Analyses of risk from natural hazards for early planning of new highways in Norway

Background

Norway’s new state-owned road company ‘Nye Veier AS’ wanted to establish a method or a process for assessments of natural hazards in the early planning phase of new road projects.

The aim of the assessments were

- Hazard identification; Identify critical areas with regards to natural hazards in the planning areas.
- Risk analyses: Analyse the risk, based on the hazard and the economic consequences of a closed road, combined with consequences for emergency operations.
- Risk management; Assess potential risk reducing measures

Analyses were carried out for a total of 700km new roads.
The roads

Located in many parts of Norway, and different climate zones.

Assessing the effects of climate change was part of the project.
Three project phases

1. Development of method
   - Simple analysis along corridors. I.e. within polygons along planned roads.
   - GIS analysis based on existing, publicly available data.
   - Establish a simple tool, which can be operated by the client, in their own premises

2. Detailing the method
   - Quantifying risk along a given road stretch:
     - Identify critical objects (e.g. bridges, tunnel entrances, etc.)
     - Assess consequences and risk
     - Assessing climate and climate change
     - Mitigation measures
     - Validate the method in the field; visit hazardous segments identified in the GIS analyses.

3. Carry out Risk and Vulnerability analyses for the entire 700km of planned roads
   - Results delivered in interactive map products
   - Support for decision-making with regards to final routing and need for mitigation.
The GIS analysis

Hazards to be assessed:
- Snow avalanches
- Debris slides / flows
- Rockfall
- Quick clay (very sensitive clays)
- Flooding
- Wind / snow drift
- (Storm surge)

To be analysed along corridors, to provide improved base for final routing and to assess the need for mitigation measures.

Data from publicly available sources, but optimized using different techniques, as most of the available susceptibility maps are very conservative. Used model tools for e.g. avalanches and rockfall.
The GIS-analysis, examples

**Snow avalanches**, data background:
- DEM
- Forest data, spatial resolution 25m
- Climate data
- Simulations in ‘NAKSIN’ (model tool developed at NGI)

**Rockfall**, data background:
- DEM
- Quaternary geology map, w/ landslide deposits
- Simulations with ‘RockyFor3D’ (© ecorisQ – www.ecorisq.org)
3 Hazard levels: Low, medium, high

Individual assessment for each hazard type

Ex. Rockfall (Rockyfor 3D):

<table>
<thead>
<tr>
<th>Haz. level</th>
<th>Definition</th>
</tr>
</thead>
</table>
| 3          | Reach Probability (RP) > 70  
or  
RP 40-70 and mapped landslide deposits  
or  
slope > 44° |
| 2          | RP 40-70  
or  
RP < 40 and mapped landslide deposits |
| 1          | RP < 40   |
| 0          | No RP     |

Ex. Debris flows:

<table>
<thead>
<tr>
<th>Haz. level</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Susceptibility zone and relevant historical event within 50m of the zone.</td>
</tr>
<tr>
<td>2</td>
<td>Susceptibility zone and susceptibility class 3 or 4</td>
</tr>
<tr>
<td>1</td>
<td>Susceptibility zone and susceptibility class 1 or 2</td>
</tr>
</tbody>
</table>
### Probability / return period

<table>
<thead>
<tr>
<th>Probability class</th>
<th>Description of return period</th>
<th>Nominal probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>5: Very high</td>
<td>More often than every 4. yr</td>
<td>&gt;0.25/yr</td>
</tr>
<tr>
<td>4: High</td>
<td>Every 4. – 20. yr</td>
<td>0.25/yr – 0.05/yr</td>
</tr>
<tr>
<td>3: Moderate</td>
<td>Every 20. yr – 100. yr</td>
<td>0.05/yr – 0.01/yr</td>
</tr>
<tr>
<td>2: Low</td>
<td>Every 100. yr – 500. yr</td>
<td>0.01/yr – 0.002/yr</td>
</tr>
<tr>
<td>1: Very low</td>
<td>More seldom than every 500. yr</td>
<td>&lt;0.002/yr</td>
</tr>
</tbody>
</table>

*These follow Norwegian regulations and are modified for ‘per 1 km road’.*
Simplified field work with Excel based ‘pluck-lists’

<table>
<thead>
<tr>
<th>Closure (down) time</th>
<th>Recommended measure</th>
<th>Cost of measure (NOK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 days</td>
<td>Bolts/cleansing/nets</td>
<td>Low: &lt; 100,000</td>
</tr>
<tr>
<td>3-4 days</td>
<td>Rockfall fence</td>
<td>Medium: 100,000 - 1 million</td>
</tr>
<tr>
<td>5 days - 3 weeks</td>
<td>Channeling</td>
<td>High: &gt; 1 million</td>
</tr>
<tr>
<td>3 weeks - 3 months</td>
<td>Sediment nets</td>
<td></td>
</tr>
<tr>
<td>&gt; 3 months</td>
<td>Avalanche fences</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Erosion control measures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remove / add load</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enlarged ditch/Raised embankment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barrier</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stream control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Culvert / debris flow bridge</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bridge</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pipe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other measures</td>
<td></td>
</tr>
</tbody>
</table>

Probability, closure time, measures and costs are assessed in the field and controlled afterwards.
Assessing consequences

2 variables:
- Indirect Economic Consequences (IEC)
- Societal security / Emergency preparedness.

Closure time and detour possibilities are key elements for both

**IEC**
- Costs due to closed road.
- Function of closure time, traffic density and redundancy (detour options).

**Societal security**
- The possibility for key actors (police, fire brigades, etc.) to deliver their services.
- Affected by:
  - Redundancy (alternative routes)
  - Importance for critical infrastructure (hospitals, airport, defence, etc.)
  - Interconnection between population, critical infrastructure and geographical importance (local, regional, national).
Assessing consequences

- To the extent possible, differentiate per hazard type along the road.
- Use the most severe consequence class in the risk assessment

<table>
<thead>
<tr>
<th>Indirect Economic Consequence</th>
<th>Societal security</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 – Very high</td>
<td>Cost due to closed road &gt; 100 000 001 NOK</td>
</tr>
<tr>
<td>4 - High</td>
<td>Cost due to closed road 60 000 001-100 000 000 NOK</td>
</tr>
<tr>
<td>3 - Medium</td>
<td>Cost due to closed road 30 000 001-60 000 000 NOK</td>
</tr>
<tr>
<td>2 - Low</td>
<td>Cost due to closed road 8 000 001-30 000 000 NOK</td>
</tr>
<tr>
<td>1 - Very low</td>
<td>Cost due to closed road &lt; 8 000 000 NOK</td>
</tr>
</tbody>
</table>
Results: Risk & Vulnerability along the roads

E6 Kvænangsfjellet (northernmost Norway)
Example shows the crossing of a large river, with potential hazards from flooding (‘Flom’; green line) and wind w/ snowdrift (‘Vind/snødrift’; orange line). Since the wind hazard has the highest probability, it leads to the highest risk (medium) in this example (brown line).
By clicking one of the hazard lines, a ‘fact sheet’ with more information appears (next slide)
Fact sheet (one of 795)

- Contains detailed information about the site (sorry for the language!)
- The text explains the probability and the consequences
- Present-day risk is marked with a blue dot in the matrix in the lower right.
- Climate change (precipitation) is assessed, and affects the probability. Risk in year 2100 is marked with a red dot.
Some take-home messages

- The analyses are for the ‘early planning phase’ and are not very detailed.
  - They point out locations where more detailed investigations must be carried out for the detailed design.
  - They are important for planning of the final routing.
- Available national susceptibility maps are conservative, and routines for optimizing the hazard information had to be developed.
- A first assessment tool, to be used by the client in future projects had to be simple and available for ‘everyone’ in the organization.
- Both the first assessment tool (the GIS-tool) and the final deliverable (the interactive map with fact sheets) were developed in close cooperation with the client.
- The hazard and consequence assessments were discussed with stakeholders with local knowledge, such as staff from the client’s regional offices, and corrected if necessary.
- Both these deliverables are now installed at the client’s premises, and are being used.
- The client is very pleased with the deliverables, and the communication around the development has been very fruitful for both parties.
- The work has led to cost savings for the client of several hundred million NOKs.
Thank you