Landslide risk mapping
for the entire Swiss national road network

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Risk

Voluntary | Large self-control | Partial self-control | Non-voluntary

10^{-2} | 20 cigarettes/day | 10^{-3} | Driving a motorcycle | 10^{-4} | Car driving 10000 km highway | 10^{-5} | Mountain hiking | 10^{-6} | Building fire

Responsibility of collectivity

Acceptance area

Individual responsibility

Train passenger
## Studied natural hazards

<table>
<thead>
<tr>
<th>Main process type</th>
<th>Natural hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>Rockfall</td>
</tr>
<tr>
<td></td>
<td>Rock avalanche</td>
</tr>
<tr>
<td></td>
<td>Icefall</td>
</tr>
<tr>
<td>Snow avalanche</td>
<td>Flowing avalanche</td>
</tr>
<tr>
<td></td>
<td>Powder avalanche</td>
</tr>
<tr>
<td></td>
<td>Snow gliding</td>
</tr>
<tr>
<td>Flood / Debris flow</td>
<td>Flooding</td>
</tr>
<tr>
<td></td>
<td>Debris deposition</td>
</tr>
<tr>
<td></td>
<td>Bank erosion</td>
</tr>
<tr>
<td>Landslide</td>
<td>Spontaneous landslide</td>
</tr>
<tr>
<td></td>
<td>Permanent landslide</td>
</tr>
<tr>
<td></td>
<td>Shallow debris slide</td>
</tr>
<tr>
<td>Collapse</td>
<td>Dolines</td>
</tr>
</tbody>
</table>
Studied Landslide Types

- Shallow debris slide
- Spontaneous slide
- Permanent slide
Goal I: Past events database
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Goal II: existing protective measures
Goal III: Intensity maps (INT)

- Intensity: low, medium, high
- Deposit heights
- How often
- $P_{\text{Spatial Occurrence}}$
- Process specific attributes: e.g., Avalanche Pressure kN, Rockfall energy in kJ
Goal IV: Swiss-wide risk map
## INT Map – process intensity

<table>
<thead>
<tr>
<th>Process</th>
<th>Intensity:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Slide</td>
<td>$v &lt; 2 \text{ cm/yr}$</td>
</tr>
<tr>
<td>Rock fall</td>
<td>$E &lt; 30 \text{ kJ}$</td>
</tr>
<tr>
<td>Rock avalanche</td>
<td>-</td>
</tr>
<tr>
<td>Earth flow and Debris flow</td>
<td>$e &lt; 0.5 \text{ m}$</td>
</tr>
<tr>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

$v =$ mean annual velocity of slide  
$E =$ kinetic energy  
$e =$ thickness of the unstable layer  
$h =$ thickness of debris deposit
INT Map – How often

“Continuous” processes
- slides

Intensity
high
medium
low

“Spontaneous” processes

- rock avalanche

RED: high hazard

- rock fall
- slides and flows

BLUE: moderate hazard

YELLOW: low hazard

Probability
high
medium
low

30
300 years
100
## Occurrence Probability

<table>
<thead>
<tr>
<th>Return period</th>
<th>Occurrence probability</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 10 years (x)</td>
<td>$= 1/x - 1/10$</td>
<td>Value x based on past events</td>
</tr>
<tr>
<td>&gt; 10 - 30 years</td>
<td>$= 1/10 - 1/30 = 0.067$</td>
<td></td>
</tr>
<tr>
<td>&gt; 30 - 100 years</td>
<td>$= 1/30 - 1/100 = 0.023$</td>
<td></td>
</tr>
<tr>
<td>&gt; 100 - 300 years</td>
<td>$= 1/100 - 1/300 = 0.0067$</td>
<td></td>
</tr>
<tr>
<td>&gt; 300 years</td>
<td>$= 1/300 - 1/1000 = 0.0023$</td>
<td>Only for flooding</td>
</tr>
</tbody>
</table>
INT Map - $P_{\text{Spatial Occurrence}}$
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$35 \text{ m} \quad 100 \text{ m}$

$P_{\text{Spatial Occurrence}} = 0.35$
Case study
Case study
Perimeter Risk Analysis

Risk calculation

Only intensity
Risk analysis – damage types

• Damage types:
  • (Direct impact, Collision, Deposits on road, Closure after event, Preventive closure)

• Mean traffic parameters:
  • Mean Daily Traffic (MDT)
  • Max. Speed and Traffic jam information
  • Costs of infrastructure (bridges), ….

• Human life = 3.10^6 Euro / 5.10^6 CHF
Risk calculation

\[ R = (Df \times Dam) + (Dftj \times Damtj) = 3.58E-4 \quad (= 1788 \text{ CHF/yr}) \]

where

\[ Df = f_j \times (1 - psp) \times (1 - ptj) = 0.006 \]

\[ Dftj = f_j \times (1 - psp) \times ptj = 1.6E-6 \]

\[ psp = 0.9 \]

\[ Dam = Pso \times Nc \times Or \times \lambda = 0.057 \quad (Or = 1.74) \]

\[ Damtj = Pso \times Nptj \times \lambda = 7.3 \]

\[ Nctj = 140 \times nDL \times Sw / 1000 = 28 \]

\[ ptj = ptj/yr \times ptj/day = 0.00026 \]
Swiss-wide risk map
Implications - Discussion
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