CRITERIA FOR CLOSING MOUNTAIN PASSES BASED ON FRICTION MEASUREMENT AND CROSSWIND

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ABSTRACT

In 2006 there was a bus accident on a mountain pass in Norway called “Dovrefjell”. Strong crosswind in combination with slippery road led to an accident with personal injuries. The Accident Investigation Board Norway investigated the incident and they had several recommendations which could improve the traffic safety on mountain passes like this.

The Norwegian Public Roads Administration together with research organisation SINTEF and the maintenance contractor Mesta, are now working on a project trying to find criteria for when is not safe to drive over this pass. The project should also look at how to better inform the road-users regarding the road condition during the wintertime.

Reducing the speed limit when driving conditions are difficult is one measure for upholding the traffic safety. We know that heavy vehicles are more vulnerable for crosswinds than passenger cars so one alternative could be diversified speed limits.

The project will also try to test a warning system with input from the wind speed and direction, the visibility and the friction level on the road. In the future it can be a possibility to have an automatic closing of the road based on these data. Today the decision is made by the contractor and the client jointly.

1. BACKGROUND

During the night of November 24th, the coach “Lavprisekspressen” was heading south from Trondheim to Oslo on the E6 highway. The coach was a double-decker MAN Neoplan Skyliner. There were 53 passengers on board on the bus. When the bus was reaching the highest point on the route, the mountain pass Dovrefjell, there was strong wind combined with ice covered road. As a result of this very strong crosswind and the slippery conditions the bus lost the grip on the front wheels and the driver couldn´t control the bus. The bus went into the ditch and turned over and landed on it´s right side when reaching the flat ground. [1]

Figure 1 - The recovery operation after the accident. (Source: The Accident Investigation Board Norway).

Those passengers who did not wear seat belts where thrown around and one person seated in the second floor was trapped under the coach. A total of 30 persons were injured in the accident, 4 of them seriously. [1]

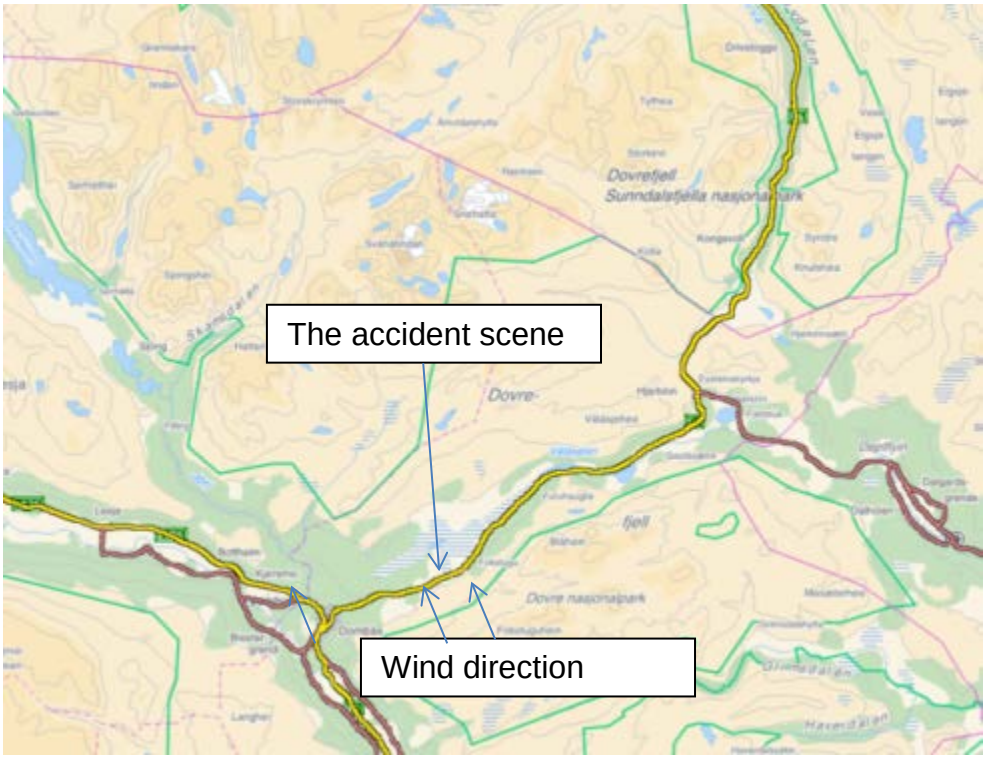

Figure 2 - The accident scene on Dovrefjell. (Source: NVDB)

The wind phenomena this night can be characterised as “down slope wind storms”. The investigations shown that the coach had been exposed for one or more gusts up to 25 m/s, and the coefficient of friction between the tires and the road surface was probably under 0.20. [1]

The Accident Investigation Board of Norway (AIBN) has made 6 safety recommendations after this accident, and 3 of these are related to areas that the Norwegian Public Roads Administrations are responsible for:

1.1 Safety recommendation nr 1

There was no up to date information for the road users. If the bus driver had information about wind- and road conditions he would have had better possibility for right decision-making for safe crossing the mountain. Better information system for the road users are the first recommendation.

1.2 Safety recommendation nr 2

The highway E6 crossing Dovrefjell was neither salted nor gritted before the accident. The contractor had considered the wind so strong that the gritting material would blow off the road immediately and give no friction effect. The Norwegian Public Roads Administration should look at possible methods for gritting under such conditions.

1.3 Safety recommendation nr 3

Closings of mountain passes in Norway are normally related to snowstorms and danger for cars to get stuck in snow, and to the visibility conditions. The weather condition this specific day with strong side wind and slippery road are not a part of the factors considering for closing a road. Clearer directives regarding management and closing of roads when such conditions appear is another recommendation.

The background for this project was just these safety recommendations from the AIBN.

2 DESCRIPTION OF THE PROJECT

The project is a collaboration between Norwegian Public Roads Administration, the research organisation SINTEF and the maintenance contractor Mesta. The aim of the project is to find criteria for when the road should be open, closed or they should introduce convoy driving. Better information to the road users about the driving condition is another issue the project wants to look at, and also how we can improve the friction when the wind is strong and it is difficult to grit in a normal way.

2.1 Instrumentation

There are installed three weather stations in this section of the road. The weather stations give data about the temperature (road surface and air), wind (speed and direction), air humidity and precipitation. On two of this station there are also road surface state sensors which give us a friction index based on registration of the road condition in a little area on the road.

Figure 3 - Weather station with wind sensor, web camera, surface- and air temperature and a road surface state sensor.

There are now installed three cameras on the mountain pass and “home-made” signpost so the operators can consider the visibility for the road-users from the office. An example of this you can see in Figure 5. The contractor can then consider the visibility based on how many signpost he can see. The webcameras are open for public and can be seen at www.vegvesen.no/webkamera.The pictures are updated every 5 minutes.

These weather stations are connected to variable signpost located in two small villages (Dombaas and Oppdal) on both side of the mountain pass. Here the road-users get information about the strength of the wind on the mountain and also information if the mountain pass is open, closed or if it is introduced convoy driving.

Figure 4 - Variable signpost in Dombaas. The sign says that the road is open and the wind strength is 2 m/sec.

Figure 5 - Webcamera on E6 Fokstugu with visibility signposts.

3 PRELIMINARY RESULTS

3.1 Information to the road users

After the accident in 2006 a new weather station was installed and also variable signpost showing the strength of the wind on the mountain pass (see Figure 4). There is information about the driving conditions on the internet together with “online” web cameras. The winter season 2012/2013 a new service was opened with a SMS-warning informing the road users about the driving conditions on this specific section.

3.2 Actions to increase friction during a storm

During a storm and especially when the wind is strong it is difficult to spread sand or salt on the road. The grains of sand or salt will go with the wind before they reaches the road surface. One solution to this is a mixture of hot water and sand. This mixture have been developed and used in Norway since 1998 and there are today two suppliers which produce spreaders that are custom-made for this use.
The mixture of hot water and sand will stick to the ice and create very good friction if temperatures in the ground are below zero.
This method also works best when there is little wind, but the method has normally long duration and action can be done before the storm starts. If the weather is cold and stable this method can increase friction for several days. The contractor in this area has invested in a spreader for mixing hot water and sand. The project has also challenged one supplier of spreaders to come up with a solution for a windshield back on a spreader so that action can be done even if it is quite strong crosswind.

3.3 Guidelines for introducing convoy driving or closure of the road

One of the objectives for the project is to find guidelines and limit values for introducing convoy driving and closure of the mountain pass.
The project has prepared an application for mobile phone where input data are visibility, wind strength and friction. There are two ways the road can be closed with use of application: Wind + friction or visibility + friction. It is separated in three different vehicle types: Passenger cars, ordinary bus and double-decker (named coach in the figures).
The background for the calculation of the wind strength and influence on the different types of busses are done by Storm Weather Center for the AIBN [1]. Based on side forces and lifting forces on the bus, they have calculated how low the coefficient of friction could be before the bus loose the road grip.

Observed values			Limit value for closure[1]	
Quantity	**Value**	**Unity**		
Measured visibility (minimum)	500	m	min	20
Measured average wind speed (10 min)	16,7	m/s	max	24,5
Measured friction (minimum)	0,19	1	min	0,14
Snow conditions[(2)]	Ingen	-	-	-

(1): Limit value for closure, meaning that closing is introduced based on one value and not a combination of several.

(2): Snow condition are not a direct parameter in this calculation model.

Estimated speedlimit				
Measured values	**Vehicle type**	**Speed limit**		**Traffic**
Visibility and friction	All	80	km/h	Open
Wind and friction	passanger car	na	km/h	Open
Wind and friction	Bus	60	km/h	Open
Wind and friction	Coach	30	km/h	Convoy driving
Road status		**30**	km/h	**Convoy driving**

Figure 6 - Example of results with the mobile phone application. The application recommends convoy driving under such conditions.

In Figure 6 the values from the bus accident in 2006 are used as an input. The visibility was good (Put to 500 m here). The wind gusts this night was around 25 m/s which normally give a measured average wind speed of around 16 m/s, and the friction was low probably under 0.20 says the report (0.19 used here). If we use this data in our model the road status says convoy driving at low speed (30 km/h).

Convoy driving as a traffic control measure is distinctively a Norwegian phenomenon. Convoy driving can be introduce if the weather- and road conditions are so difficult that cars can get stuck in snow or there are a risk for accidents because of bad visibility or narrow road.

Roads shall be fully closed when storm, danger of avalanches or other safety issues makes it indefensible to take the convoy over the mountain.

The Norwegian Public Roads has guidelines for when traffic control can be introduced. Normally traffic control are introduced when the visibility is low because of snow drifting, there is narrow road because of accumulated drifting snow or when the cross wind is so strong that there is a danger for vehicles to blow off the road. The combination of strong wind and slippery conditions is not mentioned in the national guidelines.

All roads with convoy driving have their own instructions and there are a maximum number of vehicles and persons that can be in a convoy. The responsible snow-clearing crew have the opportunity to exclude vehicles that are not suitable for driving over the mountain pass. The convoy should always have an escort car (usually a snow plough) in front and also an escort car at the end. The speed should not be over 40 km/h. Before the convoy starts the snow-clearing crew should know the number of vehicles in the convoy, and they have to check the number again when the convoy is guided over the mountain.

Another measure when the conditions on the mountain are difficult is reduced speed limits. We know that truck, caravans, buses and especially double decker's are more vulnerable for crosswinds than passenger cars. Today there are not any variable signs for the speed limit on this section.

Observed values			Limit value for closure[1]	
Quantity	**Value**	**Unity**		
Measured visibility (minimum)	50	m	min	20
Measured average wind speed (10 min)	20,0	m/s	max	24,5
Measured friction (minimum)	0,19	1	min	0,14
Snow conditions[(2)]	Ingen	-	-	-

(1): Limit value for closure, meaning that closing is introduced based on one value and not a combination of several.

(2): Snow condition are not a direct parameter in this calculation model.

Estimated speedlimit				
Measured values	**Vehicle type**	**Speed limit**		**Traffic**
Visibility and friction	All	24	km/h	Open
Wind and friction	passanger car	na	km/h	Open
Wind and friction	Bus	30	km/h	Open
Wind and friction	Coach	20	km/h	Convoy driving
Road status		**20**	km/h	**Closed**

Figure 7 - Example of results. The application say closed road with these parameters.

In Figure 7 it is an example with strong wind, low friction and bad visibility. The application suggests closing of the road under such conditions.

Table 1 show all closing and convoy driving for the winter season 2011/2012. The road was closed in 6 periods, with a total closure of 86 hours and 35 minutes. This is a bit more

than normal during a winter. There were two occurrences with convoy driving, a total of 14 hours and 35 minutes.

Nr	Start	End	Closure time [h]	Convoy time [h]	Reason
1	01.12.2011 18:30	02.12.2011 00:00	05:30		Wind/friction
2	25.12.2011 20:00	26.12.2011 03:00	07:00		Wind/friction
3	26.12.2011 18:15	26.12.2011 23:00	04:45		Wind/friction
4	12.01.2012 13:55	13.01.2012 22:15	08:20		Snowstorm
5	25.01.2012 23.05	26.01.2012 08:35	09:30		Snowstorm
	26.01.2012 08:35	26.01.2012 16:05		07:30	Snowstorm/wind/friction
	26.01.2012 16:05	27.01.2012 14:25	22:20		Snowstorm/wind/friction
6	14.02.2012 15:50	14.02.2012 21:00	05:10		Snowstorm
	14.02.2012 21:00	15.02.2012 04:05		07:05	Snowstorm
		SUM	**86:35**	**14:35**	

Table 1 - Periods with closing and convoy driving the winter season 2011/2012.

Figure 8 shows the weather data from one snowstorm which led to a closing of the road this winter season. The reason for closing was strong crosswind (over 20 m/sec, values over 10 min average), and the friction was also low with ice- and snow covered road.

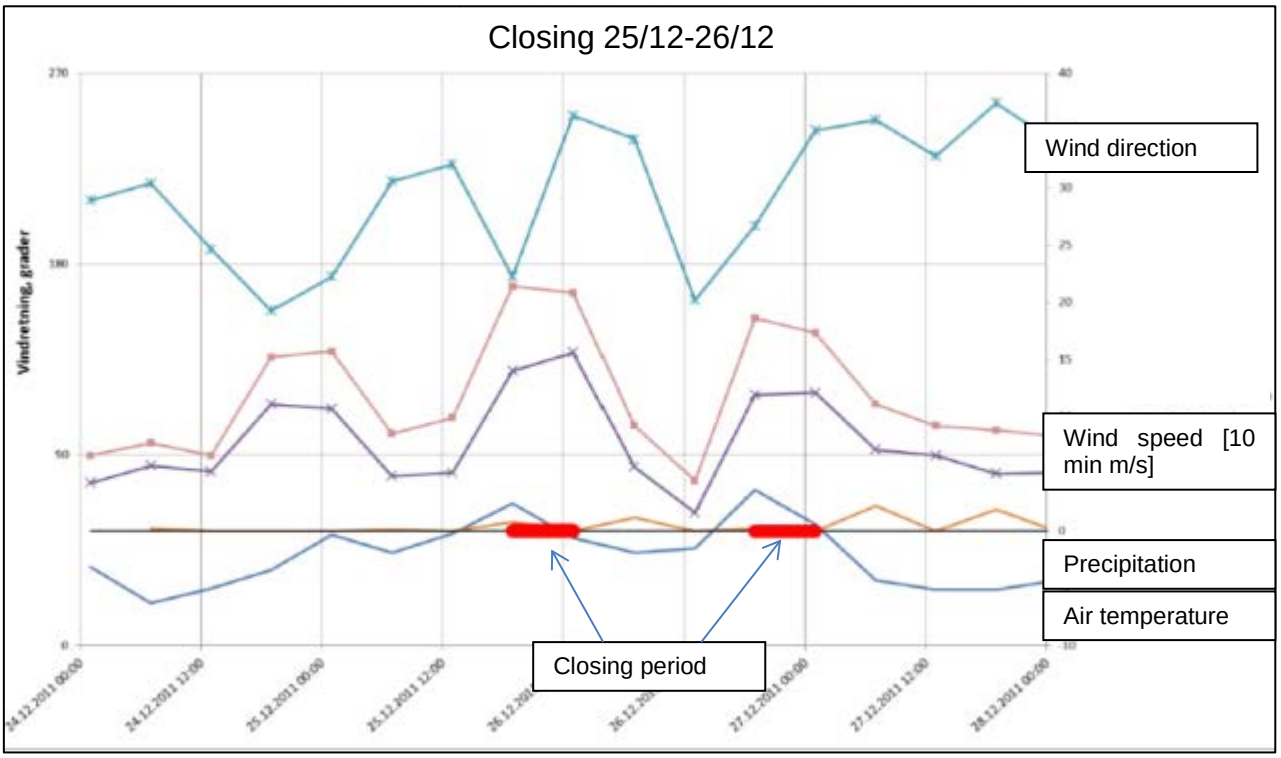

Figure 8 - Weather data from Fokstugu weather station during a storm.

4 DISCUSSION / FURTHER WORK

The variable signposts situated on each side of the mountain pass, state the wind strength in meter per second. Not all road users are familiar with the wind scale and know what 20 m/s means. Maybe the sign should have said something like: Very strong wind instead?

Today the contractor and the client decide if the road should be open or not. In the future it can be a possibility to have an automatic closing of the road based on data from the

weather station. There are gates on both side of the mountain which today is controlled by the contractor and road transport informatics. Automatic closing like they do in many tunnels will be possible, but then we have to know the number of vehicles between the gates.

REFERENCES

1. The Accident Investigation Board Norway (2009). Report of an accident with a coach on the E6 highway on Dovrefjell 24th of November 2006. (Only in Norwegian, with a English summary)