4th International Probabilistic Symposium 2006

Source: Kt. St. Gallen, Switzerland

Integrating Bayesian Networks into a GIS for avalanche risk assessment

Matthias Schubert

ETH Zürich, Institute for Structural Engineering, Group Risk & Safety

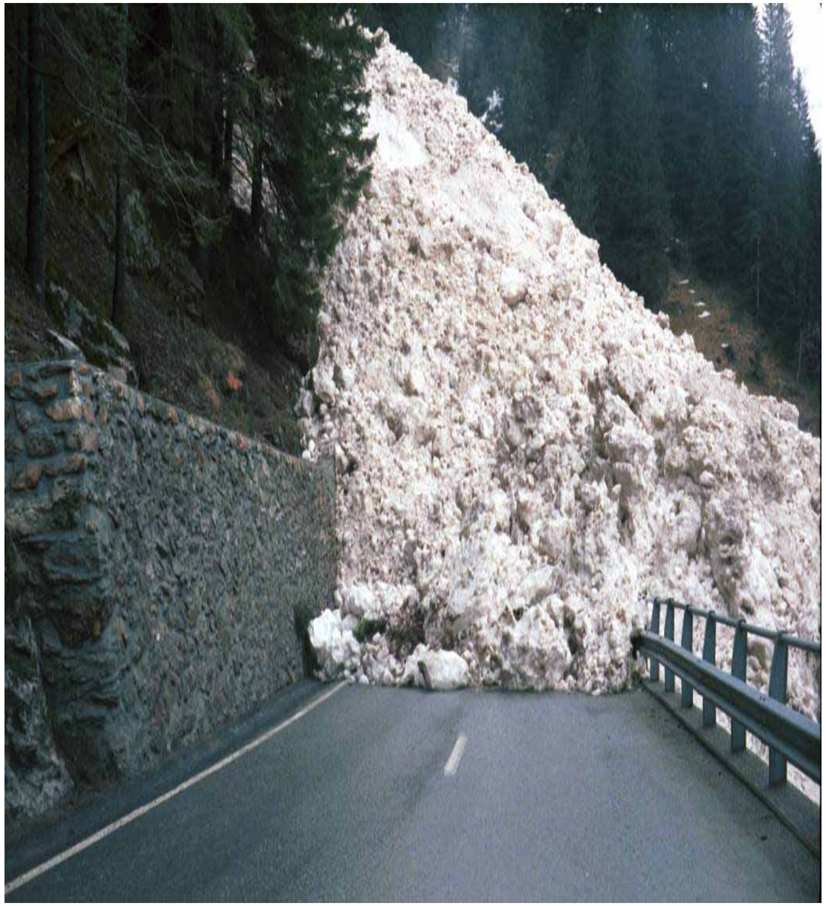
Adrienne Grêt-Regamey

WSL, Swiss Federal Institute for Snow and Avalanche Research, Division Alpine Environment

Daniel Straub

UC Berkeley, Civil and Environmental Engineering Department

Introduction & Motivation



Source: Kt. St. Graubünden, Switzerland

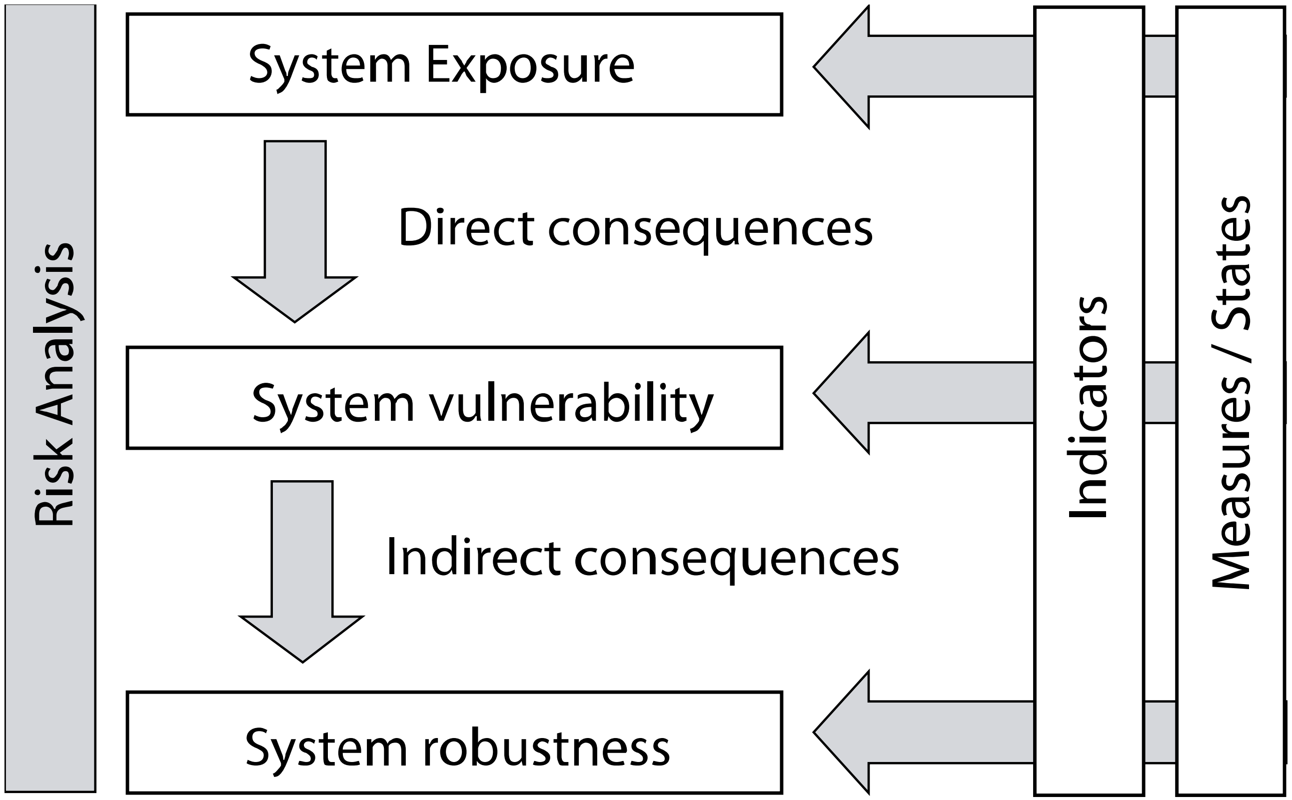
- Avalanches cause each year significant monetary losses in mountainous regions
- Society spends high amounts of resources for mitigation measures
- In regard to societal decision-making, tools for a consistent risk assessment are crucial

Introduction & Motivation

- **Tools should**
  - be based on decision theory to ensure consistency
  - include physical models
  - fully account for past observations of events and expert knowledge
  - must be spatially explicit

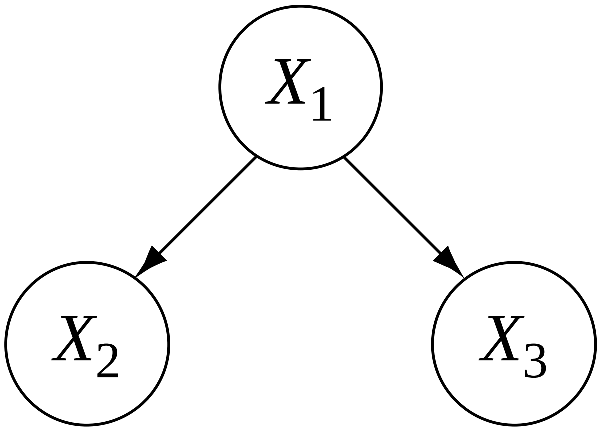
- **Tools are required**
  - for hazard mapping and zoning (land-use planning)
  - for optimization of other mitigation measures
  - to facilitate and support risk communication

Risk analysis framework



Bayesian Networks and Influence Diagrams

- Probabilistic models based on directed acyclic graphs
- Represent the joint probability distribution of a set of variables
- Efficient due to the factoring of the joint probability distribution into conditional distributions given the parents



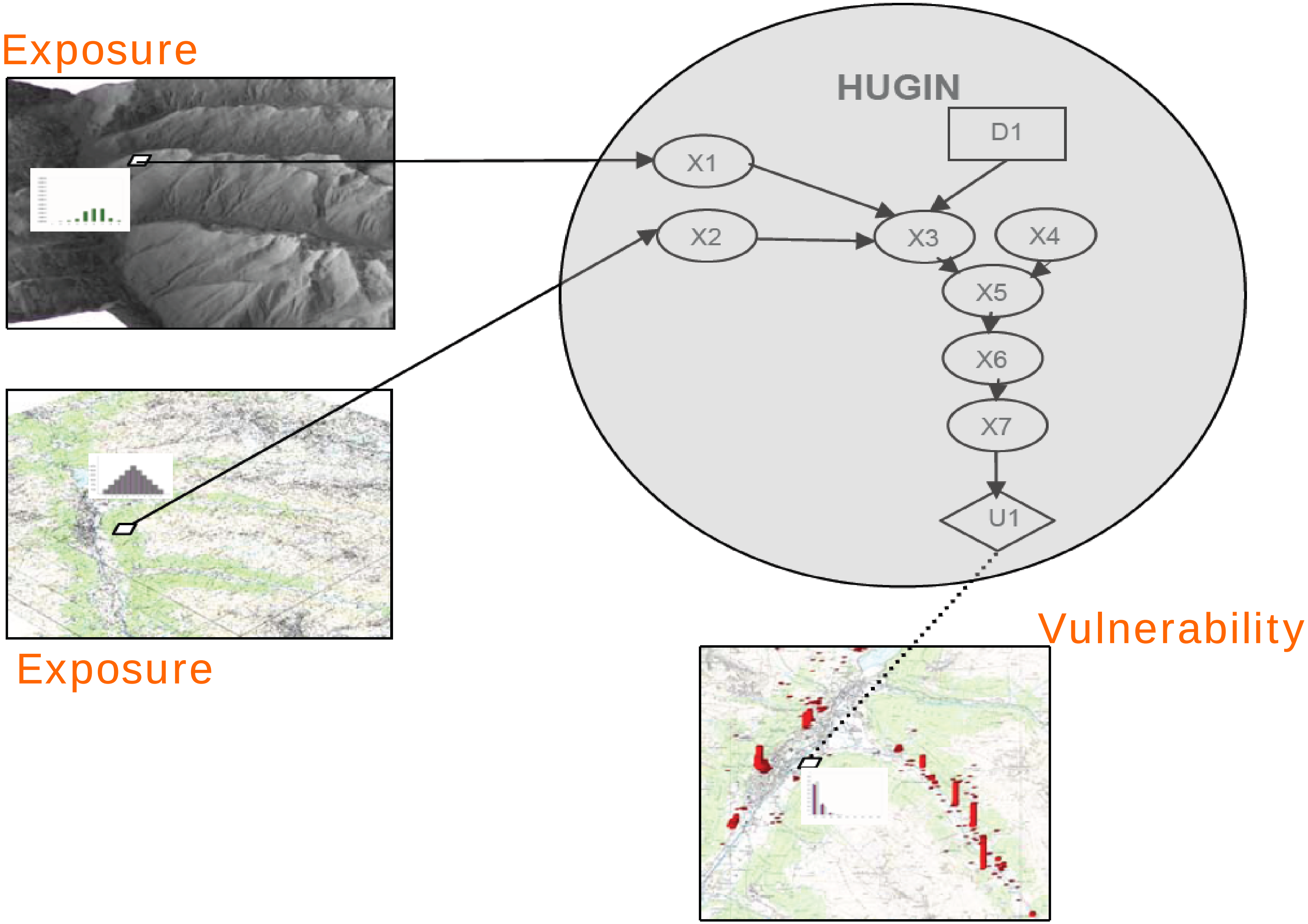
here:

$$P(x_1, x_2, x_3) = P(x_1)P(x_2|x_1)P(x_3|x_1)$$

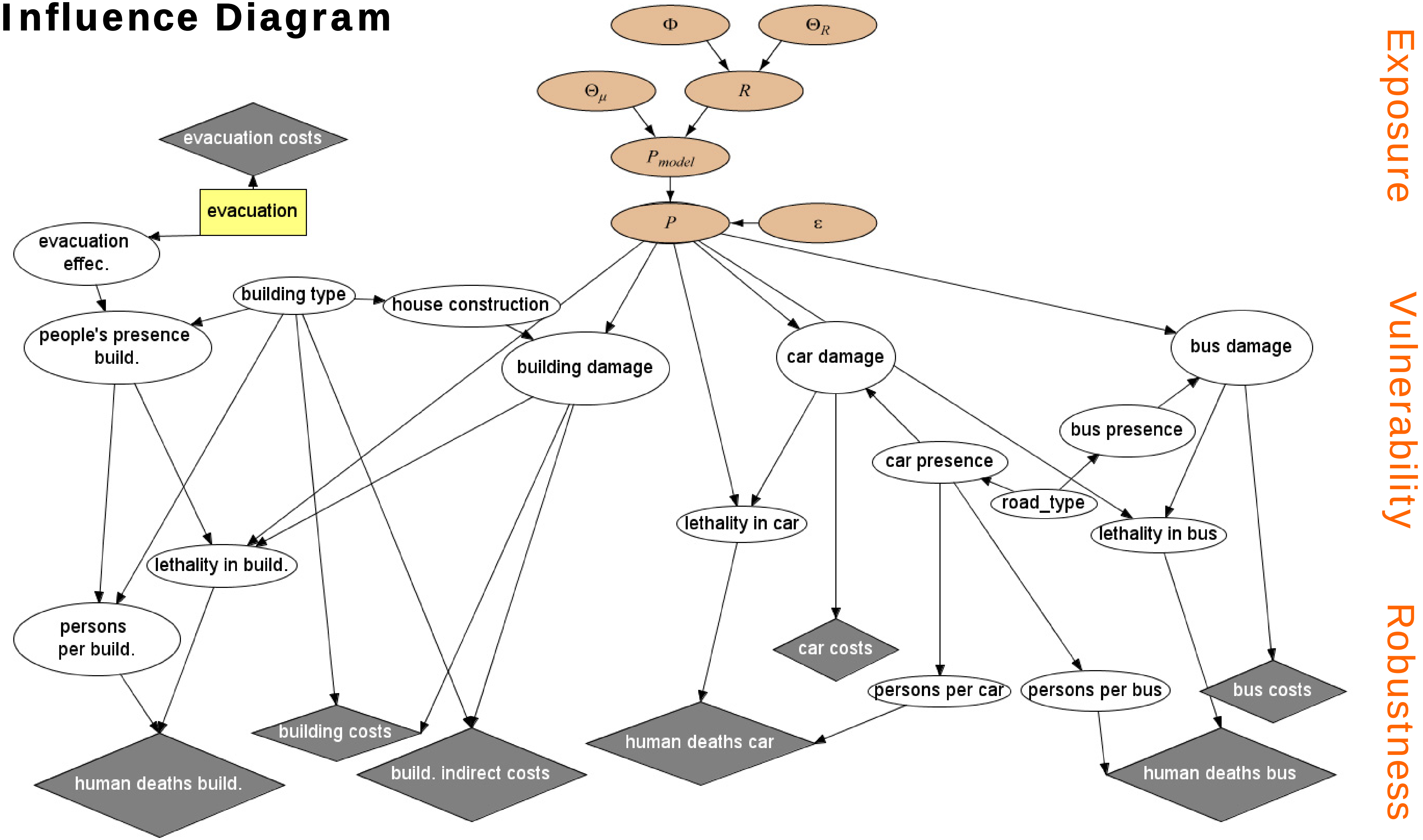
general:

$$P(\mathbf{x}) = P(x_1, \ldots, x_n) = \prod_{i=1}^{n} P(x_i|pa_i)$$

Bayesian Networks and Influence Diagrams

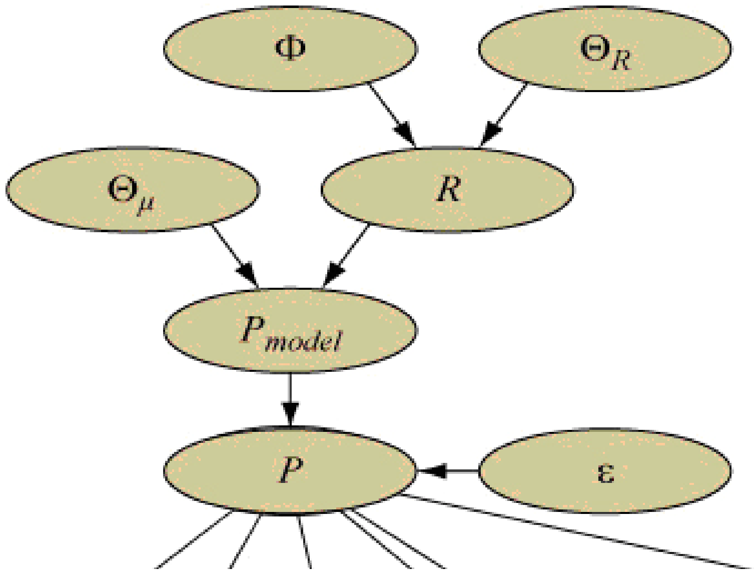


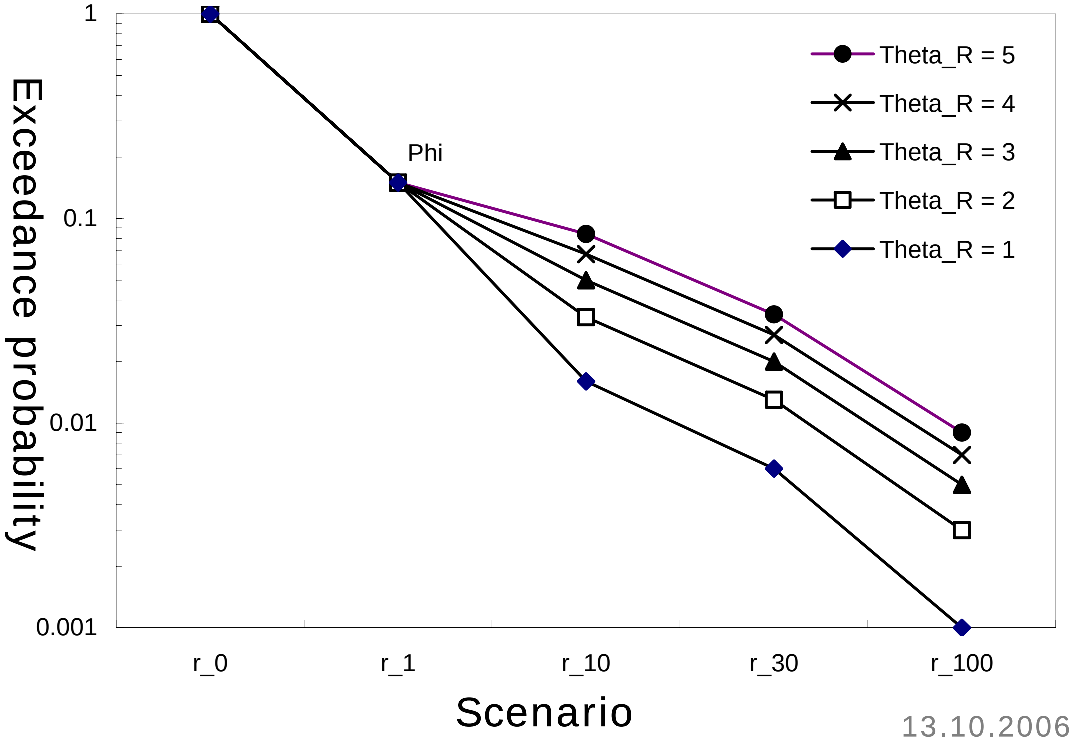
Influence Diagram



Probabilistic Avalanche Model

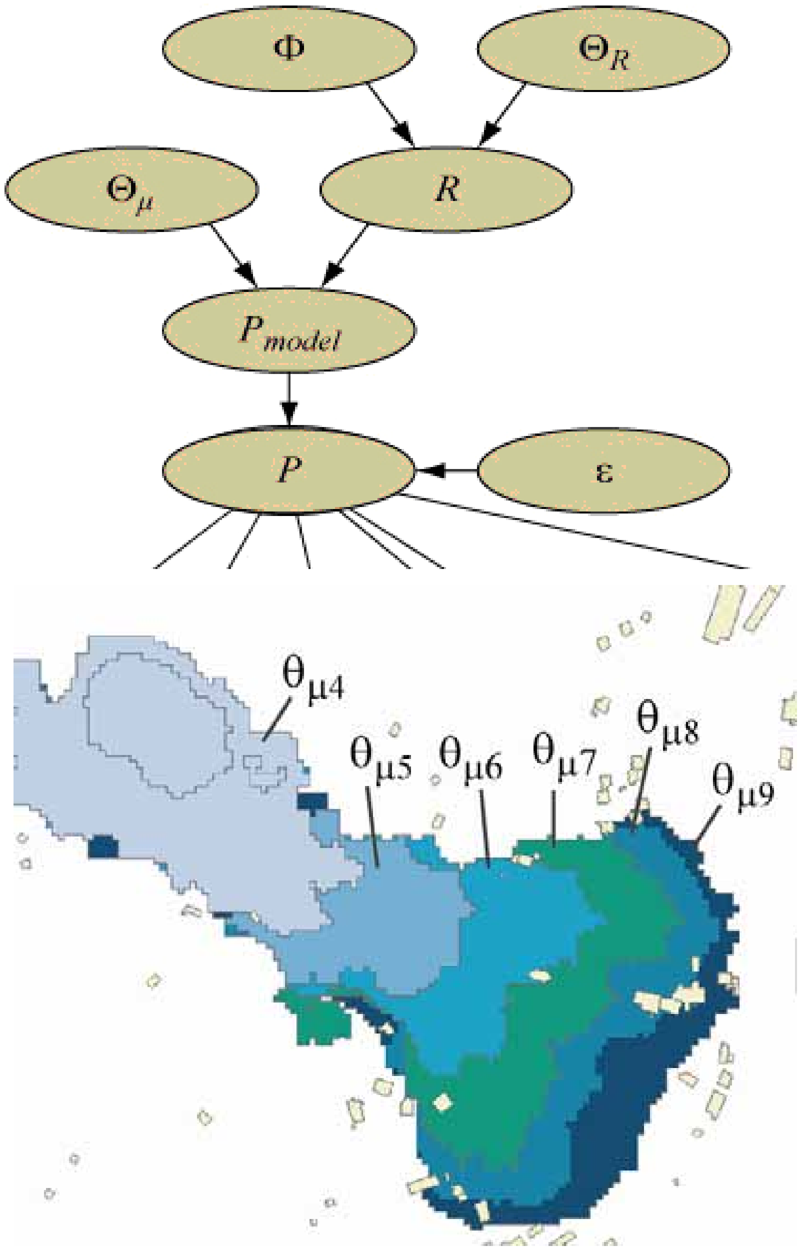
- **Release modelling**
  - Exceedance probability of the yearly maximum snow volume
  - Five release scenarios are considered
  - A nil-scenario is introduced to model frequent avalanches with no potential for damage



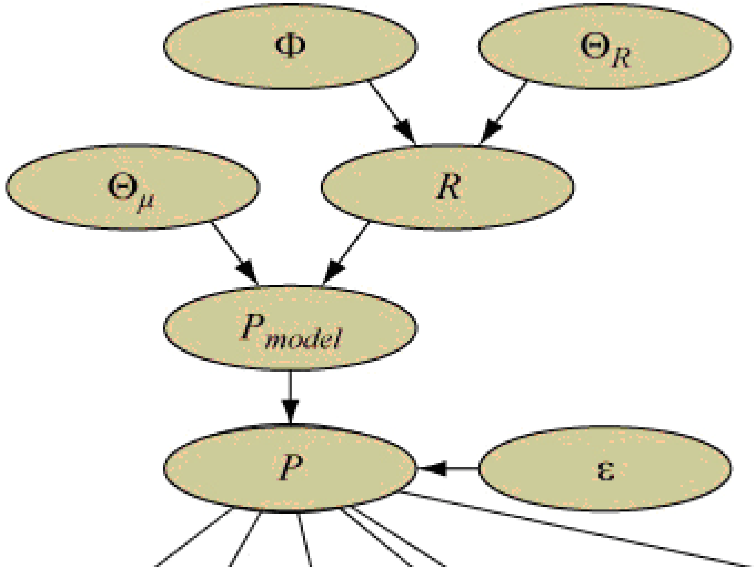


Probabilistic Avalanche Model

- **Avalanche modelling**
  - The value of the friction μ depends on the topography and the area
  - Nine different combinations of μ values are identified



Probabilistic Avalanche Model



- **Avalanche modelling**
  - The calculation of the run-out distance is based on an existing dynamic avalanche model (AVAL-2D, Gruber 1999)
  - The model uncertainty is accounted for by an error term ε(u)

$$P\left(\mathbf{u},\boldsymbol{\theta}\right)=\mathrm{f}_{AVAL}\left(\mathbf{u},\boldsymbol{\theta}\right)+\varepsilon\left(\mathbf{u}\right)$$

Updating

- Available avalanche records for the past 60 years

- Spatial information is not used, instead the observed run-out distance along a line (the flowpath) is considered: o_i

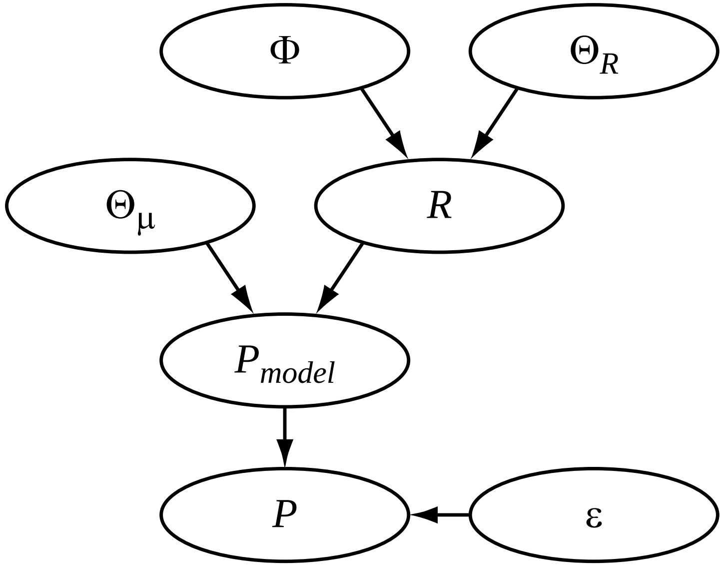
- All observations of $o_i < o_{thres}$ are only considered as censored data

- Bayesian updating:

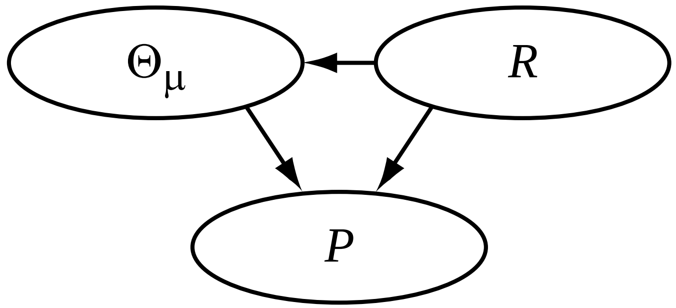
$$p_{\boldsymbol{\Theta}|\mathbf{q}}(\boldsymbol{\theta}) \propto \left(\prod_{i=1}^{N-M} f_\delta\left(o_i - d_{AVAL}(\boldsymbol{\theta})\right)\right)\left(\prod_{i=1+M}^{N} F_\delta\left(o_{thres} - d_{AVAL}(\boldsymbol{\theta})\right)\right) p_{\boldsymbol{\Theta}}(\boldsymbol{\theta})$$

Updating

- Prior BN-Model

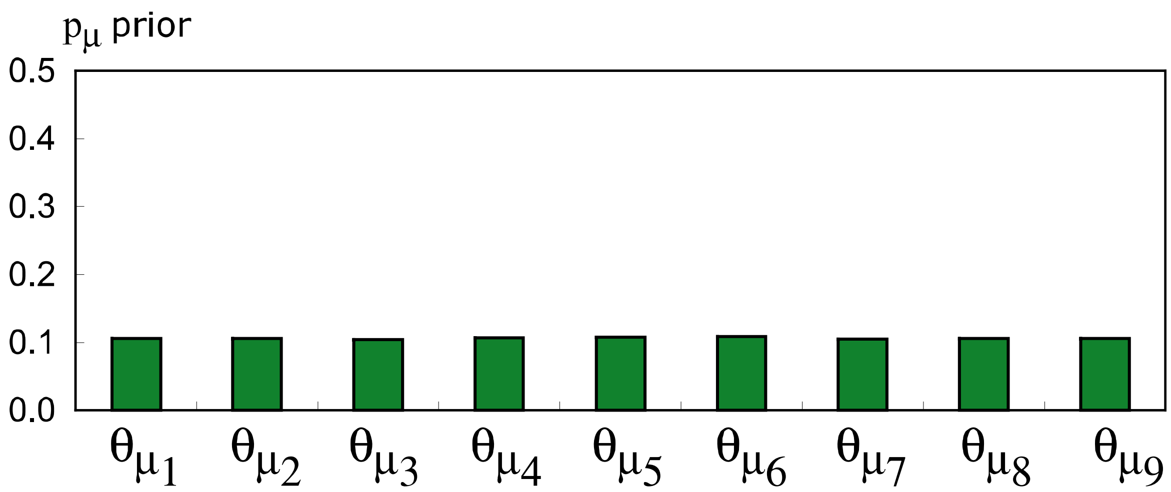


- Posterior BN-Model (used in the risk assessment)

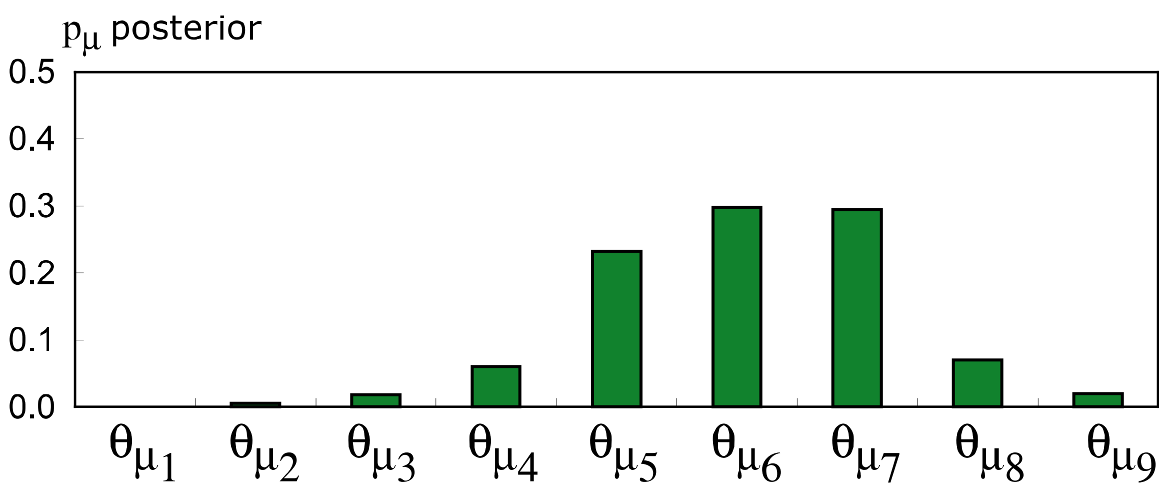


Updating the friction parameter

- Prior distribution

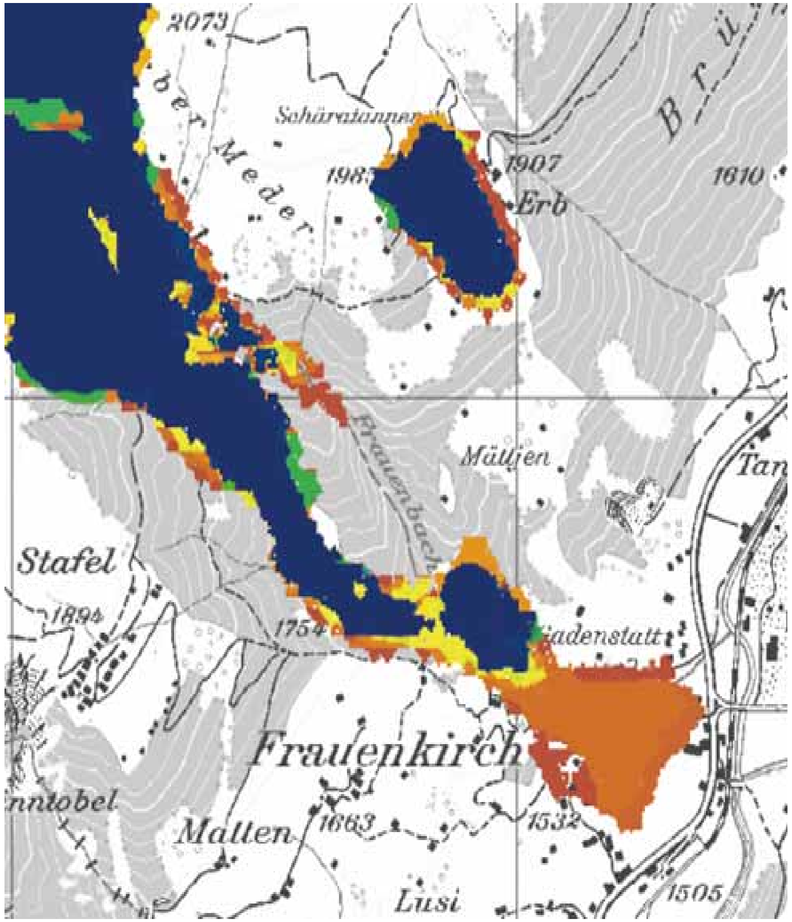


- Posterior distribution



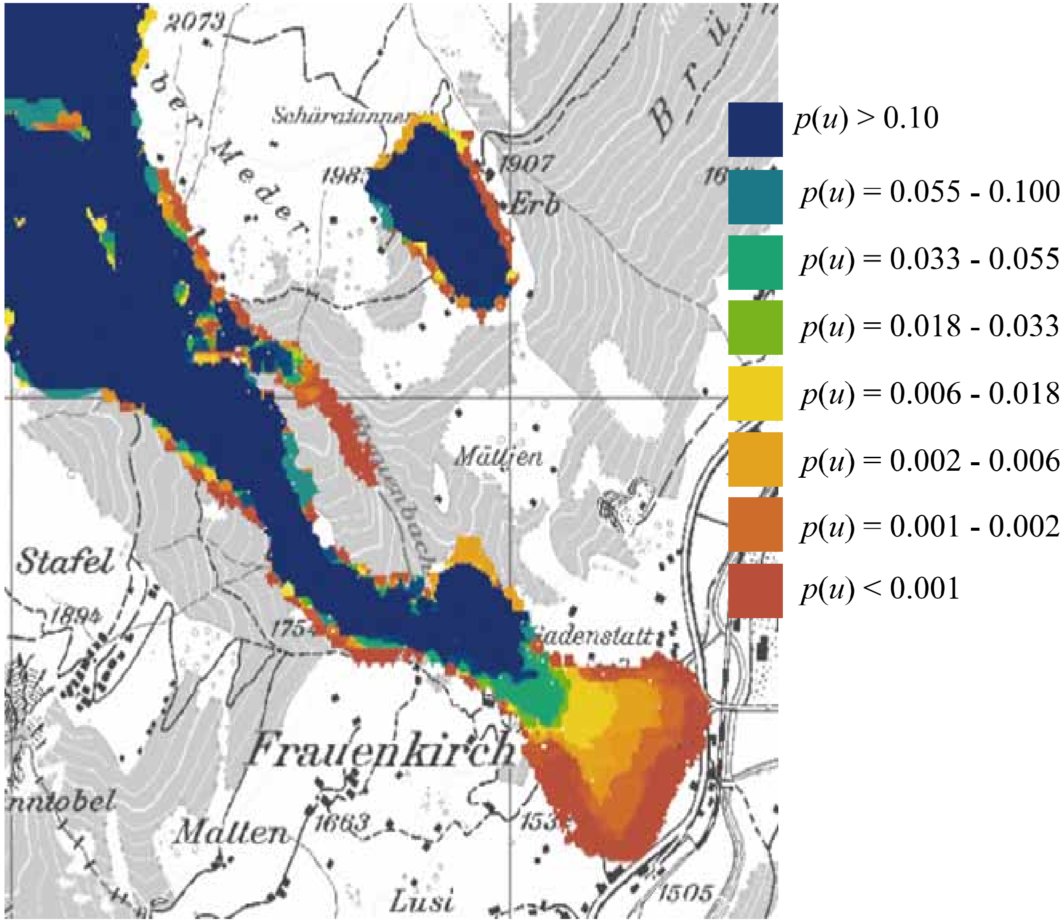
Results

Traditional Approach



E[C]=3850 CHF/yr

Using Bayesian Networks

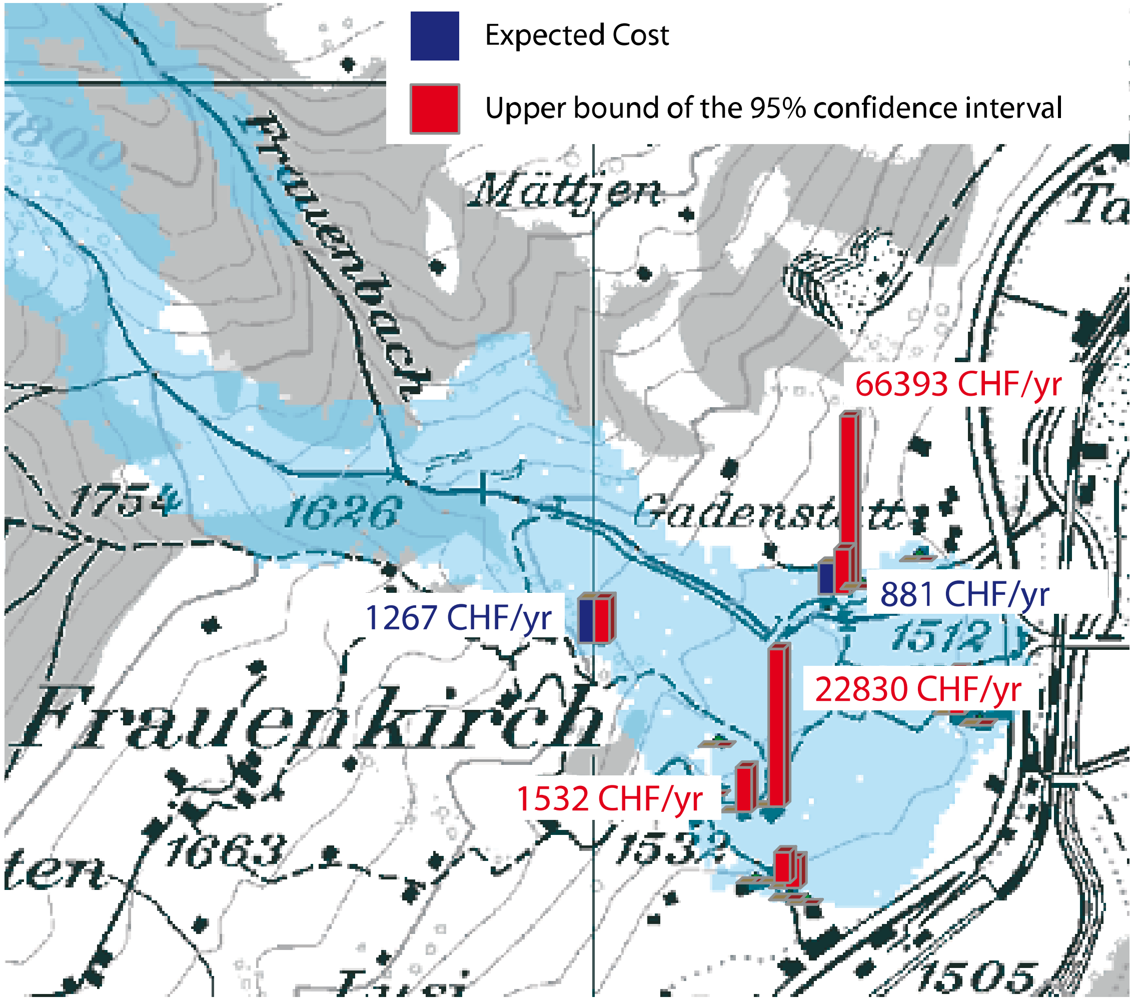


E[C]=4970 CHF/yr

Results

- Large uncertainties in the run out zones

- Nodes with the largest impact on the expected costs
  - “pressure”
  - “house construction”
  - “people present”



Conclusions and outlook

- Combining BN and GIS provides a practical tool for the consistent risk assessment
- Expert knowledge and observations can be utilized
- Uncertainties are considered in a spatially explicit manner

- Inclusion of societal follow-up consequences
- Checking and improving the criteria for hazard mapping and land use planning
- Use of the model in risk management (e.g.- planning of evacuation, road closures etc)

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Thank you for your attention