	2.1	5.0	1.3
San Miguel County	6.4	3.8	2.1	5.0	3.8
Eagle County	4.3	5.0	2.9	5.0	3.8
Saguache County	8.6	3.8	2.1	5.0	1.3
Archuleta County	9.3	3.8	0.0	5.0	2.5
Rio Grand County	7.9	3.8	2.1	5.0	1.3
Hindsdale County	7.1	5.0	1.0	3.3	2.5
Summit County	7.1	3.8	2.9	3.3	2.5
Denver Regional	7.9	5.0	0.8	3.3	2.5
Alamosa County	8.6	2.5	0.0	5.0	1.3
Conejos County	8.6	2.5	0.0	5.0	1.3
Grand County	2.9	5.0	0.4	3.3	3.8
Fremont County	1.4	5.0	0.4	5.0	2.5
Routt County	8.6	2.5	0.0	0.0	1.3
La Plata County	5.0	2.5	0.4	1.7	1.3
Boulder County	4.3	3.8	0.0	0.0	2.5
Huerfano County	2.1	2.5	0.4	3.3	1.3
Park County	2.1	2.5	0.8	0.0	0.0
Average	**6.7**	**3.9**	**1.6**	**3.9**	**2.7**

The component tied for the second highest mean score for all sampled HMPs was the Coordination component with an overall mean score of 3.9 out of 10. The minimum score was 0 (Routt and Park counties), and the maximum score was 6.7 (Ouray County). The range for this component was 6.7 over all sampled HMPs.

The other component tied for the second highest mean score for all sampled HMPs was the Goals and Objectives component. This component had an overall mean score of 3.9 out of a possible 10. The minimum score was 2.5 (Huerfano, La Plata, Routt, Conejos, Park and Alamosa counties). The maximum score was 5.0 (corresponding to each of 8 different counties including: Pitkin, Lake, Gunnison, Eagle, Hindsdale, Denver Regional, Grand, and Fremont counties. The range for this component was 2.5 over all sampled HMPs.

The component with the second lowest mean score for all sampled HMPs was the Implementation component, this component had an overall mean score of 2.7 out of a possible

10. The minimum score was 0 (Park County). The maximum score was 10 (Pitkin County). The range for this component was 8.7 over all sampled HMPs.

The component with the lowest mean score for all sampled HMPs was Policies, Tools Strategies, with an overall mean score of 1.6 out of a possible 10. The minimum score was 0 and was issued to 5 different counties including: Boulder, Routt, Conejos, Alamosa, and Archuleta counties. The maximum score was 5.8 for Gunnison County. The range for this component was 5.8 over all Colorado sampled HMPs.

Relation of Plan Quality to Presence or Absence of Ski Resorts

The results demonstrate that the presence or absence of ski resorts does not appear to have a notable association with the quality of avalanche HMPs. Table 6 shows the mean scores for HMPs with and without ski resorts. The means and the mean patterns suggest that counties where ski resorts are present have higher scores on average (19.9) than counties that do not have ski resorts (18.3) on average. However, the mean difference in overall scores between the two types of counties was only 1.6 points. The low scores achieved by Boulder, La Plata, and Routt counties considerably decreased of the overall mean score for counties that do have ski resorts, while the high scores achieved by Larimer, Mineral, and Saguache counties increased the overall mean scores considerably for counties that do not have ski resorts.

Table 6. County Quality Score Comparison: Ski Resort Presence vs. No Ski Resort Presence

Counties without Ski Resort Presence	Overall Score
Alamosa	17.3
Conejos	17.3
Fremont	14.3
Hindsdale	19.6
Huerfano	9.6
Larimer	28.0
Mineral	21.4
Park	5.5
Ouray	27.5
Rio Grand	19.9
Saguache	20.7
Average	**18.3**
Counties with Ski Resort Presence	**Overall Score**
Archuleta	20.5
Boulder	10.5
Eagle	21.0
Grand	15.4
Gunnison	28.3
La Plata	10.8
Lake	29.6
Pitkin	30.1
Routt	12.3
San Miguel	21.0
Summit	19.6
Average	**19.9**

Relation of Scores to Historic Avalanche Fatalities

The results indicate that that the number of historic avalanche related fatalities does appear to have an association with the quality of avalanche HMPs. Table 7 shows the mean scores for counties that have experienced 10 or more avalanche related fatalities and counties that have experienced 0 to 9 avalanche related fatalities. The means and the mean patterns suggest that counties that have experienced 10 or more avalanche related fatalities have higher overall avalanche mitigation planning scores (24.1) than counties that have experienced 9 or less avalanche related fatalities (16.3), on average. The mean difference in overall scores between the two types of counties was seven points. The seeming trend between the association of avalanche fatalities and the quality of the HMPs is shown in Table 7 and Figure 14. It is a positive relationship, but is weak at best given the number of cases examined.

Table 7. County Quality Score Comparison: Counties with 10+ Avalanche Related Fatalities vs. <10

Counties with >=10 Avalanche Fatalities	Overall Score
Pitkin County	30.1
Lake County	29.6
Gunnison County	28.3
Ouray County	27.5
San Miguel County	21.0
Eagle County	21.0
Summit County	19.6
Grand County	15.4
Average	**24.1**
Counties with <10 Avalanche Fatalities	**Overall Score**
Larimer County	28.0
Mineral County	21.4
Saguache County	20.7
Archuleta County	20.5
Rio Grand County	19.9
Hindsdale County	19.6
Alamosa County	17.3
Conejos County	17.3
Fremont County	14.3
Routt County	12.3
La Plata County	10.8
Boulder County	10.5
Huerfano County	9.6
Park County	5.5
Average	**16.3**

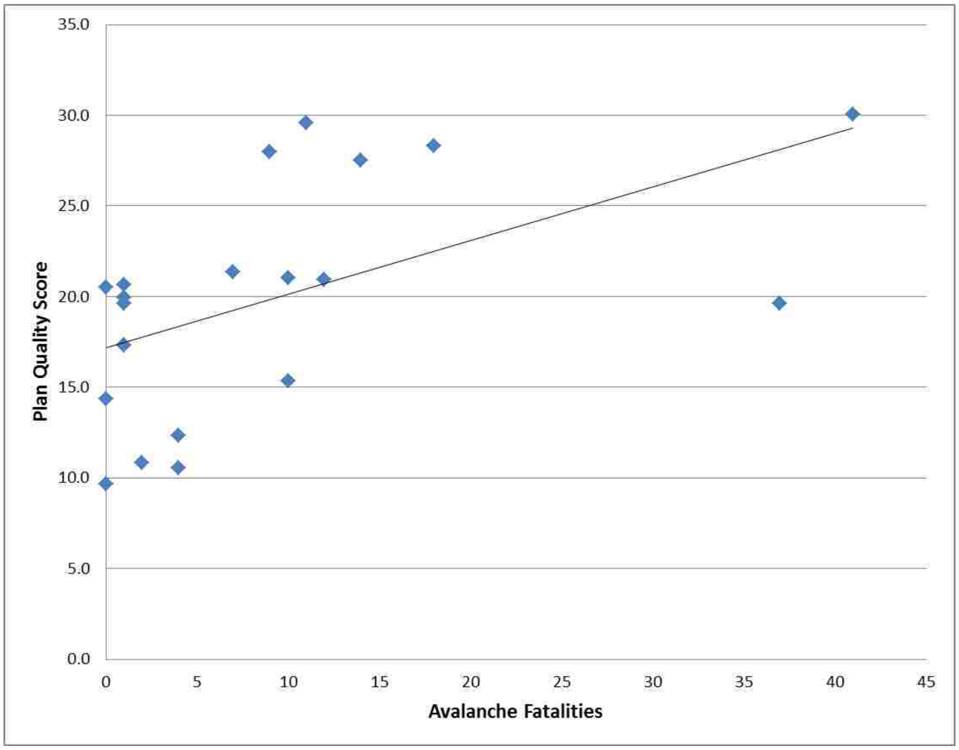


Figure 14. HMP Quality Score Compared to Number of Avalanche Fatalities

DISCUSSION

Colorado planners at the local and regional level face the challenge of developing detailed and comprehensive hazard mitigation plans that effectively address multiple natural and man-made hazards. This challenge extends beyond the borders of Colorado and is shared universally within the planning community. In order to accomplish this task, a more focused approach that better addresses specific individual hazards, such as avalanches, requires continual development and collaborative efforts. Currently there is no generally accepted practice that measures the quality of hazard specific content within local hazard mitigation plans. The subjective nature of HMP evaluation processes, the differences among governmental regulations and policies, and the variation of unique needs and objectives required for different jurisdictions all account for the difficulties of defining what a good HMP might look like versus a poor HMP. In this study, an assessment was conducted in order to evaluate the quality of current avalanche hazard mitigation plans corresponding to 24 Colorado counties and Juneau, Alaska, with the use of an adapted scoring protocol.

Findings of this Study

The results of this study address all four of the research questions posed for this study. The findings pertaining to the first question ("to what extent are counties and regions within Colorado's Rocky Mountain region actively including avalanches as a hazard type within their HMPs?") indicate that of the 24 HMPs reviewed; only one county (Costilla) neglected to include avalanches as a hazard type within its HMP.

In relation to the second question ("historically, what is the frequency and magnitude of avalanche events in these communities if any?") CAIC data indicate that Colorado (and this includes the entirety of the study area) experiences an estimated 20,000 avalanches each year and accounts for approximately one-third of all avalanche deaths in the U.S. since 1950; however, the vast majority of these fatalities did not occur within urban settings. Rather, these avalanche-related fatalities have occurred primarily within backcountry settings where victims were engaging in winter recreational activities such as skiing, snowboarding, snowmobiling, snowshoeing and hiking. Though most avalanches in Colorado are unobserved and cause no harm, the CAIC estimates that about 3 to 4% damage property, block roads, and injure or kill people. Additionally, avalanches destroy stands of timber resulting in economic losses. Information pertaining to financial losses due to avalanches was found to be very limited within the sampled HMPs. The third question asked: "how comprehensive are these HMPs regarding avalanche hazard mitigation?" The scores derived from the assessment of HMPs through the use of the adapted avalanche scoring protocol indicate that the sampled Colorado HMPs were generally not comprehensive when addressing avalanche hazard mitigation; numerous components corresponding to the protocol were not addressed.

And, the findings demonstrate that the answer to the final question ("are there specific HMPs that seem to represent "best practices" for avalanche hazard mitigation?") Juneau Alaska's avalanche HMP exhibits the strongest representation of best practices in terms of avalanche hazard mitigation. This is not necessarily surprising given Juneau's unique setting in avalanche prone terrain and its strong history of avalanche mitigation planning. It is notable, though, that Pitkin and three other counties did show overall scores that were within approximately 2-6 points of Juneau's, indicating that these counties appear to have relatively robust avalanche hazard mitigation plan components in place.

The results of this study confirm that the avalanche specific mitigation planning within Colorado is generally in need of improvement. With the nation's highest overall level of avalanche related mortalities, likely owing to Colorado's high level outdoor recreation participation during the winter months. Given the risk of avalanche events in these jurisdictions, it is imperative that local planning powers work to develop HMPs of the highest level of quality in order to effectively mitigate losses to human life and property damage.

Comparison with Similar Studies

The results of this study also exhibit consistencies with previous studies that also attempt to assess the extent that HMPs effectively address specific individual hazards. Tang et al. (2008) and Fu et al. (2013) found that HMPs addressing specific individual hazards such as tsunami

(Tang et al. 2008) and drought (Fu et al. 2013) were lacking and in need of improvements. The results of Tang et al. (2008) showed that few Pacific coastal counties were not well prepared for tsunamis (average plan scored 12.25 out of possible 50) and that most plans were found to have a weak factual basis, unclear goals, and objectives, weak policies and few coordination and implementation mechanisms. The results of Fu et al. (2013) indicate that state drought plans were generally weak in establishing strong goals, mitigation and adaptation, public involvement, plan updates, and implementation.

The results of this study are also consistent with those of previous studies which have found that the quality of comprehensive HMPs (which address all hazards) as a whole are generally low (Srivastava and Laurian 2006 and Berke et al. 2012). For instance, Srivastave and Laurian (2006) found that Arizona counties do not plan equally well for all hazards. Rather, they tended to have stronger planning for droughts than wildfire and floods (which were determined to be in need of much improvement). The results for Berke et al. (2012) showed that HMPs for 30 coastal states scored low-to-moderate for plan quality based on six principles of plan quality.

This study, like others, employed a scoring protocol to determine HMP quality for a specific hazard and resulted in a ranking of five components (Factual Basis, Coordination, Goals and Objectives, Implementation, and Policies, Tools, and Strategies) that contribute to the quality of avalanche HMPs in Colorado. The findings obtained here exhibit inconsistencies with previous studies (Berke et al. 1996, Brody 2003, and Tang et al. 2008) which concluded that the most notable weaknesses are generally found within the Factual Basis and Goals and Objectives hazard plan components. However, the number of plan components and the indicators included within those components used varied slightly in each of these previous studies. The most similar scoring protocol utilized by Tang et al. (2008) found that component quality for tsunami hazard mitigation planning within analyzed HMPs ranked from strongest to weakest were: 1. Goals and Objectives, 2. Factual Basis, 3. Coordination, 4. Policies, Tools and Strategies, and 5. Implementation. It is assumed that the differences found in the results of this study compared to previously conducted studies are due to the differences in the type of hazard being assessed, the geographical location of the study area, and finally the variation of indicators and components used within each study. It should go without saying that mitigation strategies for avalanches will require different planning actions than that of tsunamis, drought, wildfire, floods etc. The extent of population and property affected by these natural hazards differ substantially, therefore different planning actions are necessary. For instance, when compared to wildfire and flood hazards, areas likely to be affected by avalanche events are much easier to predict and encompass smaller areas of danger.

Recommendations for Future Avalanche HMP Improvements

Like Tang et al. (2008) and Fu et al. (2013), this study makes a modest but meaningful contribution to the hazard planning discipline. The modified scoring protocol utilized in this study to address the quality of avalanche specific planning is a useful quantitative tool that aids in the identification of strengths and weaknesses within HMPs. The application of this scoring protocol empirically documents the gaps in current avalanche HMPs and provides insight on what improvements are necessary. Through this process of identifying the deficient areas within avalanche HMPs, planners and policy-makers can be more direct with efforts to advance safety measures and reduce damage to property within their jurisdictions. Specifically, avalanche HMPs should refer to the indicators outlined within the five plan components listed in Table 3.

The avalanche hazard mitigation plan coding protocol utilized in this assessment was modified so that it would incorporate components and indicators that are intended to support best practices as identified throughout the body of research related to natural hazard mitigation (specifically avalanches). In order for jurisdictions to improve future developments and HMPs, planners and policy-makers must work to address the best practices that have been outlined within the scoring protocol used in this assessment.

First, considerable improvements are particularly necessary within the Policies, Tools, and Strategies component of avalanche HMPs, as it achieved the lowest score among plan components overall. Policy-makers, planners, and recreational providers (e.g., ski resorts) must work closely to advance avalanche awareness for residents and visitors alike. This is accomplished by providing more avalanche-related information to the public through avalanche danger signs and the development of educational programs. Also, community engagement activities, such as the formation of community groups that focus on avalanche safety, should be encouraged to aid in the dissemination of avalanche safety information. However, it is important to recognize the difficulty involved with achieving this task due to public's generally low amount of participation during the hazard mitigation planning process, despite the threat of damaged property and loss of life (Godschalk et al. 2003). It is also important to recognize the challenges that exist for planners and policy-makers when attempting to develop, modify, and enact policies, as well as the level of support they must gain in order to effectively do so.

Second, the Implementation component achieved the second lowest score among plan components overall. Colorado jurisdictions should work to identify specialized tasks, designate unambiguous responsibilities to specific governmental departments and agencies, make necessary allocations of financial resources and staff for support, and establish clear timelines for policy implementation and other task completion. It appears that the low frequency of catastrophic urban avalanches might be related to the relative lack of effort put forth by planners and policy-makers in developing their avalanche HMPs.

Third, the Goals and Objectives component scored the third lowest among plan components, overall. Colorado jurisdictions within the Rocky Mountains should commit to extensive goals and detailed objectives in their avalanche HMPs. This is not a simple task to accomplish due to the seeming low priority of avalanche risk in many Colorado jurisdictions. Though other hazards such as wildfire, drought, and flood were not scored in this assessment, it is apparent that these hazards have a much higher priority within the HMPs. That being said, avalanche hazard mitigation demands many of the same actions required for other natural hazards in the Rocky Mountains of Colorado such as landslides, floods, and wildfire (especially goals and objectives to promote safety). For example, many actions for risk and vulnerability assessments, hazard mitigation (hazard zonation, land-use policy) and public awareness (educational programs), are applicable to the mitigation of avalanche hazards.

Fourth, the Coordination component achieved the second highest score among plan components, overall. It is advised that local jurisdictions develop interdisciplinary coordination procedures for avalanche hazard mitigation management. It is necessary that multiple disciplines and divisions within planning (i.e., local planning and GIS departments), local government (e.g., office of emergency services), and non-governmental organizations (e.g., CAIC) integrate their efforts during the plan development process in order to promote plan improvement. Linkages between local, state, and federal government with non-governmental organizations like the CAIC are necessary for practical avalanche preparedness, continual avalanche monitoring, and postavalanche response efficiency. Coordination continues to become more important as population numbers and development continues to increase in the Rocky Mountains of Colorado.

Fifth, the Factual Basis component achieved the highest score among plan components overall; improvements to the Factual Basis component should still be viewed as a priority for future avalanche HMP development. Local planners and contracted consulting firms that prepare HMPs must meticulously identify avalanche prone areas and share this information in the form of detailed hazard maps. The incorporation of in-depth terrain analysis through the use of Geographic Information Systems (GIS) and the production of hazard information in cartographic form is crucial for improvements to avalanche HMP quality. The dissemination of the analyses and avalanche hazard maps would effectively aid in the identification of vulnerable populations and infrastructure within these local communities.

Additionally, it is advised that a detailed account of historic local avalanche events be included within each avalanche HMP. This chronicle should include the location of the avalanche, populations affected, buildings and infrastructure affected, and a detailed account of the physical and meteorological conditions. Jurisdictions that have not experienced an avalanche event could merely mention such within their avalanche HMPs as opposed to omitting any mention of such by default. The accounts of past avalanche events are vital for the process of identifying the threats that exist in communities (FEMA 2013). The establishment of a strong Factual Basis for a plan through the mapping of potential avalanche hazard areas and the analysis of past events can guide decisions regarding future events (Deyle et al. 1998).

Limitations and Future Research

As with all research, limitations were encountered during this study. First, this study utilized content analysis in order to assess the current avalanche mitigation planning quality within local Colorado HMPs. This content analysis involved a subjective coding procedure in which only one scorer was used. The elimination of personal bias during the scoring process due to the lack of multiple scorers is impossible. It is assumed that this unintentional bias was a factor during the assessment of HMPs. Future studies should conduct multiple scoring assessments on individual HMPs by employing more scorers to effectively achieve interscore reliability.

Secondly, as the first study that attempts to assess the quality of avalanche mitigation planning at the local level, this research utilized previously constructed scoring protocols intended for other hazard types and made modifications to the components and indicators in order to better address the specifics regarding avalanche events. A total of 30 indicators were organized within 5 different components in order to assess the quality of current avalanche mitigation planning at the local level in Colorado. This singular scoring protocol was then used to systematically evaluate the obtained HMPs. Though the scoring protocol was modified to specifically focus on best practices for avalanche hazards, it does not address the variation of jurisdictional attributes and resources that exist within the sampled HMPs. These variations include: community financial standing, political priorities, education, and planning staff and resources. Future research should develop and employ scoring protocols consisting of both broad and community specific components and indicators in addition to the hazard specific components and indicators; such scoring protocols would be valuable for examining regions and/or communities with similar jurisdictional attributes but dissimilar avalanche mitigation planning emphasis. Research could then be furthered by scrutinizing what factors influence avalanche mitigation planning quality among counties with similar jurisdictional attributes.

Thirdly, this research was subject to the availability of HMPs within the ten CAIC avalanche forecasting zones. Approximately 37% of the counties that contain portions of the CAIC avalanche forecasting zones were absent from the assessment process due to lack of available current and approved HMPs. This lack of data resulted in a much lower sample size than originally anticipated, ultimately precluding any attempt ascertain statistical relationships. Future research should look to expand upon the sample of local mitigation planning efforts to multi-regional samples in areas that are susceptible to avalanche events including Idaho, Utah, California, Montana, Oregon, and Washington to draw conclusions on the quality of avalanche mitigation planning.

Overall, future research efforts should seek to identify the factors that influence avalanche mitigation plan quality. Future assessments of avalanche mitigation plan quality, as well as other specific natural hazards in Colorado and elsewhere, will need to address the efforts of multiple planning agencies in order to evaluate the plan implementation process and the resulting impacts on natural hazard mitigation planning.

In addition, future research should seek to examine the deficiencies that exist within avalanche HMPs, specifically, how the benchmarks set by the Disaster Mitigation Act of 2000 influence the quality of HMPs. It is hypothesized that many HMPs are being developed or modified only to the extent that is necessary to meet the standards required by the DMA for FEMA approval. If the overall goal is to meet standards rather than protect populations and property, this practice is likely to diminish the quality of HMPs and continue to place communities in positions of vulnerability to this hazard.

CONCLUSION

Avalanche frequency and magnitude has the potential to increase in the future due to changing weather patterns, a possible increase in seismic activity, and the continual encroachment of human development in mountainous areas. Avalanche events in developed areas of Colorado, while rare, are still a considerable hazard capable of causing tremendous damage to buildings, infrastructure, and human health and life. This threat extends outside the Rocky Mountains of Colorado, and exists worldwide in areas with dramatic mountain landscapes that experience high accumulations of snow. Communities that reside within, or adjacent to, avalanche prone terrain should continue to be concerned with the possibility of avalanche events and work to continually improve upon mitigation efforts within their HMPs. Natural hazards such as avalanches are better and more sustainably mitigated through proactive planning measures such as those detailed in HMPs than through post-disaster recovery efforts (Burby et al. 2000).

This study focused on assessing the quality of local avalanche mitigation planning as detailed within HMPs in Colorado. A total of 24 HMPs from Colorado and one HMP from Juneau Alaska, were evaluated through content analysis and the incorporation of a scoring protocol adapted from previous individual hazard mitigation planning quality studies.

The result of the plan evaluation reveals notable findings, especially that while plan quality varies substantially across the evaluated HMPs, on average avalanche mitigation planning is of low quality and improvements are needed. The plan evaluation also reveals that the Policies, Tools, and Strategies component of the sampled plans were generally weak and requires the most attention for improvement. Though, the Factual Basis component on average had the highest score, considerable improvements could still be made. In particular, updated and detailed maps that highlight areas most prone to avalanche events should be a priority in every HMP.

In addition to these empirical findings, this study demonstrates the usefulness of utilizing a scoring protocol tool to assess the extent and quality of specific natural hazard planning in a local setting. This methodology is systematic and can be used to evaluate and compare the quality of mitigation measures for avalanche planning as well as other natural hazard planning scenarios outside of Colorado.

This study has shown the versatility of utilizing a scoring protocol that is capable of being modified in order to address specific natural hazards such as avalanches. Similar methodologies can be used by local planners to effectively identify the strengths and weaknesses that exist within specific hazard sections of HMPs. The utilization of this methodology would also enable planners to effectively re-evaluate developed plans and improve proactive mitigation planning strategies as well as promote more sustainable hazard-resistant communities.

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APPENDIX

Avalanche Hazard Mitigation Plan Coding Protocol ALAMOSA COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	1				
	Avalanche maps	1				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	12	0.857142857	8.571428571	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	0				
	Preserve the natural and built environment	0	2	0.25	2.5	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	0				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				17.32142857
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	0				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	0	0	0	
Coordination	Coordinate with neighboring/state/federal agencies	2				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	0	3	0.5	5	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	1	0.125	1.25	

Avalanche Hazard Mitigation Plan Coding Protocol ARCHULETA COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	2				
	Avalanche maps	2				
	Vulnerable populations	1				
	Vulnerable infrastructure and facilities	2	13	0.928571429	9.285714286	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	0	3	0.375	3.75	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	0				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				20.53571429
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	0				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	0	0	0	
Coordination	Coordinate with neighboring/state/federal agencies	2				
	Coordinate avalanche monitoring, warning and response	0				
	Link science, technology, and policy	1	3	0.5	5	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	0				
	Necessary technical assistance	1				
	Identify reliable financial support	0	2	0.25	2.5	

Avalanche Hazard Mitigation Plan Coding Protocol BOULDER COUNTY, CO

Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	0				
	Avalanche maps	0				
	Vulnerable populations	0				
	Vulnerable infrastructure and facilities	0	6	0.428571429	4.285714286	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	0	3	0.375	3.75	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	0				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				10.53571429
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	0				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	0	0	0	
Coordination	Coordinate with neighboring/state/federal agencies	0				
	Coordinate avalanche monitoring, warning and response	0				
	Link science, technology, and policy	0	0	0	0	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	2	0.25	2.5	

Avalanche Hazard Mitigation Plan Coding Protocol CONEJOS COUNTY, CO

Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	1				
	Avalanche maps	1				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	12	0.857142857	8.571428571	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	0				
	Preserve the natural and built environment	0	2	0.25	2.5	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	0				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				17.32142857
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	0				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	0	0	0	
Coordination	Coordinate with neighboring/state/federal agencies	2				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	0	3	0.5	5	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	1	0.125	1.25	

Avalanche Hazard Mitigation Plan Coding Protocol COSTILLA COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	0				
	Regional/local topographic settings	0				
	Records of historical avalanche events	0				
	Delineation of avalanche risk areas	0				
	Avalanche maps	0				
	Vulnerable populations	0				
	Vulnerable infrastructure and facilities	0	0	0	0	
Goals and Objectives	Protect safety of population	0				
	Reduce property damage	0				
	Minimize socioeconomic impacts from avalanche	0				
	Preserve the natural and built environment	0	0	0	0	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	0				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				0
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	0				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	0	0	0	
Coordination	Coordinate with neighboring/state/federal agencies	0				
	Coordinate avalanche monitoring, warning and response	0				
	Link science, technology, and policy	0	0	0	0	
Implementation	Designation of responsibility	0				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	0	0	0	

Avalanche Hazard Mitigation Plan Coding Protocol DENVER REGIONAL, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	1				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	2				
	Avalanche maps	0				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	11	0.785714286	7.857142857	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	1	4	0.5	5	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	1				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				19.52380952
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	0				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	2	0.083333333	0.833333333	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	0	2	0.333333333	3.333333333	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	2	0.25	2.5	

Avalanche Hazard Mitigation Plan Coding Protocol EAGLE COUNTY, CO

Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	0				
	Avalanche maps	0				
	Vulnerable populations	0				
	Vulnerable infrastructure and facilities	0	6	0.428571429	4.285714286	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	1	4	0.5	5	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	2				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	1				20.952381
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	2				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	2	7	0.291666667	2.916666667	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	1	3	0.5	5	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	1				
	Necessary technical assistance	0				
	Identify reliable financial support	0	3	0.375	3.75	

Avalanche Hazard Mitigation Plan Coding Protocol FREMONT COUNTY, CO

Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	0				
	Regional/local topographic settings	2				
	Records of historical avalanche events	0				
	Delineation of avalanche risk areas	0				
	Avalanche maps	0				
	Vulnerable populations	0				
	Vulnerable infrastructure and facilities	0	2	0.142857143	1.428571429	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	1	4	0.5	5	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	0				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				14.345238
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	1				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	1	0.041666667	0.416666667	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	2				
	Link science, technology, and policy	0	3	0.5	5	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	2	0.25	2.5	

Avalanche Hazard Mitigation Plan Coding Protocol GRAND COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	0				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	0				
	Avalanche maps	0				
	Vulnerable populations	0				
	Vulnerable infrastructure and facilities	0	4	0.285714286	2.857142857	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	1	4	0.5	5	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	0				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				15.357143
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	1				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	1	0.041666667	0.416666667	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	0	2	0.333333333	3.333333333	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	1				
	Necessary technical assistance	0				
	Identify reliable financial support	0	3	0.375	3.75	

Avalanche Hazard Mitigation Plan Coding Protocol GUNNISON COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	2				
	Avalanche maps	2				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	14	1	10	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	1	4	0.5	5	
Policies, tools, and strategies	Land use permits	2				
	Indicative avalanche hazard zonation	2				
	Building code controls	0				
	Organizational avalanche response procedure	1				
	Avalanche monitoring and warning system	2				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				28.333333
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	1				
	Avalanche guidance for tourists and visitors	2				
	Posting of avalanche danger signs	2				
	Effective accessibility, notification, and dissemination for info	2	14	0.583333333	5.833333333	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	1	3	0.5	5	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	2	0.25	2.5	

Avalanche Hazard Mitigation Plan Coding Protocol HINDSDALE COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	0				
	Avalanche maps	0				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	10	0.714285714	7.142857143	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	1	4	0.5	5	
Policies, tools, and strategies	Land use permits	2				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				19.642857
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	1				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	4	0.166666667	1.666666667	
Coordination	Coordinate with neighboring/state/federal agencies	0				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	1	2	0.333333333	3.333333333	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	1				
	Necessary technical assistance	0				
	Identify reliable financial support	0	2	0.25	2.5	

Avalanche Hazard Mitigation Plan Coding Protocol HUERFANO COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	0				
	Regional/local topographic settings	2				
	Records of historical avalanche events	0				
	Delineation of avalanche risk areas	0				
	Avalanche maps	1				
	Vulnerable populations	0				
	Vulnerable infrastructure and facilities	0	3	0.214285714	2.142857143	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	0				
	Preserve the natural and built environment	0	2	0.25	2.5	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				9.6428571
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	0				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	1	0.041666667	0.416666667	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	0	2	0.333333333	3.333333333	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	1	0.125	1.25	

Avalanche Hazard Mitigation Plan Coding Protocol JUNEAU, AK						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	2				
	Avalanche maps	2				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	14	1	10	
Goals and Objectives	Protect safety of population	2				
	Reduce property damage	2				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	0	5	0.625	6.25	
Policies, tools, and strategies	Land use permits	2				
	Indicative avalanche hazard zonation	2				
	Building code controls	2				
	Organizational avalanche response procedure	2				
	Avalanche monitoring and warning system	2				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				34.16666667
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	2				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	2	14	0.583333333	5.833333333	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	2				
	Link science, technology, and policy	2	5	0.833333333	8.333333333	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	1				
	Necessary technical assistance	0				
	Identify reliable financial support	0	3	0.375	3.75	

Avalanche Hazard Mitigation Plan Coding Protocol LA PLATA COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	0				
	Avalanche maps	1				
	Vulnerable populations	0				
	Vulnerable infrastructure and facilities	0	7	0.5	5	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	0				
	Preserve the natural and built environment	0	2	0.25	2.5	
Policies, tools, and strategies	Land use permits	1				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	0				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				10.833333
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	0				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	1	0.041666667	0.416666667	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	0				
	Link science, technology, and policy	0	1	0.166666667	1.666666667	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	1	0.125	1.25	

Avalanche Hazard Mitigation Plan Coding Protocol LAKE COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	2				
	Avalanche maps	2				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	14	1	10	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	1	4	0.5	5	
Policies, tools, and strategies	Land use permits	2				
	Indicative avalanche hazard zonation	1				
	Building code controls	1				
	Organizational avalanche response procedure	1				
	Avalanche monitoring and warning system	2				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				29.583333
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	0				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	1	8	0.333333333	3.333333333	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	1	3	0.5	5	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	1				
	Necessary technical assistance	0				
	Identify reliable financial support	2	5	0.625	6.25	

Avalanche Hazard Mitigation Plan Coding Protocol LARIMER COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	1				
	Avalanche maps	0				
	Vulnerable populations	1				
	Vulnerable infrastructure and facilities	0	8	0.571428571	5.714285714	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	0	3	0.375	3.75	
Policies, tools, and strategies	Land use permits	1				
	Indicative avalanche hazard zonation	1				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				21.964286
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	2				
	Avalanche guidance for tourists and visitors	1				
	Posting of avalanche danger signs	2				
	Effective accessibility, notification, and dissemination for info	1	9	0.375	3.75	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	1	3	0.5	5	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	0				
	Necessary technical assistance	1				
	Identify reliable financial support	0	3	0.375	3.75	

Avalanche Hazard Mitigation Plan Coding Protocol MINERAL COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	1				
	Delineation of avalanche risk areas	2				
	Avalanche maps	2				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	13	0.928571429	9.285714286	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	0	3	0.375	3.75	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				21.369048
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	2				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	2	5	0.208333333	2.083333333	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	1	3	0.5	5	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	1	0.125	1.25	

Avalanche Hazard Mitigation Plan Coding Protocol OURAY COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	2				
	Avalanche maps	2				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	14	1	10	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	0	3	0.375	3.75	
Policies, tools, and strategies	Land use permits	2				
	Indicative avalanche hazard zonation	1				
	Building code controls	2				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				27.5
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	1				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	1	8	0.333333333	3.333333333	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	2				
	Link science, technology, and policy	1	4	0.666666667	6.666666667	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	1				
	Necessary technical assistance	1				
	Identify reliable financial support	0	3	0.375	3.75	

Avalanche Hazard Mitigation Plan Coding Protocol PARK COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	1				
	Regional/local topographic settings	2				
	Records of historical avalanche events	0				
	Delineation of avalanche risk areas	0				
	Avalanche maps	0				
	Vulnerable populations	0				
	Vulnerable infrastructure and facilities	0	3	0.214285714	2.142857143	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	0				
	Preserve the natural and built environment	0	2	0.25	2.5	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	1				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	0				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				5.4761905
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	1				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	2	0.083333333	0.833333333	
Coordination	Coordinate with neighboring/state/federal agencies	0				
	Coordinate avalanche monitoring, warning and response	0				
	Link science, technology, and policy	0	0	0	0	
Implementation	Designation of responsibility	0				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	0	0	0	

Avalanche Hazard Mitigation Plan Coding Protocol PITKIN COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	0				
	Avalanche maps	0				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	10	0.714285714	7.142857143	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	1	4	0.5	5	
Policies, tools, and strategies	Land use permits	1				
	Indicative avalanche hazard zonation	1				
	Building code controls	1				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				30.059524
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	2				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	1	7	0.291666667	2.916666667	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	1	3	0.5	5	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	2				
	Necessary technical assistance	2				
	Identify reliable financial support	2	8	1	10	

Avalanche Hazard Mitigation Plan Coding Protocol RIO GRANDE COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	1				
	Delineation of avalanche risk areas	2				
	Avalanche maps	2				
	Vulnerable populations	1				
	Vulnerable infrastructure and facilities	1	11	0.785714286	7.857142857	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	0	3	0.375	3.75	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				19.940476
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	2				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	2	5	0.208333333	2.083333333	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	1	3	0.5	5	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	1	0.125	1.25	

Avalanche Hazard Mitigation Plan Coding Protocol ROUTT COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	2				
	Avalanche maps	2				
	Vulnerable populations	1				
	Vulnerable infrastructure and facilities	1	12	0.857142857	8.571428571	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	0				
	Preserve the natural and built environment	0	2	0.25	2.5	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	0				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				12.321429
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	0				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	0	0	0	0	
Coordination	Coordinate with neighboring/state/federal agencies	0				
	Coordinate avalanche monitoring, warning and response	0				
	Link science, technology, and policy	0	0	0	0	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	1	0.125	1.25	

Avalanche Hazard Mitigation Plan Coding Protocol SAGUACHE COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	1				
	Avalanche maps	1				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	12	0.857142857	8.571428571	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	0	3	0.375	3.75	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				20.654762
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	2				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	2	5	0.208333333	2.083333333	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	1	3	0.5	5	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	0	1	0.125	1.25	

Avalanche Hazard Mitigation Plan Coding Protocol SAN MIGUEL COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	1				
	Regional/local topographic settings	2				
	Records of historical avalanche events	0				
	Delineation of avalanche risk areas	1				
	Avalanche maps	1				
	Vulnerable populations	2				
	Vulnerable infrastructure and facilities	2	9	0.642857143	6.428571429	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	0	3	0.375	3.75	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	0				
	Building code controls	0				
	Organizational avalanche response procedure	1				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				21.011905
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	2				
	Avalanche guidance for tourists and visitors	0				
	Posting of avalanche danger signs	0				
	Effective accessibility, notification, and dissemination for info	1	5	0.208333333	2.083333333	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	1	3	0.5	5	
Implementation	Designation of responsibility	2				
	Clear timetable for implementation	0				
	Necessary technical assistance	0				
	Identify reliable financial support	1	3	0.375	3.75	

Avalanche Hazard Mitigation Plan Coding Protocol SUMMIT COUNTY, CO						
Component	Indicators	Score	Sum of Indicator Scores	Sum/Total Possible	Normalize by *10	Plan Quality Score
Factual Basis	Avalanche risk identification and probability estimation	2				
	Regional/local topographic settings	2				
	Records of historical avalanche events	2				
	Delineation of avalanche risk areas	1				
	Avalanche maps	0				
	Vulnerable populations	1				
	Vulnerable infrastructure and facilities	2	10	0.714285714	7.142857143	
Goals and Objectives	Protect safety of population	1				
	Reduce property damage	1				
	Minimize socioeconomic impacts from avalanche	1				
	Preserve the natural and built environment	0	3	0.375	3.75	
Policies, tools, and strategies	Land use permits	0				
	Indicative avalanche hazard zonation	1				
	Building code controls	0				
	Organizational avalanche response procedure	0				
	Avalanche monitoring and warning system	1				
	Environmental hazard review for avalanche	0				
	Volunteer/community groups for avalanche	0				19.642857
	Initiate and encourage avalanche insurance	0				
	Avalanche education program	2				
	Avalanche guidance for tourists and visitors	1				
	Posting of avalanche danger signs	1				
	Effective accessibility, notification, and dissemination for info	1	7	0.291666667	2.916666667	
Coordination	Coordinate with neighboring/state/federal agencies	1				
	Coordinate avalanche monitoring, warning and response	1				
	Link science, technology, and policy	0	2	0.333333333	3.333333333	
Implementation	Designation of responsibility	1				
	Clear timetable for implementation	1				
	Necessary technical assistance	0				
	Identify reliable financial support	0	2	0.25	2.5	