



Reducing the risk from natural hazards on critical infrastructure in Norway

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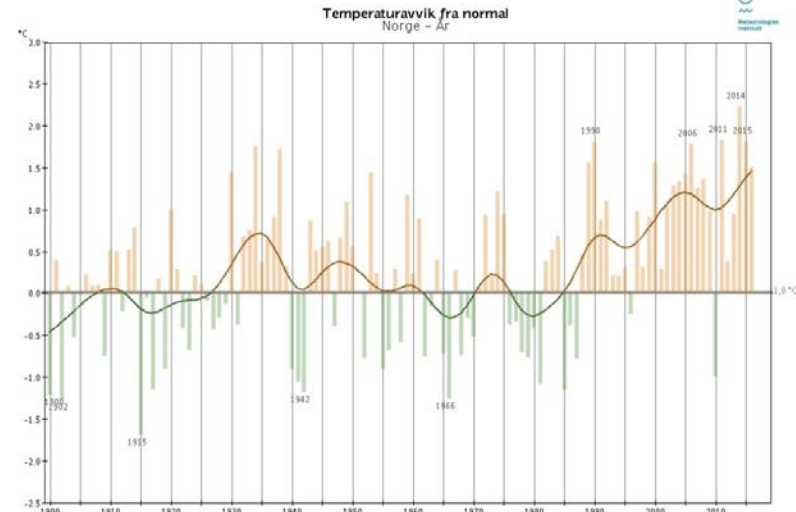
Havana, Cuba, 6.July, 2017

Natural hazards in Norway



- Debris slides, debris flows, and landslides in sensitive clays ('Quick clay')
- Snow avalanches – Dry, wet and slushflows
- Rock slides and rock fall
- Tsunamis triggered by landslides
- Flooding, Storms and storm surge,
- Extreme temperatures

Most are climate related!



Water initiated hazards to the infrastructure



Very often 'assisted' by human activity

Quick clay: A major hazard and expense to all infrastructure



Snow avalanches – major problem for roads.....

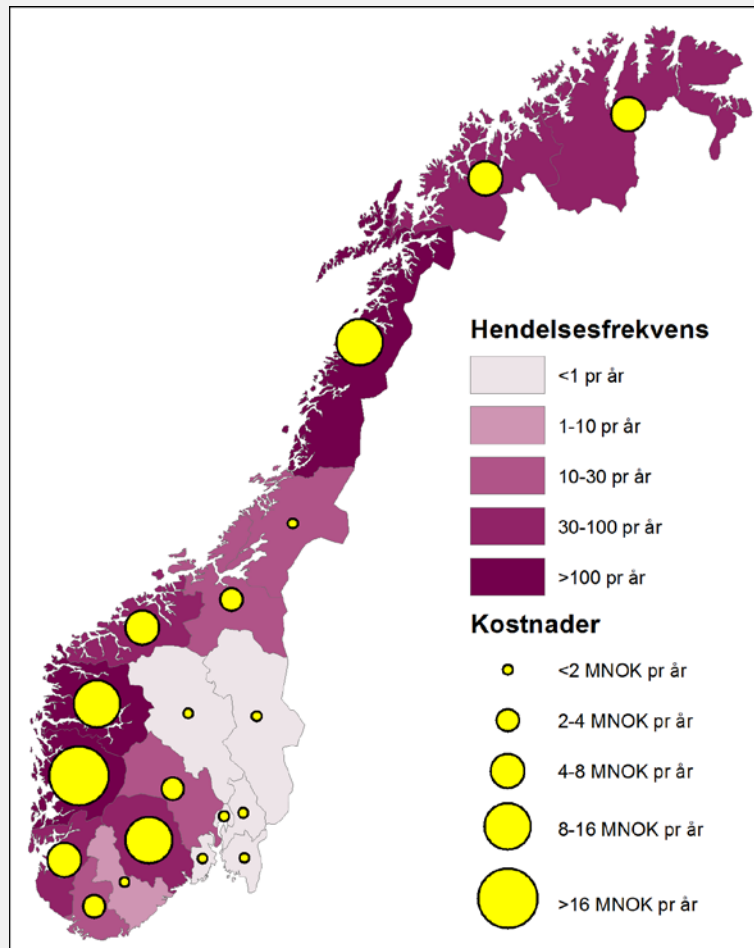


as well as for railroads



Annual road closures caused by natural hazards, Norway

- All types of landslides and snow avalanches for the entire road network.
- Based on registered events in the period 2000 – 2010
- Largest cost related to delays and detours
- Most likely underestimated costs



<http://www.ngi.no/en/prosjektnett/infrarisk>

Mitigation to protect important infrastructure.



High voltage pylons and snow avalanches

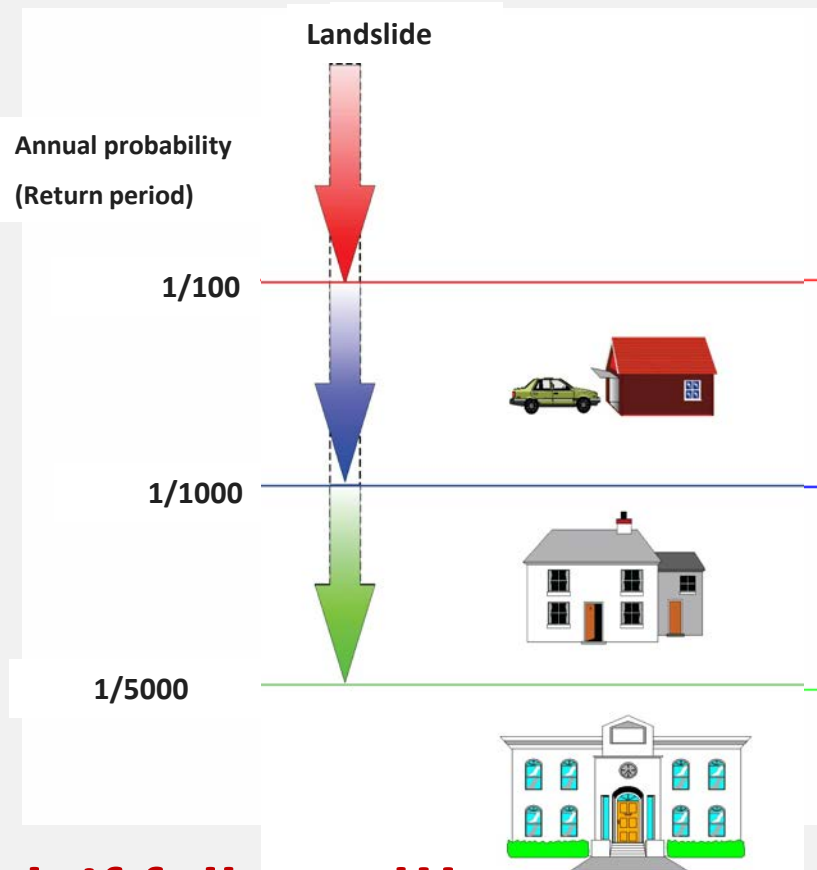


The Norwegian Planning and Building Act

- Definition of acceptable hazard for different types of buildings
- Based on annual probability (return period)
- Only for new buildings.

Equivalent for flood hazard

Safety class, flood	Consequence	Largest annual probability
F1	Small	1/20
F2	Medium	1/200
F3	Large	1/1000



NGI The PBA is a very good tool, if followed!!

Preparedness = Adaptation = Risk reduction

$$\text{Risk} = \text{Hazard (probability)} \times \text{consequences}$$

(or Risk = $H \cdot V \cdot (E) \cdot U$)

↗ Mapping

- National, Regional or detailed mapping of hazard and risk

↗ Awareness

- Knowledge and capacity at all levels
- Evacuation and rescue plans

↗ Measures

- Physical mitigation measures (barriers, nets, etc..)
- Non-physical measures; Monitoring and early warning, road closures, reduced speed on railway, etc.
- **Proper land use planning and safe location of critical infrastructure.**



Railroads (and other linear infrastructure)

➤ Railways of Norway

- 4219 km
- Norwegian National Railroad Administration
- **Much of the railroad network is 50-100years old!**

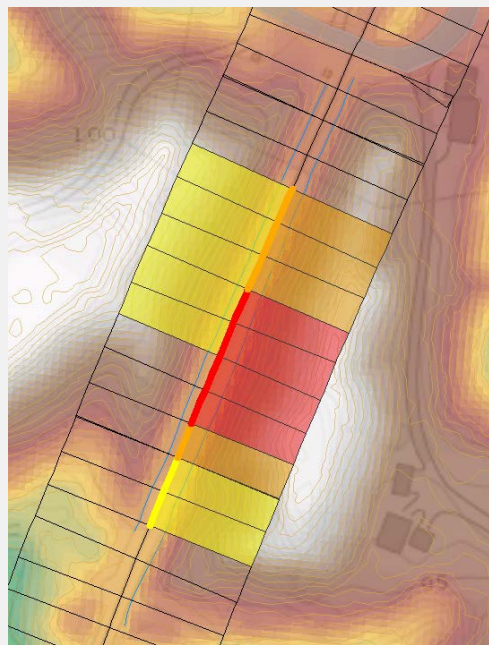
➤ Challenging environment

- Flooding
- Landslide
- Avalanche
- Rock fall

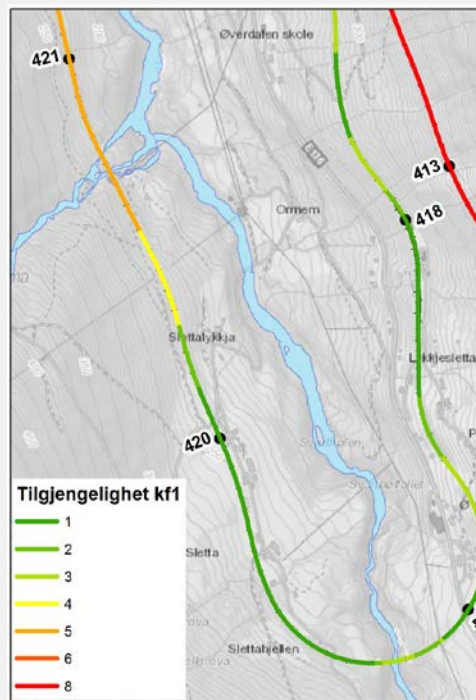


Risk mapping along the railroad; 'the NGI method'

Combines a series of parameters for hazard and consequence and provides maps for each km. The GIS analyses is followed up by field work at the hotspots.

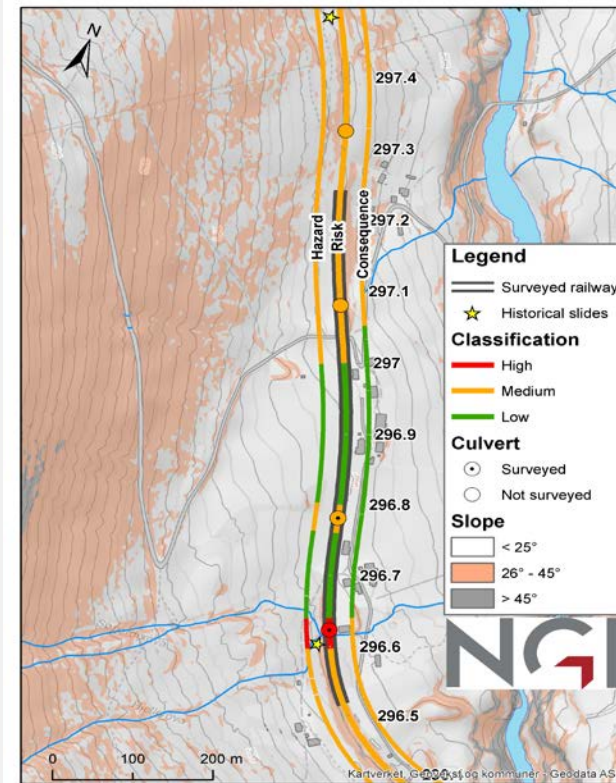


Landslide hazard



Accessibility (vulnerability)

Result, risk assessment



Center for Research Based Innovation (SFI): 'KLIMA2050'



- Risk reduction through climate adaptation of buildings and infrastructure
- 20 Partners from research, public sector, and industry.
- 8 years; 2015-2023
- Total budget NOK 221 mill. (24 mill. EURO)

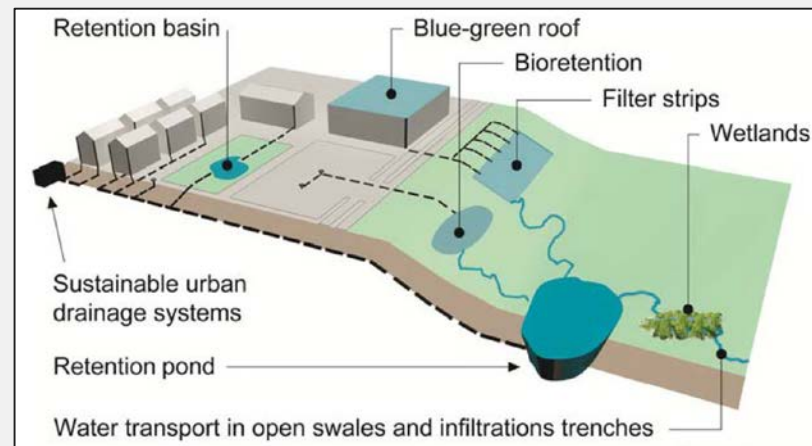
WP 1: Climate adaptation of buildings

WP2: Urban flooding

WP3: Water triggered landslides(NGI)

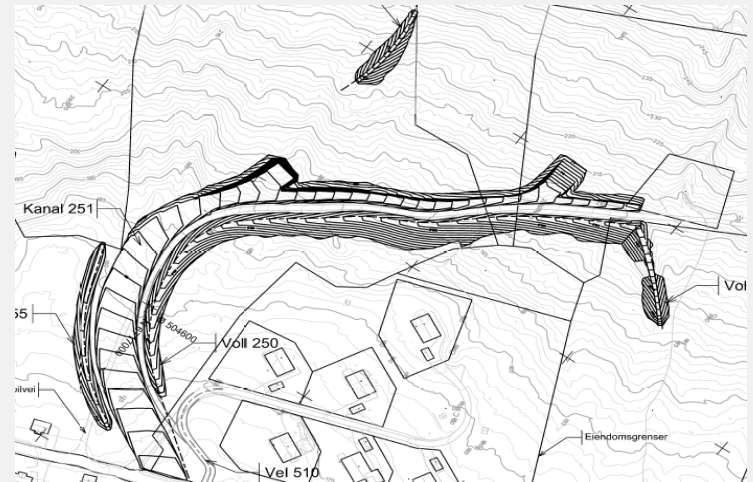
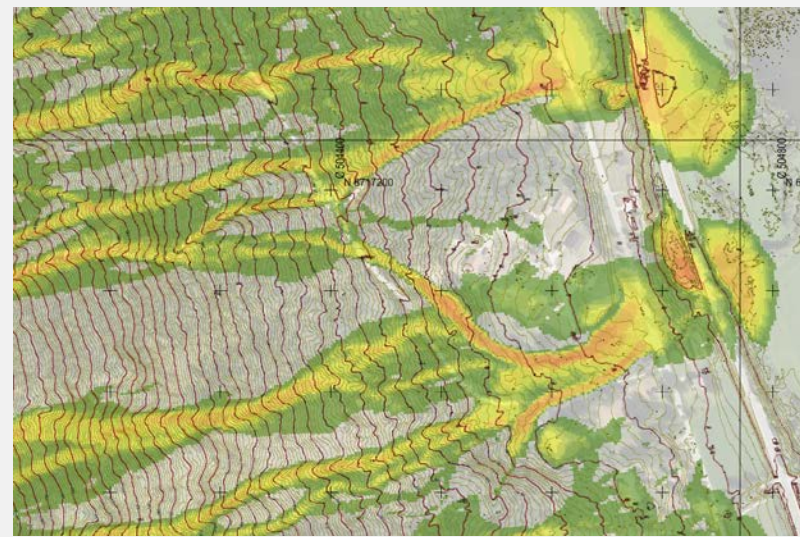
WP4: Management and decision processes

NGI www.klima2050.no



WP3 Sub-work packages

- WP3.1 – Development of analytical and numerical codes
- WP3.2 - Environmentally sustainable methods for improving drainage and stabilizing soil and rock slopes
- WP3.3 - Protection of critical infrastructure (CI) from landslides
- WP3.4 - Early warning systems (EWS)
- WP3.5 – Management of landslide risk



Mitigation measures – New, smart(er) solutions needed

- Norway is a steep and landslide-prone country.
- New, innovative, solutions, which are more space –and cost effective, as well as environmentally friendly, are needed.



- Much focus on ‘green, nature based solutions’ in upcoming research!

Web based toolbox of mitigation measures

Example web page

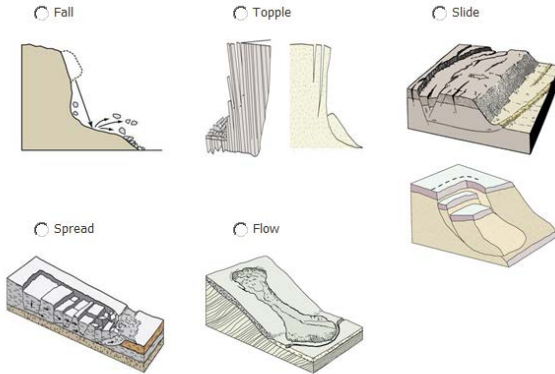
Previous Next New Open View Save Save As Delete Print



What type of slope is of concern?

- Rock slide
- Landslide
- Debris flow

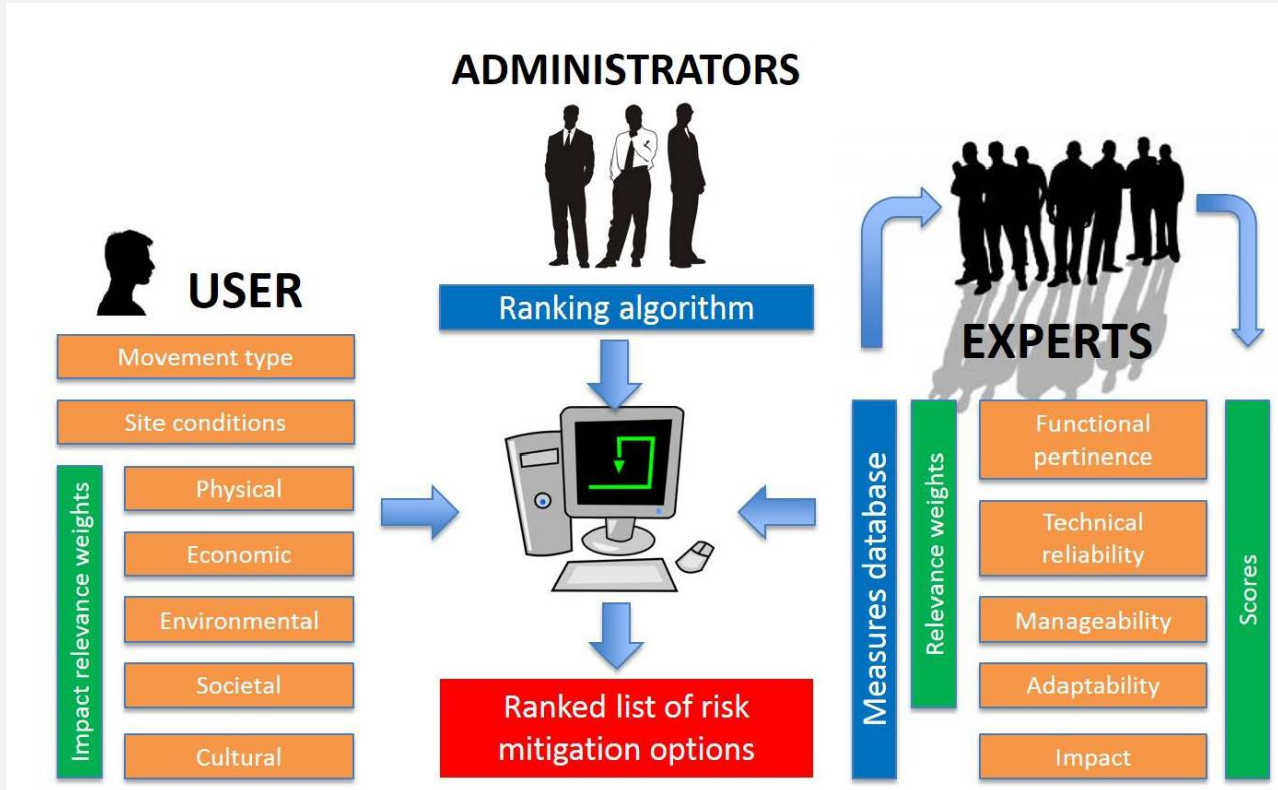
What type of movement do you expect?



Structural measures included

- ↗ Surface erosion and surface erosion control
- ↗ Modifying slope geometry
- ↗ Modifying surface drainage
- ↗ Modifying groundwater regime – deep drainage
- ↗ Modifying mechanical characteristics of unstable mass
- ↗ Transfer of loads to more competent strata
- ↗ Retaining structures
- ↗ Deviating the path of landslide debris
- ↗ Dissipating the energy of debris flows
- ↗ Arresting/containing landslide debris or rockfall

Mitigation toolbox – Operational flowchart



Some take-home messages

- ↗ Norway is a steep country, with ‘lots of weather’, and natural hazards will always be present.
- ↗ Climate change leads to more frequent landslides and floods, which often lead to disruption of the transport and electricity infrastructure
- ↗ Risk can be reduced, but not eliminated!
- ↗ Best adaptation measure is proper land use planning and building techniques, with ‘climate effect added’ on most dimensions.
- ↗ Research is crucial, with active stakeholder involvement as a very important factor.
- ↗ The ‘mitigation business’ faces prosperous times!



Muchas Gracias

