Choosing the Right Tool for the Job

A Comprehensive Technology Assessment for Avalanche Hazard Management:

Developing and applying an avalanche hazard technology optimization process to a case study on US Route 189-191 in Hoback Canyon, Wyoming

Figure 1. The Cow-of-the-Woods Avalanche on US Route 189-191 in Hoback Canyon, Wyoming

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PROBLEM STATEMENT

There are nearly a dozen different methods and technologies, sub-divided into two major categories, that can be used to management snow avalanche hazards on mountain roadways. There is an unmet challenge in the development and implementation of structured decision support tools to assist transportation facilities planners in choosing the right avalanche hazard management method and technology for any given, specific site. Moreover, the financial, technical and operational demands of road avalanche hazard management have led to continued development of new technology to address the problem; indicating that there is no single, optimal method/technology applicable to all sites and situations. As an example, Technologie Alpine de Securite' (TAS) has recently developed a portable, remotely operable avalanche initiating blast source that is evolutionary on their existing, fixed gas blast source technology. This latest active control technology is poised to be introduced domestically.

This research will develop a generic, broadly applicable, structured process to optimize the choice of avalanche hazard management methods and technology for a given roadway application, including an assessment of the state-of-the-art TAS O'Bell portable, remotely operable gas blaster for active avalanche control. This transportation facility planning tool will then be exercise for the Cow-of-the-Woods avalanche on US Route 189-191 in Hoback Canyon, Wyoming utilizing data mined from the Jackson Maintenance facility as inputs to the decision support process, along with lessons learned from an implementation trial of the TAS O'Bell.

BACKGROUND

The consequences of snow avalanche hazards and delays on the mountainous roads of the western US include the potential for injury, loss-of-life, property damage, and significant travel delays. Depending on the avalanche hazard management method and technology chosen, significant DOT personnel resources may be required, often during severe winter storms when this resource is at a premium.

There are a plethora of avalanche hazard management methods and technologies available to domestic DOT's for this purpose. They can be sorted into two effective, but otherwise very different categories: Avalanche forecasting and active control, and constructed/passive avalanche defense. Avalanche forecasting and active control involves forecasting the propensity for avalanching to occur based on winter storm characteristics and existing snowpack conditions, and then pro-actively attempting to release threatening avalanches with various shock sources and delivery systems while the roadway is closed. Constructed/passive avalanche defense is just that; engineered and constructed facilities in the avalanche starting zone that supports the snowpack in-place and precludes the onset of avalanching and artificial avalanche tunnels (commonly known as avalanche sheds or galleries) that pass any avalanche that may occur over the affected roadway. As the term implies, passive avalanche defense does not require DOT personnel to be actively engaged during severe winter storms for these systems to be effective in reducing avalanche hazard to roadways.

Avalanche Hazard Forecasting and Active Control

The art and science of avalanche hazard forecasting is a well developed and well documented methodology, having been pioneered and practice in the US and Canada for over sixty (60) years [1]. It is a personnel intensive activity requiring learned skills. Though the avalanche forecasting skill set is widely applicable, it can often take several years to develop proficiency and expertise with the nuances of a given region. Avalanche hazard forecasting and active control is practiced by DOT's, ski areas, regional public service entities for winter recreational back-country users, mining companies, and both the Alaska and Canadian national railroads. North America leads the international community in the development of this methodology, which is now being taken-up readily in the avalanche prone European Alps, as well as in Asia. In almost every instance where an avalanche hazard forecast for a transportation corridor indicates a high probability for avalanches, there are pro-active actions taken by DOT personnel to reduce the exposure of motorists to this evolving hazard. The simplest action is to close the affected roadway until the hazard subsides. These delays can be on the order of days to weeks. Alternative, pro-active action can be taken to release or bring down the offending avalanche(s) while the roadway is temporarily closed, working from the premise that once it has avalanched, that site is unlikely to avalanche again until the next severe storm. There are a variety of ways in which the shock needed to release the avalanche can be delivered in or onto the snowpack in the avalanche's starting zone. They all involve an explosion and include:

1. Hand delivered explosive charges of dynamite or similar blasting agents.
2. Helicopter delivered explosive charges.
3. Explosive charges delivered by light cableway systems expressed for this purpose, operated from the roadway or similar.
4. Explosive charges delivered by compressed air canons from the roadway or similar.
5. Explosive military artillery rounds delivered from the roadway or similar.
6. Explosive charges delivered by "mortars" located in the avalanche starting zone and operated remotely by personnel at the roadway or similar.
7. Explosive combustion of gas mixtures in fixed facilities located in the avalanche starting zone and operated remotely by personnel at the roadway or similar.
8. Explosive combustion of gas mixtures in portable facilities (i.e. the State-of-the-art TAS O'Bell) located in the avalanche starting zone and operated remotely by personnel at the roadway or similar.

Figure 2. Explosive charges used to initiate avalanches while a threaten roadway is temporarily closed.

Figure 3. A remotely operable avalanche control "mortar" in the starting zone of an avalanche that threatens the roadway below.

Figure 4. Technologie Alpine de Securite' (TAS) fixed, remotely operable avalanche initiating gas blaster.

The fact that such a plethora of technology exists for this specific application is indicative of the fact that no single avalanche shock source technology is optimal for all sites and none are without their drawbacks. Furthermore and regardless of the specific technology being utilized, avalanche forecasting and active control is fraught with three (3) distinct and demanding challenges:

1. It is a personnel intensive activity that to be effective must be practice by skilled individuals at the local/maintenance facility level, and in the event that active control activities are successful an ensuing clean-up may be required and these most often require equipment and operators of the front-end-loader and/or rotary snowplow variety.
2. The avalanche hazard on an affected roadway does not leap to "high" at the instant that DOT personnel close the road to motorists. The hazard is escalating, even while the road is still open, and if avalanche control activities are not successful in dislodging the offending avalanches, the hazard may remain high, leaving DOT personnel with the quandary of whether or not to re-open the road.
3. Active avalanche control requires road closures and subsequent delays, and in one its great ironies, if avalanche control is successful in bringing down the avalanches, these delays are exacerbated to include the requisite clean-up period, as well.

Figure 5. The consequences of successful active avalanche control can be exacerbated roadway closures for clean-up.

Constructed/Passive Avalanche Hazard Reduction

Unlike avalanche hazard forecasting and active control, constructed/passive avalanche defense systems were pioneered in Europe [2] where the density of population and travel corridors precluded the implementation of regular roadway (and rail corridor) closures and the purposeful initiation of avalanches onto populated valley floors.

Despite the dramatic differences in their guise and implementation, constructed/passive avalanche defense is as effective in managing roadway avalanche hazard as avalanche hazard forecasting and active control; the former now under consideration for North American roadways [3,4].

As the name would imply, constructed/passive avalanche defense utilizes engineered and constructed facilities in the avalanche starting zone to preclude the onset of avalanche in the first place or facilities at the roadway that allow naturally releasing avalanches to safely pass over the roadway. These include:

9. Snow supporting structures (snow bridges) in the avalanche starting zone that support the snowpack's weight in place and preclude the onset of avalanching.
10. Avalanche sheds or galleries at the roadway where it is crossed by the offending avalanche; allowing the avalanche to pass over the roadway without risk or delay to motorist on the affected roadway.

Figure 6. An example of both snow supporting structures and an avalanche shed or gallery for roadway avalanche hazard defense.

INVESTIGATIVE METHODOLOGY

In the face of this plethora of choices, identifying the general category, and optimal method and technology for avalanche hazard management for any given roadway can be a daunting challenge, fraught with the potential for both risky and costly errors.

The primary value of this research will be the development of decision support metrics that will allow WYDOT and other state DOT transportation facility planners to make these decisions in a structured and near optimal way. To test the value of this research in a practical setting, the capabilities arising from this research will be utilized as transportation facility planning decision support in a case study to determine the optimal methodology and technology for the problematic Cow-of-the-Woods avalanche path on US Route 189-191 in Hoback Canyon, Wyoming. US Route 189-191 in Hoback Canyon is a significant Rural Principal Arterial roadway, connecting I-80 to the south with Jackson, Wyoming and points to north and east in Idaho, central Wyoming and Montana. It carries as a mixed fleet of local and regional motorists, and regional and trans-continental long haul trucking averaging in excess of 2200 vehicles per day [5]. These traffic volumes are evenly distributed across both days-of-the-week and monthly.

Traditionally, decision support takes the form of Cost/Benefit analysis. That much is easy to say. The challenge in this specific endeavor – avalanche hazard management on roadway corridors – is the novel nature of developing metrics of cost and benefits, and then being able to compare them to each other on and "apples to apples" basis. This is uniquely possible at WYDOT's Jackson Maintenance facility, where nearly all of the available avalanche hazard management technologies cited above have either been implemented operationally or on a trial basis there, and the State-of-the-art TAS O'Bell gas blaster will be subject to an implementation trial.

Task 1: Develop and Assembling Cost and Benefit Metrics

Metrics of avalanche hazard management method or facility costs range from obvious and simple, to relatively obscure, and include, for each of the ten (10) methods and technologies cited above, the following:

1. The costs of technology or facility design and procurement.
2. Personnel costs associated with the operation of the any given method or facility.
3. Technology operating and maintenance costs, including consumables, inspection, maintenance and replacement amortization.
4. The costs of local and regional transportation delays.
5. The costs associated with environmental and NEPA considerations.
6. The costs of addressing resulting liability.

Similarly, the metrics of avalanche hazard management method or facility benefits include, for each of the ten (10) methods and technologies cited above, the following:

1. Impact of each method/technology on DOT personnel resources during severe storm periods when these resources are at a premium.
2. Maintenance and/or recovery of roadway level-of-service on the continuum ranging from closed to open, and capable of safe and un-interrupted travel.
3. The spectrum of applicability and ease of operation of each method/technology and the consequence of loss-of-benefit due to narrowly applicable methodology or technology.
4. Capacity of any given method/technology to meet or exceed "reasonable and prudent" through "best practices" for roadway avalanche risk hazard management.

Each of these Cost and Benefit metrics will be assembled for each of the ten (10) available roadway avalanche hazard management methods and technologies using data mined from the WYDOT Jackson maintenance facility. In a similar fashion, Benefit metrics will also be assembled utilizing WYDOT's Jackson maintenance facility experiences, and local supply, commerce and enterprise travel data sources.

In the case of constructed/passive avalanche defense facilities, whose costs are site specific, design concepts and first order costs estimates will be generated for both an avalanche shed at the roadway and avalanche starting zone snow supporting structures for the Cow-of-the-Wood avalanche path on US Route 189-191 in Hoback Canyon.

Task 2: Assessing Cost/Benefit Metrics of Cutting Edge Portable Gas Blaster Technology

The value and importance of portable, remotely operable gas blaster technology for active avalanche control has led to continued development of new, State-of-the-art systems in this vein. The most recent evolution of this technology includes the Technologie Alpine de Securite' (TAS) O'Bell active control blast source system.

As an element of this research, this technology will also be subjected to an implementation trial on the Cow-of-the-Woods avalanche on US Route 189-191 in Hoback Canyon, Wyoming. Cost/Benefit metrics for the O'Bell gas, based on European experiences to date, and data and experience with TAS O'Bell implementation trial in Hoback Canyon, Wyoming.

As an element of the domestic implementation trial and in an effort to manage procurement costs of the O'Bell unit, a variety of options will be explored with TAS, including but not limited to: Cooperative, no-cost trial usage. Lease usage during the research phase of the investigation with an option to purchase, pending research results. A price reduction from retail, based on the research component of the facility's use as well as TAS' opportunity for USA domestic market penetration with a "first of a kind found in practice" O'Bell unit.

Task 3: Trial/Case Study for Optimal Avalanche Hazard Management Method/Technology for Cow-of-the-Woods, Hoback Canyon, Wyoming

The results of Task 1 and 2 will be use to assess optimal transportation facility planning for avalanche hazard management method/technology at the Cow-of-the-Woods avalanche path on US Route 189-191 in Hoback Canyon, Wyoming.

It is anticipate that the results of this research will continue to support WYDOT's state-of-the-art roadway avalanche hazard management capacity in the Jackson area, and have exportable value to both domestic DOT's in the western US who are grappling with these same issues, and the international transportation community, including and perhaps especially in the developing regions of South America and south-central Asia.

Research dissemination will include WYDOT's Research Division, and venues and publications of both the avalanche community (the International Snow Science Workshop (ISSW) and the Journal of Cold Regions Science and Technology) and the transportation community (via the TRB Annual Meeting and the Transportation Research Record).

Figure 7. Cow-of-the-Woods Avalanche, US Route 189-191 in Hoback Canyon, Wyoming.

COST ESTIMATES

Task One:

Personnel	
InterAlpine Senior Personnel, cumulatively 2.00 month FTE @ $13,120/month	$ 26,240.00
Employee Related Expense (ERE) @ 34%	$ 8,922.00

Subtotal: Personnel	$ 35,162.00
Travel	
Car Rental $130.00 days *12 days	$ 1,560.00
Airfare	$ 5,800.00
Per Diem 230.00 days * 12 days	$ 2,760.00

Subtotal: Travel	$ 10,120.00
Total, Direct Costs	$ 45,282.00
Indirect Cost Recovery @ 39% of Modified Direct Costs (Personnel Only)	$ 13,713.00

Total, Task One	*$ 58,995.00*

Task Two:

Personnel	
InterAlpine Senior Personnel, cumulatively 2.00 month FTE @ $13,120/month	$ 26,240.00
Employee Related Expense (ERE) @ 34%	$ 8,922.00

Subtotal: Personnel	$ 35,162.00
Travel	
Car Rental $130.00 days * 6 days	$ 780.00
Airfare	$ 1,400.00
Per Diem 230.00 days * 6 days	$ 1,380.00

Subtotal: Travel	$ 3,560.00
TAS O'Bell Portable Avalanche Gas Blaster, estimated @$155K, installed	$155,000.00
Total, Direct Costs	$193,722.00
Indirect Cost Recovery @ 39% of Modified Direct Costs (Personnel Only)	$ 13,713.00

Total, Task Two	*$207,435.00*

Task Three:

Personnel	
InterAlpine Senior Personnel, cumulatively 1.00 month FTE @ $13,120/month	$ 13,120.00
Employee Related Expense (ERE) @ 34%	$ 4,461.00

Subtotal: Personnel	$ 17,581.00
Travel	
Car Rental $130.00 days * 6 days	$ 780.00
Airfare	$ 1,400.00
Per Diem 230.00 days * 6 days	$ 1,380.00

Subtotal: Travel	$ 3,560.00
Total, Direct Costs	$ 21,141.00
Indirect Cost Recovery @ 39% of Modified Direct Costs (Personnel Only)	$ 6,857.00

Total, Task Three	*$ 27,998.00*
Total, All Tasks	*$294,428.00*

REFERENCES

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