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XIII INTERNATIONAL WINTER ROAD CONGRESS

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WORLD ROAD ASSOCIATION
MONDIALE DE LA ROUTE
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SUSTAINABLE WINTER SERVICE FOR ROAD USERS

Side Friction as a Parameter to optimize Winter Operations

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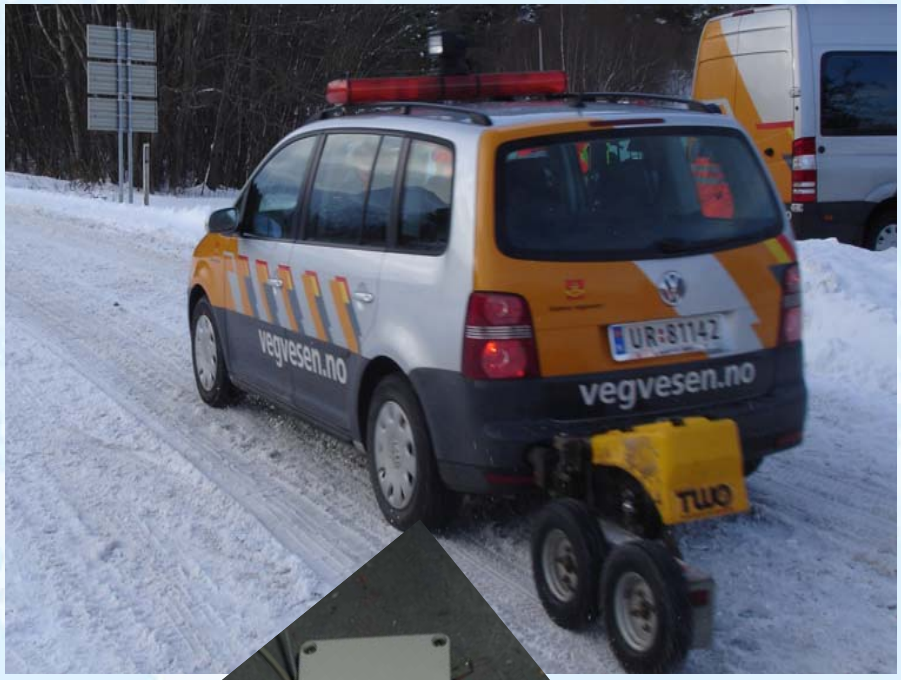
Background

- Challenge from a traffic safety point of view is to keep the risk for skidding below a certain threshold value under varying driving conditions

- The side friction factor at which skidding can happen depends on several factors, among which the most important are:
  - the speed of the vehicle
  - the type and conditions of the tyres
  - the horizontal curvature
  - the type and conditions of the roadway surface

TWO measuring device

- A new sensor has been developed combining both gyro and accelerometer
- The sensor is placed horizontally in the measuring vehicle and registers both side forces on the vehicle and the angular deflection
- Knowing the speed of the vehicle, the radius can be derived from these data and this is bases for calculation of what is denoted “critical speed”

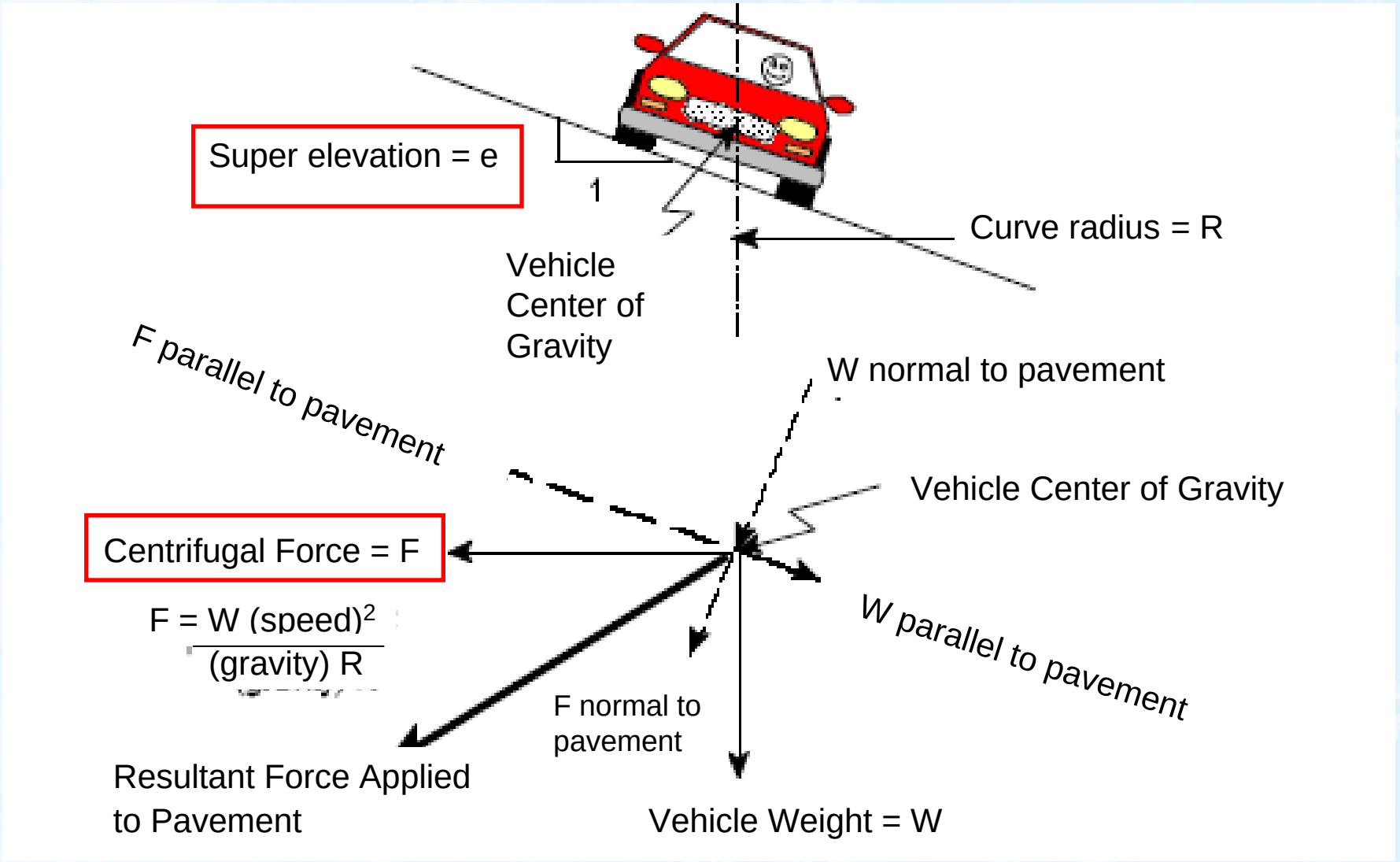


Objective

Part of the project ”R&D Indre Romsdal”

- The new measuring principle will add important information about the available road grip
- At locations where the critical speed is low when driving on winter conditions, this can be compensated by tougher demand for measures to be carried out and reinforced operational effort
- Another option will be to give information to the drivers on where and when they should be especially aware of a low safety margin when they exceed a certain speed

Friction theory



Friction theory

The remaining portion of the lateral force may act one of three ways depending on the banking and speed of the vehicle:

- If the speed is balanced for the elevation, the lateral force acting outward on the vehicle will be countered by the forces pushing the vehicle down the slope of the banking
- If the vehicle is travelling faster than the equilibrium speed, the resultant lateral force acts outward on the vehicle. At excessive speeds, the vehicle will skid or rolls off the road
- If the speed is lower than the equilibrium speed, the vehicle are forced inward. Icy conditions can cause the vehicle to slide down the banking, particularly when the tires are spinning to accelerate in stop and go traffic.

Friction factor

The simplest method for determining the friction number is to measure the braking distance to full stop for a vehicle with locked wheels during braking.

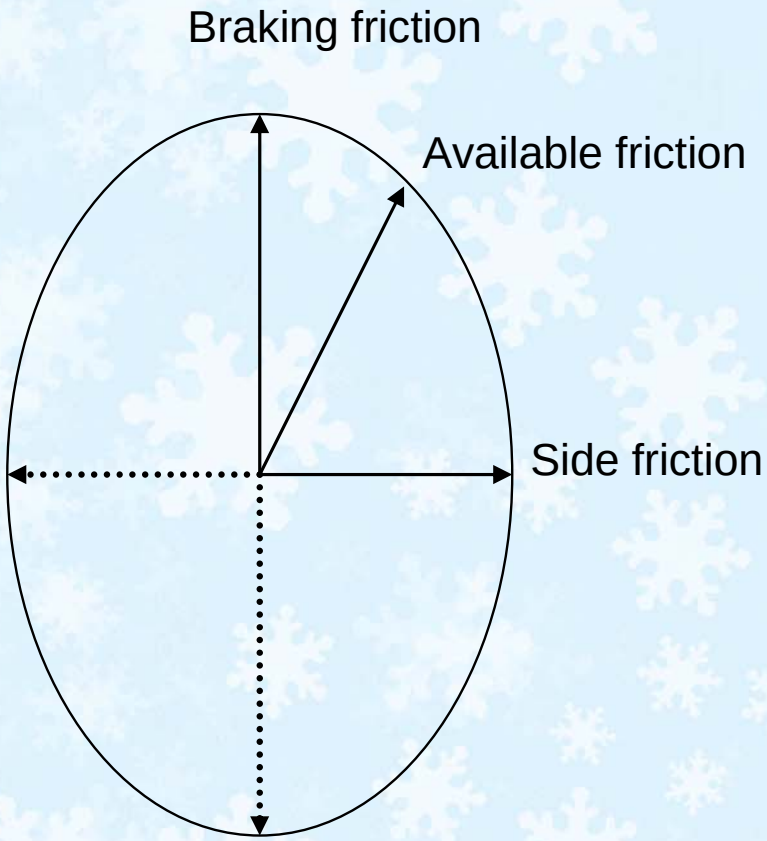
The coefficient of friction is determined from the equation:

$$\mu = \frac{v^2}{2 \times 9.81 \times d}$$

where v is the vehicle brake application speed, g is the acceleration of gravity, and d is the stopping distance.

Friction factor

It has to be taken into account that the available friction in curves has to be reduced to compensate for the fact that some of the road grip is used to counteract the side forces. This can be illustrated as follows:



Friction figure and curve speed

There is the following physical connection between utilized friction and curve speed:

$$v^2 = R \times \mu \times 9.81 \times 3.6^2$$

Where V is speed in km/h, R is curve radius and . is the friction figure. In the table below is shown the connection between V and . for R = 100 metres.

Friction figure	0,05	0,10	0,125	0,15	0,175	0,20	0,225	0,25	0,30
Maxiumum speed km/h	25,2	35,7	39,9	43,7	47,2	50,4	53,5	56,4	61,8

Calculation of critical speed

In the TWO program the critical speed is calculated in two separate ways. This results in different set of values and the lowest speed is the valid speed to determine the critical speed at any time.

The following formula is used to convert friction and braking length to critical speed:

$$v = \sqrt{254.3 \times \mu \times Lb}$$

Where =friction and Lb=Braking length (m)

In the TWO program is measured while Lb can be chosen by the user.

Calculation of critical speed

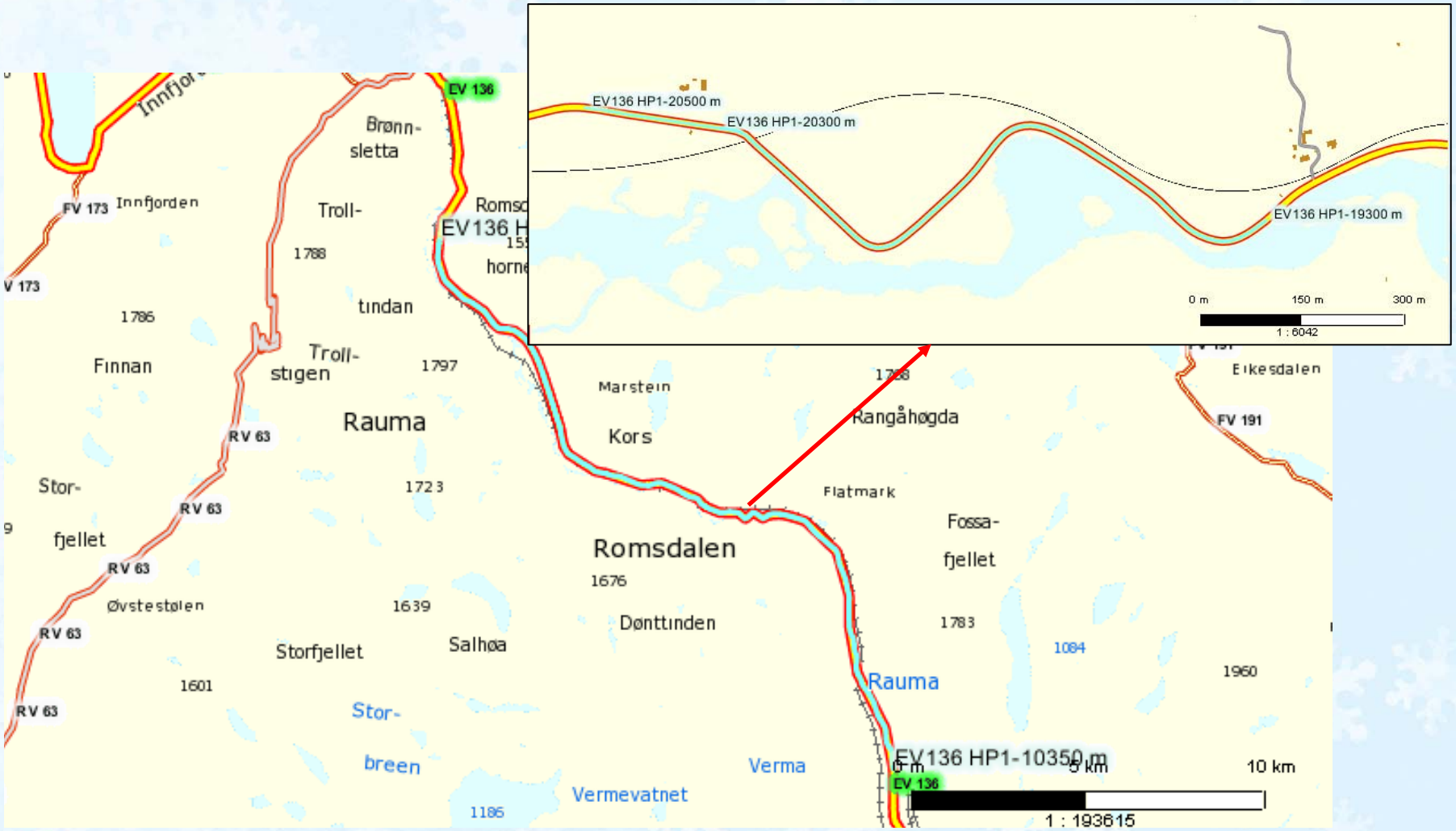
Converting of friction and curve radius to speed v [km/h]:

$$v = 3.6 \times \sqrt{9.81 \times \mu \times r}$$

Where r = curve radius calculated from measured acceleration (centrifugal force) and the speed of the vehicle:

$$r = \frac{\left(\frac{v}{3.6}\right)^2}{a}$$

Examples of measuring results



Examples of measuring results

Rapporter

Tillegg Rapporter Graf Bilde

Rapport | Data filtrering | Rapportoppsett

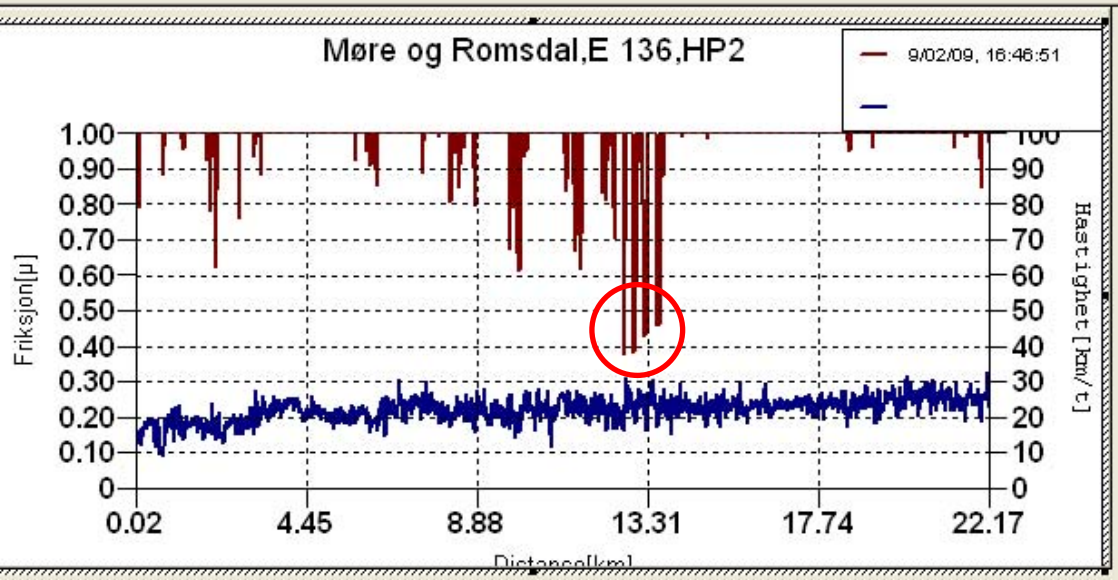
Oppdater graf

Sort on date | Sort on description

Beskrivelse	Dato	Tid	Område	Veg	HP	Km	Felt	Vannfilm
DS 02 Rise Bru - Aaheim	2009-02-09	19:11	Oppland	E 136	2	10.338	2	0.0
DS 01 Dombås - Rise Bru	2009-02-09	18:29	Oppland	E 136	1	0.119	2	0.0
DS 01 Dombås - Rise Bru	2009-02-09	18:03	Oppland	E 136	2	10.354	1	0.0
DS 02 Rise Bru - Aaheim	2009-02-09	17:47	Oppland	E 136	2	26.856	1	0.0
DS 03 Aaheim - Brøstvegen	2009-02-09	17:30	Oppland	E 136	3	13.545	1	0.0
DS 04 Brøstvegen - Sæterbø	2009-02-09	17:18	Møre og Romsdal	E 136	1	10.449	1	0.0
DS 05 Sæterbø - Trollveggen	2009-02-09	16:46	Møre og Romsdal	E 136	2	3.022	1	0.0
DS 06 Trollveggen - Innfjordstunellen	2009-02-09	16:33	Møre og Romsdal	E 136	3	6.224	1	0.0

19.2409992

Bildevisning



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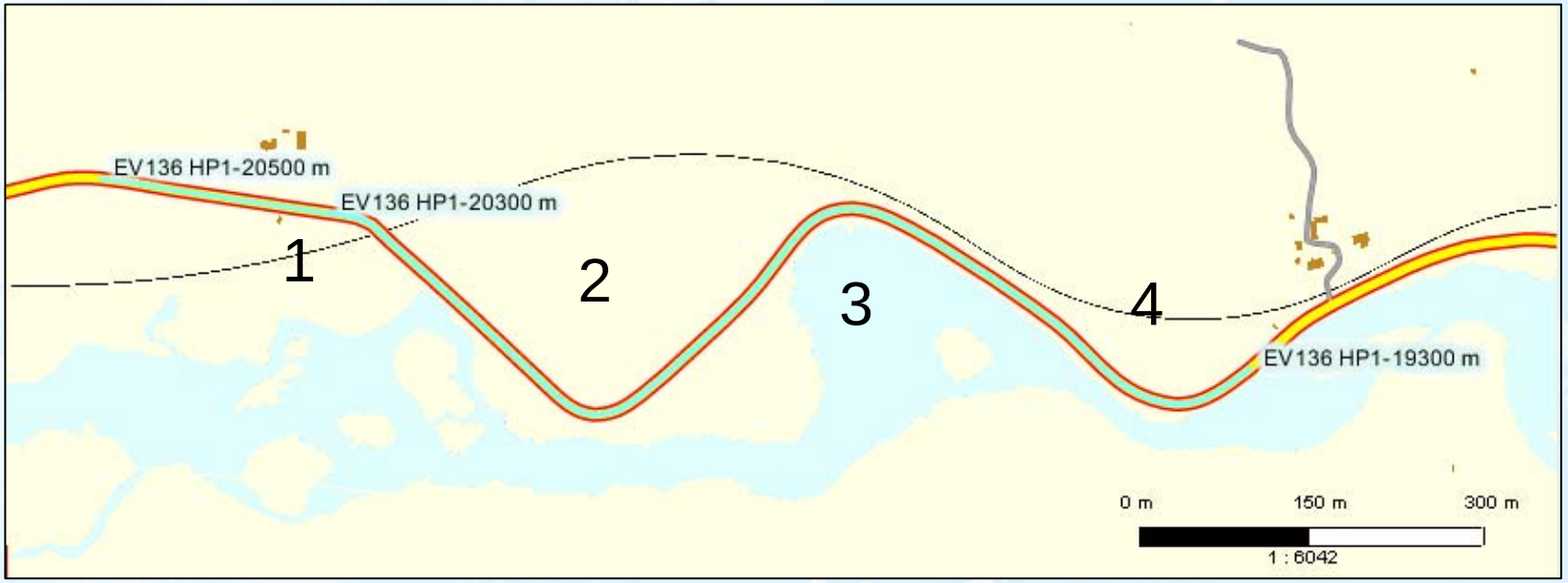
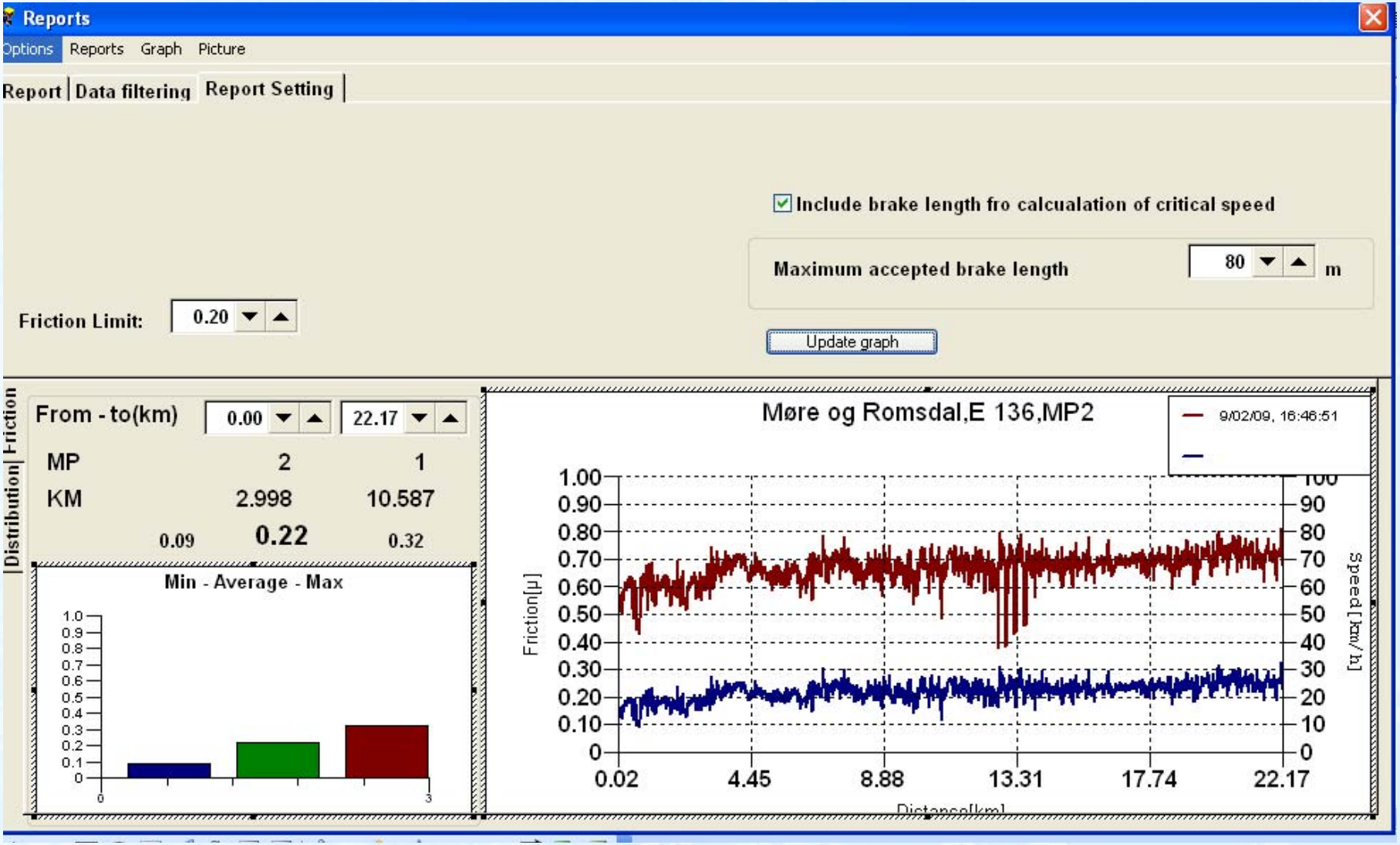
Examples of measuring results

Curve	Distance	Radius according to National road data bank	Calculated radius (m)	Coefficient of friction (km/)	Critical speed
1	12.68	96	57	0.19	38
2	12.94	46	51	0.22	38
3	13.23	69	74	0.21	43
4	13.60	66	80	0.21	46



Examples of measuring results



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Optimizing winter operations

Information about how the curvature influence on the road grip and calculation of critical speed in curves will have several areas of application:

- More focus in the driver education of how curvature influence on the driving task
- Information to the road users about the actual road grip
- Friction requirements adjusted for the side friction factor, i.e. the variation in actual road grip can be reflected in the winter standard requirements
- Support to the contractors in their daily operations

Optimizing winter operations

Other aspects:

- More focus on side friction can rise the general awareness of the risk for skidding and thereby result in safer driving in the winter time

- The first step will be to concentrate on how the calculation of critical speed can be used to optimize winter operations

Optimizing winter operations

The main idea is that the driving condition with regards to level of safety should be predictable:

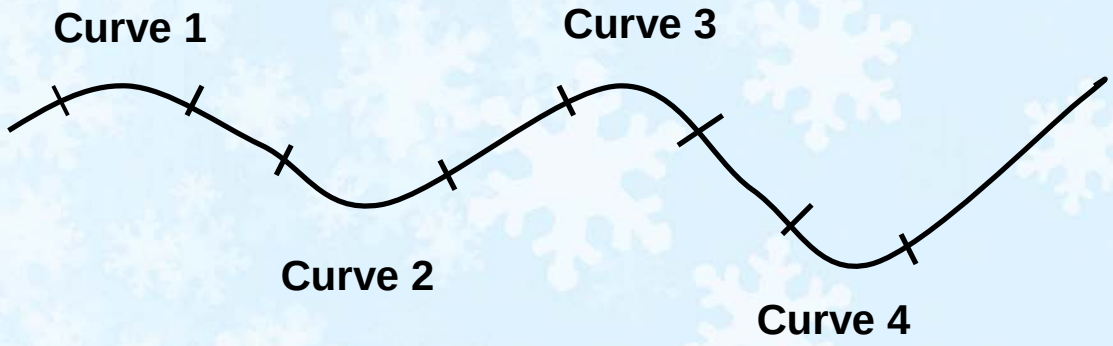
- To compensate for the influence of side forces, the friction level should be higher in curves than on straight sections even if the friction measured by the friction trailer is the same

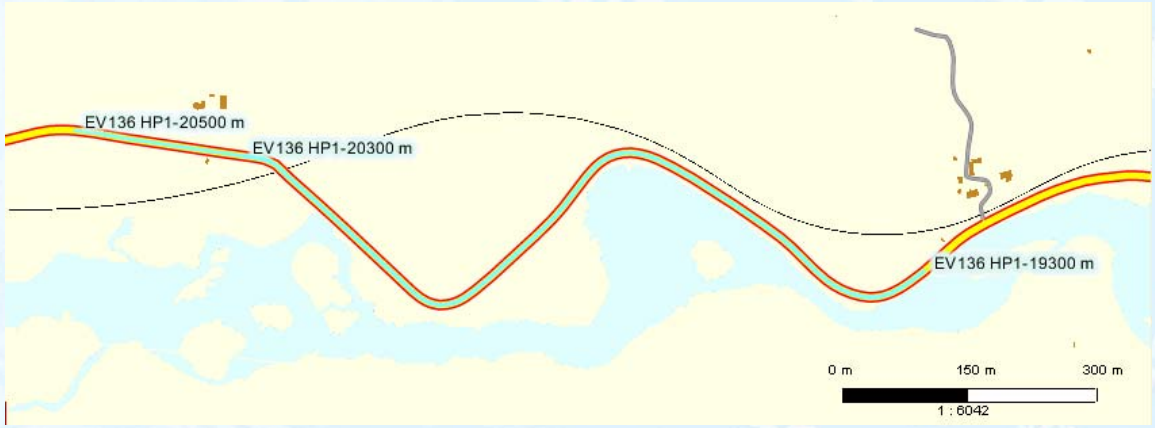
- This will result in a more flexible way of doing the winter operations and can also be a guideline to select road segments where the maintenance actions should be reinforced to keep a stable safety margin throughout a route

- One way of doing this and to have “fresh” data is to mount a friction device on the truck. This will also in general help the contractors to do their actions more correctly according to the friction requirements

Optimizing winter operations

There can be calculated a necessary level of safety in each curve based on radius, friction and super elevation:





Optimizing winter operations

- If one assumes that the level of safety is set 10 km/h above the critical speed, this will give the need for friction improvement as shown below:

Curve	Distance	Calculated radius	Coefficient of friction	Critical speed (km/h)	Safety level (km/h)	Needed friction level
1	12.68	57	0.19	38	48	0.33
2	12.94	51	0.22	38	48	0.36
3	13.23	74	0.21	43	53	0.30
4	13.60	80	0.21	46	56	0.31

- The need for friction improvement will vary with the geometry and a friction measure raising the friction up to 0.30 will not be satisfactory in the sharpest curves in the example
- If possible there should be put extra effort in those curves for additional friction improvement, or other actions like information to the drivers should be considered

Further studies

- So far the project has concentrated on the development of the friction measuring device with the basic functions in the new sensor
- The next steps will be to develop the measuring system further and to come up with recommendations for how information about side friction can be utilized in the winter operations
- Regarding the measuring system there will be made more comprehensive verification of the accuracy of the sensor readings
- There will be done controlled field tests this winter to compare calculated critical speed with actual skidding speed

Thank you for your attention

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