Avalanche risk in a changing climate
Development of a landslide and avalanche risk model

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ABSTRACT: In Norway, approximately 2000 landslides and avalanches affect the road network every year. Projected climate changes will give a milder and wetter climate in Norway with more extreme weather events. These changes are expected to affect the avalanche and landslide frequency. In order to adapt to expected climate changes, the Norwegian Public Roads Administration initiated a 4-year R&D programme in 2007 called “Climate and Transport”. One of the main topics in the programme is landslides and avalanches, and how climate changes are expected to change the probability for and frequency of these events. Within the subject of avalanche and landslide risk on the road network, the level of acceptable risk has not been established, and in an attempt to describe the avalanche and landslide risk more thoroughly, a risk model concerning these conditions has been developed. The model is still in a premature state, and testing on certain road sections will be done in near future.

KEYWORDS: Climate change, landslide and avalanche frequency, acceptable risk level

1 INTRODUCTION

In Norway the climate change is expected to bring higher precipitation, more frequent and intense rainfall, milder winters, warmer summers and an increase in storm frequency. These factors will affect the road network and change the avalanche and landslide frequency.

In order to adapt to climate change the Norwegian Public Roads Administration NPRA started a 4-year programme in 2007 called “Climate and Transport”. The main goal is to take climate change into consideration by planning, design, operation and maintenance of roads. The programme consists of seven sub-projects, where “Avalanches and landslides” is one of the most important related to our problems with natural hazards.

2 LANDSLIDES IN NORWAY

From the NPRA register of natural hazards we have an average record of 1500-2000 landslides and avalanches a year. More than half of these are rock falls, but the record of snow avalanches and icefalls are 15 % and 16 %, see also figure 1. About one third of these events cause partly or fully closed roads.

Natural hazards play an important role in keeping the highways and roads open and safe for the public. We have also considerable costs connected to opening, repairs and inconvenience for the road-users waiting for the road to open or as they are forced to do detours to avoid the exposed transport routes.

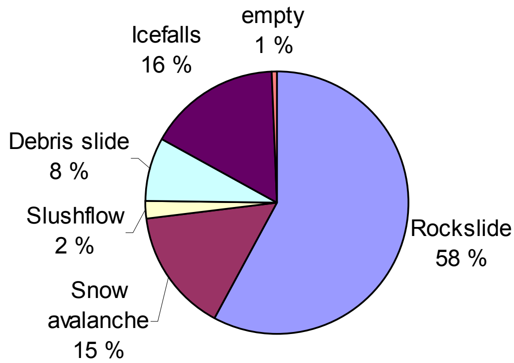

Figure 1 Distribution of different types of landslides and avalanches.

Statistically an average of two persons are killed, and about one person is seriously injured in a landslide or avalanche every year. In addition to this, living with landslide and avalanche risk is also a serious threat to residents depending upon travel along exposed road sections on their way to work, school, leisure activities etc.

Through regional plans for protection against landslides and avalanches about 1700 spots are identified as the most exposed. A rough estimate of the cost for protecting of these are 3 000 million Euros.

2.1 Expected changes in landslide activity

Changes in temperature and precipitation are important factors when it comes to the frequency of landslides and avalanches. Higher

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temperatures in winter will lead to less snow in the lower and coast near areas in winter. We can already observe a reduction in the frequency of snow avalanches in some areas.

On the other hand an increasing precipitation and increasing storm frequency will give an higher probability for snow avalanches in higher mountain areas where the temperatures still remain cold. These effects could also trigger avalanches with increasing mass/volume giving a longer run out than already recorded.

Intense rainstorms are expected to increase the frequency for mud flows, debris slides, rockfalls and slush avalanches.

How these changes in frequency will affect the road network is one of the main tasks in our research program.

3 LANDSLIDE AND AVALANCHE RISK

In order to study this more closely, we decided to develop a landslide and avalanche risk model. One of the conditions in the development was to go beyond the statistics and create a tool to be used independent of where landslides, rock falls and avalanches occur today. This will give a model more robust to climatic variations that might lead to higher hazard in some areas, and lower hazard in other areas

Another major issue when working with landslide and avalanche risk is defining the level of acceptable risk. In Norway this level is defined in our building code, but not for the transport sector. The only guideline is the general vision of zero killed in road accidents. This makes the acceptable risk level to be defined in every single project, and perhaps very randomly chosen.

3.1 Features of the risk model

In the risk model, landslides and avalanches are divided in nine different types: snow avalanches, slush flows, icefalls, rock falls, rockslides, large rockslides, debris slides, debris flows and quick clay slides.

For each type a fault tree describing factors affecting the release of a landslide or an avalanche is established. The fault trees include factors describing exposed terrain, geological parameters, weather conditions and others. An example of a fault tree is given in figure 2. All the factors are given a score and weight contributing to the risk value calculated for a particular road section.

3.2 Challenges in developing the risk model

The development of a risk model describing the nature and natural processes forces engineers and geologists to systematise knowledge and expertise about landslide and avalanche probability. Furthermore, complicated relations must be expressed simply and not at least correctly.

3.3 Consequences of landslides

Landslides and avalanches hitting the road is a risk for those travelling the road. It might also cause damage to the road and the road equipment in addition to the road being closed during clearing and repairing. While the road is closed, road users must travel detours, or wait until the road reopens.

In the risk model, consequences is expressed as a relation to the traffic amount, amount of heavy traffic, presence of pedestrian traffic, importance of road, rerun time on bypass road.

4 CONCLUSIONS

The first uses for the risk model will be to compare different road sections regarding risk level. Further the model will be used to suggest classification of probability and consequence, and in order to evaluate climate changes the model can be used to consider changes in hazard due to climatic variations.

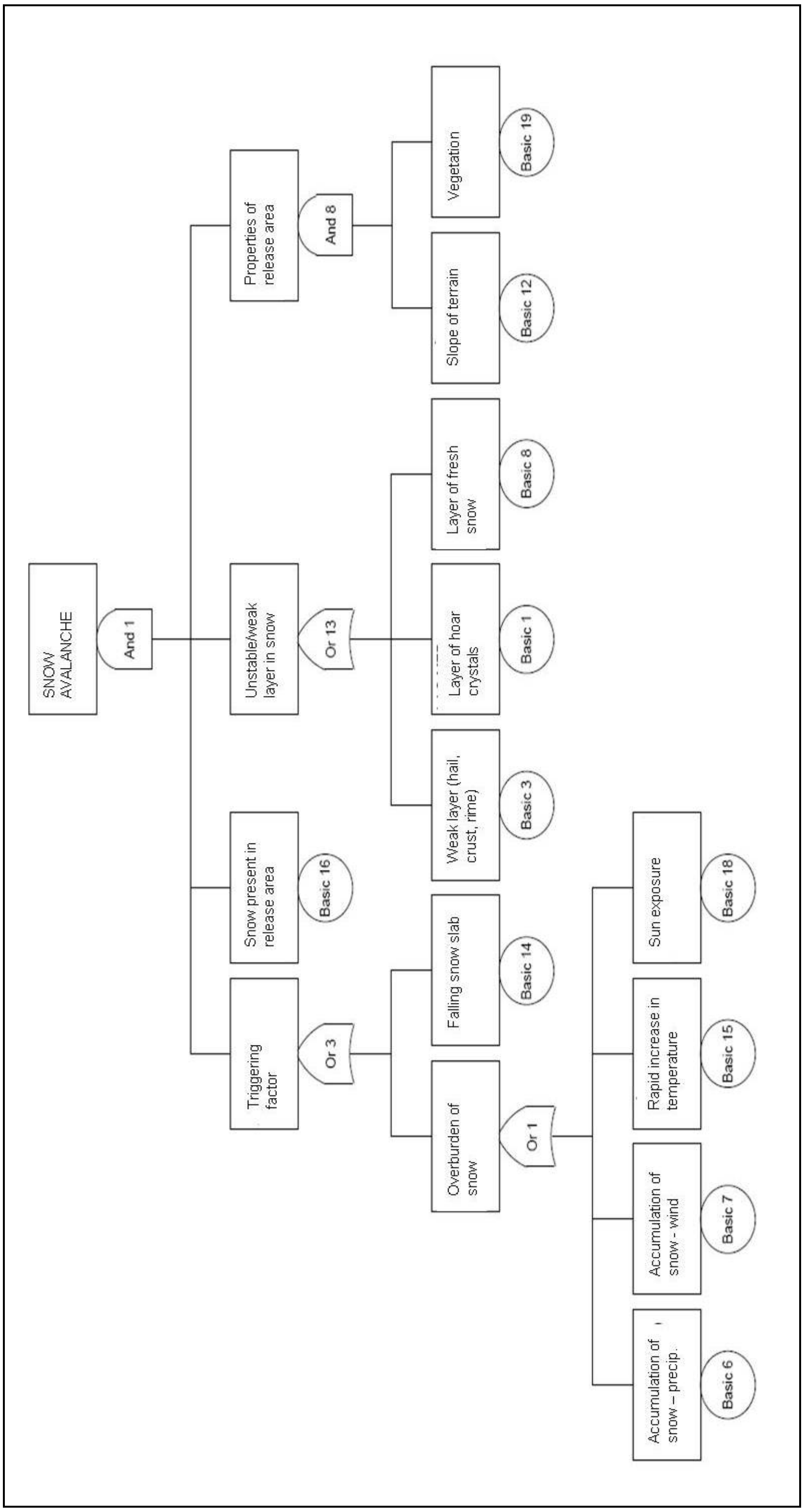

Figure 2 Fault tree showing factors affecting the probability for snow avalanches.