Network for Natural Hazards (HazNETH)

About HazNETH

- Platform for trans-disciplinary projects focused on reduction of risk due to natural hazards.
- Advisory group to the management board of ETH Zurich on issues concerning natural hazards.

Network for Natural Hazards (HazNETH)

Mission

Bring together diverse scientific disciplines within ETH Zurich to:

- Establish an integrative framework for research and teaching in the natural hazards domain.
- Build a cluster of natural hazard expertise with international recognition.

ETH

Network for Natural Hazards (HazNETH)

Purpose

- Undertake research, education and services in the natural hazards domain.
- Work towards new and improved methods and tools to facilitate integral risk management for sustainable development.
- Facilitate the exchange of scientific and technical know-how among members.

Network for Natural Hazards (HazNETH)

Purpose

- Support inter-disciplinary as well as further education in the area of integral risk management.
- Initiate and facilitate inter- and trans-disciplinary research with a focus on process analysis, hazard analysis and the vulnerability of technical, ecological, economic, social and political systems.
- Coordinate and facilitate the setting-up of joint research laboratories and test-areas for studying natural hazards, nationally and internationally.

Network for Natural Hazards (HazNETH)

Participating Departments:

- D-BAUG: Civil, Environmental and Geomatic Engineering
- D-UWIS: Environmental Sciences
- D-ERDW: Earth Sciences
- D-GESS: Humanities, Social and Political Sciences
- D-MTEC: Management, Technology and Economics

www.nathaz.ethz.ch

ETH

MAS in Natural Hazards Management

Why

- Ongoing growth of population and changing land utilization has exposed society to risks from natural hazards
- Emissions to the environment -> significant increase in frequency and magnitude of natural hazard events in the future (climate effect)
- Natural resources are endangered and reducing in stock

Hurricane Katrina, New Orleans, 2005

MAS in Natural Hazards Management

Motivation

- For protection of existing infrastructure and lives against increasing risk from natural hazards
- For decision making in respect of where (& how) to take preventive measures
- To support sustainable development
- To improve societal awareness and management with due consideration of the interaction between societal developments livelihoods, quality of the environment and economic growth

MAS in Natural Hazards Management

Aim

Specializing in:

- Operational natural hazards risk management
  - natural hazards engineering
  - atmospheric and earth sciences
  - holistic understanding of natural hazards processes
  - consequences modeling and engineering means to reduce consequences

MAS in Natural Hazards Management

Aim

Specializing in:

- Strategic natural hazards risk management
  - socio-economical aspects of risk management
  - understanding of interrelation of societal developments and natural hazards
  - understanding of how natural hazards affect societies at different scales
  - management and treatment of risks

Seminars on

Aspects of Integral Risk Management in Engineering

HIL E 6, ETH Hönggerberg

Start on 5 October

Prof. Dr. Michael H. Faber

Dr. Jochen Köhler

Contact: jochen.koehler@ibk.baug.ethz.ch

Website: http://www.ibk.ethz.ch/fa/education/Seminar

PhD seminar series

Probabilistics in Engineering:

Bayesian networks and Bayesian hierarchical analysis in engineering

Wednesdays 16:45 – 18:00, HIL E 6, ETH Hönggerberg

Start on 30 September

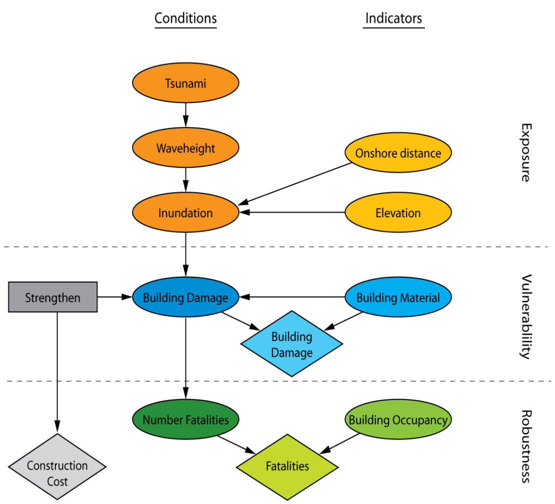
Prof. Dr. Marc A. Maes

Prof. Dr. Michael H. Faber

Dr. Kazuyoshi Nishijima

Contact: nishijima@ibk.baug.ethz.ch

ETH



CCSS – ETH Zurich, September 2009.

Recent Developments in the Management of Risks due to Large Scale Natural Hazards

M. H. Faber

Chair of Risk and Safety.
Institute of Structural Engineering, ETH.

ETH Swiss Federal Institute of Technology, Zurich

Contents of Presentation

- Motivation
- The Natural Hazards Risk Management Problem
- Framework for Risk Based Decision Making
  - System perspective
  - Knowledge and uncertainties
  - Assessment of probabilities
  - Quantification of risks
  - Risk updating and risk indicators
  - Life safety
  - Portfolios and aggregation
- Examples
  - Tropical cyclone strong wind modeling
  - Earthquake risk managemet and loss assessemnt
- Concluding Remarks

Framework for Risk Based Decision Making

How do engineers make decisons?

Actions

Models of real world

$$U(\mathbf{a}(\mathbf{T})) = \sum_{i=1}^{n} d(t_i)\left[\int_{t_i}^{t_{i+1}} u_{G_i}(t,\mathbf{a}(t_i),t_i)\,g(t-t_i)\,dt\right]$$

Indicators

Real World

Framework for Risk Based Decision Making

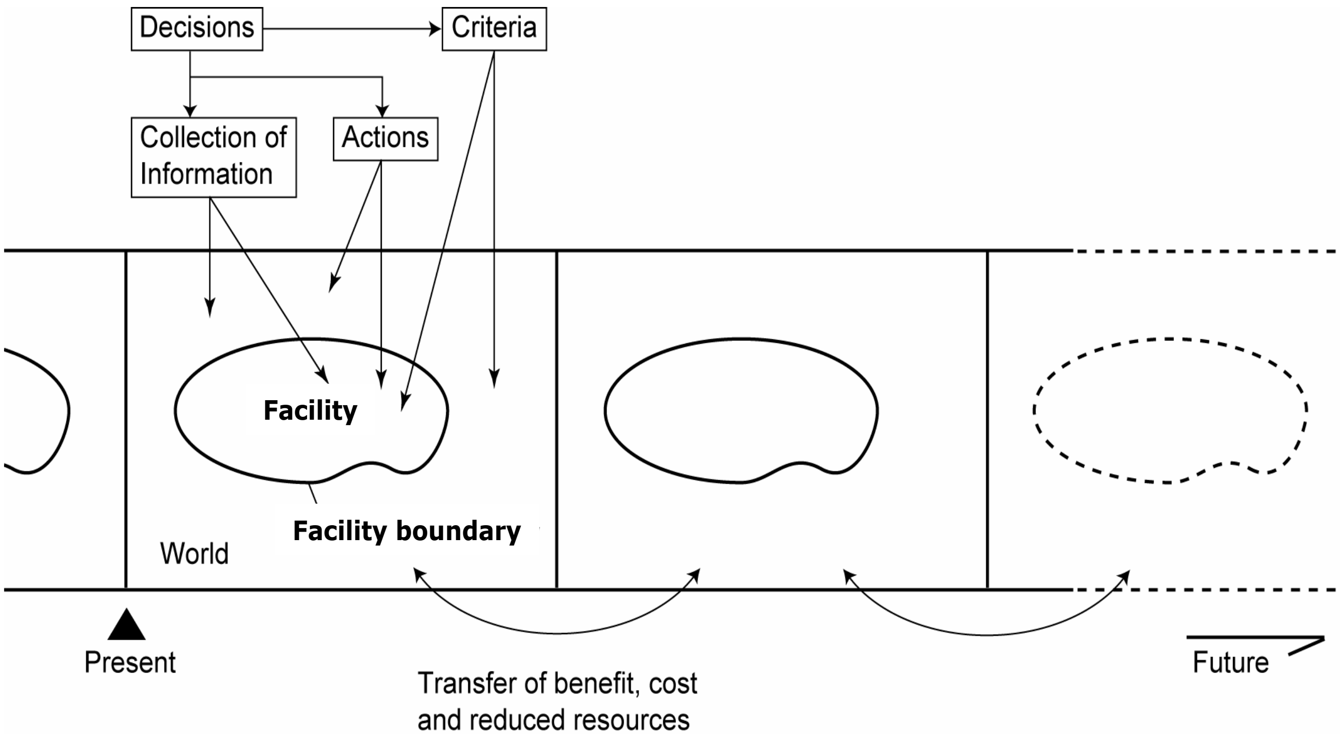
What must be accounted for in engineering modeling?

- Preferences (aim, purpose)
- Consequences (states of marginal utility)
- Uncertainties (aleatory and epistemic)
- Temporal and spatial variations/dependencies
- Options for decision making

System understanding !

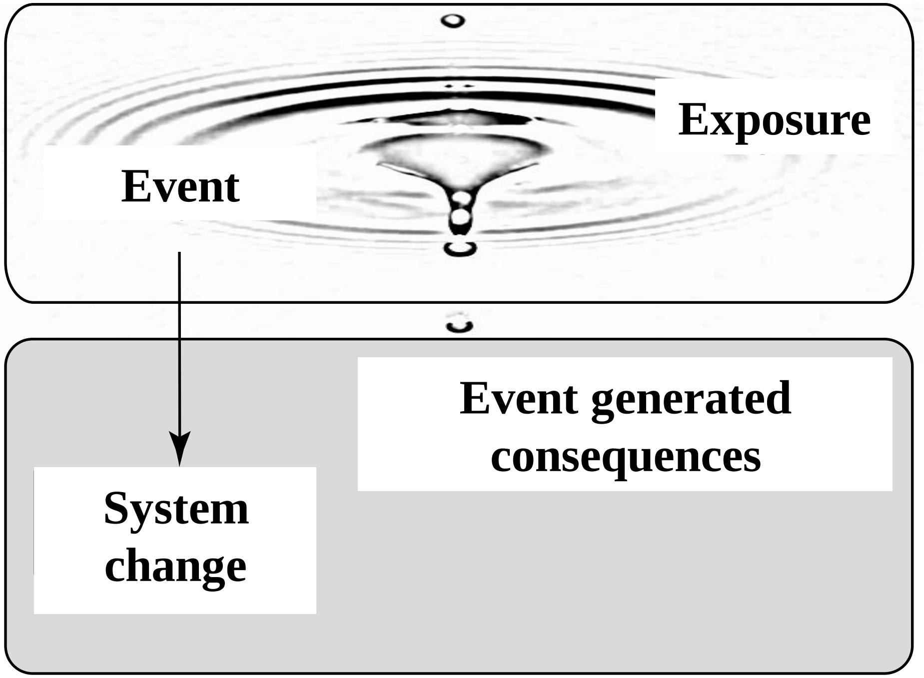
Framework for Risk Based Decision Making

System representation in risk assessment



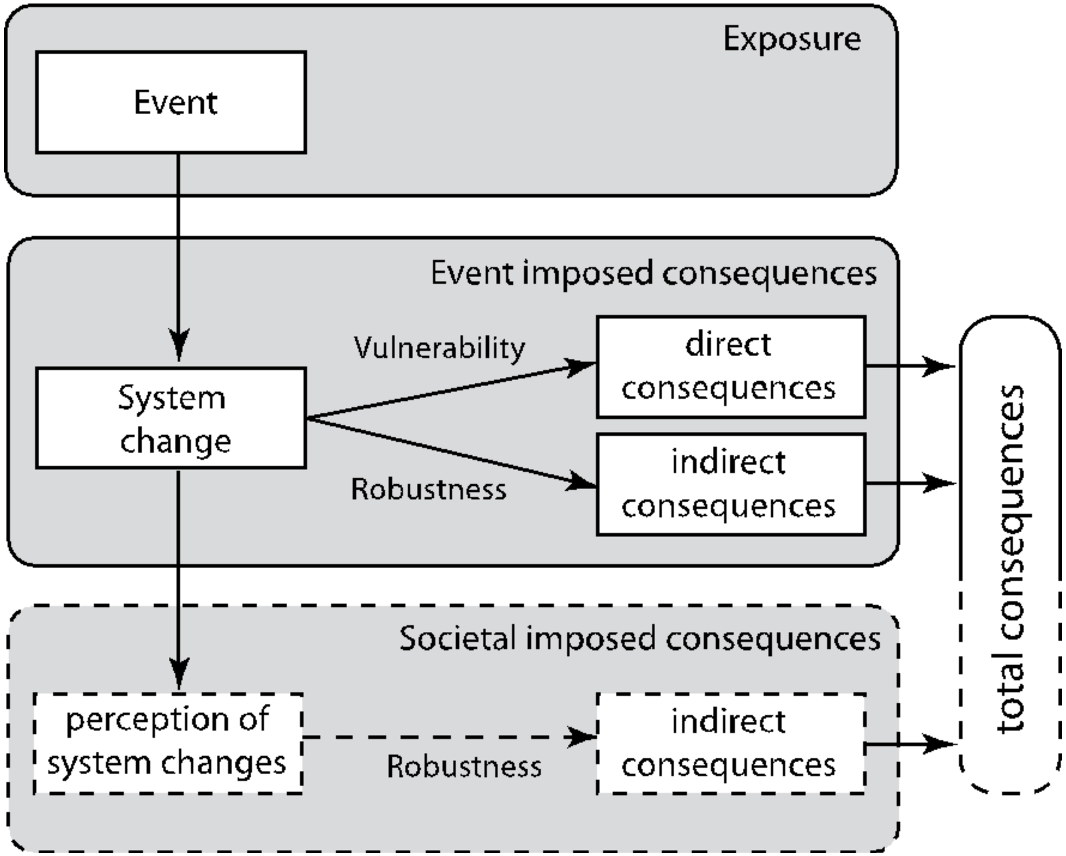
Framework for Risk Based Decision Making

How are consequences generated?



Framework for Risk Based Decision Making

How are consequences generated?



Framework for Risk Based Decision Making

Representation of knowledge

All uncertainties must be considered when the expected value of the utility is assessed

- aleatory

- epistemic

Bayesian statistics is utilized as a framework for assessing probabilities – combining subjective and frequentistic information – allowing for updating

Framework for Risk Based Decision Making

Modelling of consequences may be facilitated by explicitly accounting for:

Direct consequences In-direct consequences

$$E\left[U(A)\right] = E_{\mathbf{e}}\left[\sum_{i=1}^{n_O} p(i\,|A,\mathbf{e})u(A,O_i) + \sum_{j}^{m} p(\mathbf{O}_j\,|A.\mathbf{e})u_{FO}(A,\mathbf{O}_j)\right]$$

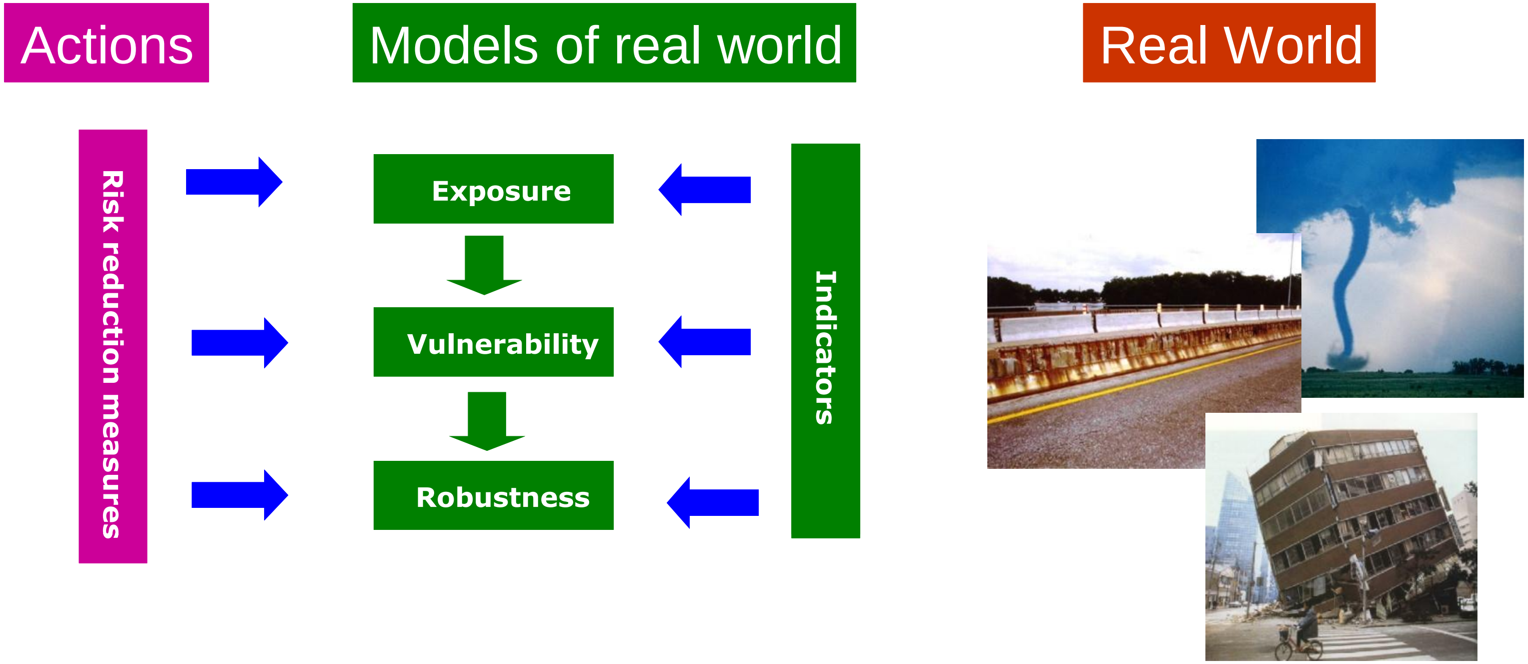
$$= \sum_{i=1}^{n_O} p(A,i)u(A,O_i) + E_{\mathbf{e}}\left[\sum_{j=1}^{m} p(\mathbf{O}_j\,|A,\mathbf{e})u_{FO}(A,\mathbf{O}_j)\right]$$

Needs more emphasis

Explicit treatment of epistemic uncertainty indicates where collection of additional knowledge may be beneficial

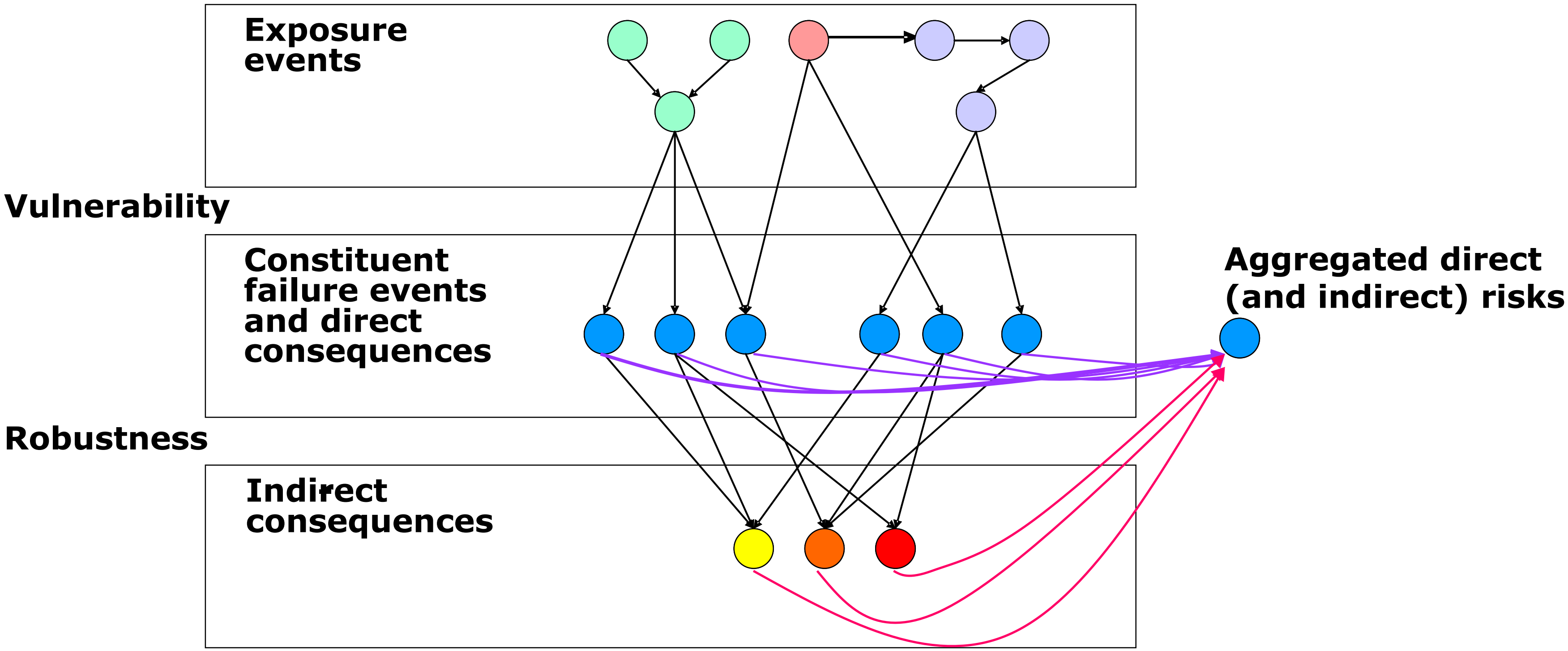
Framework for Risk Based Decision Making

Engineered systems exhibit generic characteristics

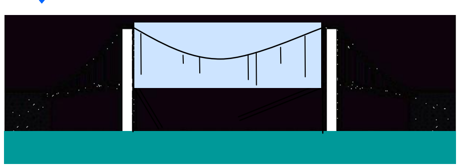


Framework for Risk Based Decision Making

How may systems be modeled?



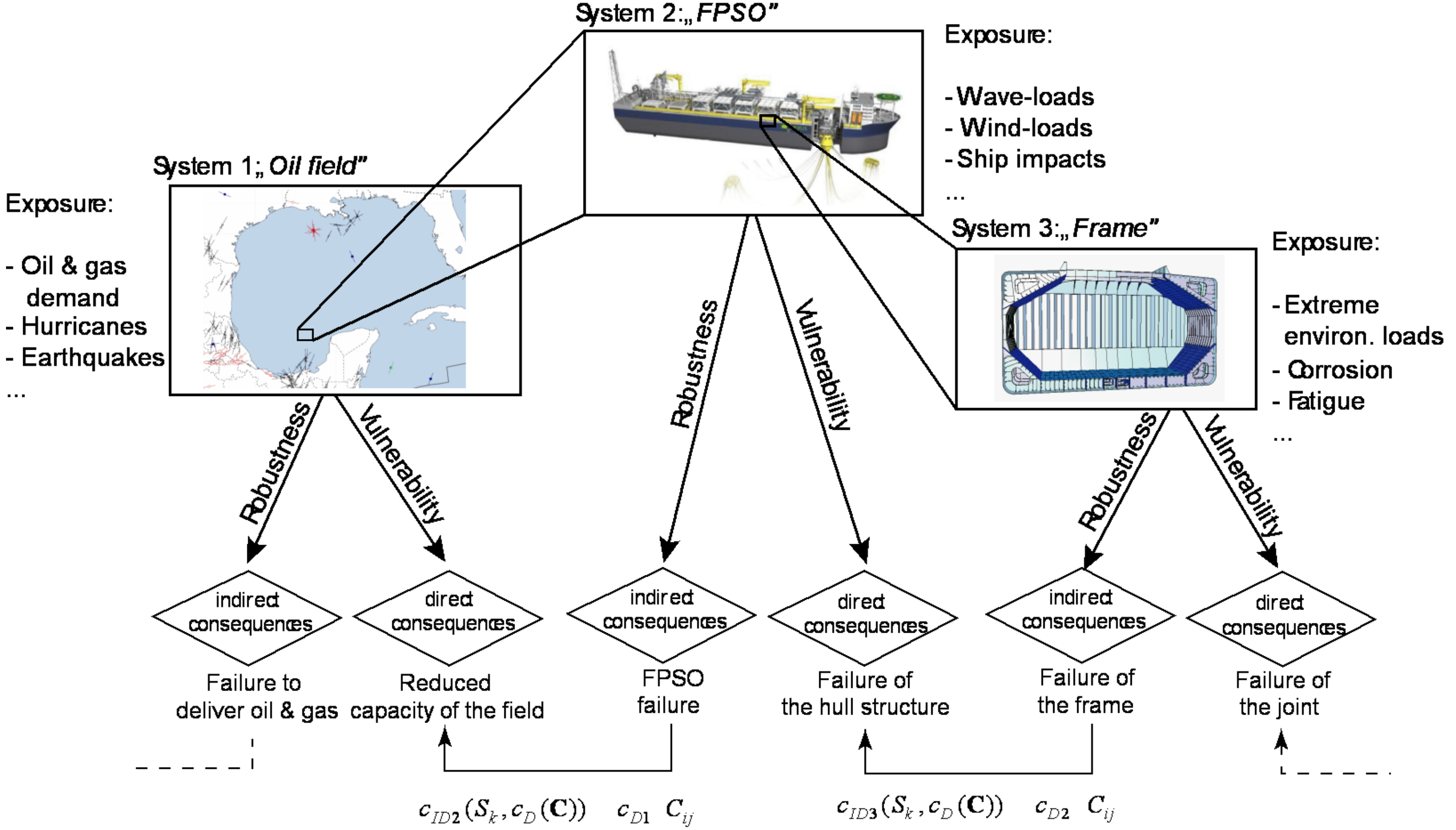
Framework for Risk Based Decision Making

Scenario representation	Physical characteristics	Indicators	Potential consequences
Exposure 	Flood Ship impact Explosion/Fire Earthquake Vehicle impact Wind loads Traffic loads Deicing salt Water Carbon dioxide	Use/functionality Location Environment Design life Societal importance	
Vulnerability 	Yielding Rupture Cracking Fatigue Wear Spalling Erosion Corrosion	Design codes Design target reliability Age Materials Quality of workmanship Condition Protective measures	**Direct consequences** Repair costs Temporary loss or reduced functionality Small number of injuries/fatalities Minor socio-economic losses Minor damages to environment
Robustness 	Loss of functionality partial collapse full collapse	Ductility Joint characteristics Redundancy Segmentation Condition control/monitoring Emergency preparedness	**Indirect consequences** Repair costs Temporary loss or reduced functionality Mid to large number of injuries/fatalities Moderate to major socio-economic losses Moderate to major damages to environment

ETH

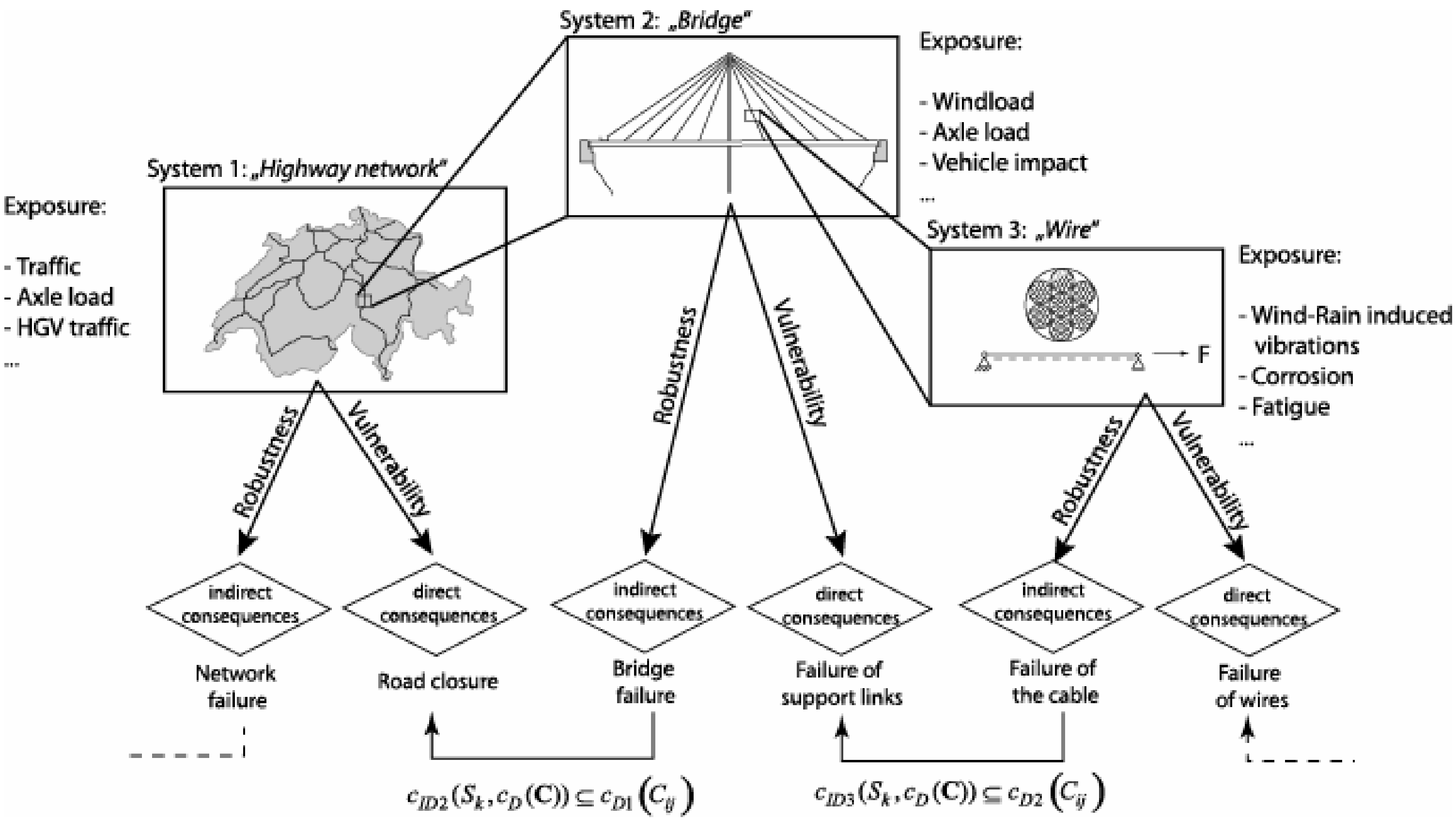
Framework for Risk Based Decision Making

Engineered systems exhibit generic characteristics



Framework for Risk Based Decision Making

Engineered systems exhibit generic characteristics



Framework for Risk Based Decision Making

Quantification of risks

Exposure $p(EX_k)$

↓

Vulnerability $p(C_{ij} | EX_k) c_D(C_{ij})$

↓

Robustness $p(S_l | EX_k) c_{ID}(S_l, c_D(\mathbf{C}))$

Direct risks:

$$R_D = \sum_{k=1}^{n_{EXP}} p(C_{ij} | EX_k) c_D(C_{ij}) p(EX_k)$$

Indirect risks:

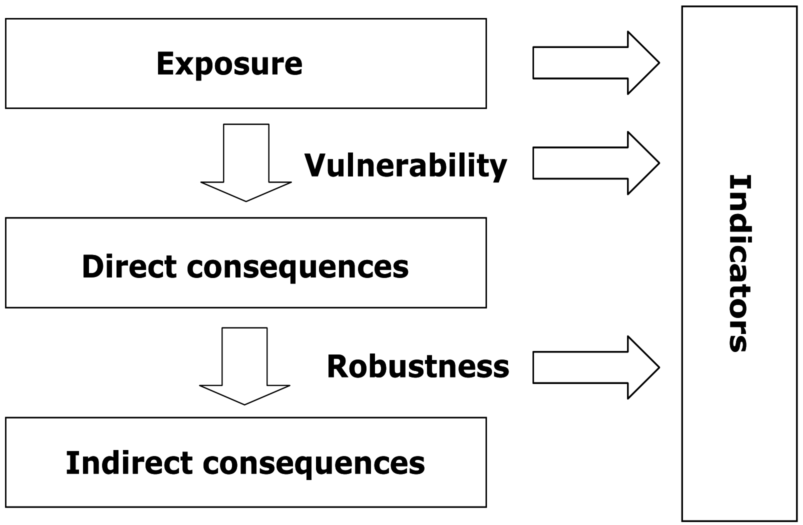
$$R_{ID} = \sum_{k=1}^{n_{EXP}} \sum_{l=1}^{n_{STA}} p(S_l | EX_k) c_{ID}(S_l, c_D(\mathbf{C})) p(EX_k)$$

Index of robustness:

$$I_R = \frac{R_D}{R_{ID} + R_D}$$

Framework for Risk Based Decision Making

Updating of risks



$$P(C_{ij} \mid e) = \frac{P(e \mid C_{ij})P(C_{ij})}{P(e \mid C_{ij})P(C_{ij}) + P(e \mid \overline{C_{ij}})(1 - P(C_{ij}))}$$

Framework for Risk Based Decision Making

Real-time information processing

- Measurements at observation stations
- Satellite images and aerial photos
- Health monitoring on structures

⬇

Real-time decision making

Framework for Risk Based Decision Making

Real-time decision making

Ranges of the time frame of "real-time" decision making on natural hazards:

- ≈ hours: e.g. rescue actions
- ≈ days: e.g. evacuation/shut-down operations
- ≈ years: e.g. mitigation measures

Framework for Risk Based Decision Making

Real-time decision making

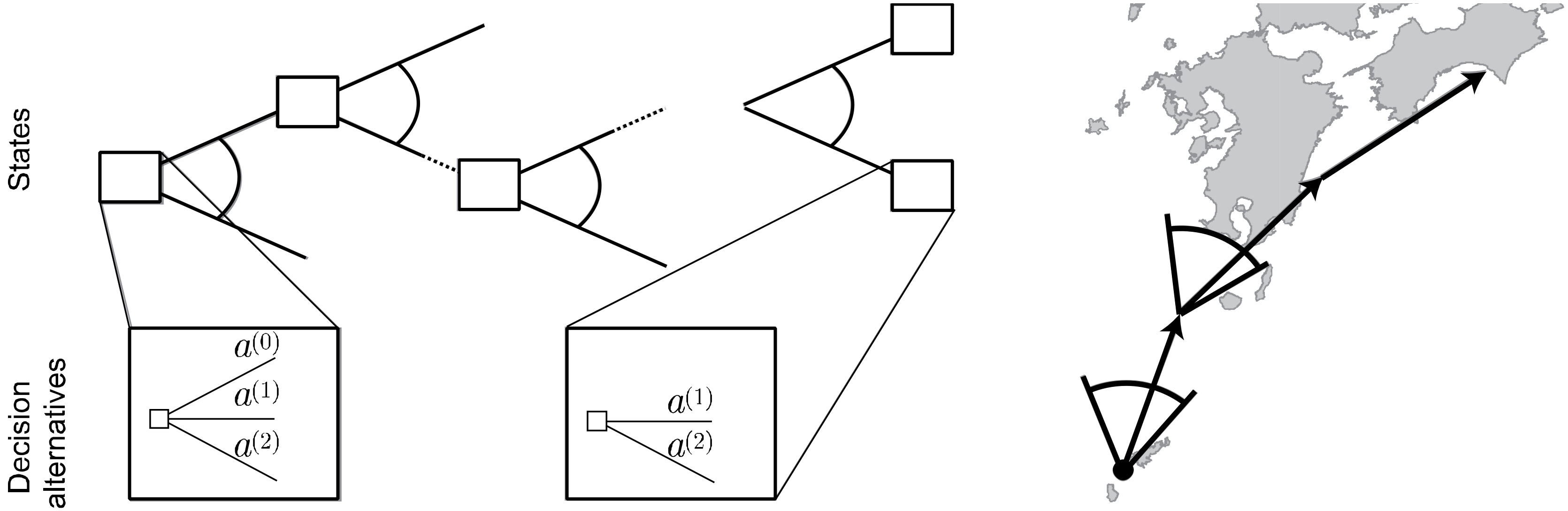
Characteristics of the real-time decision problem

- Precursors can be observed.
- Decisions are subject to uncertainties.
- Decisions can be made at any time during the event
- The decisions must be made fast.

Framework for Risk Based Decision Making

Real-time decision making

Methodology: Pre-posterior decision analysis

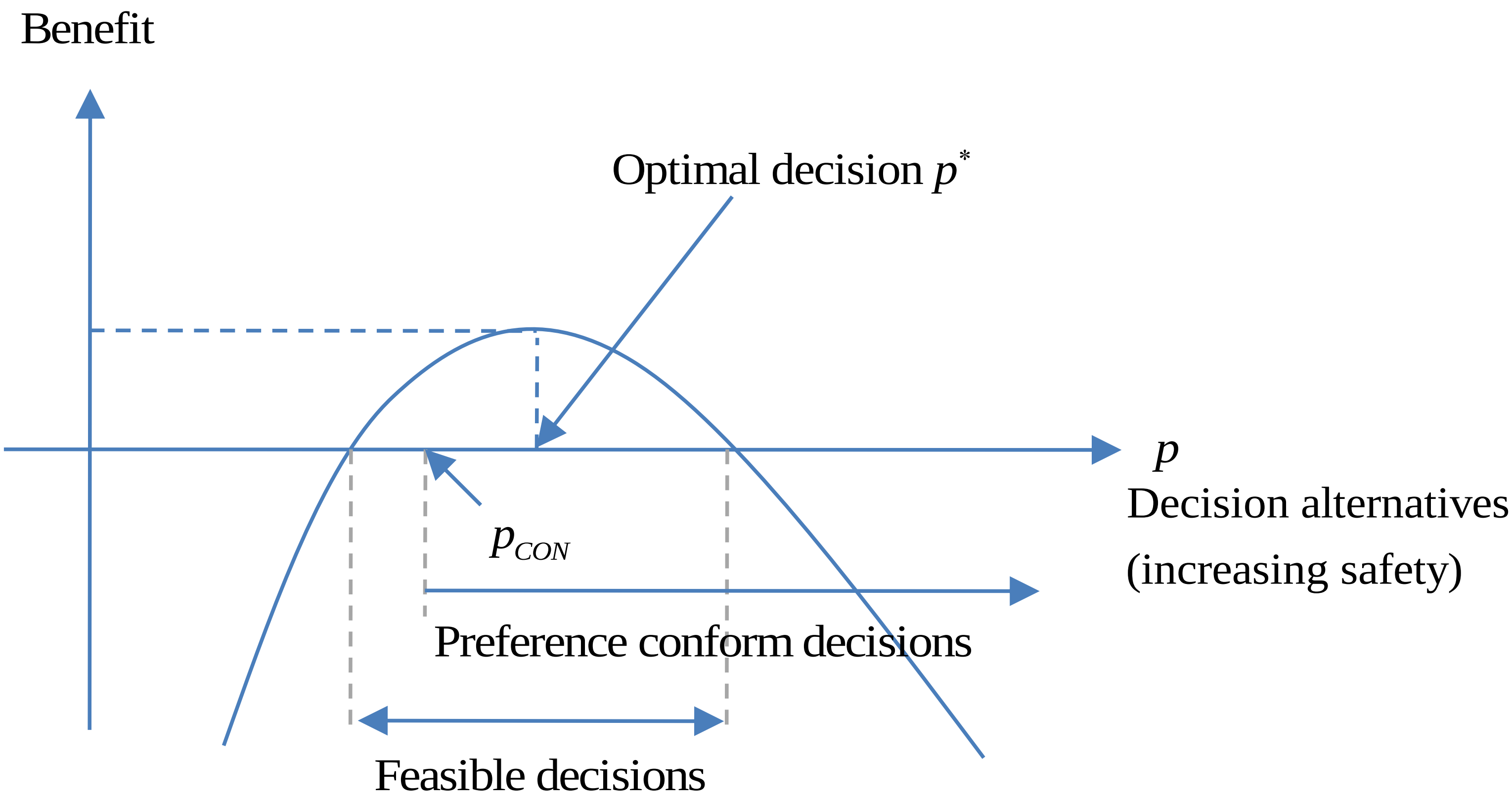


Reducing uncertainties by:

- (epistemic) collecting more information at costs
- (aleatory) “waiting”, which may result in being too late.

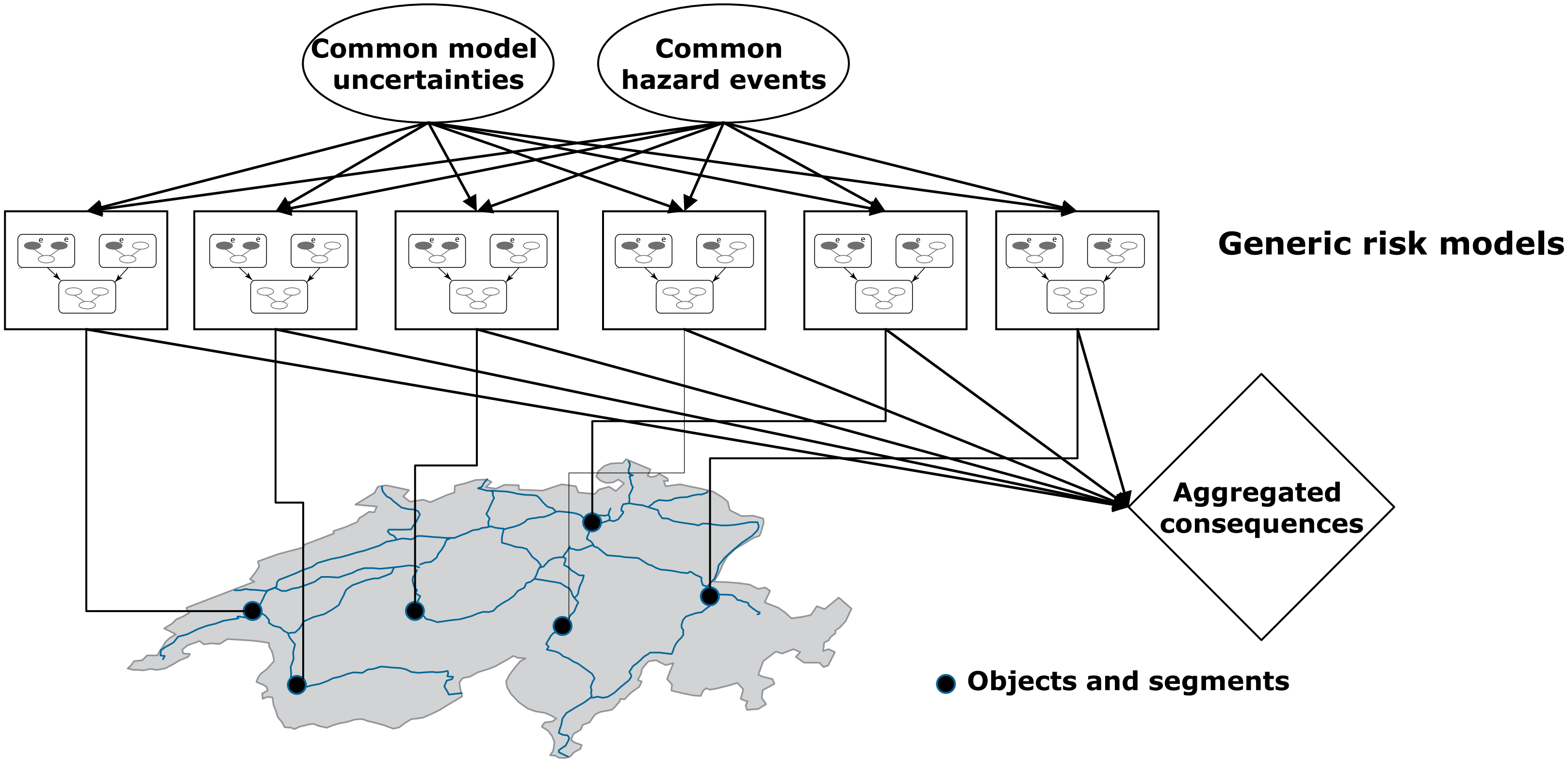
Framework for Risk Based Decision Making

Feasibility and optimality



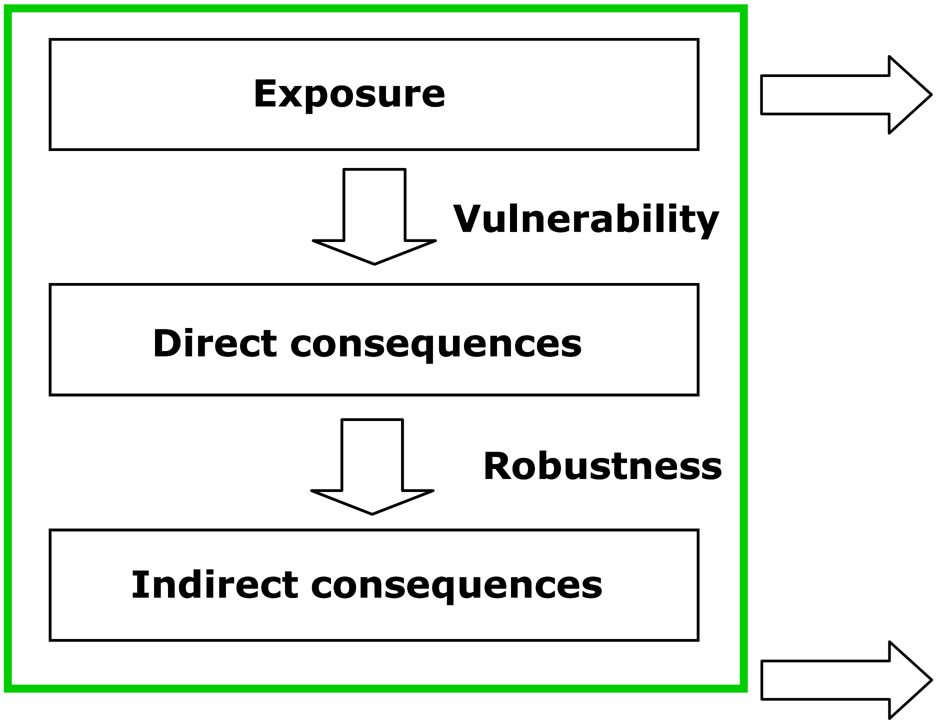
Framework for Risk Based Decision Making

Risk aggregation - portfolio risk modeling



Example Illustrations

Application of modeling concept

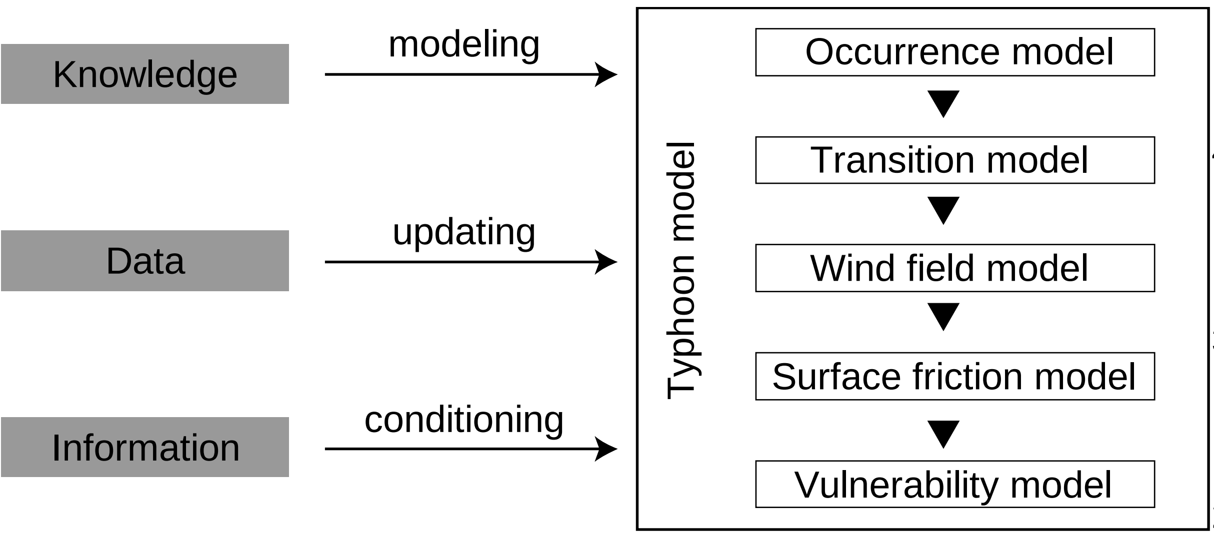


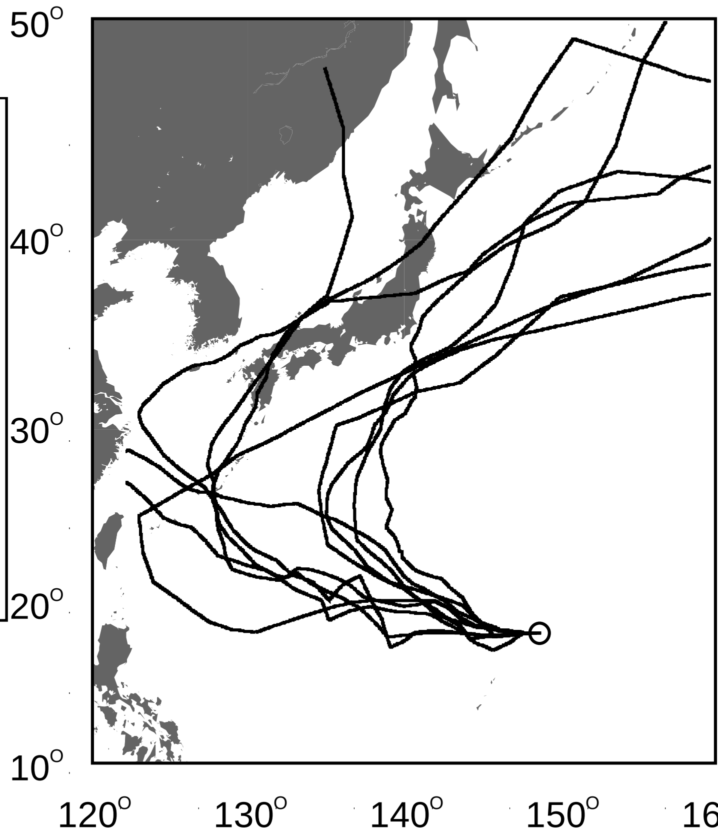
- Typhoons

Earthquake risk management

Typhoon Exposure Modeling

Representing the Event of Typhoons

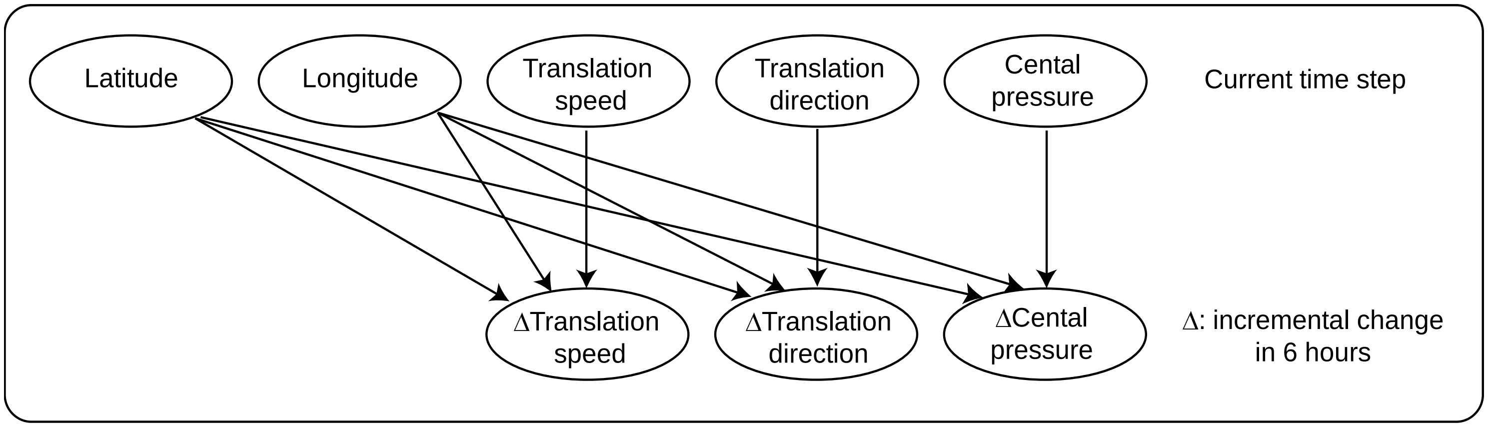




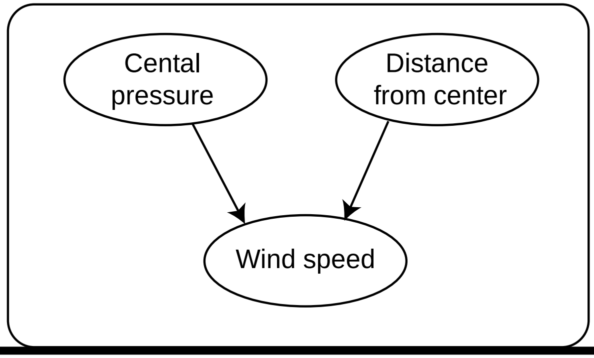
Typhoon Exposure Modeling

Representing the Event of Typhoons

Transition model

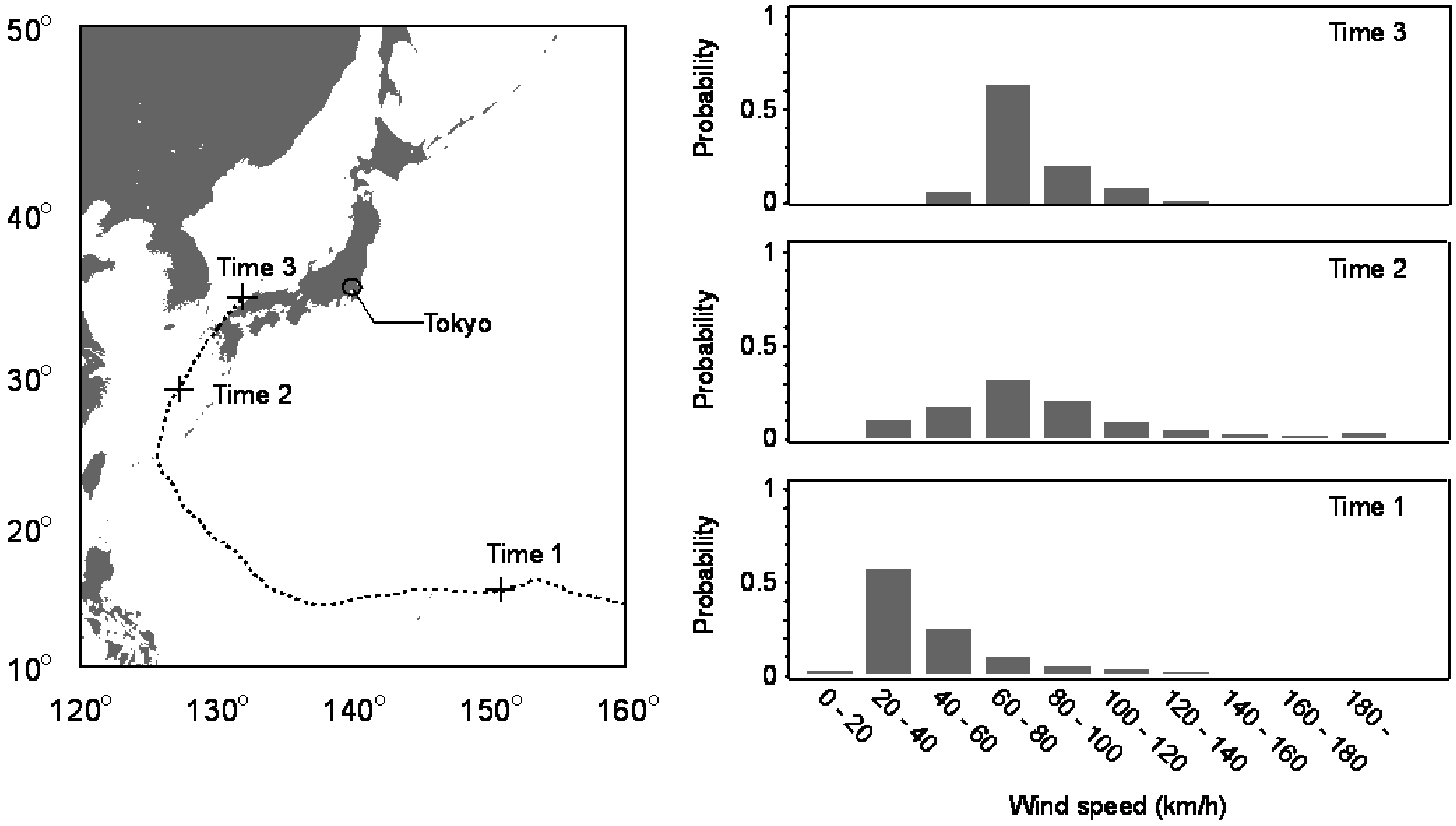


Wind field model

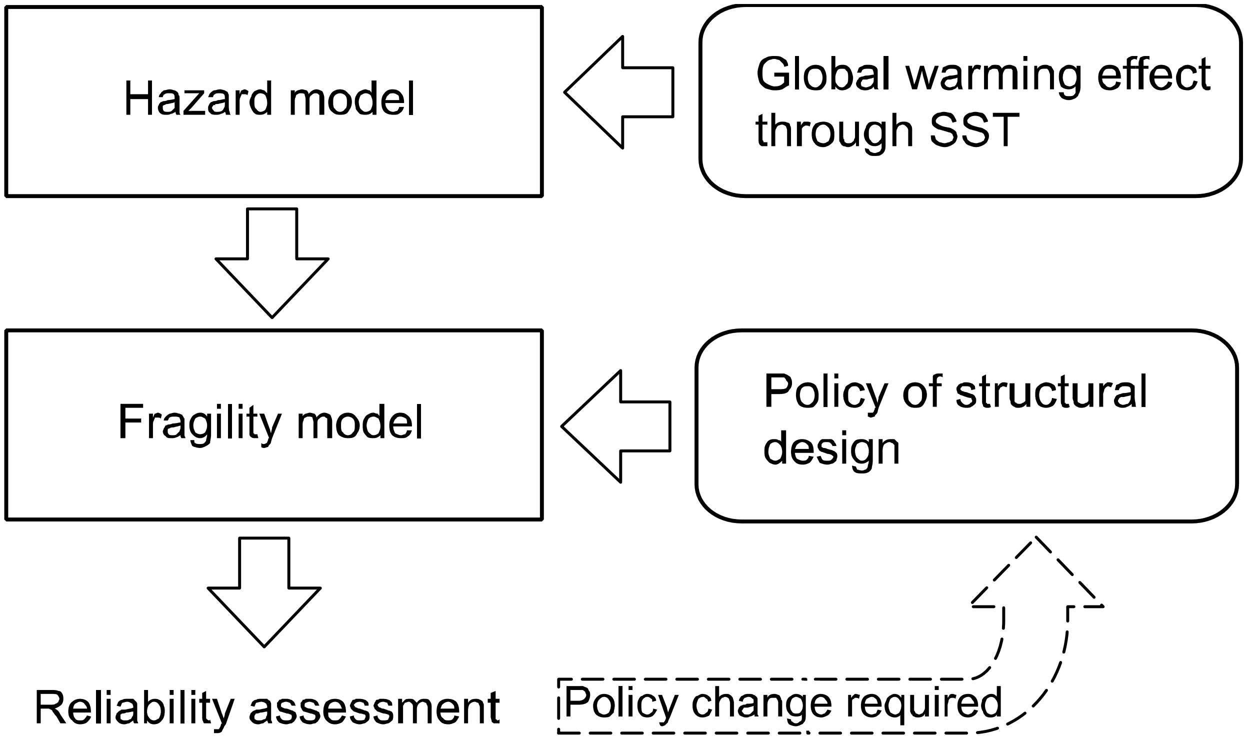


Typhoon Exposure Modeling

Representing the Event of Typhoons

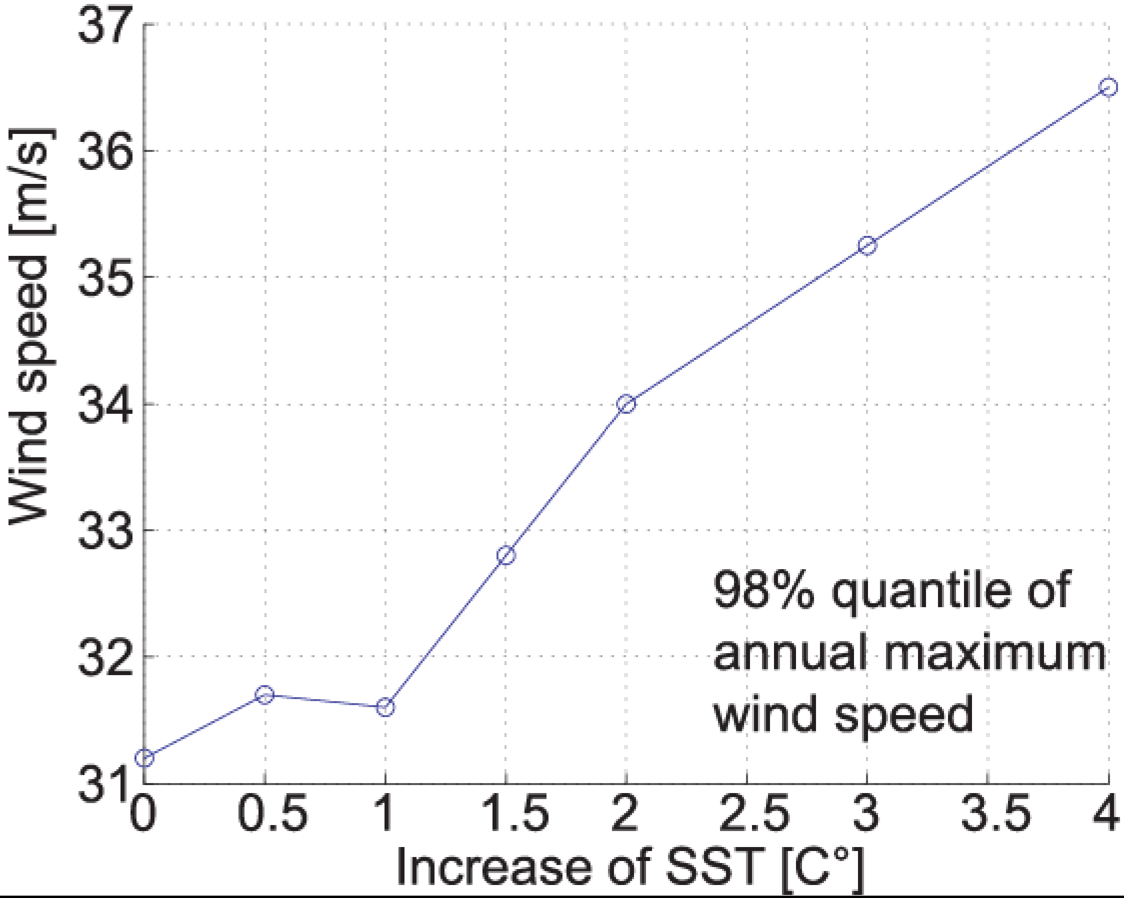


Assessing the Effect of Global Warming



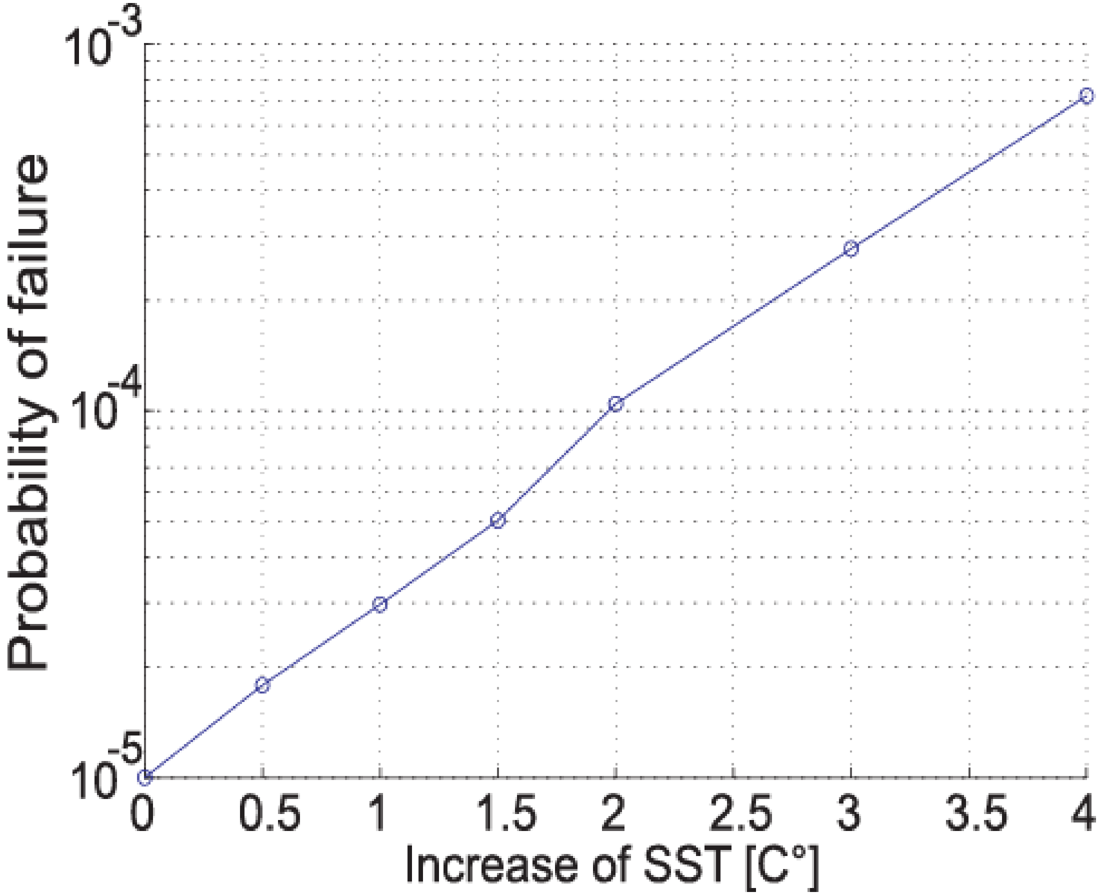
Assessing the Effect of Global Warming

Change of the characteristic value (98%-quantile value) of annual maximum wind speed



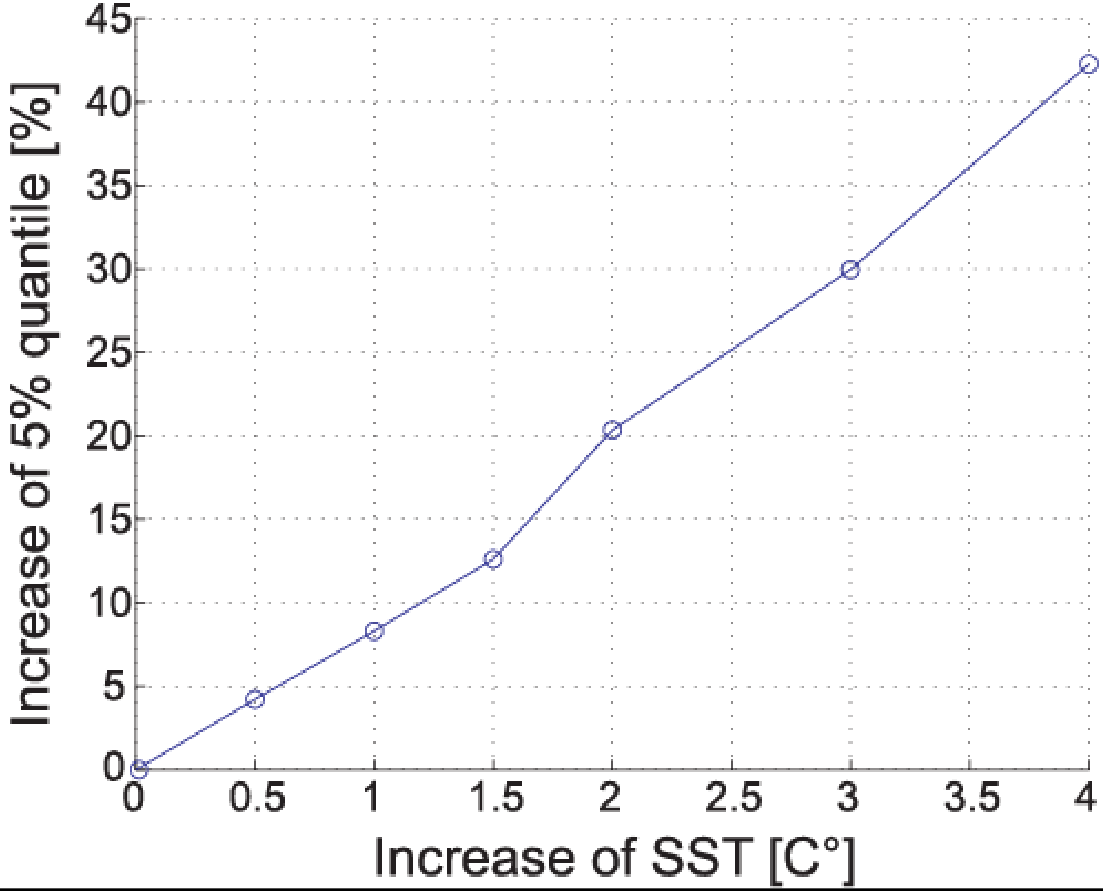
Assessing the Effect of Global Warming

Change of the probability of failure

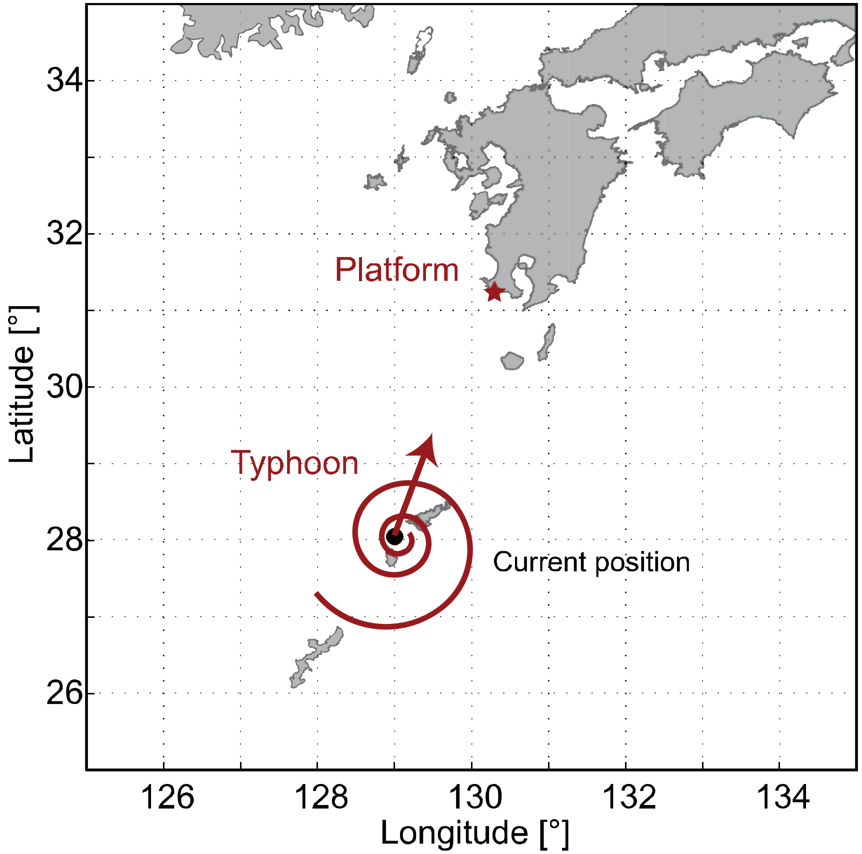


Assessing the Effect of Global Warming

Required change of the characteristic value (5%-quantile value) to maintain the target reliability $p_F \approx 10^{-5}\ 1/year$



Real-time decision making

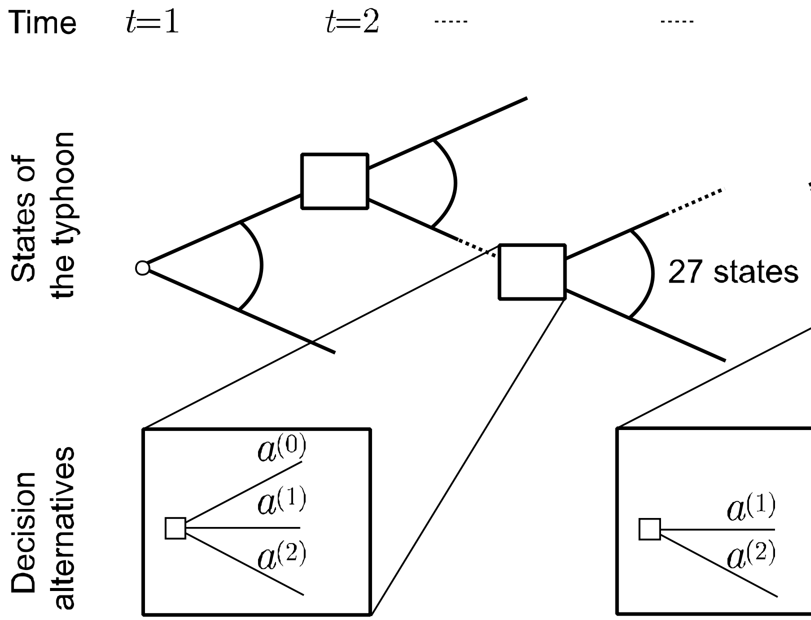


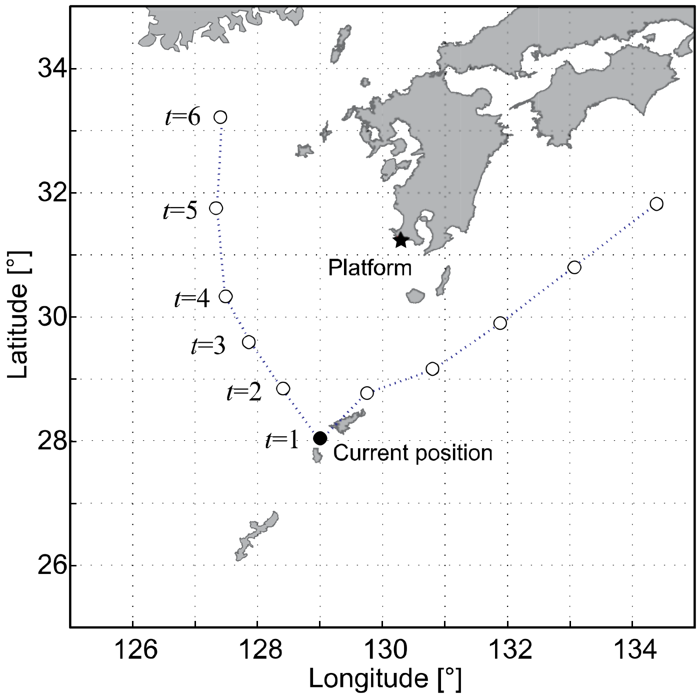
- Continue or stop the operation on the platform?
- If yes, when to stop?

Real-time decision making

Numerical calculation

Discretization (time interval = 6 hours)

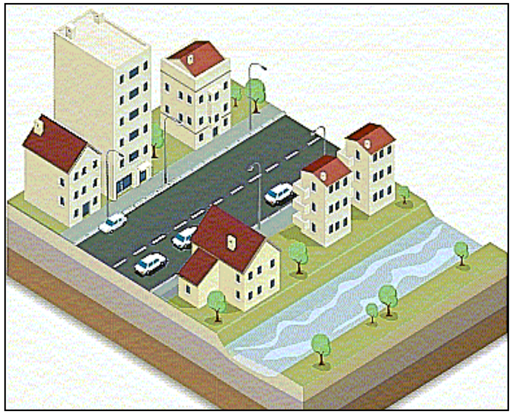




Optimal decision is **to postpone** the decision at t = 1.

Management of Risks due to Earthquakes

Large scale earthquake risk management

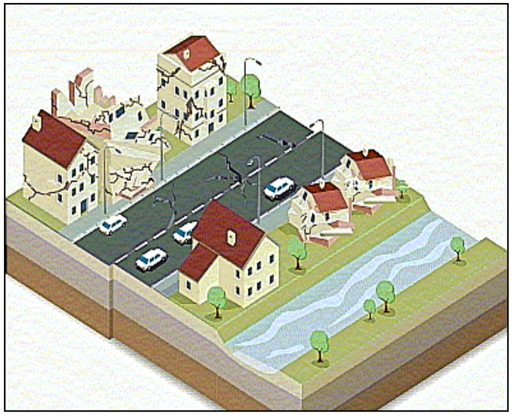


Before

Optimal allocation of available resources for risk reduction

- retrofitting
- rebuilding

in regard to possible earthquakes



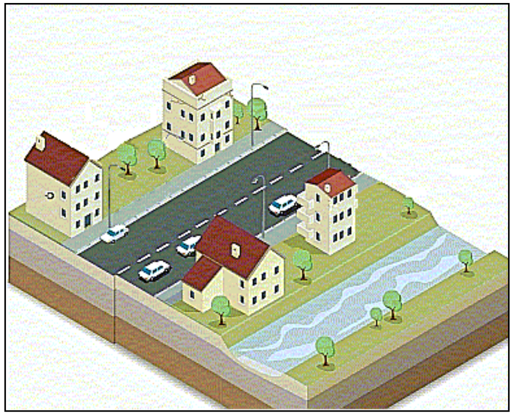
During

Damage monitoring/control

Emergency help and rescue

Aftershock hazard assessment

Identification of the seismic event



After

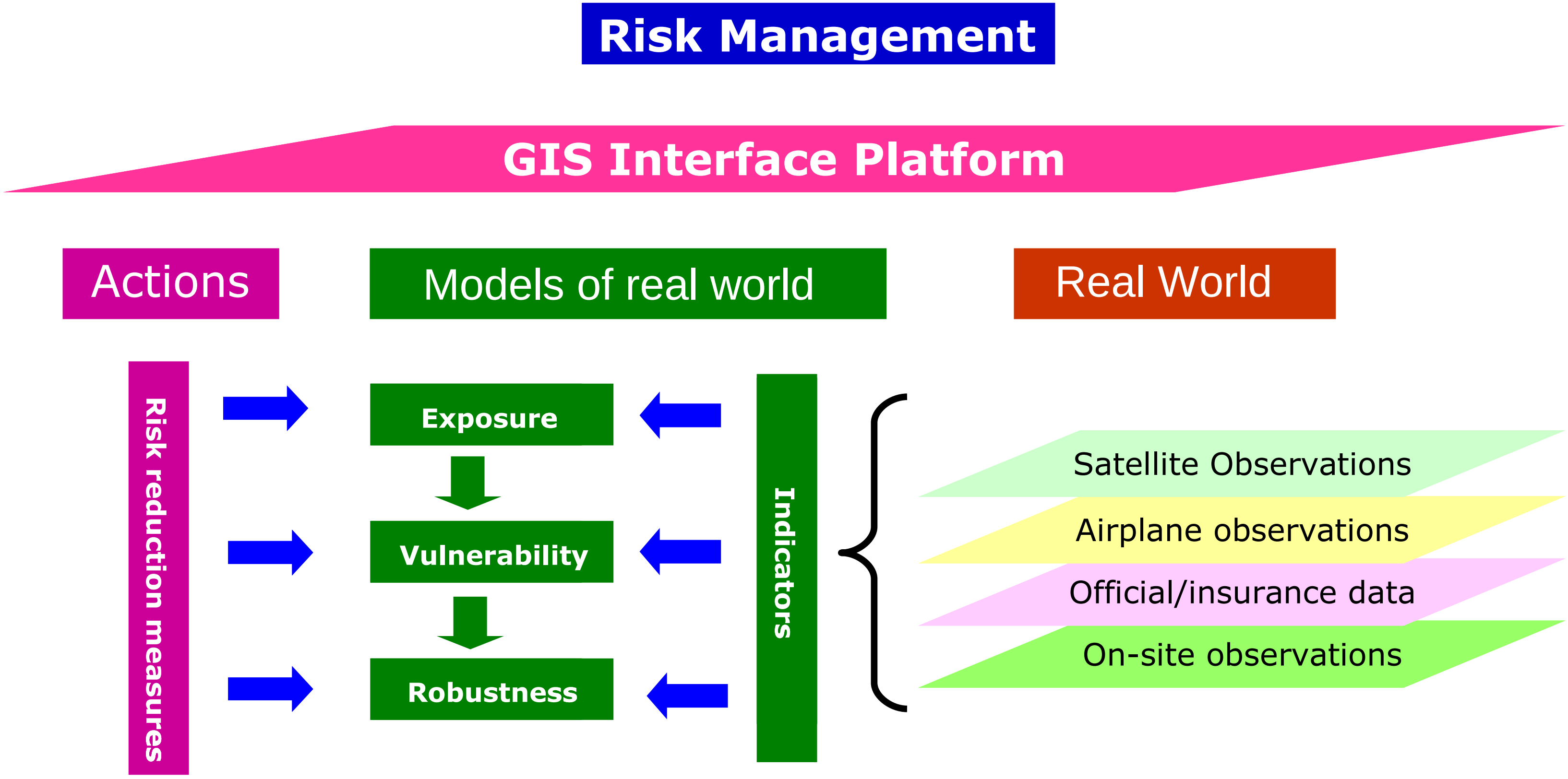
Rehabilitation of infrastructure functionality

Condition assessment and updating

Optimal allocation of resources for retrofitting and rebuilding

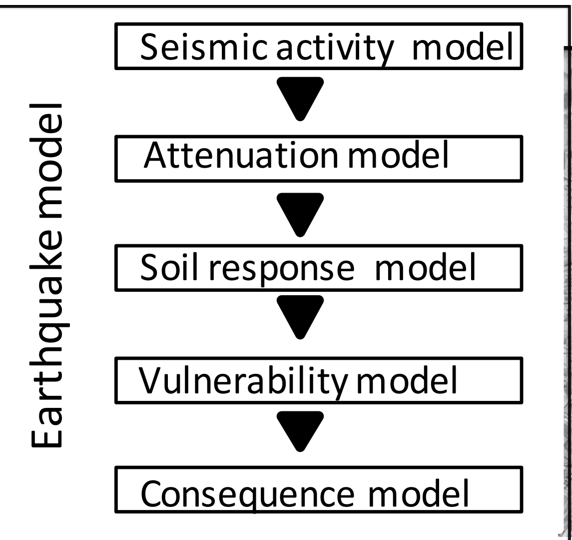
Management of Risks due to Earthquakes

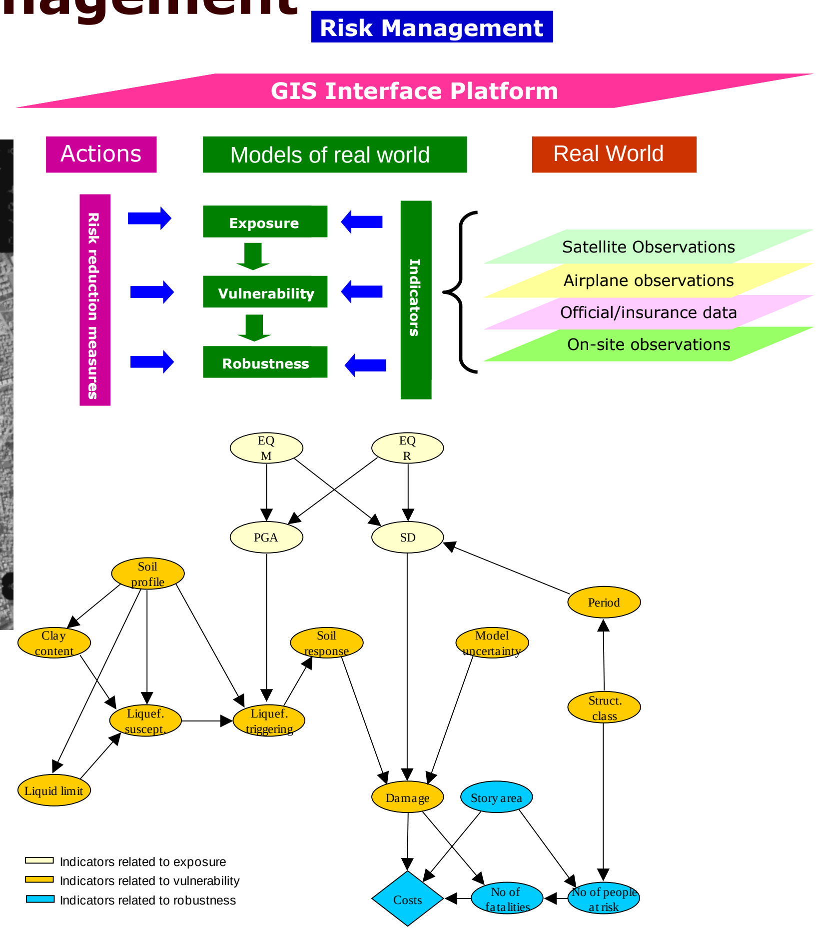
Risk assessment for large portfolios



Management of Risks due to Earthquakes

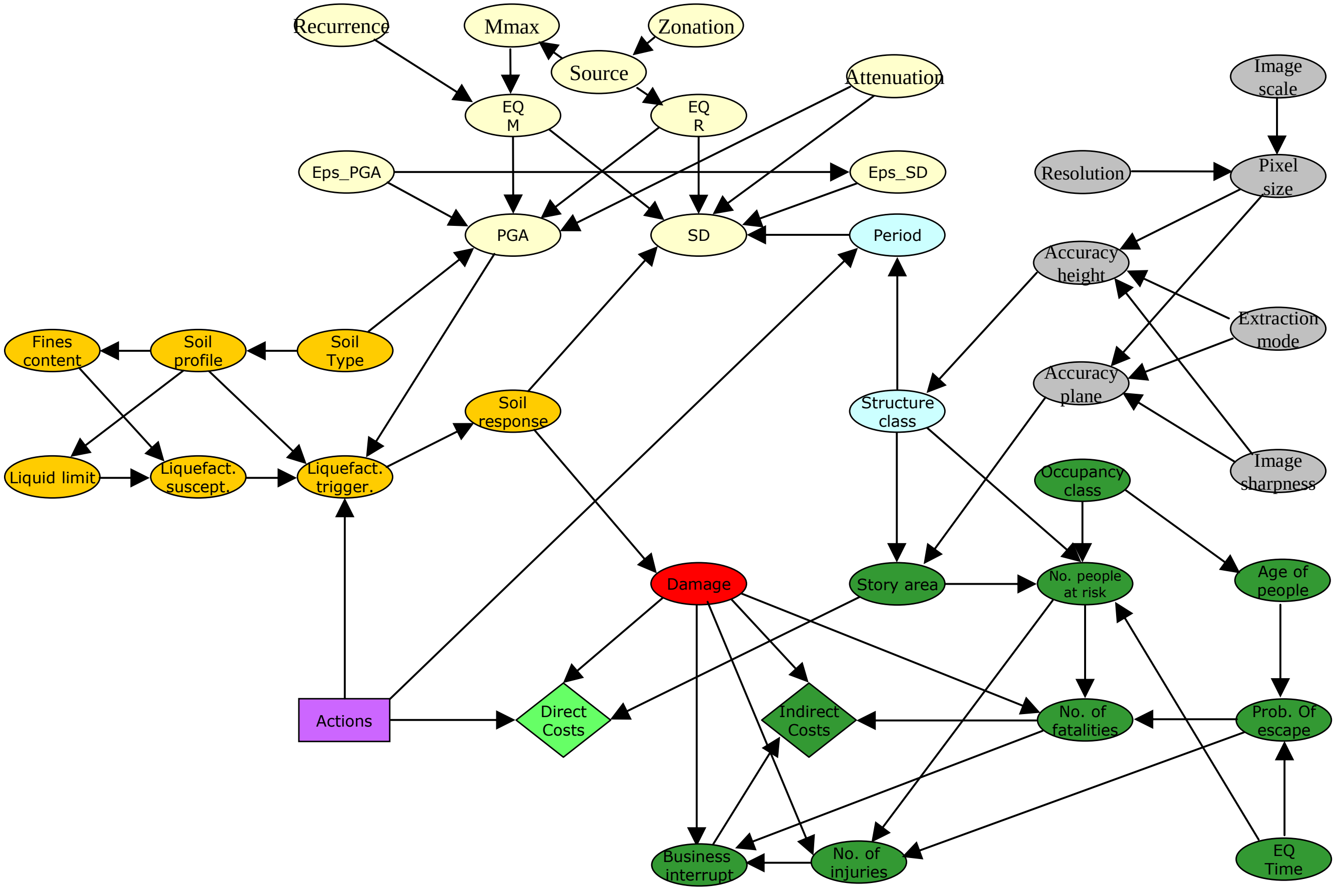
Large scale earthquake risk management





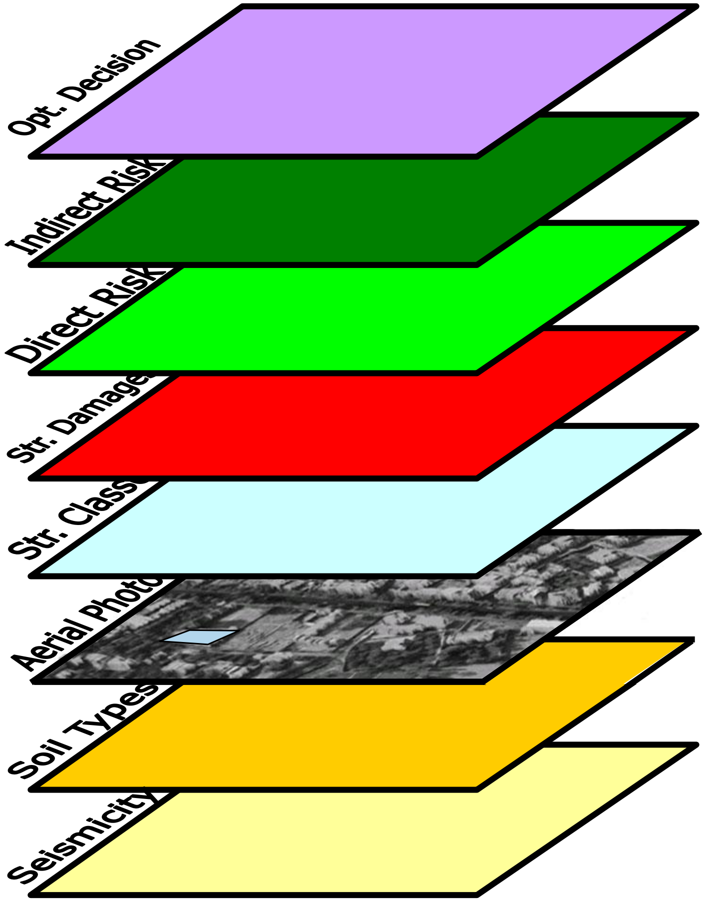
Management of Risks due to Earthquakes

Large scale earthquake risk management



Management of Risks due to Earthquakes

Large scale earthquake risk management



Before: - retrofitting of buildings
- improvement of soil
- information collection

During: - emergency management

After: - condition assessment

- Occupancy class
- Business interruption
- Fatalities
- Injuries
- Story area, etc.
- Age of people at risk
- Probability of escape
- Earthquake occurrence time

- Rebuilding costs
- Retrofitting costs
- Building content cost, etc.

- Structure type
- Number of stories
- Design code

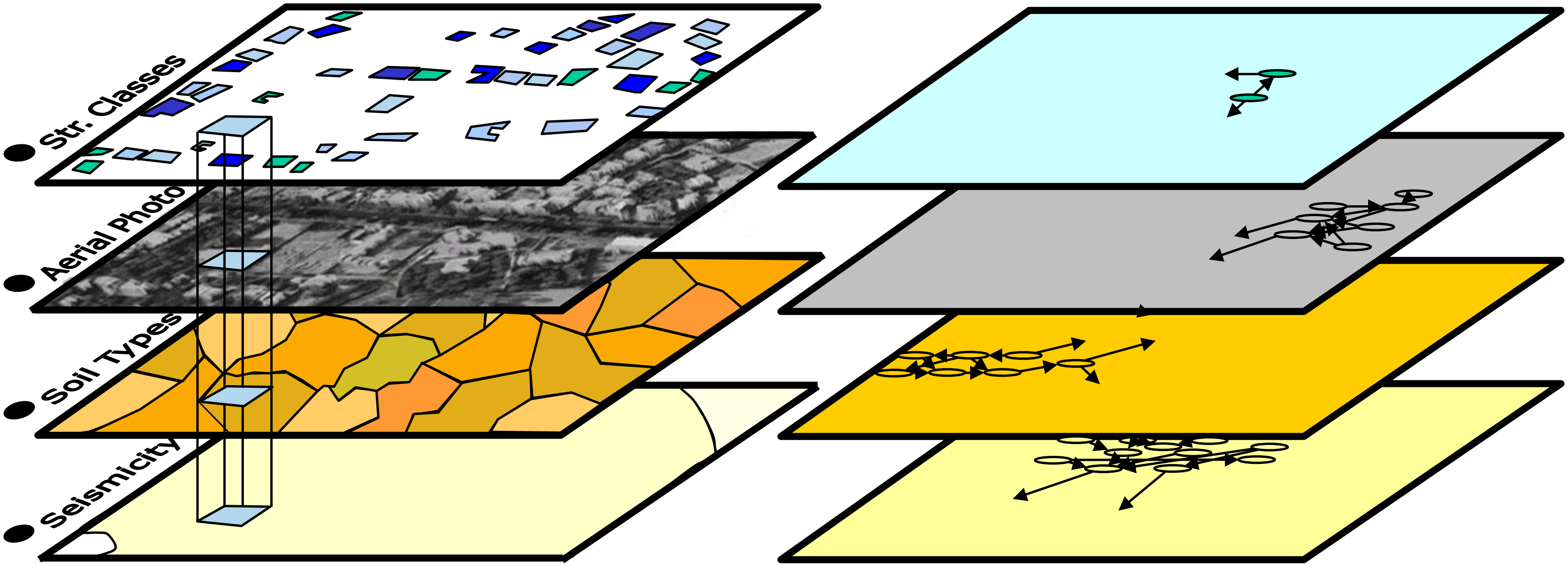
- Image scale
- Image resolution
- Extraction mode
- Image sharpness

- Soil type
- Soil profile
- Fines content, liquid limit
- Unit weight, water content, SPT

- Magnitude
- Distance
- Peak ground acceleration
- Spectral displacement
- Seismic souce model
- Attenuation model
- Reccurrence Model

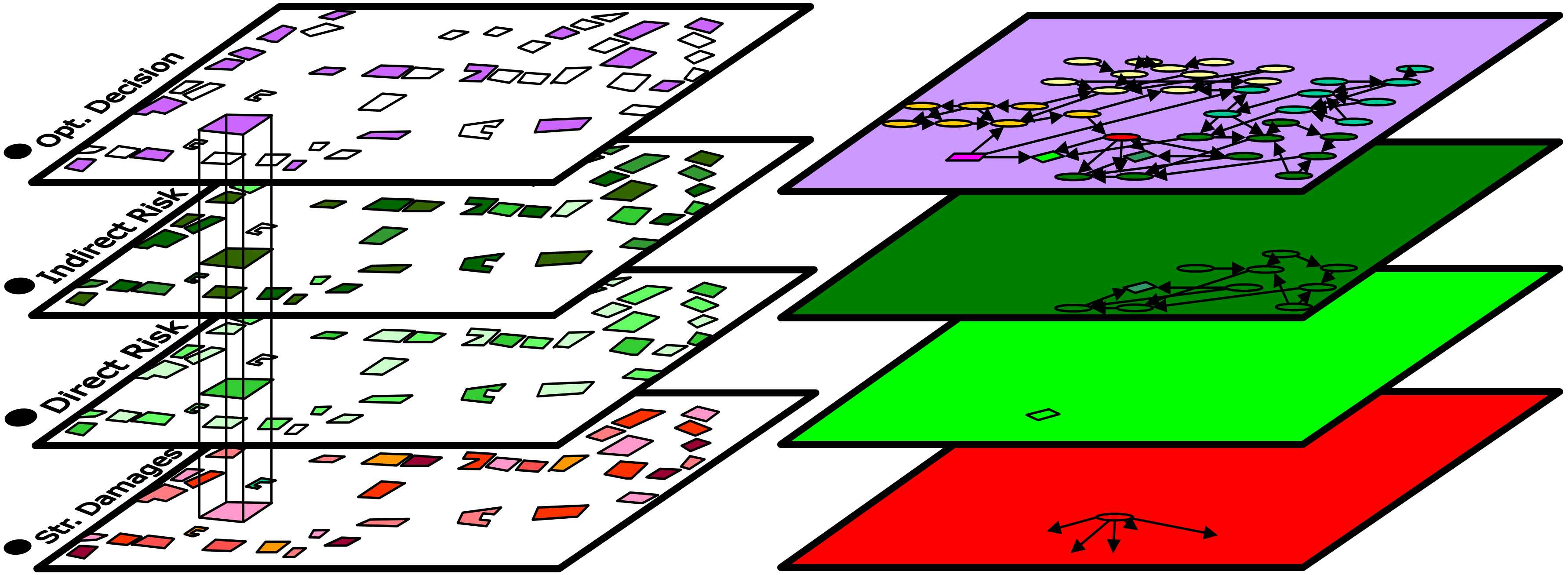
Management of Risks due to Earthquakes

Large scale earthquake risk management



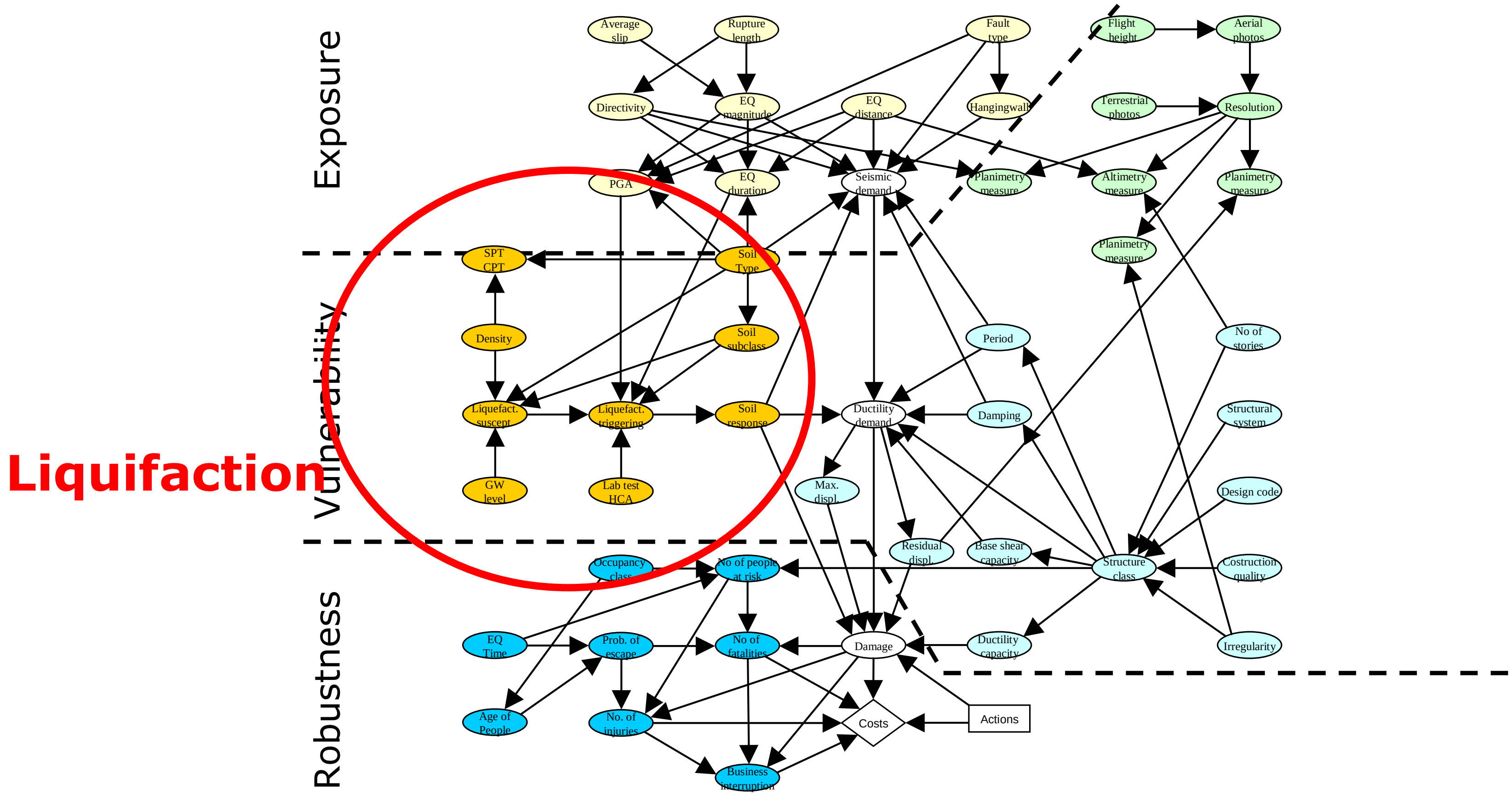
Management of Risks due to Earthquakes

Large scale earthquake risk management



Management of Risks due to Earthquakes

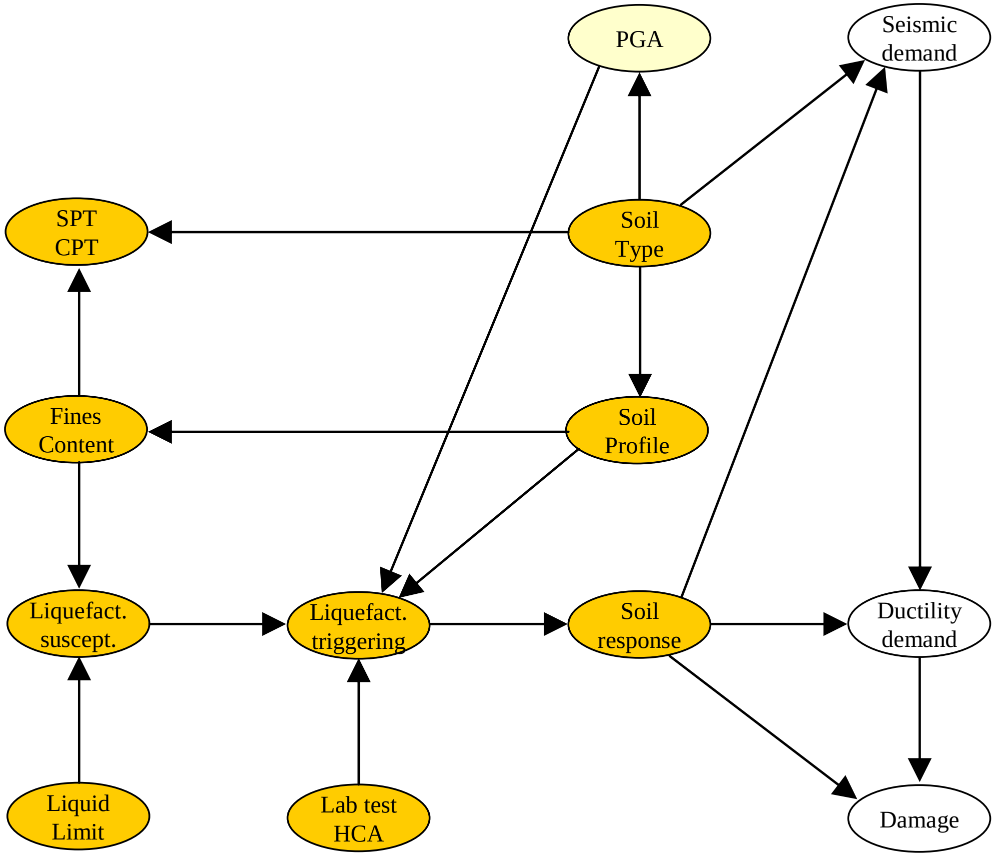
Large scale earthquake risk management



Management of Risks due to Earthquakes

Large scale earthquake risk management

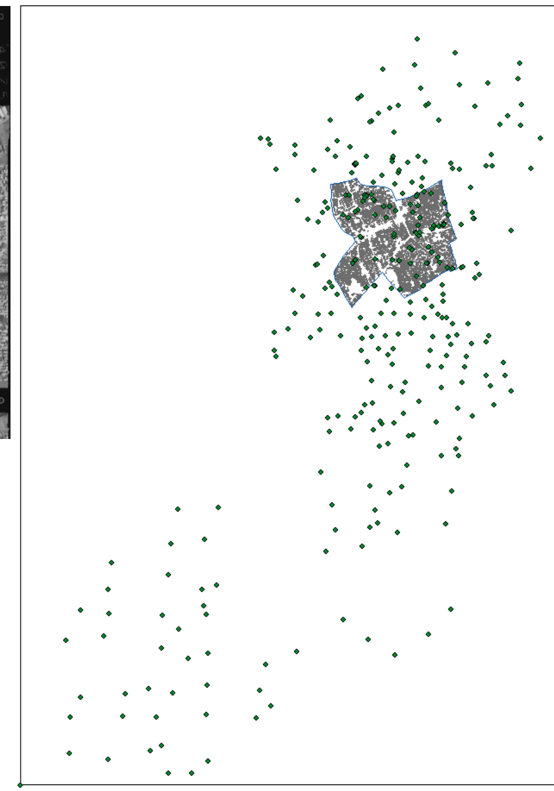
Condition indicators for liquefaction susceptibility of silty and sandy soils



Management of Risks due to Earthquakes

Large scale earthquake risk management

Vulnerability in regard to liquifaction

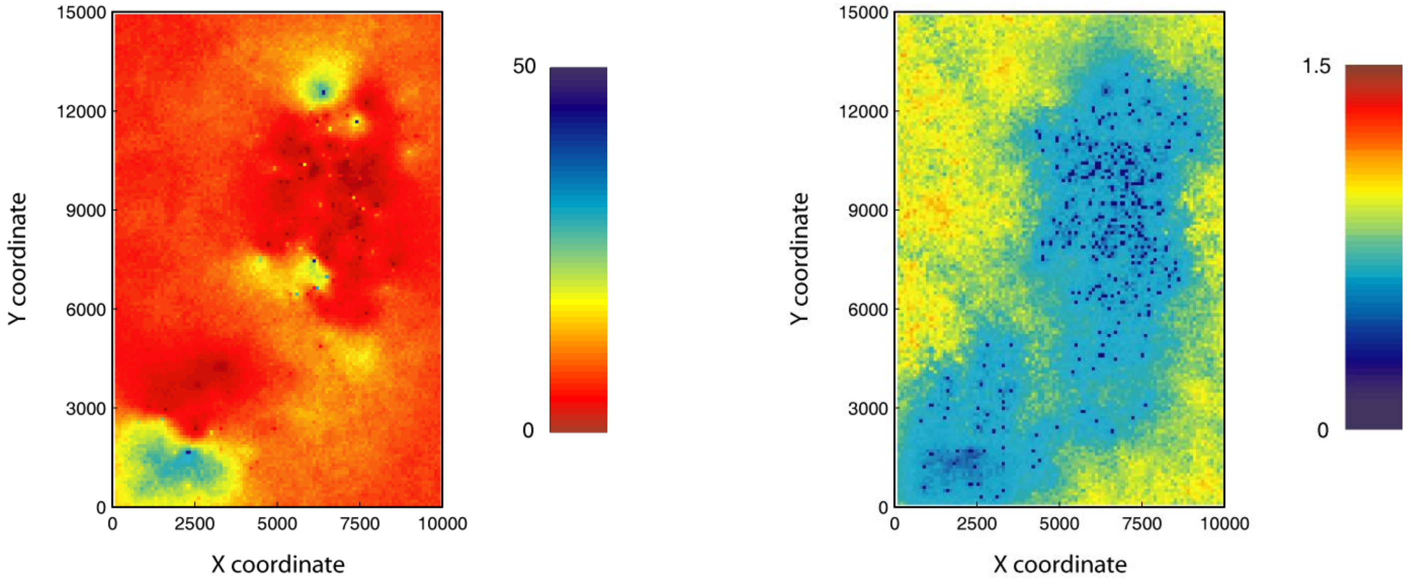


Locations of buildings and soil measurements

Management of Risks due to Earthquakes

Large scale earthquake risk management

Mean and coefficient of variation of conditional Standard Penetration Test (SPT) blowcounts $(N_1)_{60}$ simulations

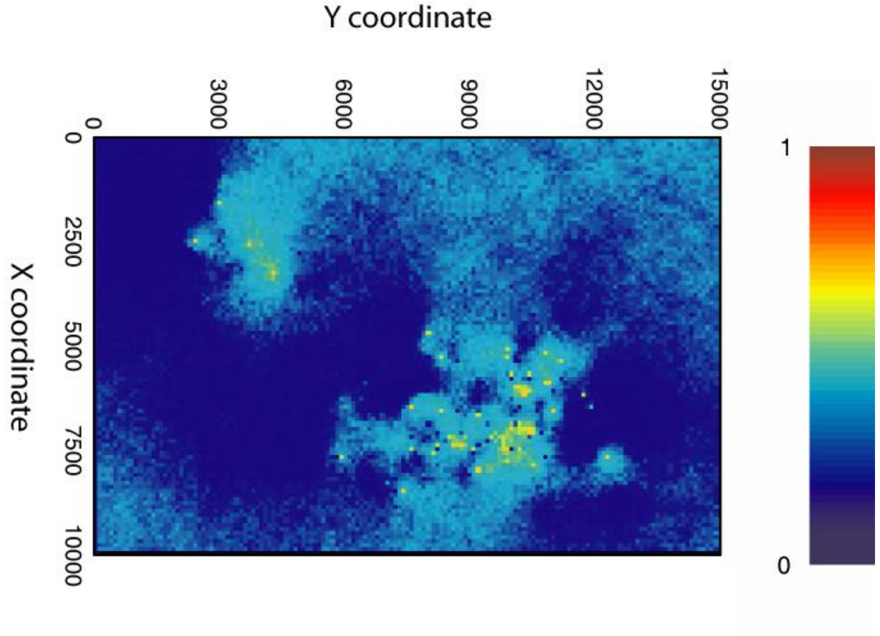


$(N_1)_{60}$ is the SPT blow count normalized to an overburden pressure of approximately 100 kPa and a hammer energy ratio of 60%.

Management of Risks due to Earthquakes

Large scale earthquake risk management

Probability of liquefaction at the study site,
given a M=7.5 earthquake causing a PGA of 0.3g



Management of Risks due to Earthquakes

Large scale earthquake risk management

Distribution of damage for a M=7.5 earthquake

Damage State

- Fully Operational
- Operational
- Life Safety
- Near Collapse
- Collapse

Management of Risks due to Earthquakes

Large scale earthquake risk management

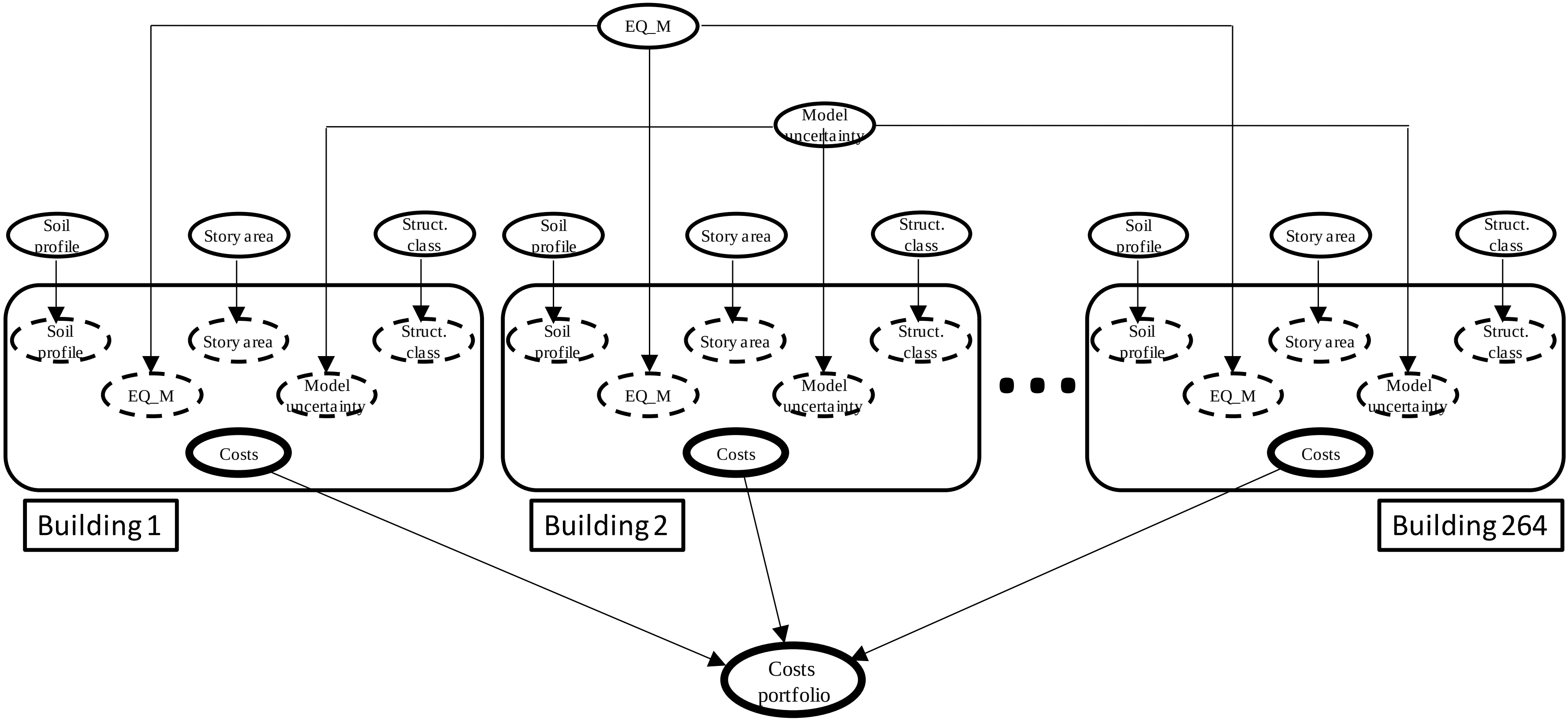
Total risks for a M=7.5 earthquake

Total Risk [$]

- 0
- 0 – 200’000
- 200’000 – 400’000
- 400’000 – 600’000
- 600’000 – 800’000

Management of Risks due to Earthquakes

Risk assessment for large portfolios



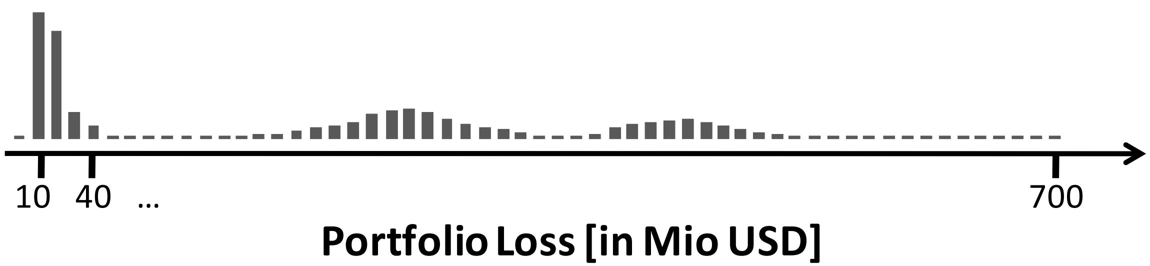
Management of Risks due to Earthquakes

Risk assessment for large portfolios

Without dependency

E[Costs]=25 Mio USD

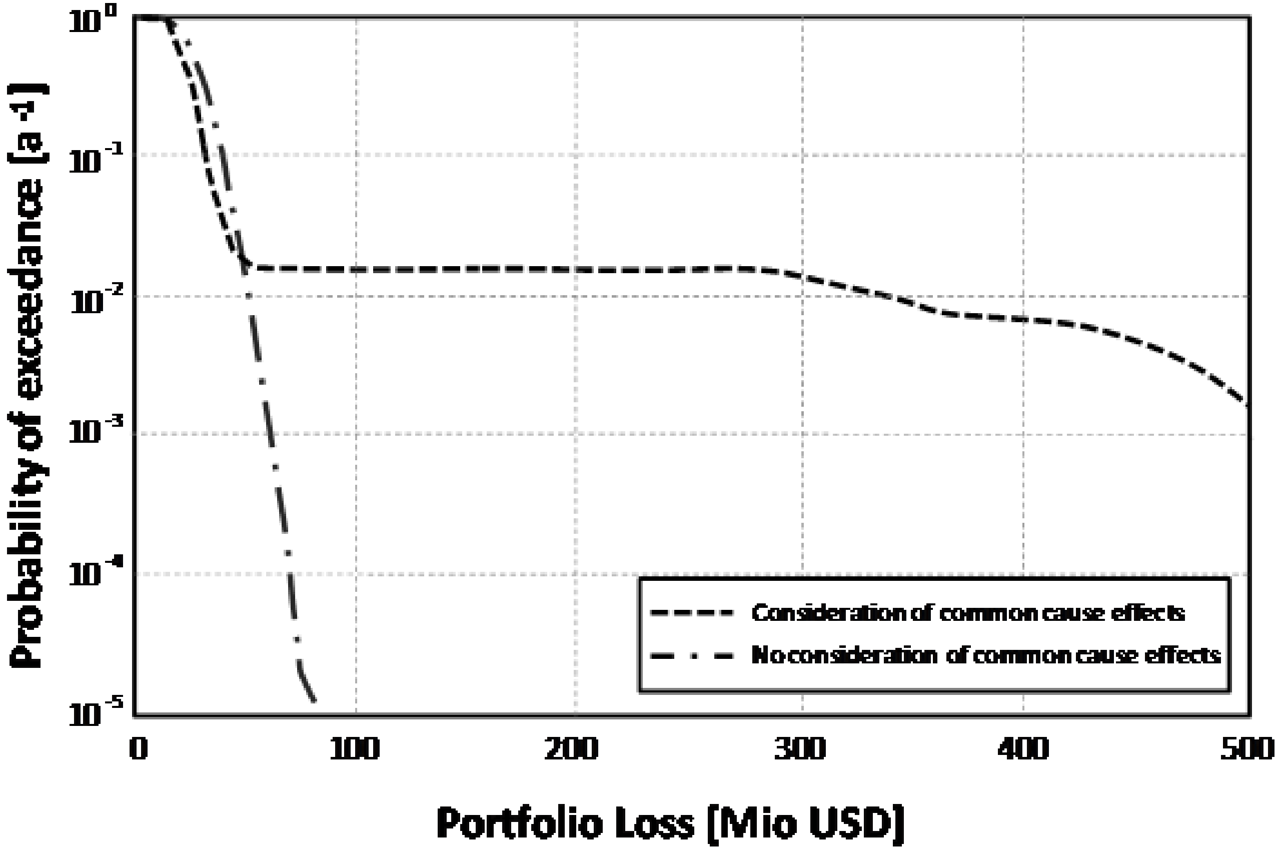
With dependency



E[Costs]=25 Mio USD

Management of Risks due to Earthquakes

Risk assessment for large portfolios



Concluding Remarks

- **As engineers we have an obligation to do our best to help the society to manage natural hazards**

- **Risk assessment and risk management considering natural hazards necessitates that certain requirements are fulfilled in the modeling**
  - Stakeholders
  - Processes

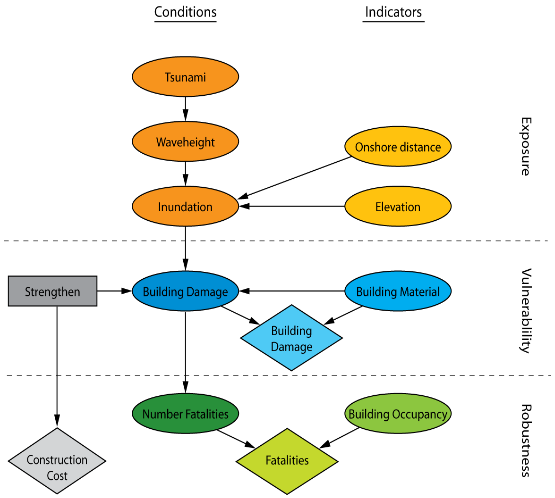
- **A general framework for risk assessment is presented based on a guideline by the JCSS, adapted to natural hazards**

- **The framework is applied to different hazards**

Concluding Remarks

- Main features are:
  - Explict consideration of direct and indirect consequences
  - Formulation of hiearchical Bayesian models for risk assessment
  - Utilization of indicators
  - Facilitates risk updating
  - Provides expected losses as function of decison alternatives
  - Provides explicit modeling and calculation of loss exceedance curves taking into account dependencies in the portfolio

- Lots of challenges ahead of us ☺



CCSS, ETH Zurich, September 2009

Recent Developments in the Management of Risks due to Large Scale Natural Hazards

Thanks for your attention !