AVALANCHE CHARACTERIZATION FOR REGIONAL FORECASTING

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ABSTRACT: In the Sunnmøre and Romsdal road districts in Western Norway, the local road authorities have compiled a register of more than 300 sites where avalanches encounter principal roads in the area. The area covered is about 5 000 km^2. The local climate varies substantially throughout the area, mainly due to elevation ranging from sea level to 1500 m, and to highly varying proximity to the coast. To conduct avalanche hazard evaluation and warning for the roads in the region, a database was constructed based on the compiled register. In addition, each avalanche path was characterized by it's sensibility to different wind directions (based on starting zone aspect and shape), starting zone height and area, local climate, steepness and the road segment's situation relative to the run out potential of the avalanche. Using this data, the road segments were grouped to identify segments exposed to avalanches that run under similar conditions. This allowed an operational probability assessment of which road segments are more likely to have an avalanche reaching the road in given weather conditions. The method can be easily implemented in a GIS application and thus give decision makers a fast overview of the anticipated situation in the road district during a given weather situation.

KEYWORDS: Avalanche forecasting, roads

1. INTRODUCTION

In Western Norway, avalanche warning and road closure during periods of high avalanche danger is the alternative where permanent avalanche protection is lacking. Periodic closures of roads can however be costly to society and decisions have to be based on assessments of the avalanche probabilities that are as reliable as possible. This work outlines a tool for use in avalanche forecasting for roads on a regional scale, more specifically the Sunnmøre and Romsdalen road districts in western Norway.

Organizational changes in the Norwegian Public Roads Administration (NPRA) the last few years, notably the discontinuation of inter-organizational road maintenance divisions has lead to a need for avalanche knowledge that is not dependent on the accumulated experience from long time road maintenance employees. In the present organization, maintenance contractors and crews may change every five years and there is no guarantee of transfer of informal knowledge about avalanche conditions along the roads. One objective of the suggested approach has been to provide a quick solution to at least in part resolve this problem. The other objective is to provide support for risk management decisions in given avalanche situations.

The work is in part based on a contract report from the Norwegian Geotechnical Institute (Kristensen, Kronholm and Sandersen, 2007) regarding a regional avalanche warning program for the NPRA Central Region (Statens vegvesen Region Midt).

Figure 2. Map of mainland Norway. Sunnmøre and Romsdal districts are shown as a shaded area.

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2. METHODS

More than 300 individual avalanche paths are considered in the warning program. The two districts cover approximately 5 000 km^2 of avalanche prone terrain which rises from sea level up to more than 1500 m (Figs. 1, 2). The distance to the coast varies from 0 to 70 km, but the avalanche climates are mostly maritime and strongly influenced by cyclonic activity from the North Atlantic.

Warnings are issued on demand, normally when the general avalanche danger degree is expected to exceed degree four (HIGH) according to the European Avalanche Danger Scale (European Working Group for Avalanche Forecasting/ICAR 1993). The general avalanche danger is inferred from local observations and an assessment of the influence of the weather conditions forecast for the next 24 hours. However, the warnings should also include an assessment of which road stretches are more likely to be affected by avalanches in the given weather situation.

The assumption is that, based on their topography and geographic situation, individual avalanches will have different probabilities of affecting the roads in given weather situations. To be able to assess which road stretches are more threatened, the avalanches are grouped according to different criteria, in addition the road's relative position to the estimated extreme run-out of the avalanche.

2.1 Mapping

The NPRA has compiled analog registers with maps that show where avalanches are known to have reached the roads, mostly at their maximum extent observed. These registers show only the affected road stretch and do not cover the path and starting zones. The first task was therefore to extend the avalanche maps, using interpretative methods combined with local knowledge. The resulting maps have then been transferred to a spatial database and a GIS. Each avalanche is then characterized according to the different features described below:

2.2 Proximity to the coast

Three zones with different proximity to the coast were established (Fig. 2). The climatic zones are reflected in the weather forecasts.

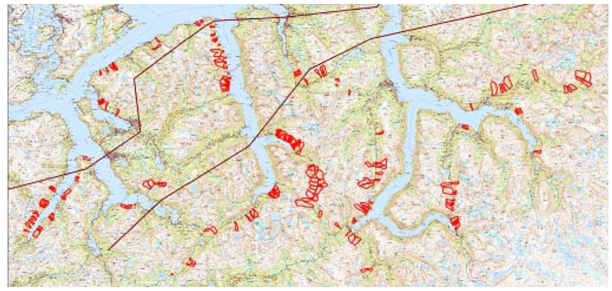


Figure 2. Avalanche map for the Sunnmøre district. The area is divided into a near coast, an intermediate and an inner fjord climatic zone.

2.3 Sensitivity to wind direction

Based on the aspect and shape of the release area, each path has been assigned a sensitivity index value to the 8 main wind directions (Fig. 3). It is assumed that this value gives the relative degree of wind loading in the starting zone in given wind directions. The method is an interpretative procedure based on assumptions of the amount of leeward accumulation and cross-loading. It is assumed that this determines which avalanches are more likely to release in the given wind direction.

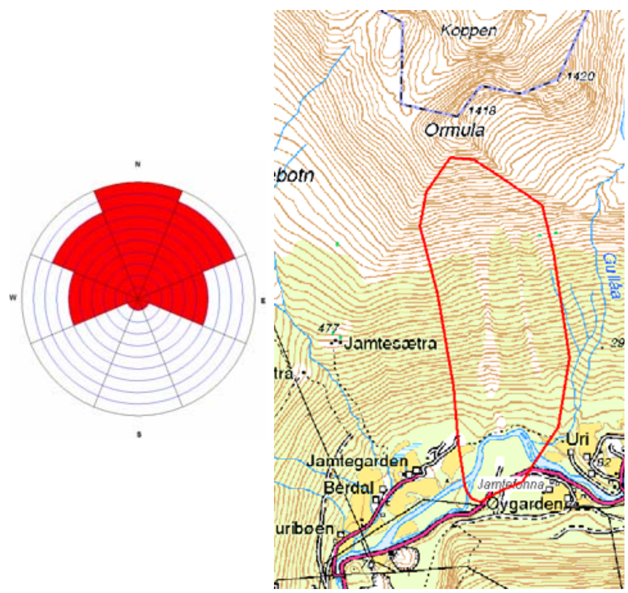


Figure 3. Example of avalanche path with assumed wind loading characteristics. In this case predominantly from northerly directions.

2.4 Starting zone elevation

The upper and lower boundaries of the starting zones, loosely defined as un-forested slopes between 30 to around 60 degrees, are assessed for each avalanche (Fig. 4). This factor is assumed to be important, especially when a temperature rise or rain on snow is considered a potential trigger for avalanche release.

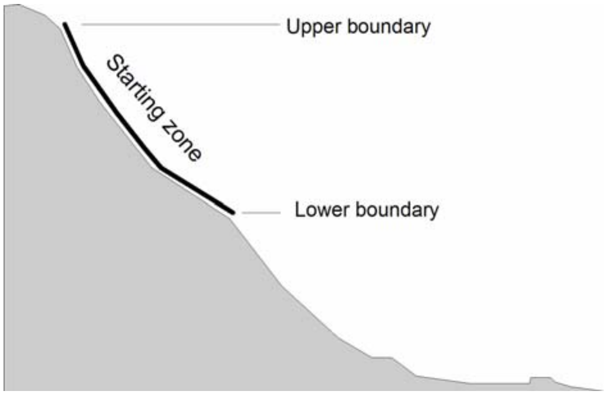


Figure 4. Upper and lower starting zone boundaries.

2.6 Avalanche size

Avalanches are given a size classification based on five volume classes given below.

1. Local slide	<100 m^3
2. Small avalanche	>100-<1000 m^3
3. Medium sized avalanche	>1000-<10000 m^3
4. Large avalanche	>10000-<100000 m^3
5. Extreme avalanche	>100000 m^3

2.7 Road position relative to Beta

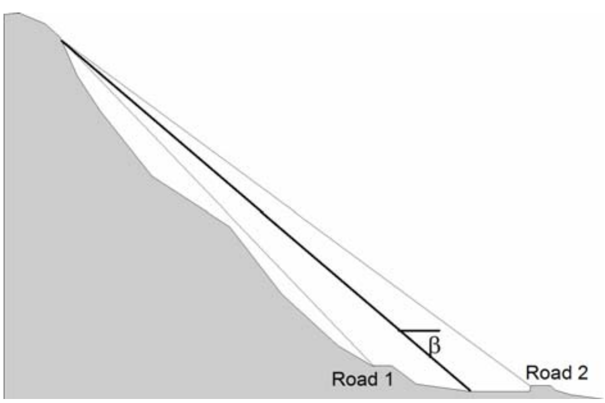
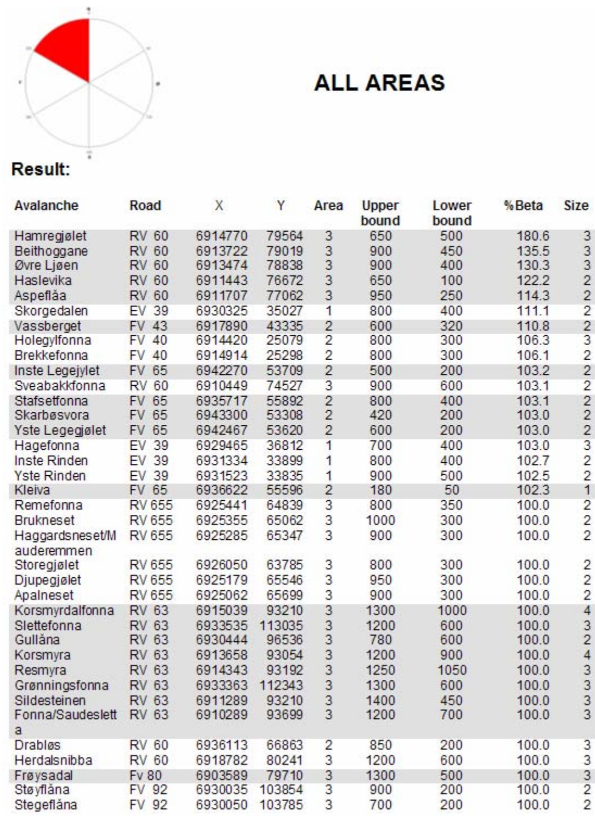


Figure 5. The Beta angle is a defined point in an avalanche profile. The road's position relative to this point indicates the relative probability of an avalanche reaching the road.

The NPRA register only occasionally give indirect estimates on the frequencies of the avalanches reaching the road. Therefore, the Beta-angle, as defined by Lied and Bakkehøi (1980), of each avalanche was mapped. The angle from the road location to the upper boundary of the staring zone is similarly measured, and then expressed as a percentage of the Beta-angle (Fig. 5). The procedure was outlined by Hamre and McCarty (2000) and indicates the relative probability of an avalanche reaching the road.

3. RESULTS AND DISCUSSION

The database of the more than 300 avalanches can be used with different search criteria, although the primary ones would normally be wind direction and climatic zone. A database search will in this case result in a list of avalanches more likely to run in the given synoptic situation (Fig. 6). In situations where temperature changes are assumed to be important, avalanches with given starting zone vertical boundaries can be chosen. The analysis can also be incorporated in a GIS for convenient visualization of the expected ava-



Avalanche	Road	X	Y	Area	Upper bound	Lower bound	%Beta	Size
Hamregjølet	RV 60	6914770	79564	3	650	500	180.6	3
Beithoggane	RV 60	6913722	79019	3	900	450	135.5	3
Øvre Ljøen	RV 60	6913474	78838	3	900	400	130.3	3
Haslevika	RV 60	6911443	76672	3	650	100	122.2	2
Aspefläa	RV 60	6911707	77062	3	950	250	114.3	2
Skorgedalen	EV 39	6930325	35027	1	800	400	111.1	2
Vassberget	FV 43	6917890	43335	2	600	320	110.8	2
Holegylfonna	FV 40	6914420	25079	2	800	300	106.3	3
Brekkefonna	FV 40	6914914	25298	2	800	300	106.1	2
Inste Legejylet	FV 65	6942270	53709	2	500	200	103.2	2
Sveabakkfonna	RV 60	6910449	74527	3	900	600	103.1	2
Stafsetfonna	FV 65	6935717	55892	2	800	400	103.1	2
Skarbøsvora	FV 65	6943300	53308	2	420	200	103.0	2
Yste Legegjølet	FV 65	6942467	53620	2	600	200	103.0	2
Hagefonna	EV 39	6929465	36812	1	700	400	103.0	3
Inste Rinden	EV 39	6931334	33899	1	800	400	102.7	2
Yste Rinden	EV 39	6931523	33835	1	900	500	102.5	2
Kleiva	FV 65	6936622	55596	2	180	50	102.3	1
Remefonna	RV 655	6925441	64839	3	800	350	100.0	2
Brukneset	RV 655	6925355	65062	3	1000	300	100.0	2
Haggardsneset/Mauderemmen	RV 655	6925285	65347	3	900	300	100.0	2
Storegjølet	RV 655	6926050	63785	3	800	300	100.0	2
Djupegjølet	RV 655	6925179	65546	3	950	300	100.0	2
Apalneset	RV 655	6925062	65699	3	900	300	100.0	2
Korsmyrdalfonna	RV 63	6915039	93210	3	1300	1000	100.0	4
Slettefonna	RV 63	6933535	113035	3	1200	600	100.0	3
Gullåna	RV 63	6930444	96536	3	780	600	100.0	2
Korsmyra	RV 63	6913658	93054	3	1200	900	100.0	4
Resmyra	RV 63	6914343	93192	3	1250	1050	100.0	3
Grønningsfonna	RV 63	6933363	112343	3	1300	600	100.0	3
Sildesteinen	RV 63	6911289	93210	3	1400	450	100.0	3
Fonna/Saudesletta	RV 63	6910289	93699	3	1200	700	100.0	3
Drabløs	RV 60	6936113	66863	2	850	200	100.0	3
Herdalsnibba	RV 60	6918782	80241	3	1200	600	100.0	3
Frøysadal	Fv 80	6903589	79710	3	1300	500	100.0	3
Støyflåna	FV 92	6930035	103854	3	900	200	100.0	2
Stegeflåna	FV 92	6930050	103785	3	700	200	100.0	2

Figure 6. Example of a list of avalanches sensitive to North-West wind loading. The avalanches are listed in descending order with regards to the Beta/road position ratio (the second rightmost column).

lanche situation.

The approach assumes that the user has means of arriving at a general danger rating. Moreover, the characterization is somewhat subjective and GIS-based procedures for calculating snow accumulation and starting zones may be useful.

4. CONCLUSION

We think that the proposed method can provide useful decision support. Together with local knowledge and other information decision makers can reach conclusions on whether to open/close roads by using a list of the most susceptible road stretches in the given situation.

5. ACKNOWLEDGEMENTS

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