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SPECIAL MOBILITY STRAND

Resilience in the Context of Insurance

Michael Havbro Faber
University of Tirana, Albania, May 9, 2019

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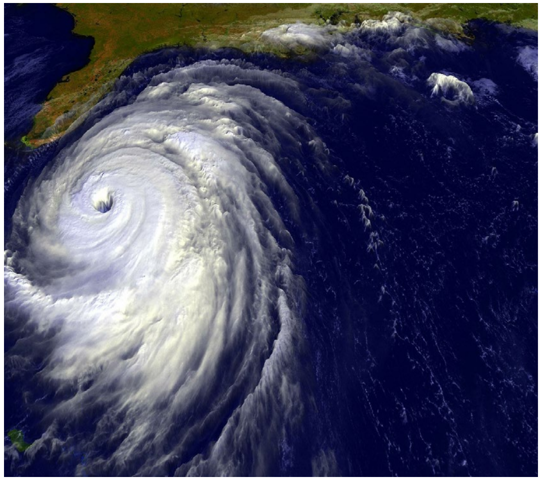

K-FORCE Lectures
University of Tirana
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Resilience in the Context of Insurance

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Department of Civil Engineering
Aalborg University, Denmark

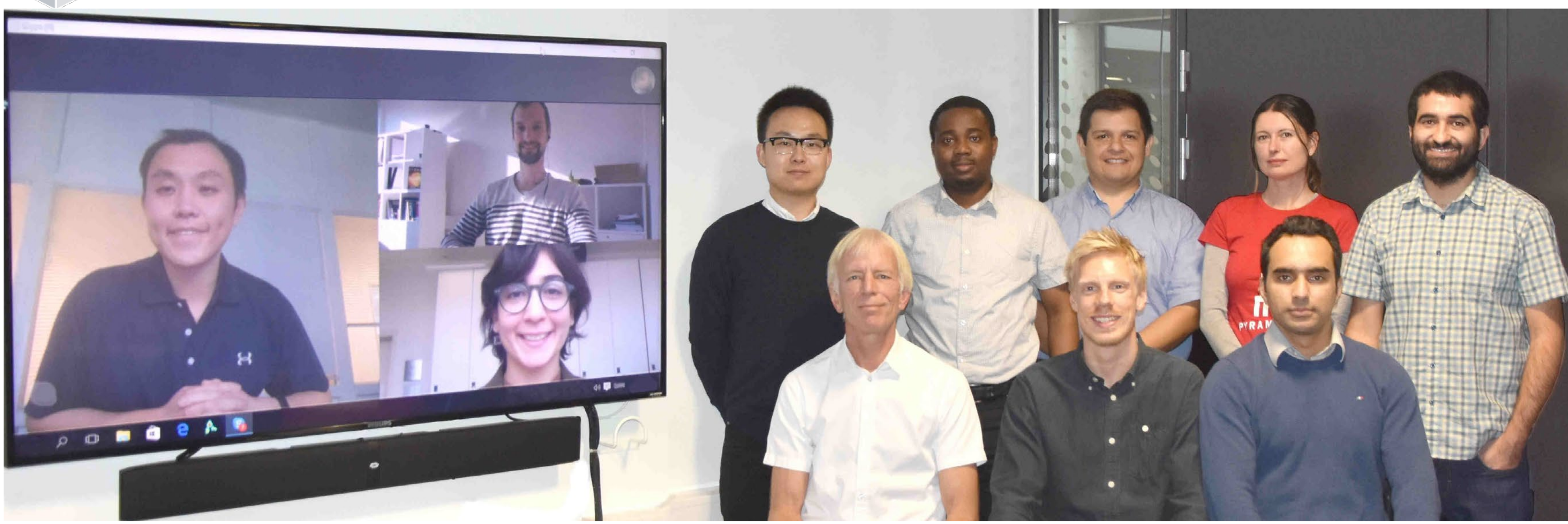
Risk
Reliabiliy
Resilience
Sustainability
Built
Environment

K-FORCE

Introduction – My Group at Aalborg University

Introduction – Members of my Team

RISK, RESILIENCE AND SUSTAINABILITY IN THE BUILT ENVIRONMENT



Introduction – Collaboration Partners

Contents of Presentation

- Introduction and problem setting
- A few examples (earthquakes, typhoons)
- Systems in risk financing
- Resilience and business interruption
- General insights on complex systems risks
- Closing remarks

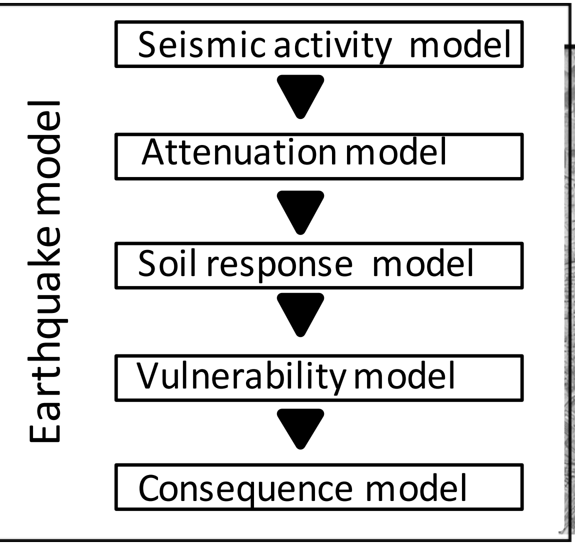
Where I Come From

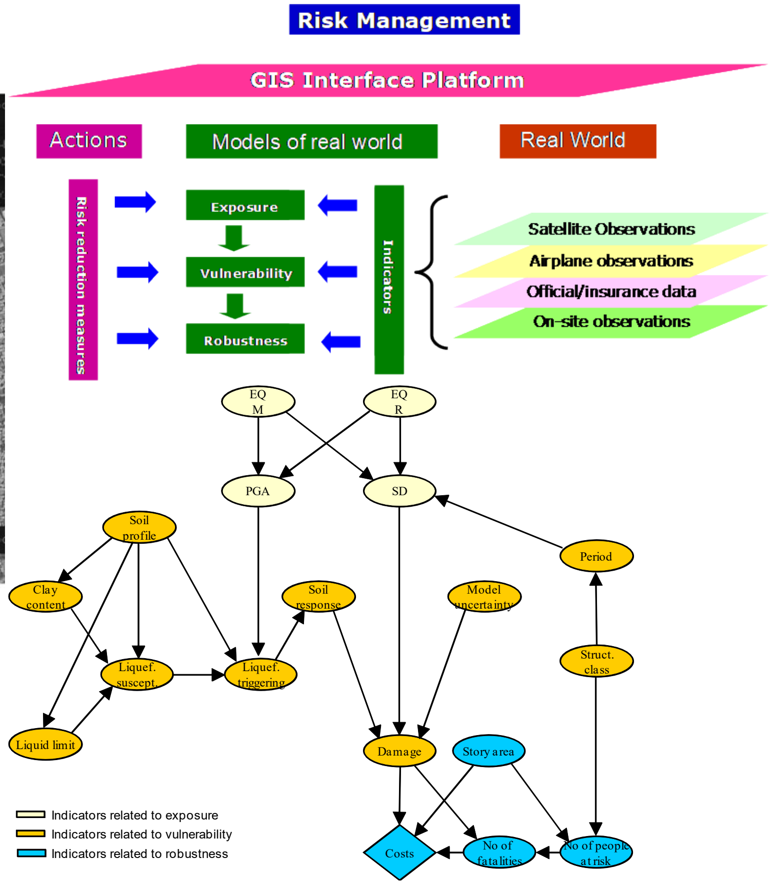
Probability theory, statistics and decision analysis

- Structural reliability (random fields, outcrossing theory)
- Design basis for structures
- Inspection and maintenance planning
- Robustness of structures
- Risk management
- Natural hazards risk modeling and management
- Fire risk modeling and management
- Terrorism risks
- Catastrophic risks
- Portfolio loss estimation
- Life safety management and criteria
- Value of Information analysis
- Resilience of systems
- Quantification of sustainability

A Few Examples - Earthquakes

Large scale earthquake risk management



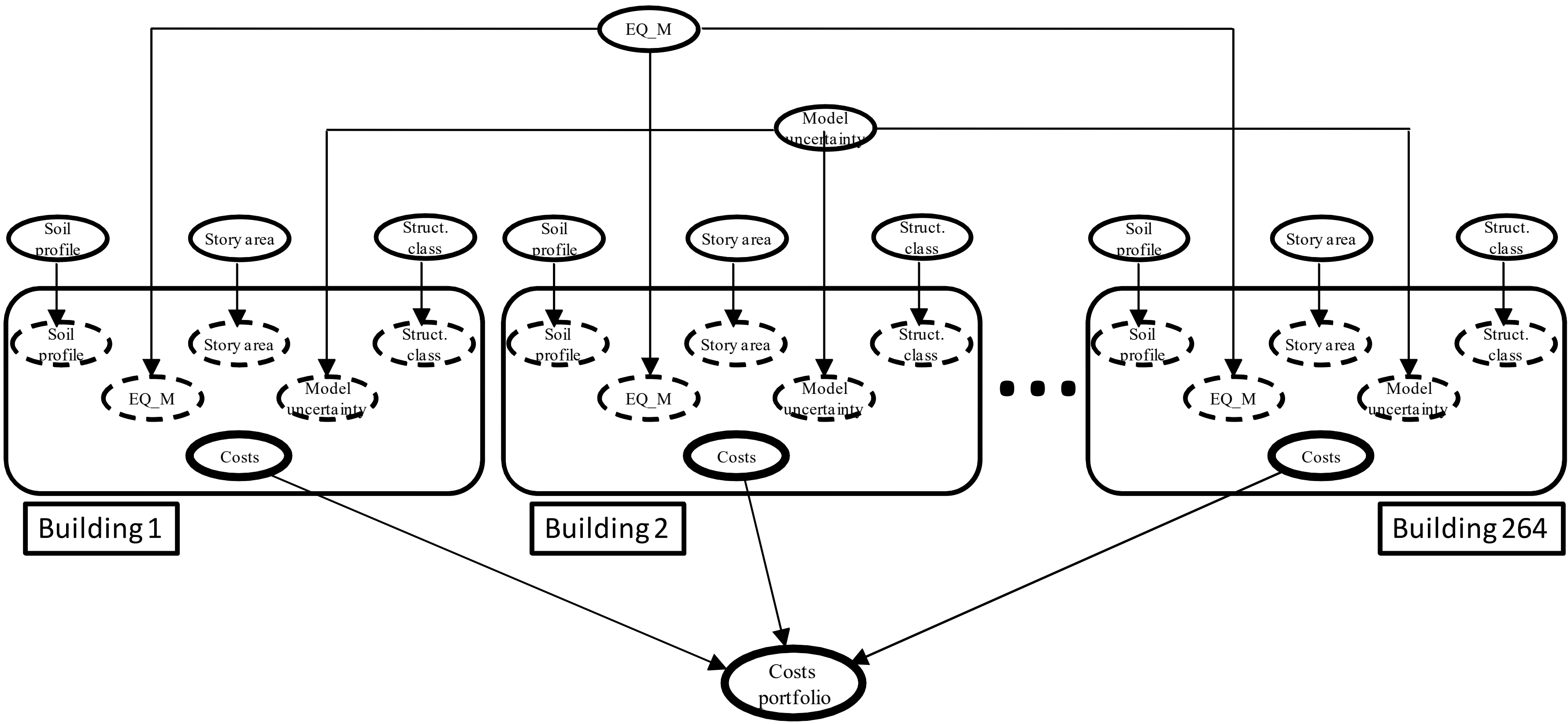


Merci project, see www//merci.ethz.ch

PhD Thesis of Y. Bayraktarli, available on https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/149520/eth-29055-01.pdf

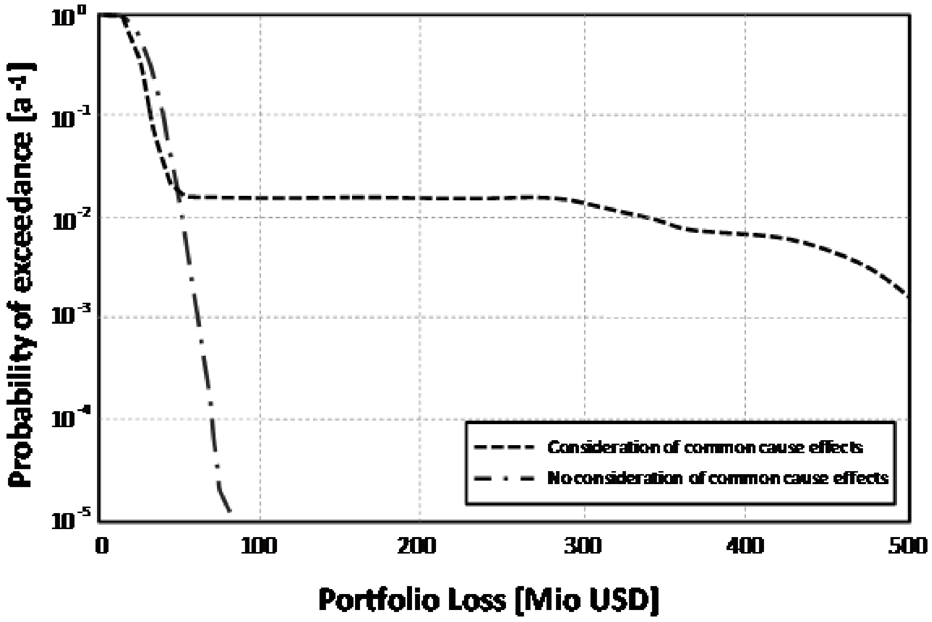
A Few Examples - Earthquakes

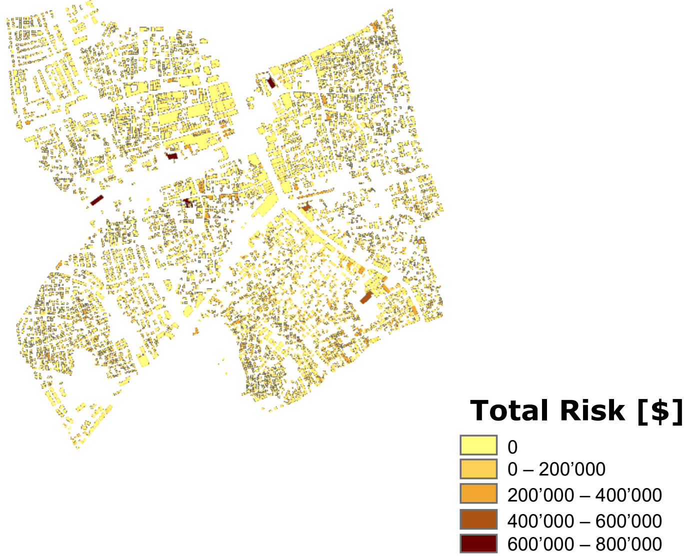
Large scale hazards risk management



A Few Examples - Earthquakes

Risk assessment for large portfolios

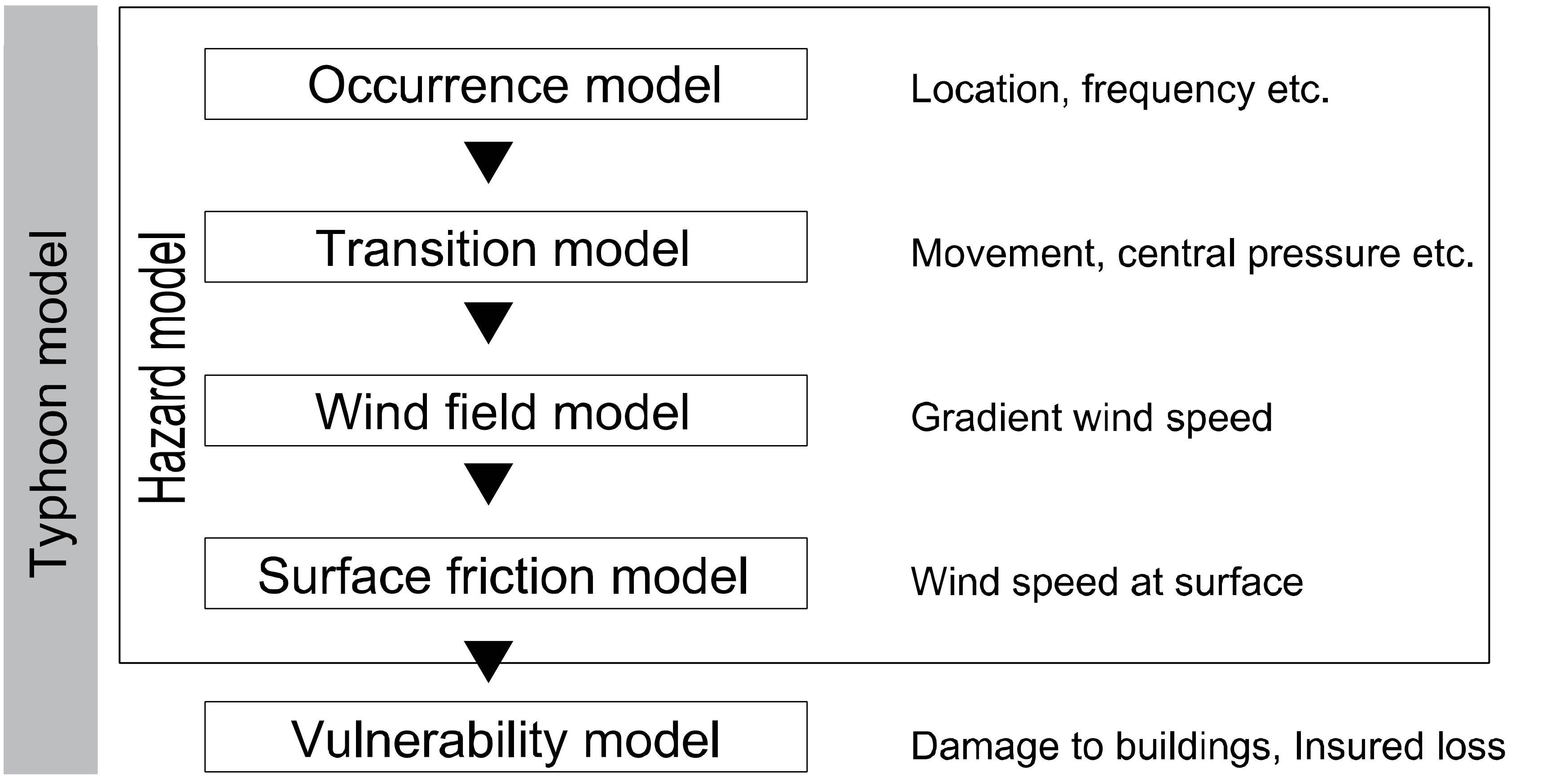




A Few Examples - Typhoons

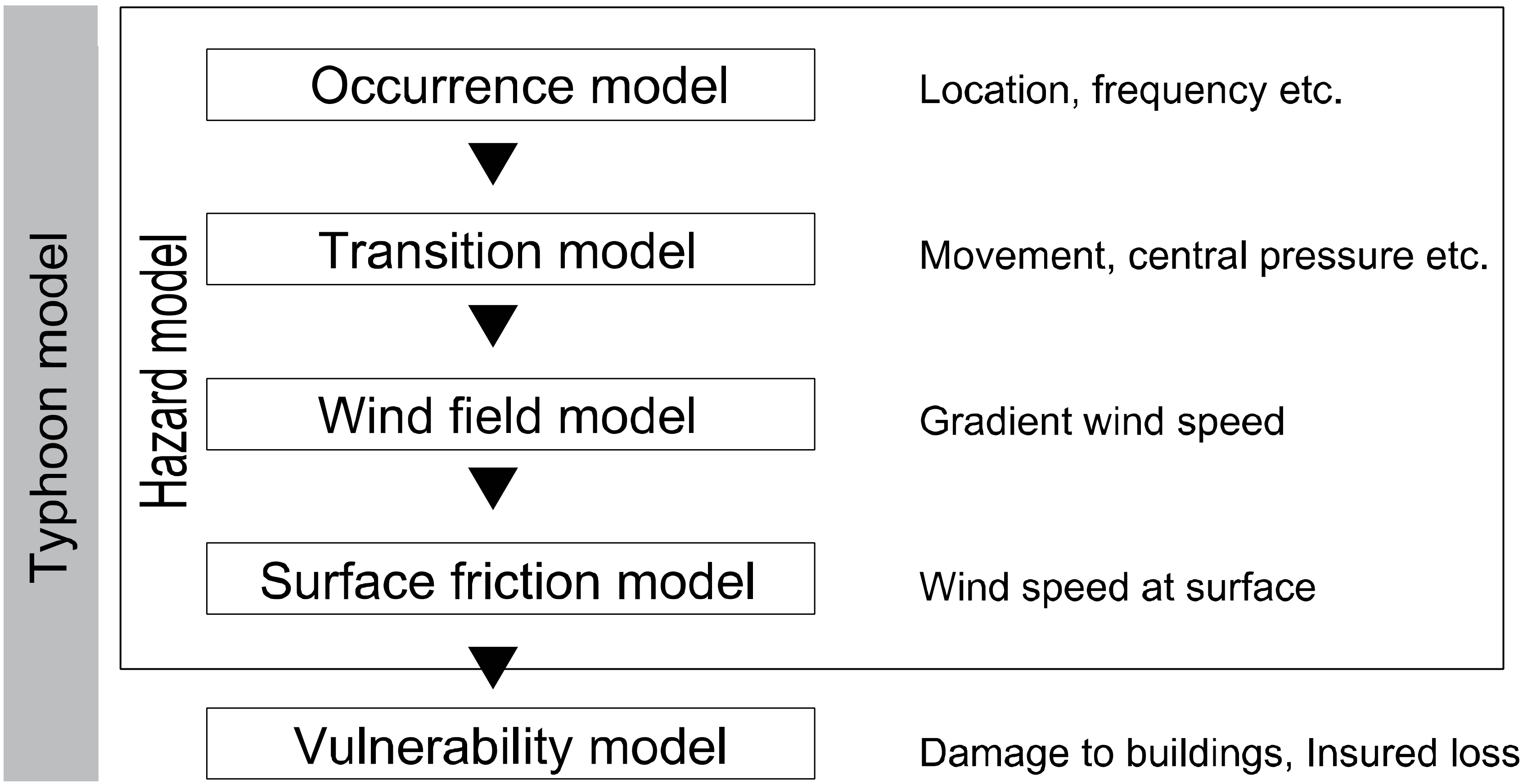
Aon Benfield
Modeling typhoon risks for the entire Japan

Components of typhoon model



A Few Examples - Typhoons

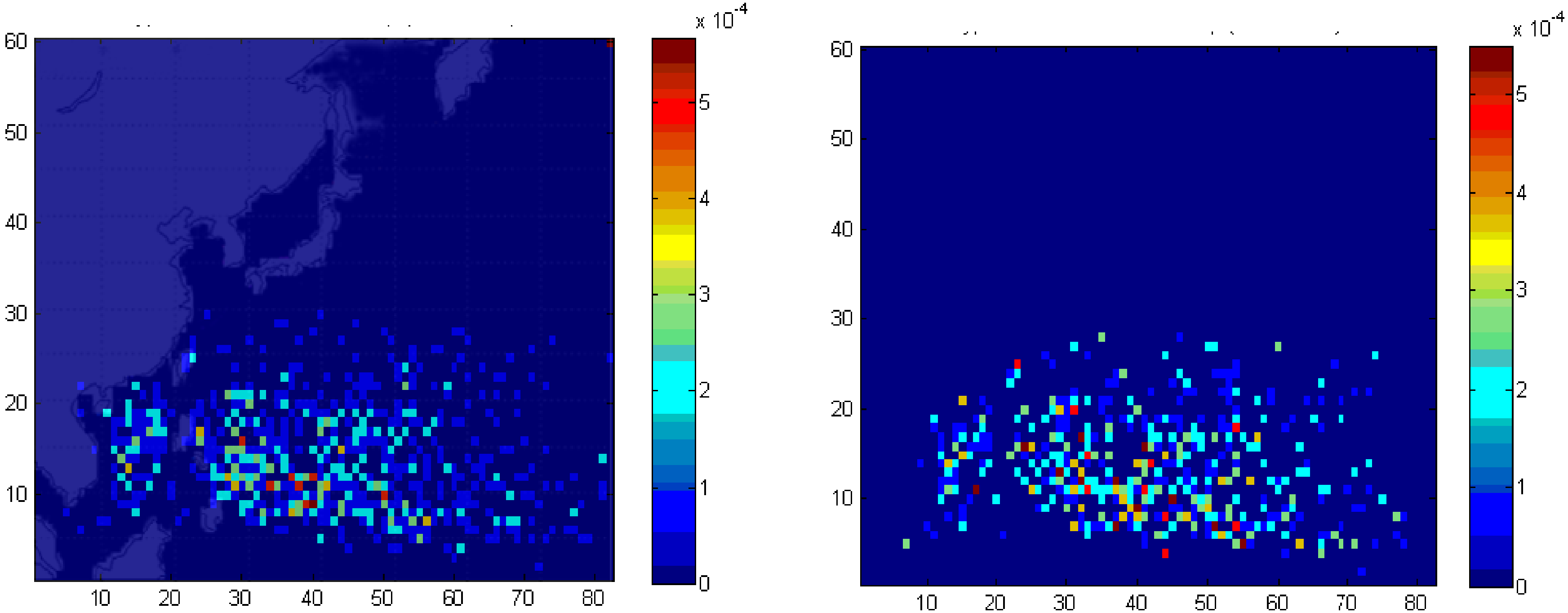
Components of typhoon model



PhD thesis: Graf, M. (2012), Bayesian framework for probabilistic modelling of typhoon risks. ETH Zurich
Available on: http//www.research-collection.ethz.ch/mapping/eserv/eth:6224/eth.

A Few Examples - Typhoons

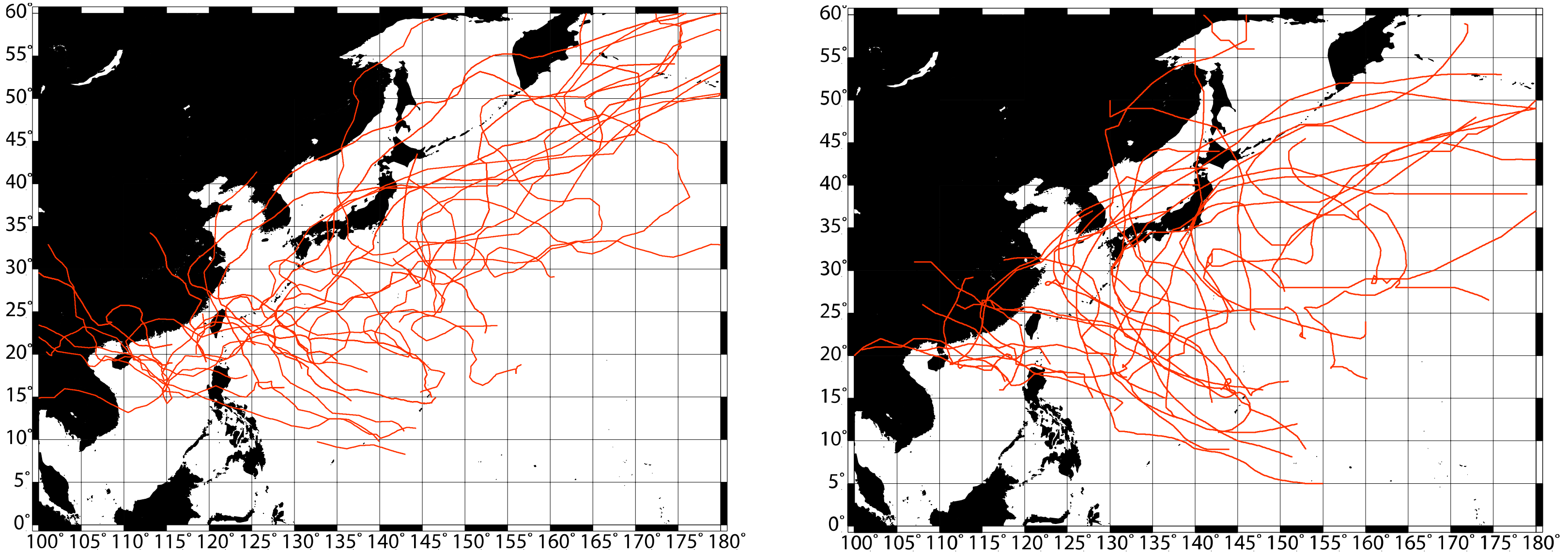
Comparison between historical data and simulation results



Occurrence rates (left: historical data, right: simulation results).

A Few Examples - Typhoons

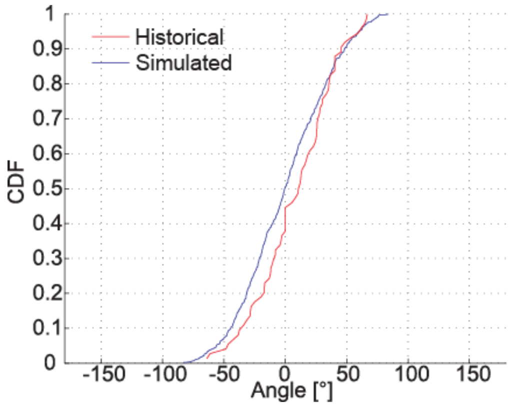
Comparison between historical data and simulation results

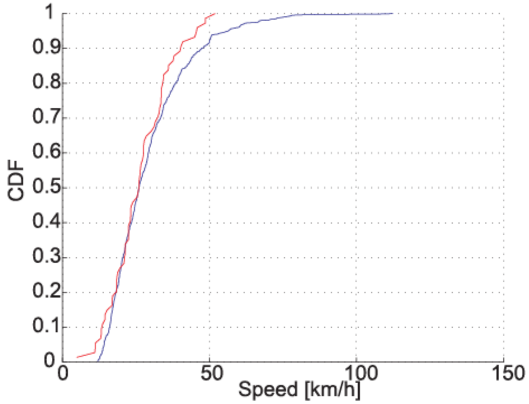


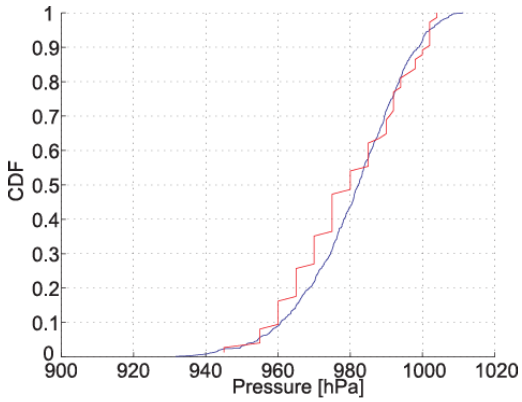
Typhoon tracks in August
(left: historical data, right: simulation results).

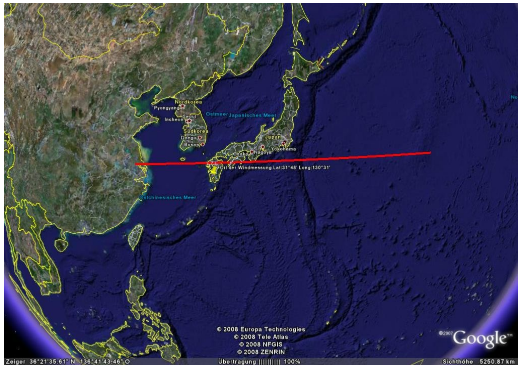
A Few Examples - Typhoons

Comparison (continued)



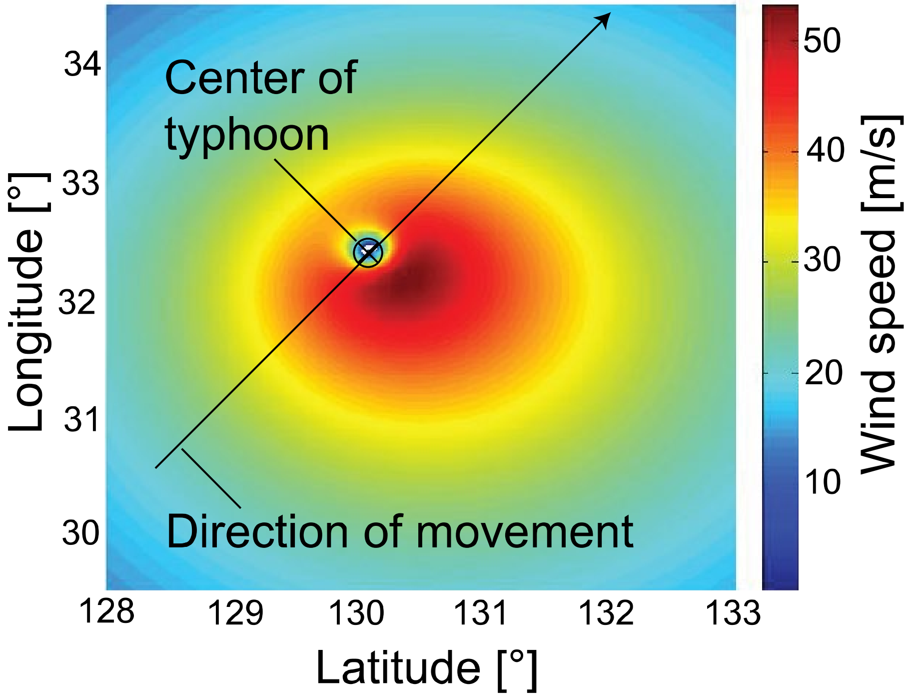






A Few Examples - Typhoons

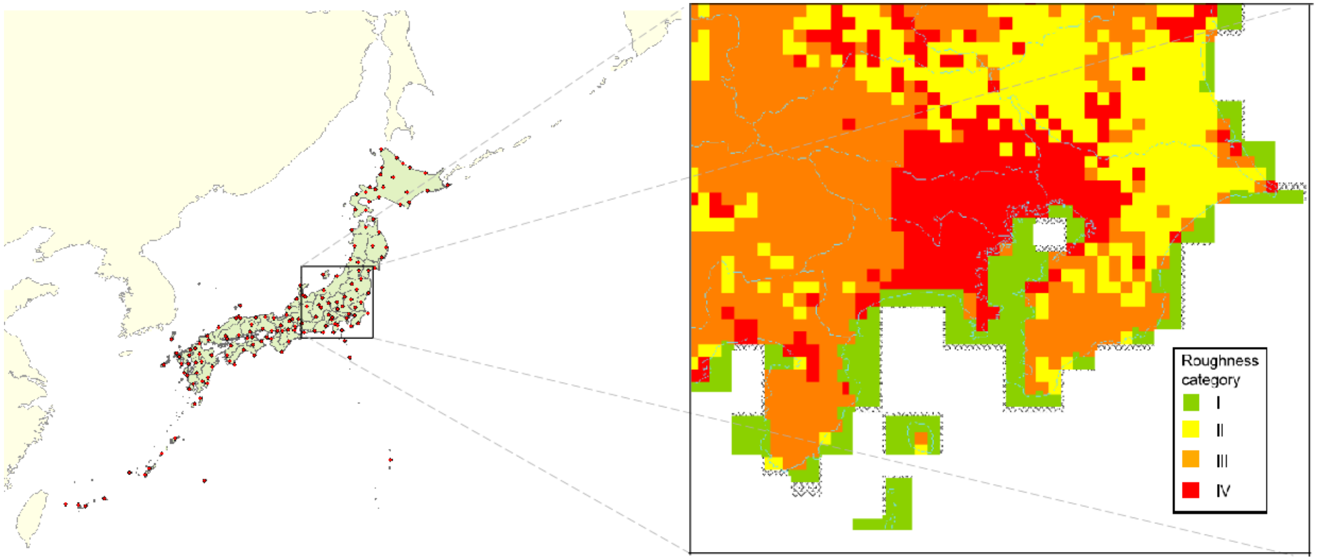
Wind field model



The wind field of typhoon Bart at gradient height reproduced using the model.

A Few Examples - Typhoons

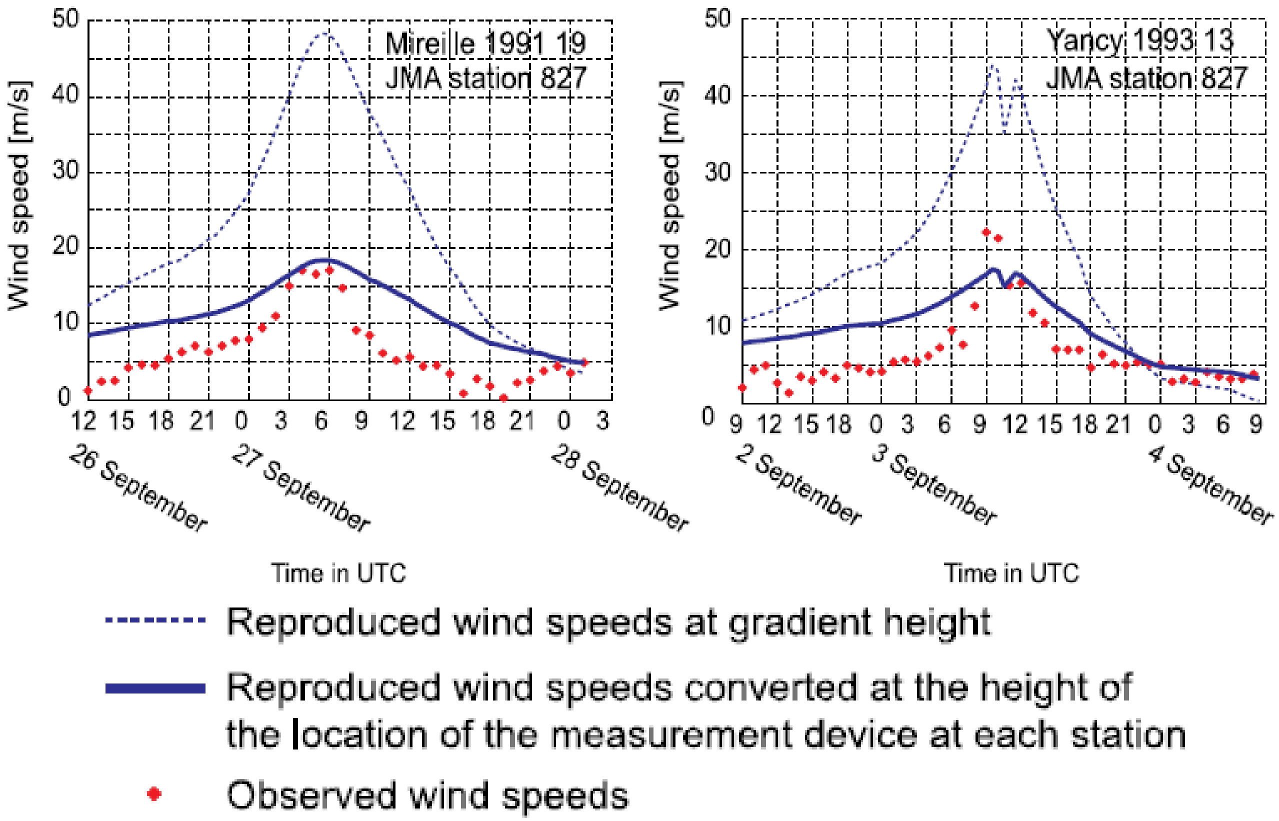
Surface friction model



Roughness category	Terrain type	Roughness length [m]
I	Very flat terrain	0.004
II	Open terrain (grassland, few tres)	0.01
III	Suburban terrain (buildings, 3-5 [m])	0.1
IV	Dense urban (buildings, 10-30[m])	1

A Few Examples - Typhoons

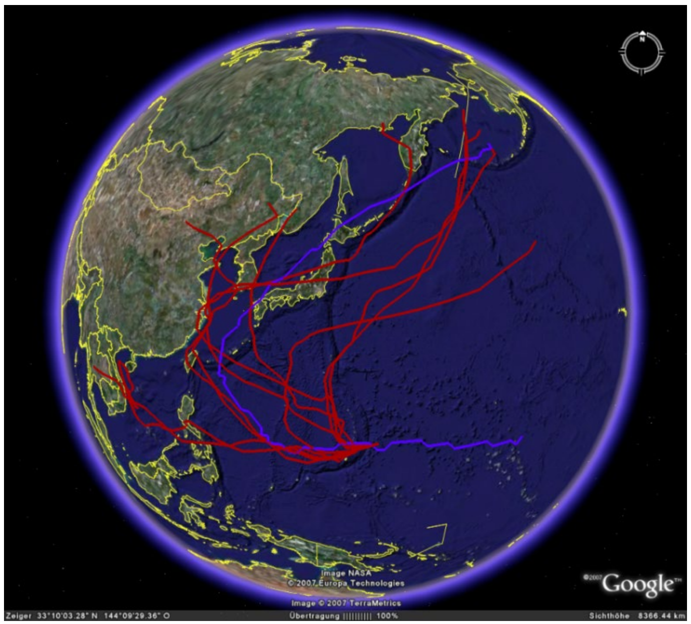
Comparison between observed wind speed and reproduced wind speed

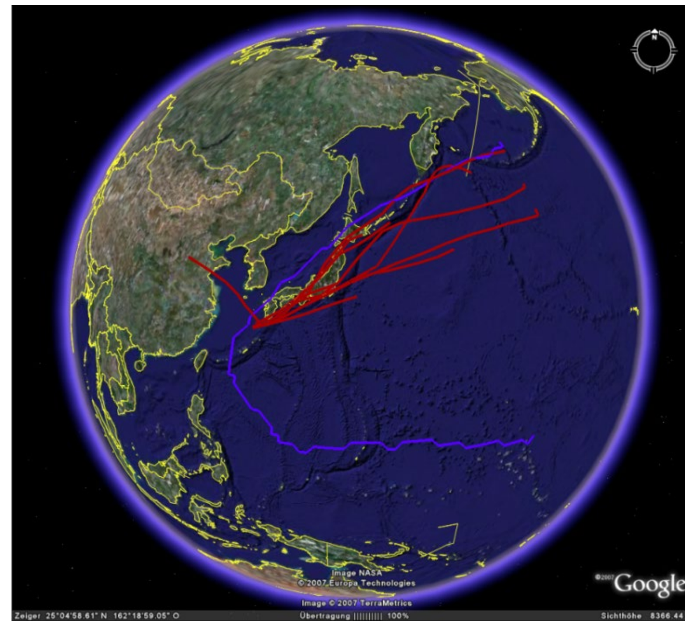


A Few Examples - Typhoons

Conditional simulation

- enables to estimate the loss due to approaching typhoons in near-real time (near-real time updating).

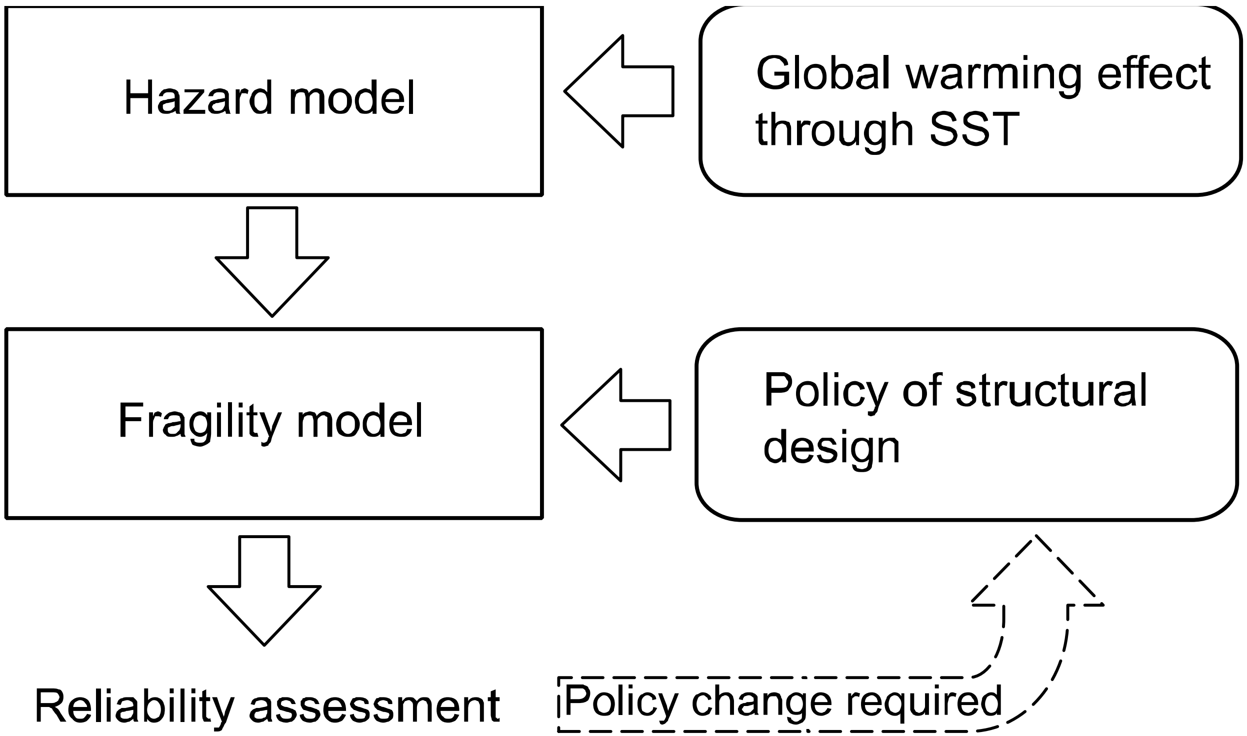




Conditional simulations when the typhoon is far from Japan (left) and close to Japan (right).

A Few Examples - Typhoons

Approach for assessing the effect of global warming on structural reliability



A Few Examples - Typhoons

Incorporation of the global warming effect into the typhoon model

- The global warming effect is considered through the change of the sea surface temperature (SST).

→ SST is the input to the transition model.

- However, the occurrence rate of typhoons is assumed not to change.

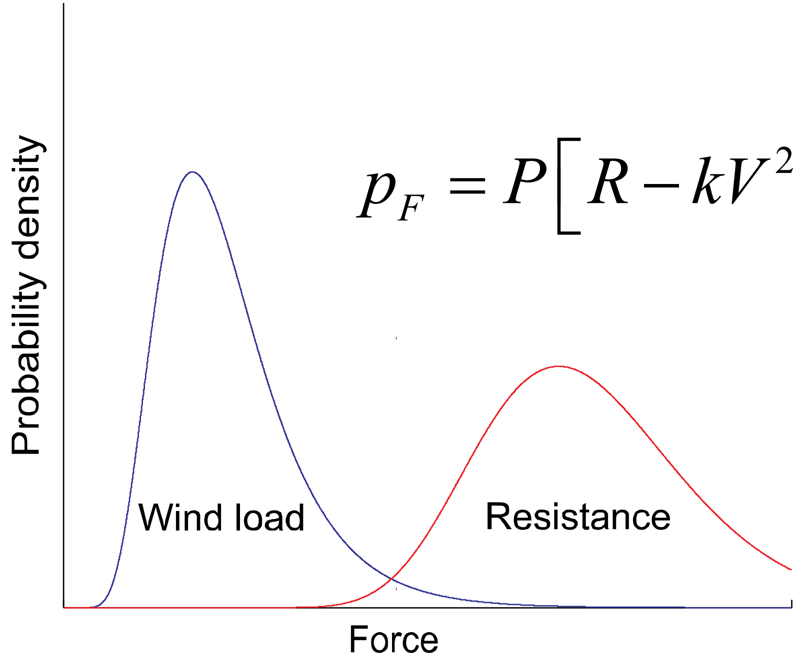
A Few Examples - Typhoons

Design problem

- Target probability of failure: $p_F \approx 10^{-5}\left[1/year\right]$

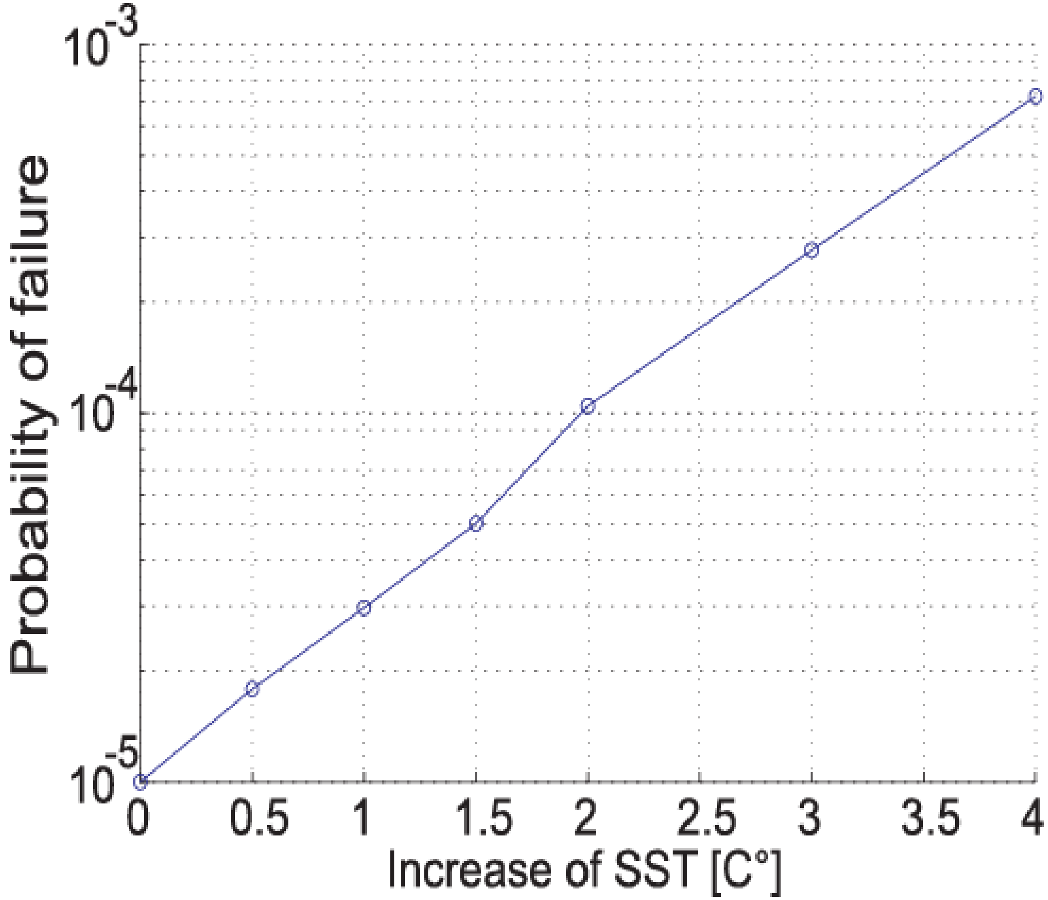
  (the JCSS Probabilistic model code (JCSS, 2002))

$$p_F = P\left[R - kV^2 < 0\right]$$



A Few Examples - Typhoons

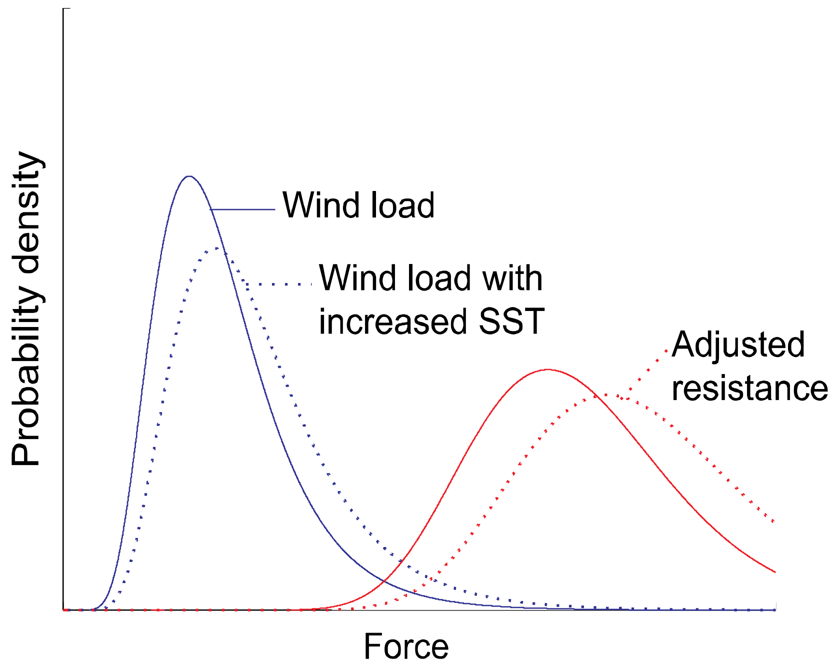
Change of the probability of failure



A Few Examples - Typhoons

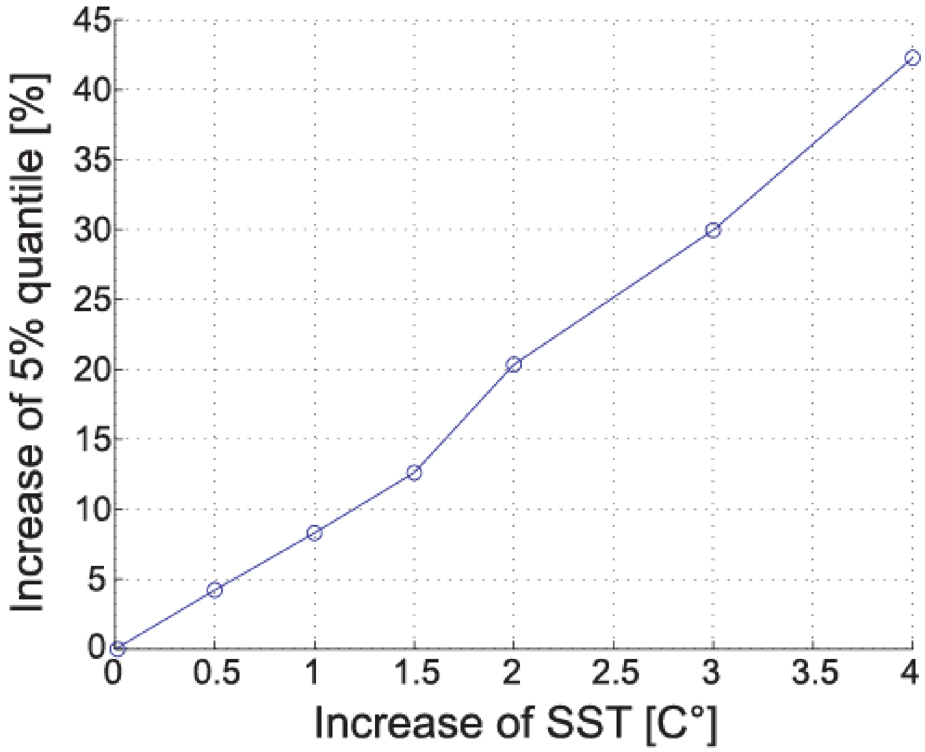
Adaption of structural design

- A change of the design policy may be required to maintain the target reliability.



A Few Examples - Typhoons

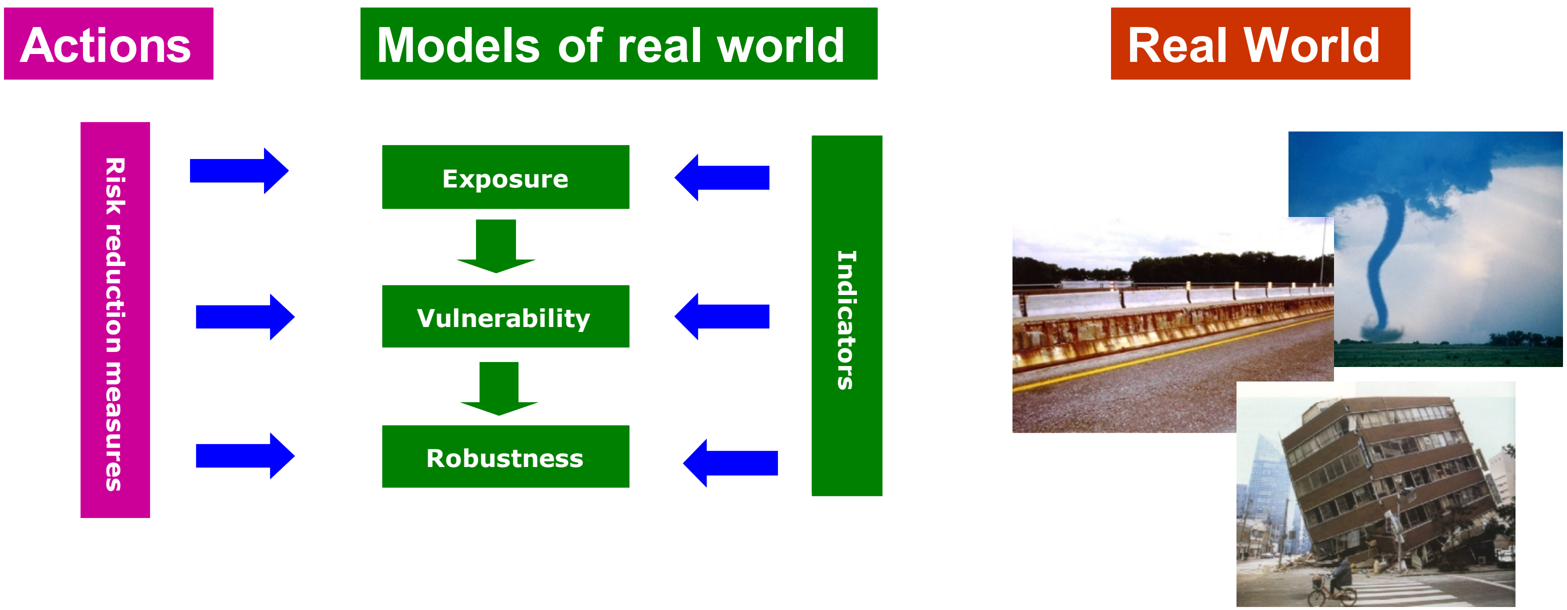
Required change of the characteristic value (5%-quantile value) to maintain the target reliability $p_F \approx 10^{-5} \left[1/\,year \right]$



Systems in Risk Financing

Problem framing

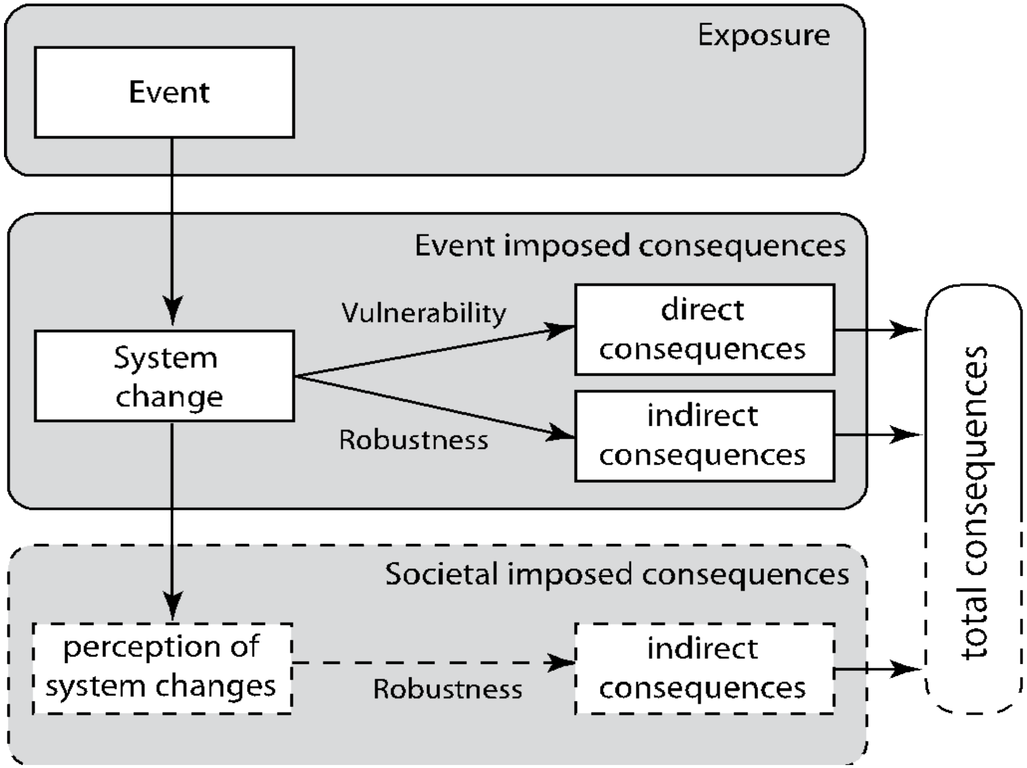
Information and knowledge influence all aspects of decision problems



Systems in Risk Financing

Problem framing

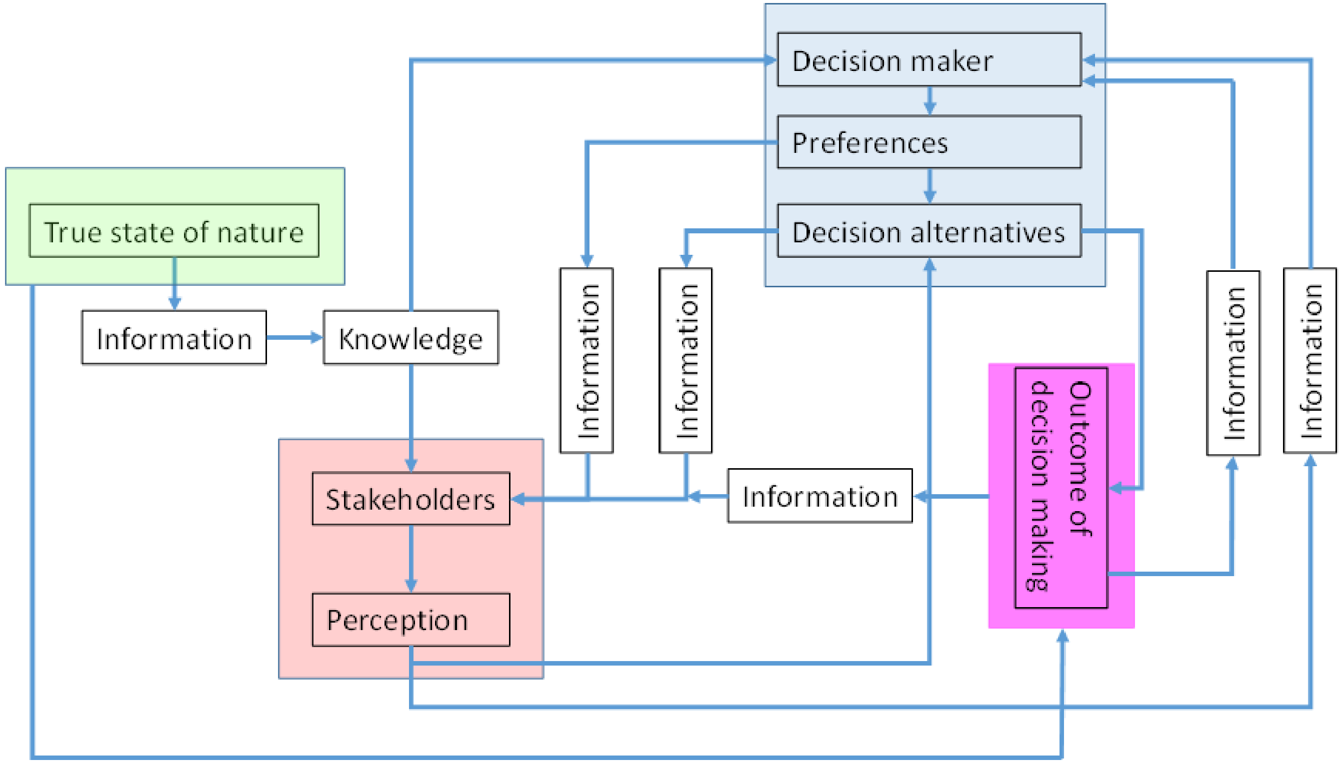
Information and knowledge influence all aspects of decision problems



Systems in Risk Financing

Problem framing

Information and knowledge influence all aspects of decision problems



Systems in Risk Financing

Problem framing

Fundamentally we do not know what the truth is.

We do not fully appreciate how knowledge and information relates to truth.

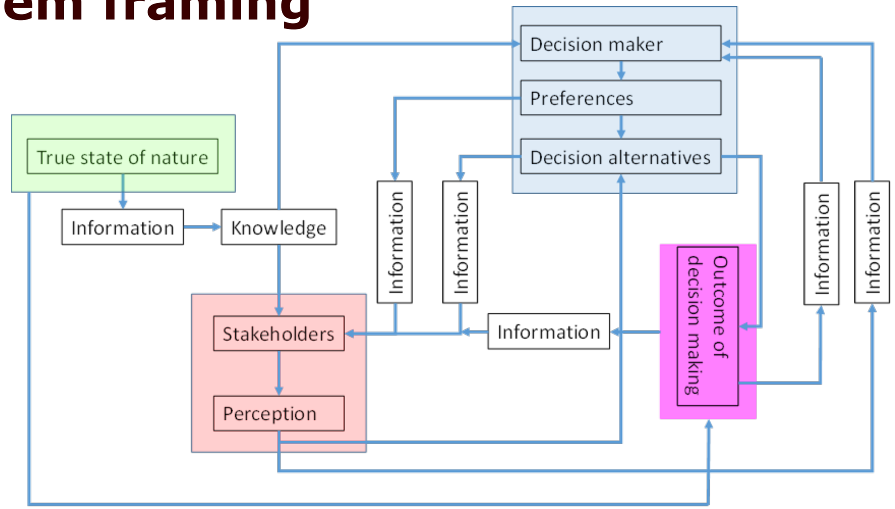
Debatable which knowledge and information is relevant in a given context.

In society any knowledge and information is on the ”free market”.

In science and engineering:
- knowledge and information might be influenced by what is fundable
- tendency to mix ”truth” with information and assumptions

Systems in Risk Financing

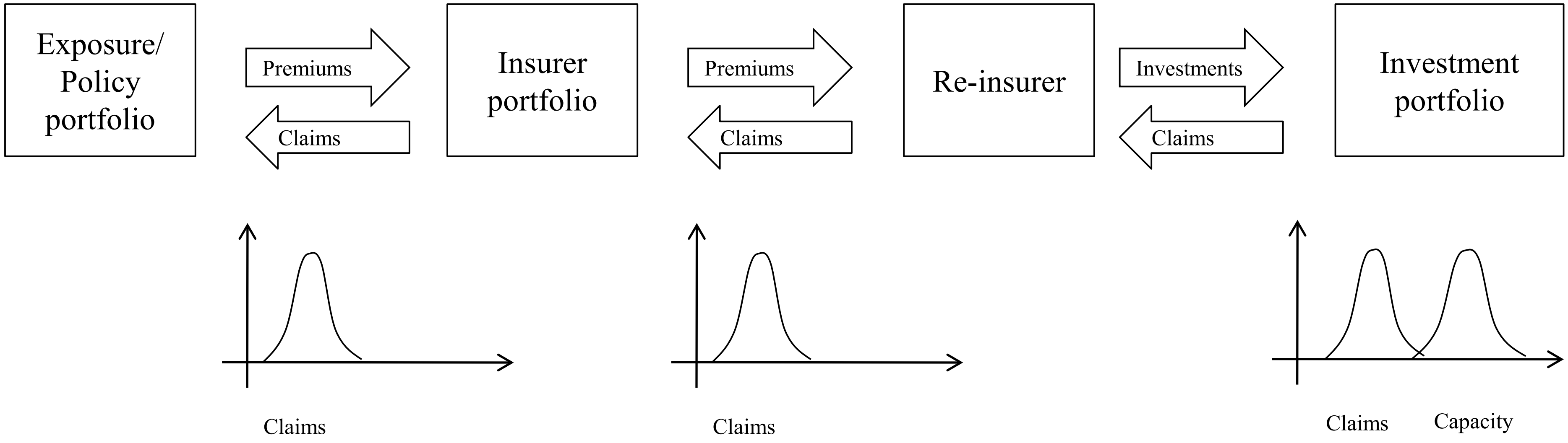
Problem framing



- The information is delayed
- The information is disrupted
- The information is relevant and precise.
- The information is relevant but imprecise.
- The information is relevant but incorrect.
- The information is irrelevant.

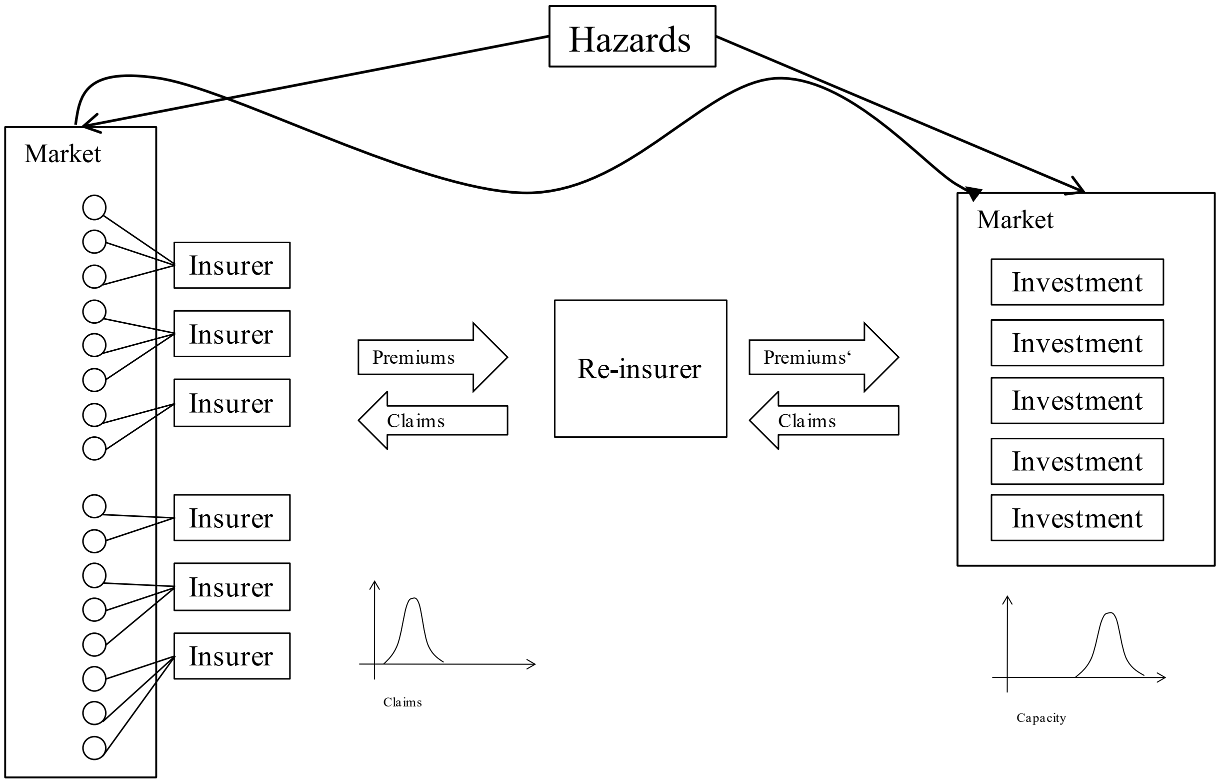
Systems in Risk Financing

The insurance risk financing "system"



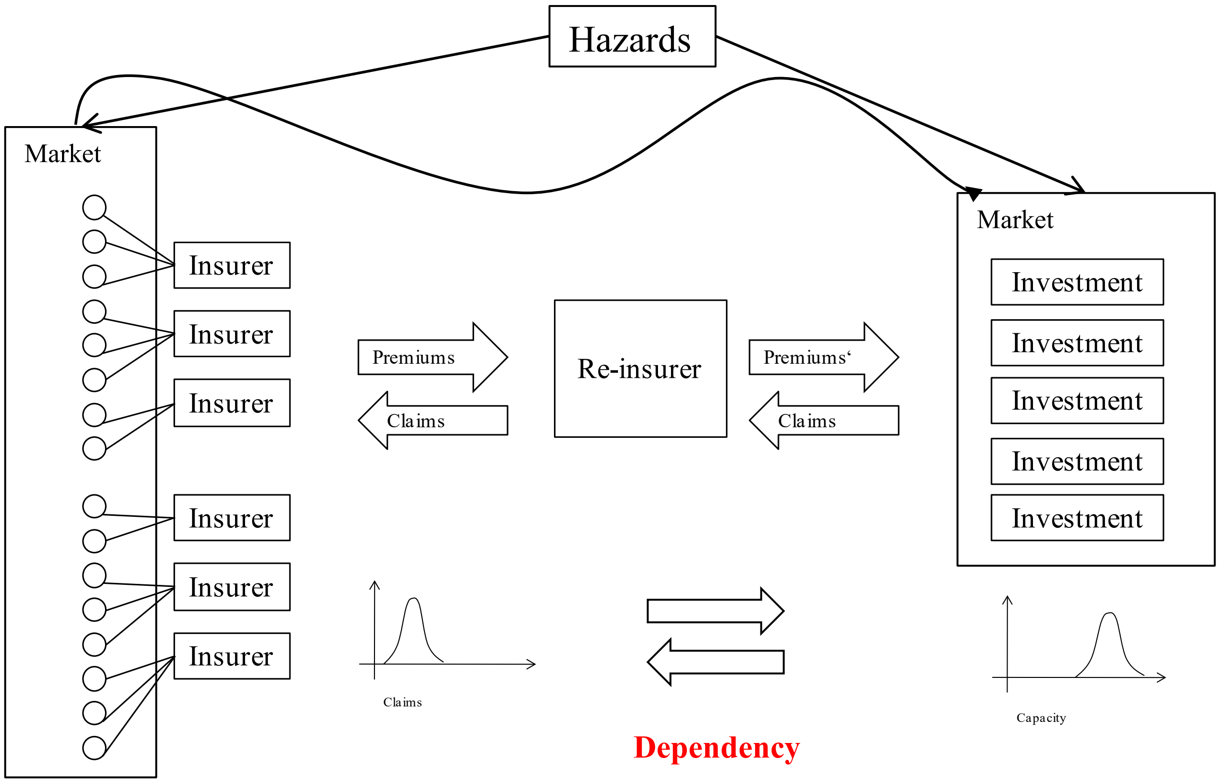
Systems in Risk Financing

The re-insurers "system"



Systems in Risk Financing

The re-insurers "system"



Resilience and Business Interruption

- The insurance industry is facing the problem of increasing losses due to business interruption related claims.
- In the past – business interruption losses – were not in the focus – and not critical – however, this has changed. This particular type of indirect consequences is now appreciated as being one of the most significant factors in loss generation.
- Whereas direct consequences seem to be adequately managed, approaches and methods are still to be established for managing risks due to indirect consequences – including business interruption losses.
- Holistic/integral perspectives must be taken.

Resilience and Business Interruption

Resilience definitions

Pimm (1984) - *Resilience….the time it takes till a system which has been subjected to a disturbance returns to its original mode and level of functionality*

Holling (1996) - *Resilience.…the measure of disturbance which can be sustained by a system before it shifts from one equilibrium to another*

Cutter (2010) - *Resilience…. capacity of a community to recover from disturbances by their own means*

Bruneau (2009) – *Resilience…. a quality inherent in the infrastructure and built environment; by means of redundancy, robustness, resourcefulness and rapidity*

National Academy of Science (NAS, USA) - *Resilience….a systems ability to plan for, recover from and adapt to adverse events over time*

Resilience and Business Interruption

- Traditional approaches for assessing and managing risks in the insurance industry – on the loss side - are data based

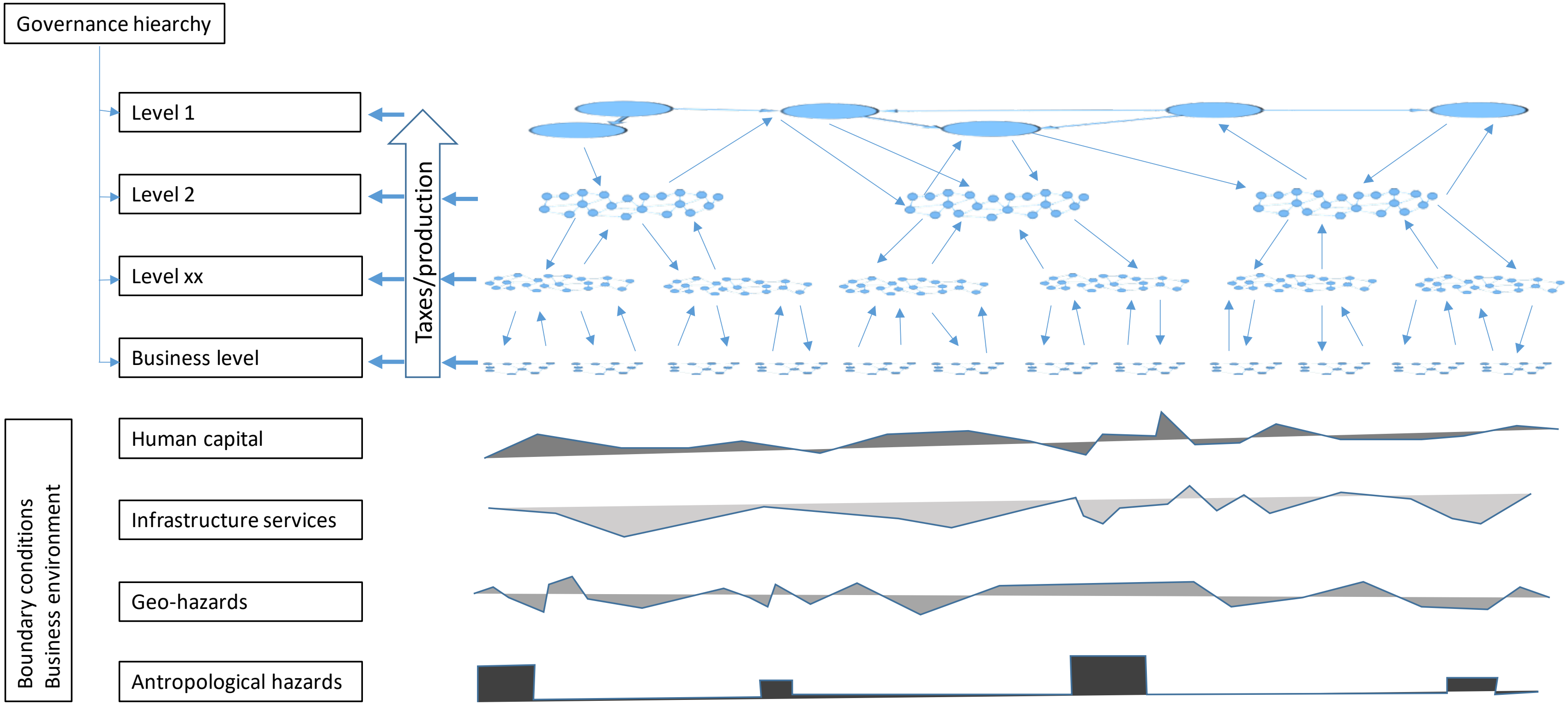
- For what concerns

  - direct property losses this is an area to which the insurance industry can provide real knowledge and value to the market
  - indirect losses in general and business interruption losses in particular – data is very sparse

- We need a modeling framework
  Systems resilience considerations may provide the basis for this

Resilience and Business Interruption

Probabilistic systems resilience modeling – corporate level



Resilience and Business Interruption

Questions to be answered

How to:

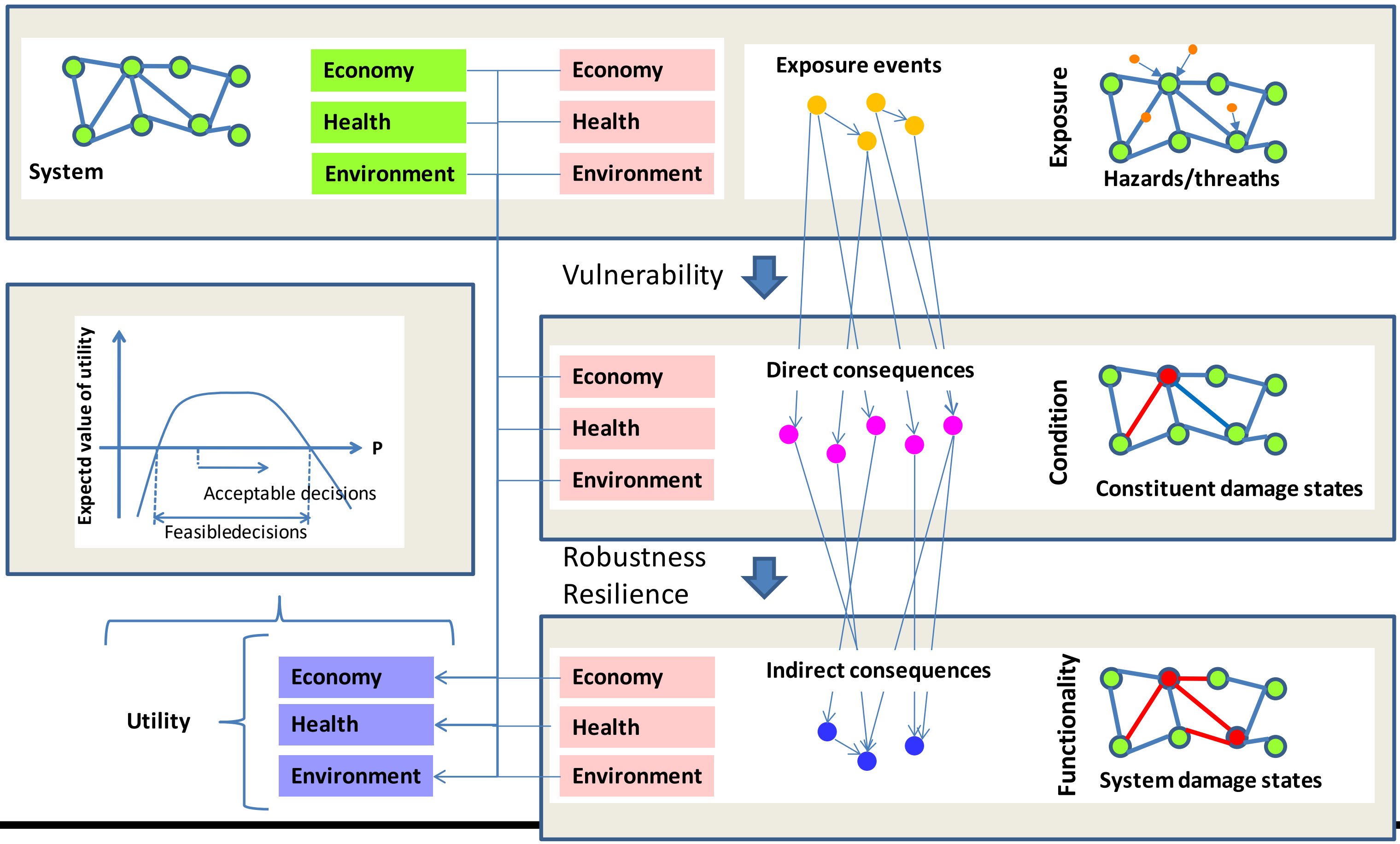
- prioritize investments on design and management of interlinked systems (economy, environment, health)
- select target reliabilities and performances of individual systems and constituents
- plan and budget for the future (economy, qualities of the environment, social capacity, health)

How resilient is resilient enough?

……at all levels in the hierarchy of societal systems utilizing communication and democratic decision making processes to decide on the allocation and sharing of resources

Resilience and Business Interruption

A generic framework

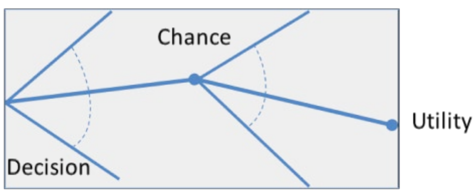


Resilience and Business Interruption

Bayesian decision analysis

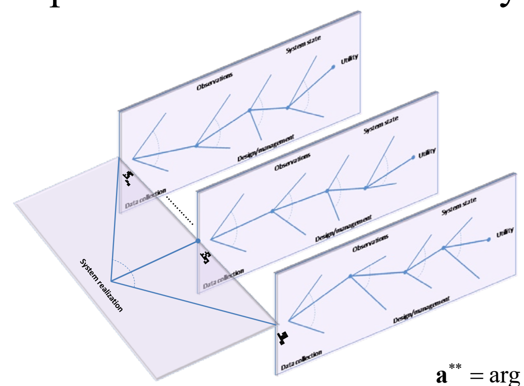
Consistent "book keeping" of the expected value of the utility associated with different decision alternatives –(Raiffa and Schlaifer (1961), von Neumann and Morgenstern (1947))

Prior decision analysis



$$\mathbf{a}^* = \arg\max_{\mathbf{a}} \left(E'_{\mathbf{X}} \left[U_{Total}(\mathbf{a}, \mathbf{X}) \right] \right)$$

Pre-posteror/VoI decision analysis



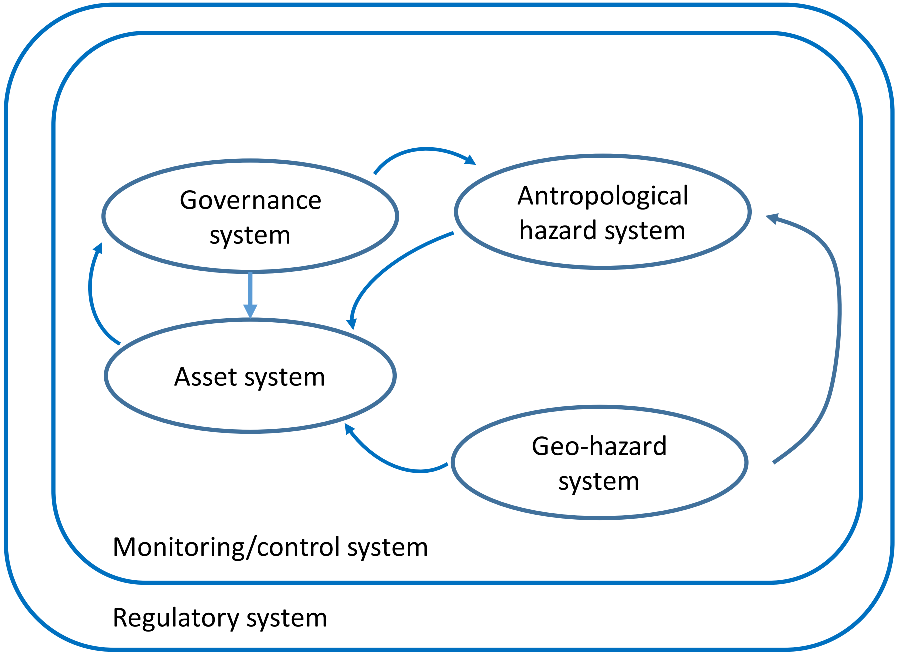
$$\mathbf{a}^{**} = \arg\max_{\mathbf{a}} E'_{\mathbf{X}\|\hat{\mathbf{Z}}=\hat{\mathbf{z}},\mathbf{M}_S=\mathbf{m}_{S_i}} \left[U_{Total}(\mathbf{a}_i, \mathbf{X}_i) \right]$$

$$\langle \mathbf{h}^{m_s}_*, \mathbf{m}^{s_i}_*, \mathbf{h}^{s_i}_*, \mathbf{a}_* \rangle = \arg\max_{\mathbf{h}^{m_s}} \left(E'_{\mathbf{M}_s} \left[\arg\max_{\mathbf{m}^{s_i}} \left(\arg\max_{\mathbf{h}^{s_i}} \left(\arg\max_{\mathbf{a}_i} \left(P''(\mathbf{M}_s = \mathbf{m}_{s_i}) \times E'_{\mathbf{X}_i} \left[E''_{\mathbf{X}_i|\mathbf{Z}=\mathbf{z},\mathbf{M}_s=\mathbf{m}_{s_i}} \left[U_{Total}(\mathbf{a}_i, \mathbf{X}_i) \right] + E''_{\mathbf{M}_s/\mathbf{m}_{s_i}|\mathbf{Z}=\mathbf{z}} \left[E''_{\mathbf{X}_i|\mathbf{Z}=\mathbf{z}} \left[U_{Total}(\mathbf{a}^{**}_i, \mathbf{X}_i) \right] \right] \right] \right) \right) \right) \right] \right)$$

Epistemic Uncertainty… System Choice - Faber, M.H. and Maes, M.A. (ICOSSAR2005)

Resilience and Business Interruption

Probabilistic systems resilience modeling



Resilience and Business Interruption

Probabilistic system representation

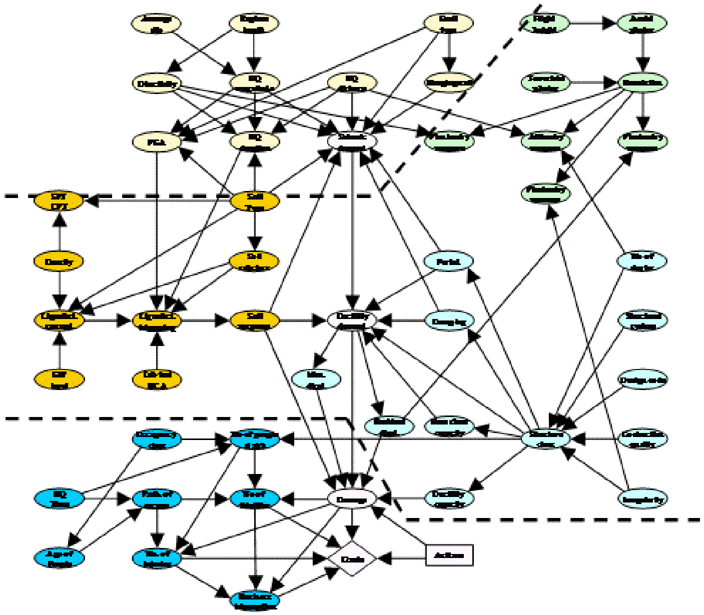
System model $\mathbf{m}_S(\mathbf{a}) = (\mathbf{m}_\Sigma(\mathbf{a}), \mathbf{m}_c(\mathbf{a},\mathbf{X}), \mathbf{X}(\mathbf{a}))^T$

Graph model $\mathbf{m}_\Sigma(\mathbf{a})$

Constituents model $\mathbf{m}_c(\mathbf{a},\mathbf{X})$

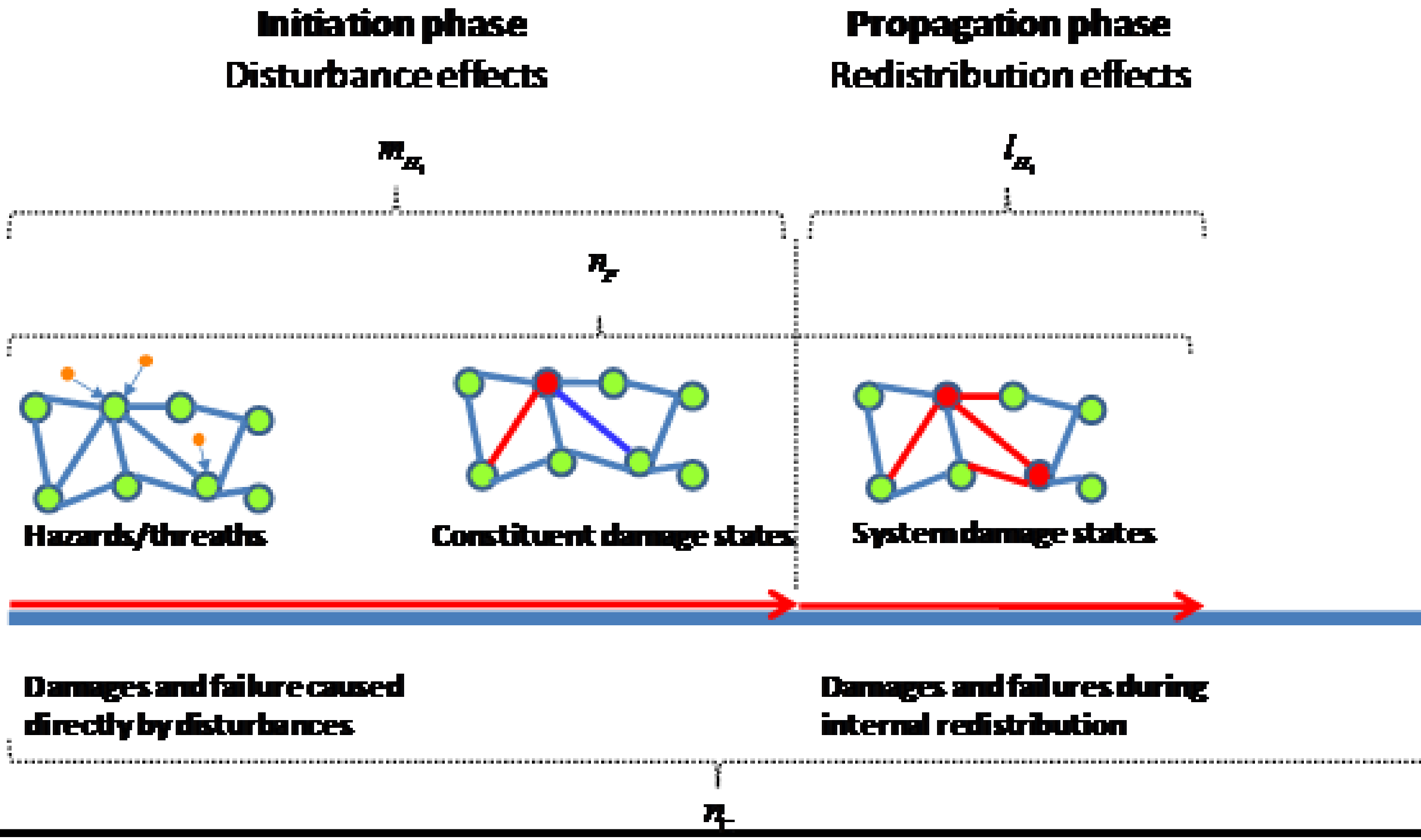
Probabilistic model $\mathbf{X}(\mathbf{a})$

Decision alternatives $\mathbf{a}$



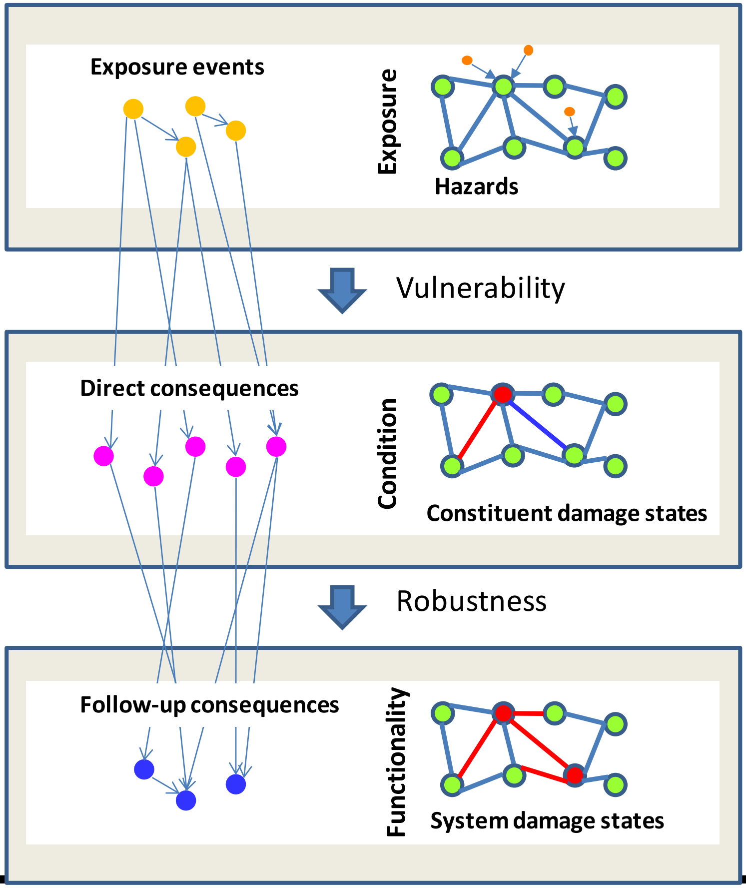
Resilience and Business Interruption

Cascading failure scenarios and evolution of consequences



Resilience and Business Interruption

Robustness modeling



It is assumed that all relevant scenarios have been identified

$$\mathbf{S} = (i, p(i), c_{D,I}(i), c_{D,P}(i), c_{ID}(i))$$

$$i = 1, 2, .., n_s$$

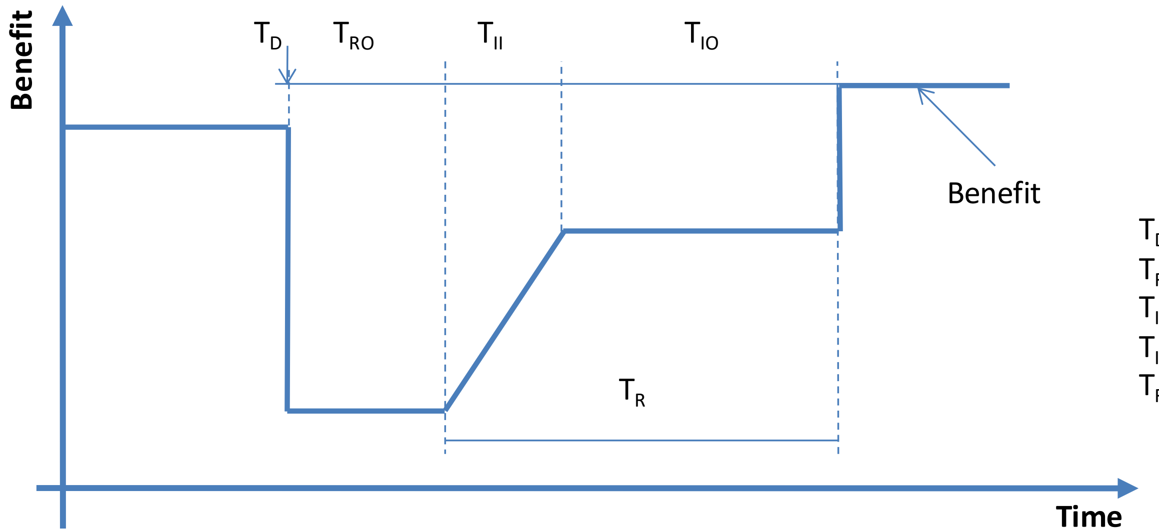
$$I_R(i) = \frac{c_D(i)}{c_T(i)}$$

$$I_R(i) = \frac{c_{D,I}(i)}{c_{D,I}(i) + c_{D,P}(i)}$$

$$I_R(i) = \frac{c_{D,I}(i) + c_{D,P}(i)}{c_{D,I}(i) + c_{D,P}(i) + c_{ID}(i)}$$

Resilience and Business Interruption

Social preparedness modeling

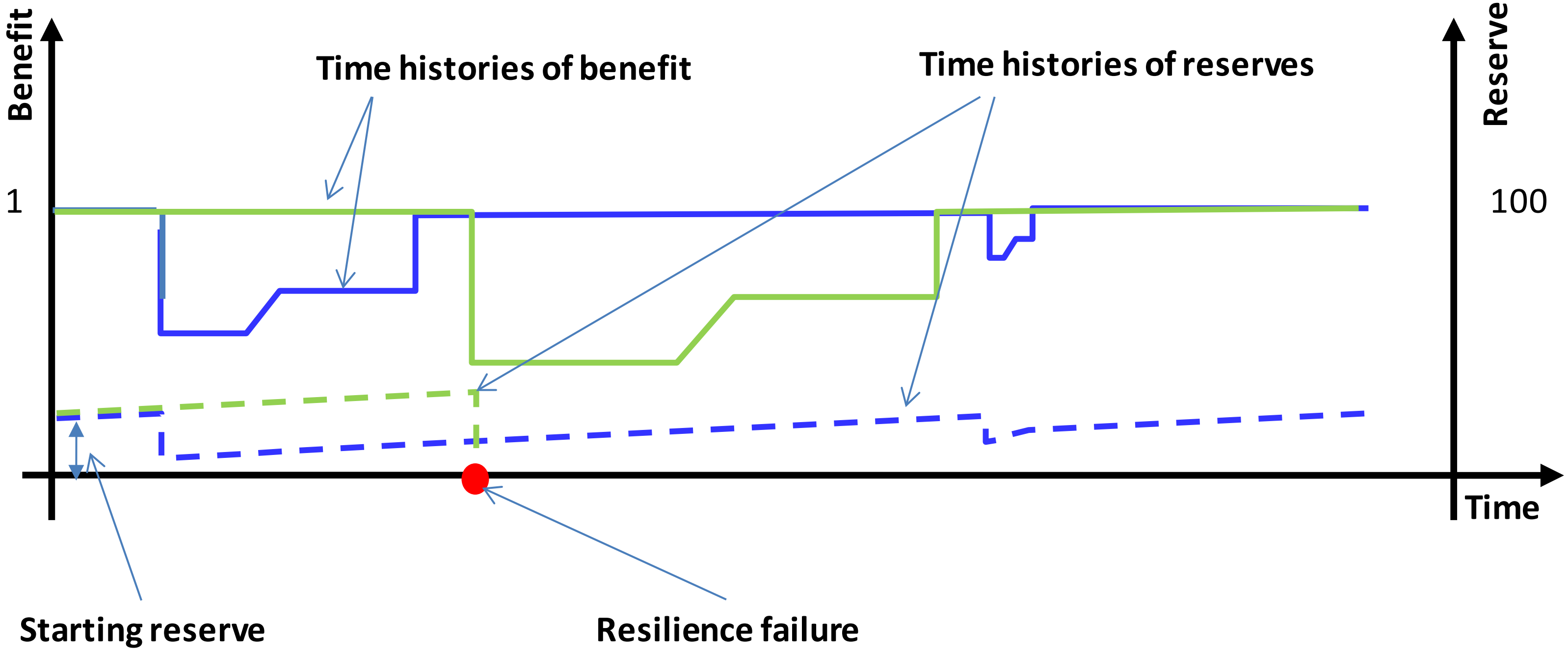


T_D :	Time of disturbance
T_{RO} :	Period of reorganisation
T_{II}:	Period of interim installments
T_{IO}:	Period of interim operations
T_R:	Period of renewal/rehabilitation

Resilience and Business Interruption

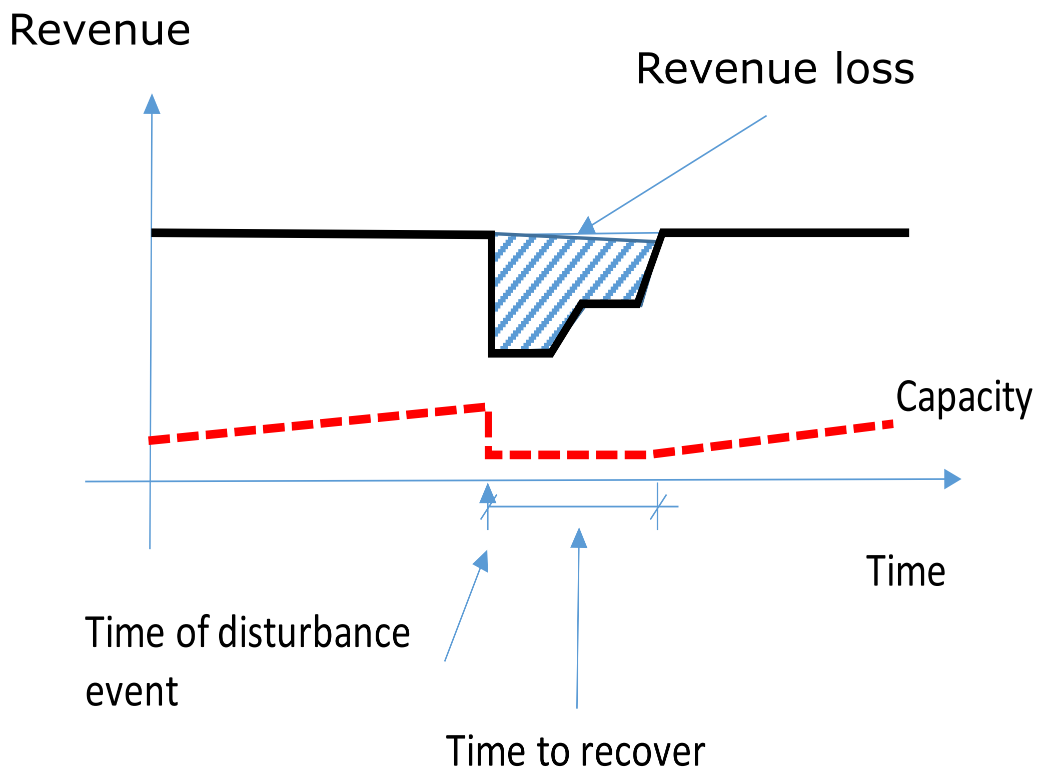
Resilience interpretation

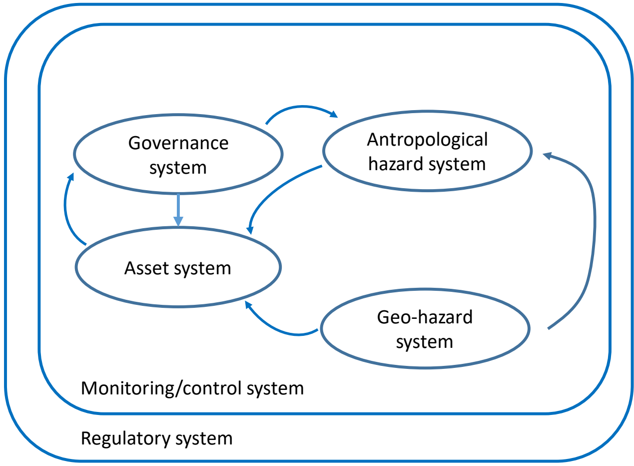
The system is not resilient if within a given timeframe one or more of its capacities/reserves are exceeded



Resilience and Business Interruption

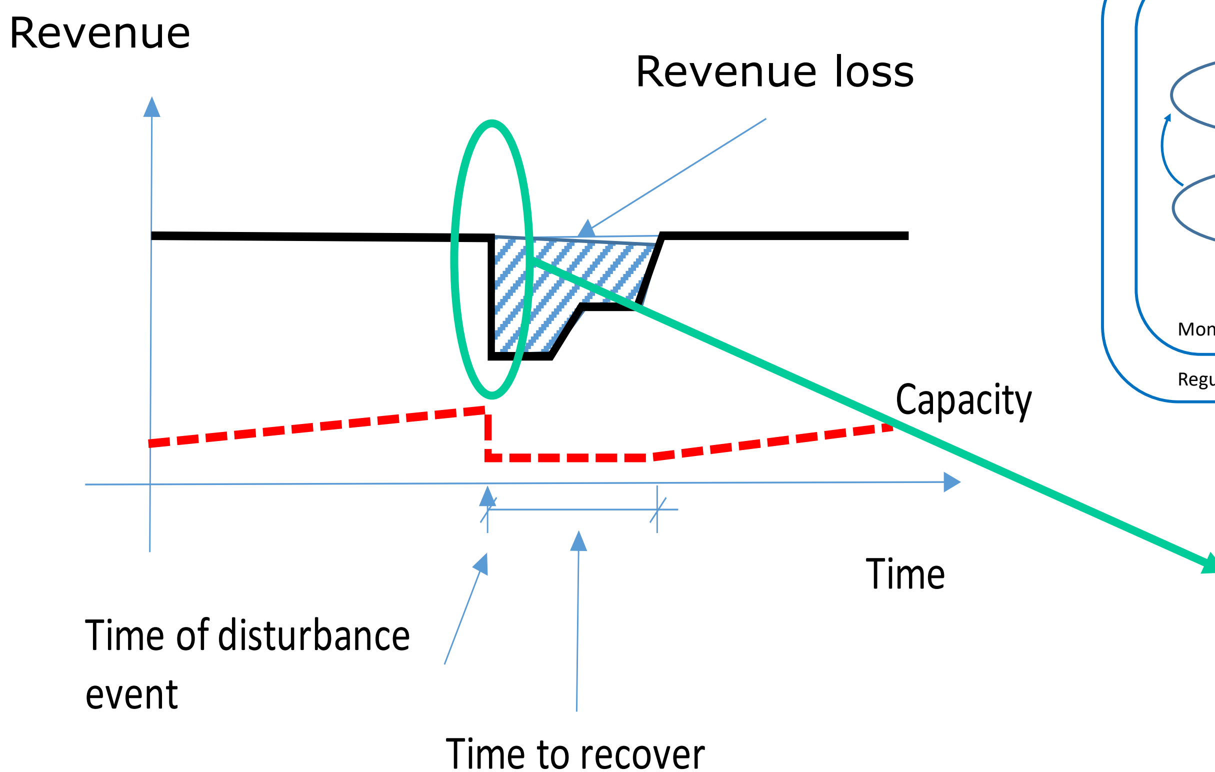
Probabilistic systems resilience modeling – business unit

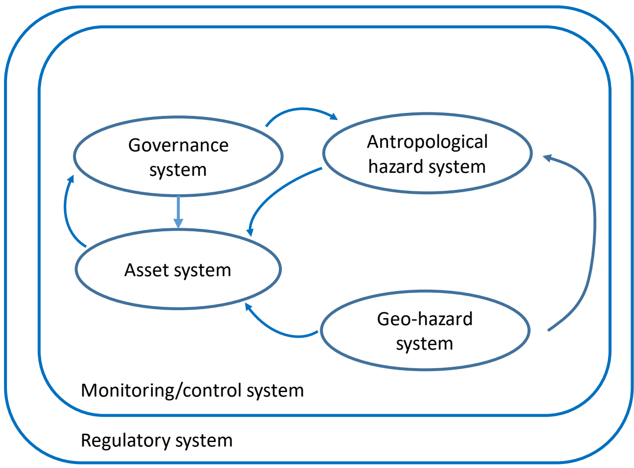




Resilience and Business Interruption

Probabilistic resilience modeling

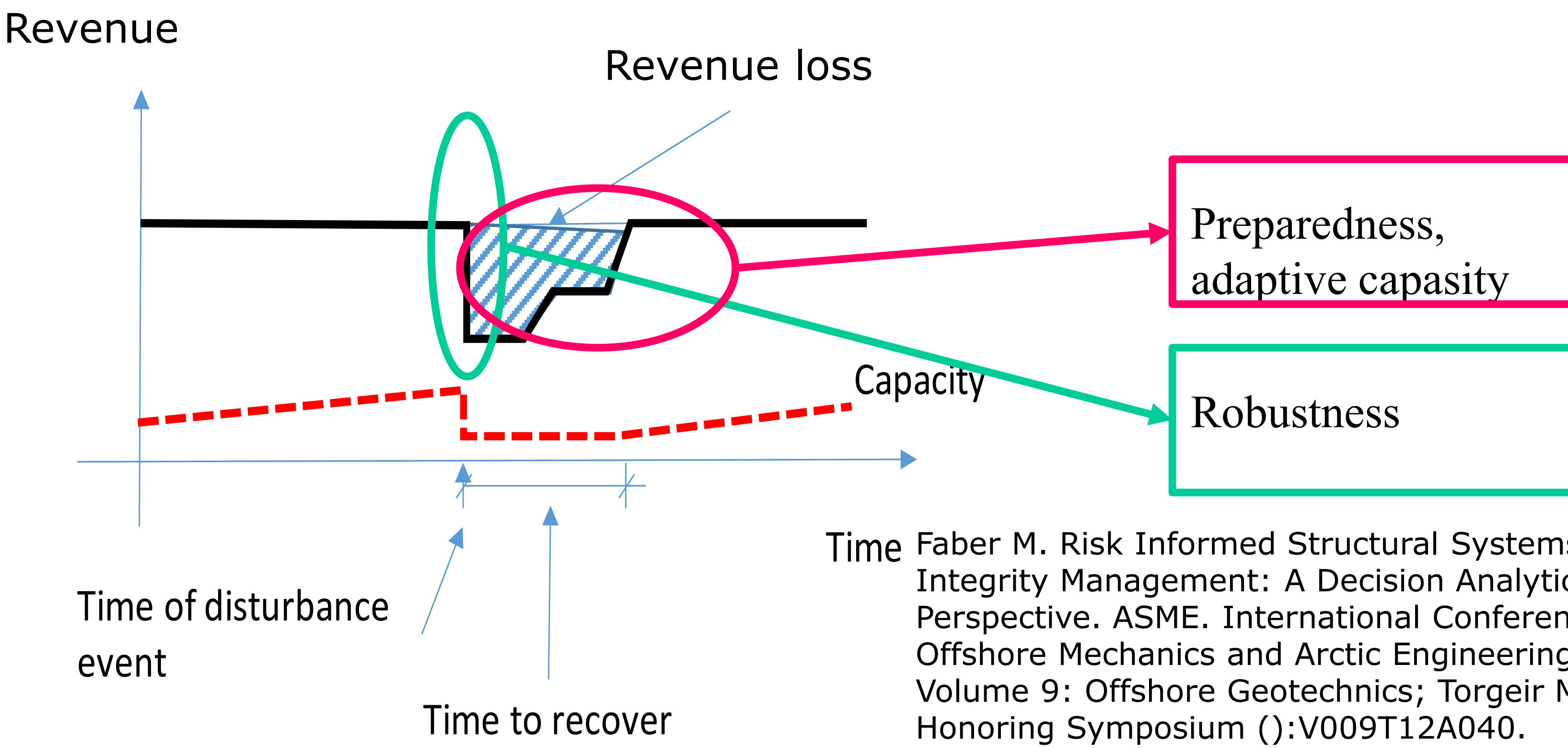




Robustness

Resilience and Business Interruption

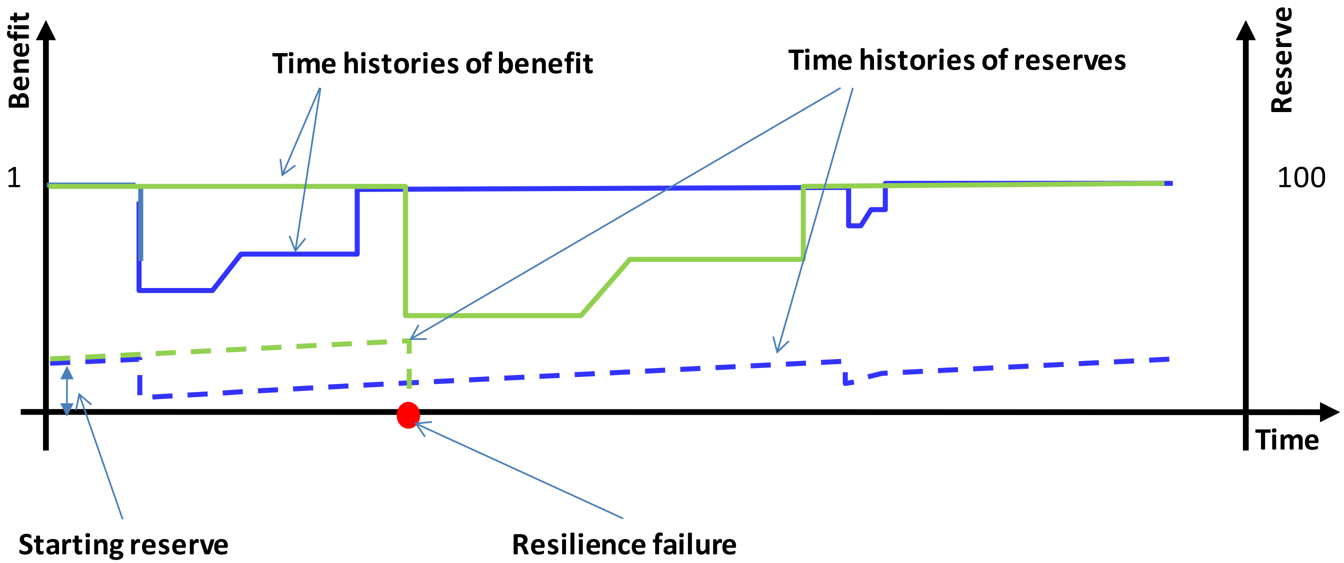
Probabilistic resilience modeling



Faber M. Risk Informed Structural Systems Integrity Management: A Decision Analytical Perspective. ASME. International Conference on Offshore Mechanics and Arctic Engineering, Volume 9: Offshore Geotechnics; Torgeir Moan Honoring Symposium ():V009T12A040. doi:10.1115/OMAE2017-62715.

Resilience and Business Interruption

Probabilistic systems resilience modeling



$$f_f(t) = \lim_{\Delta t \to 0} \frac{P(\{R(\tau) > S(\tau) \forall \tau \in [0,t[\} \cap \{R(t+\Delta t) \le S(t+\Delta t)\})}{\Delta t}$$

Faber M.H., Qin J., Miraglia S. and Thöns S. (2017).
On the Probabilistic Characterization of Robustness and
Resilience", Procedia Engineering, 198 (2017), 1070–1083.

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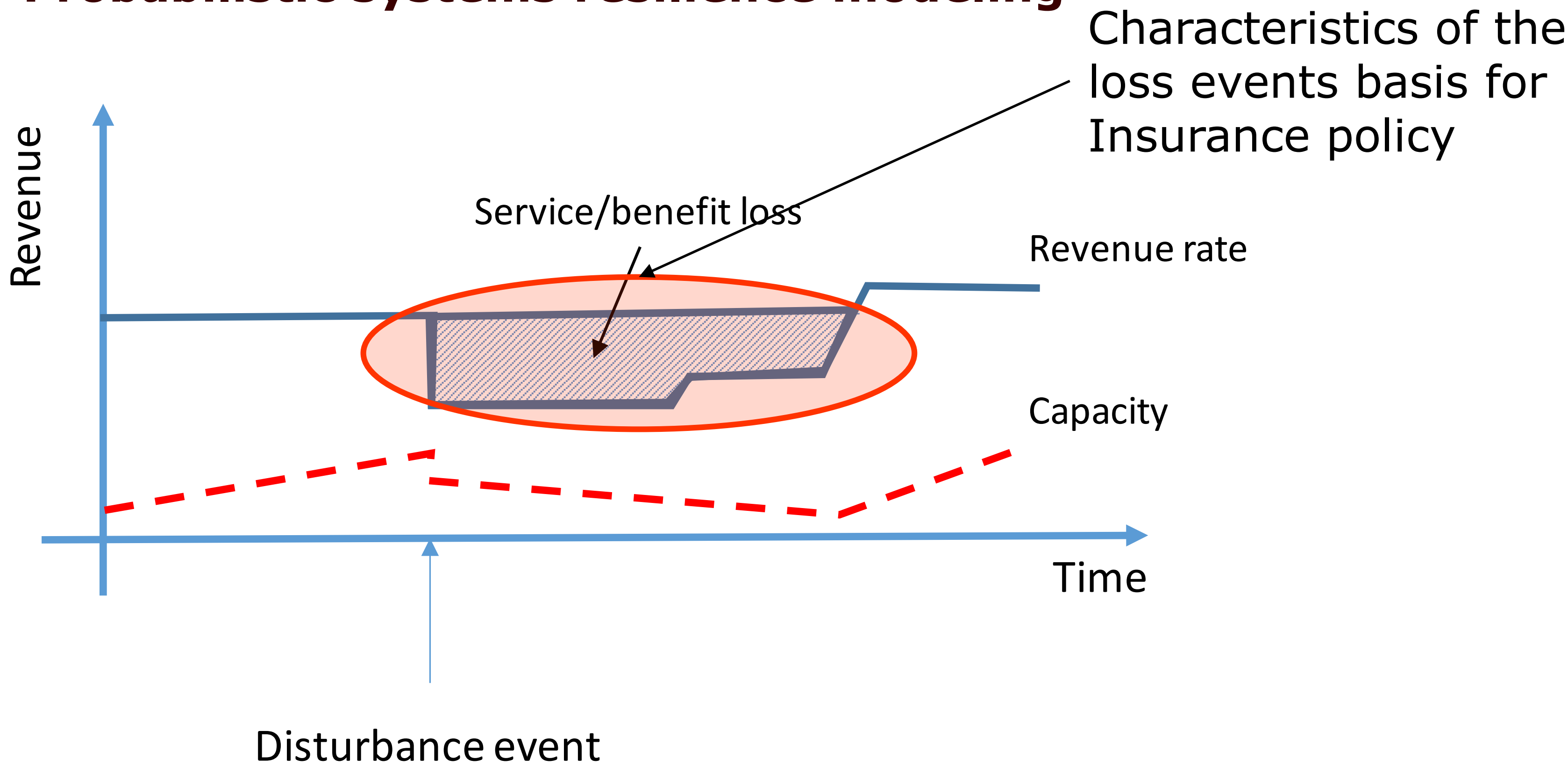
Probabilistic systems resilience modeling



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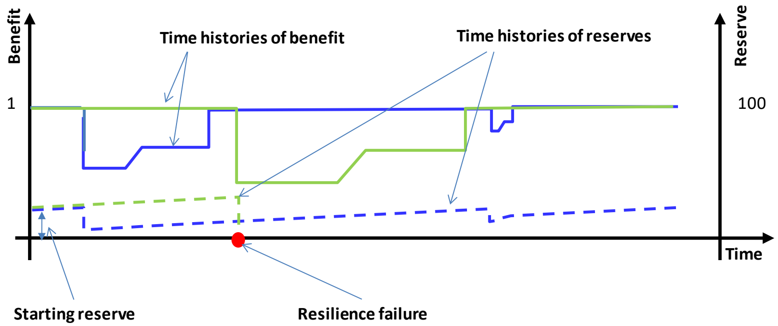
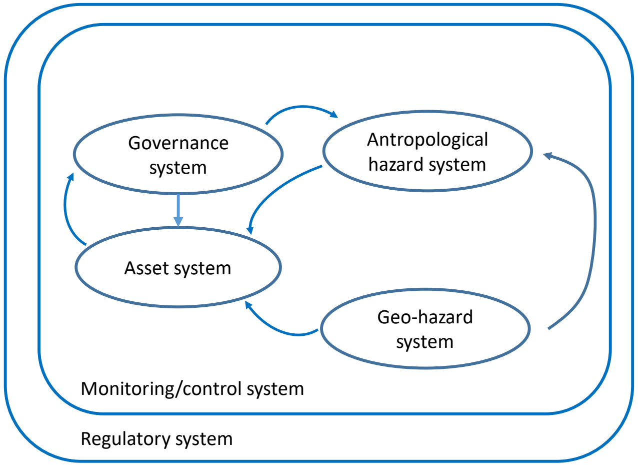
Probabilistic systems resilience modeling

By quantifying the probability that the client/policy holder will suffer resilience failure the degree of desired/required ensurance can be established

Moreover – the insurer profits from this quantification by better understanding the exposure and what contributes to this.





Resilience and Business Interruption

How to approach the modeling of Business Interruption?

Develop generic indicator-based probabilistic models for:

Scenarios of events which may influence/damage the performance of "business systems" – e.g. natural hazards – but also other events such as malevolence, economic crises etc.

Business activities – as "business systems"

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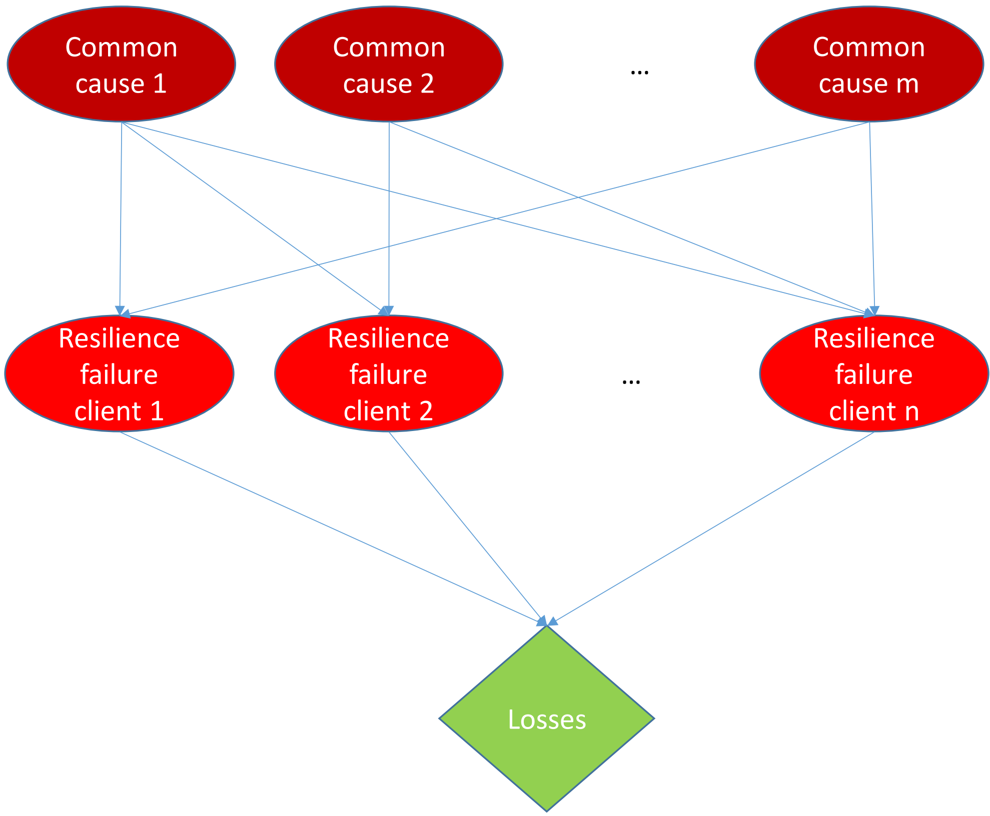
How to assess the exposure?

Business interruption risks assessed by resilience modeling may be aggregated over the entire portfolio of policies

Dependencies in business interruption losses must be carefully modelled



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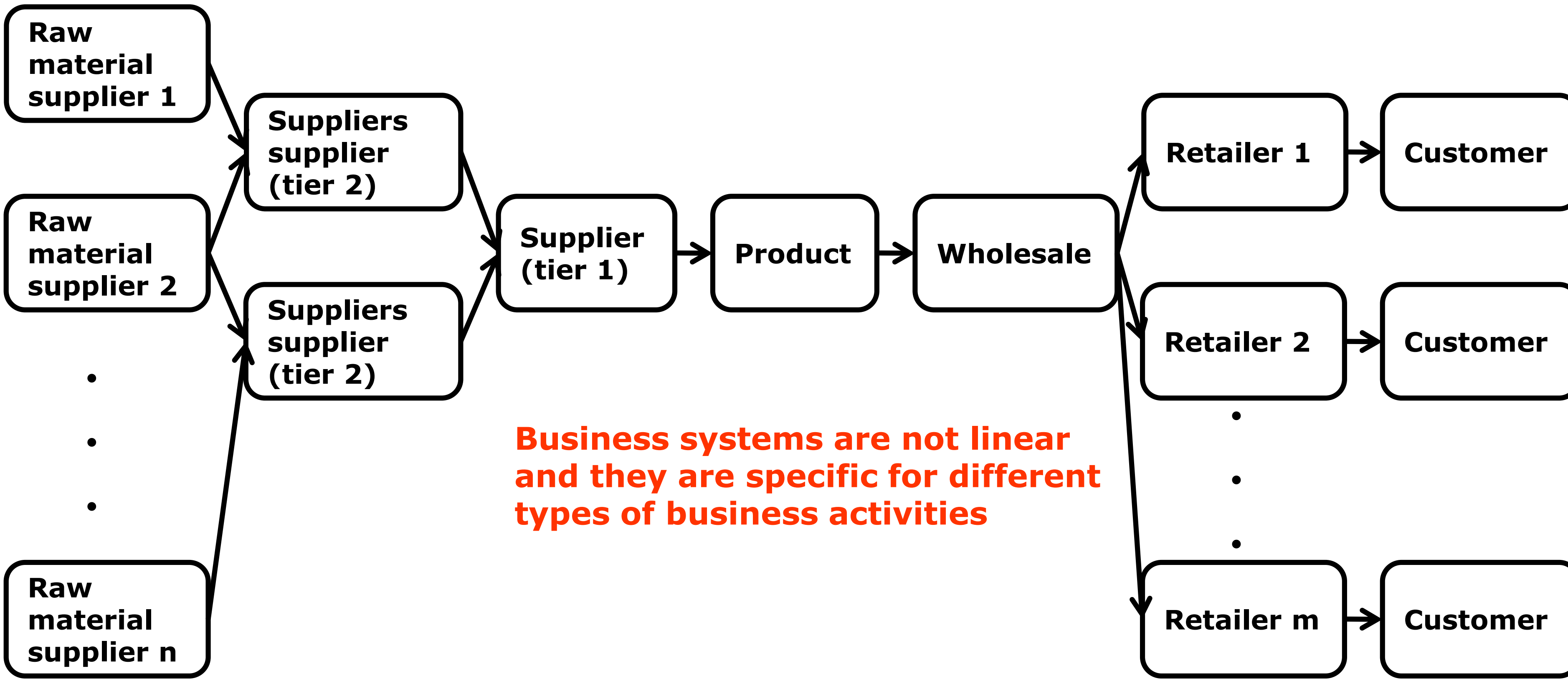
Business activities as systems – classical linear model



Business systems are not linear and they are specific for different types of business activities

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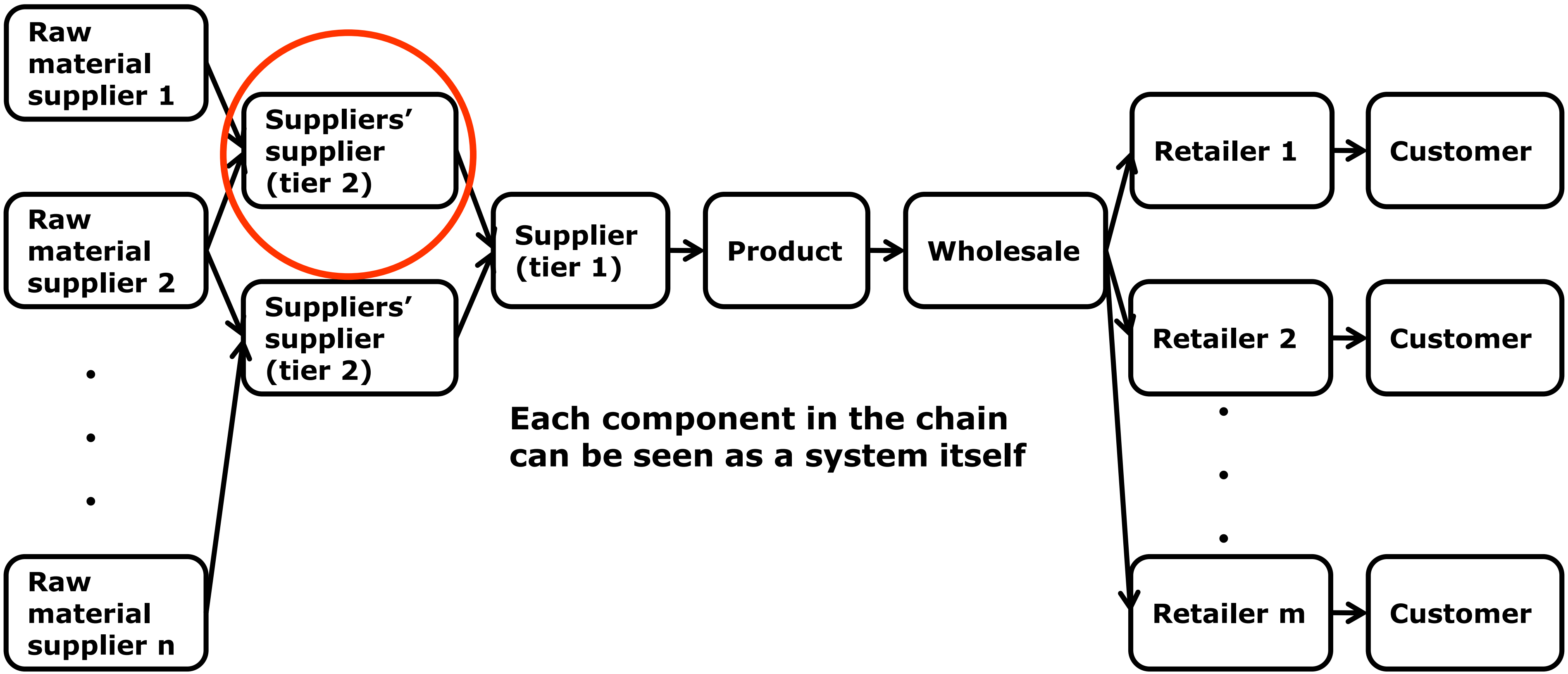
Business activities as systems
– classical linear model



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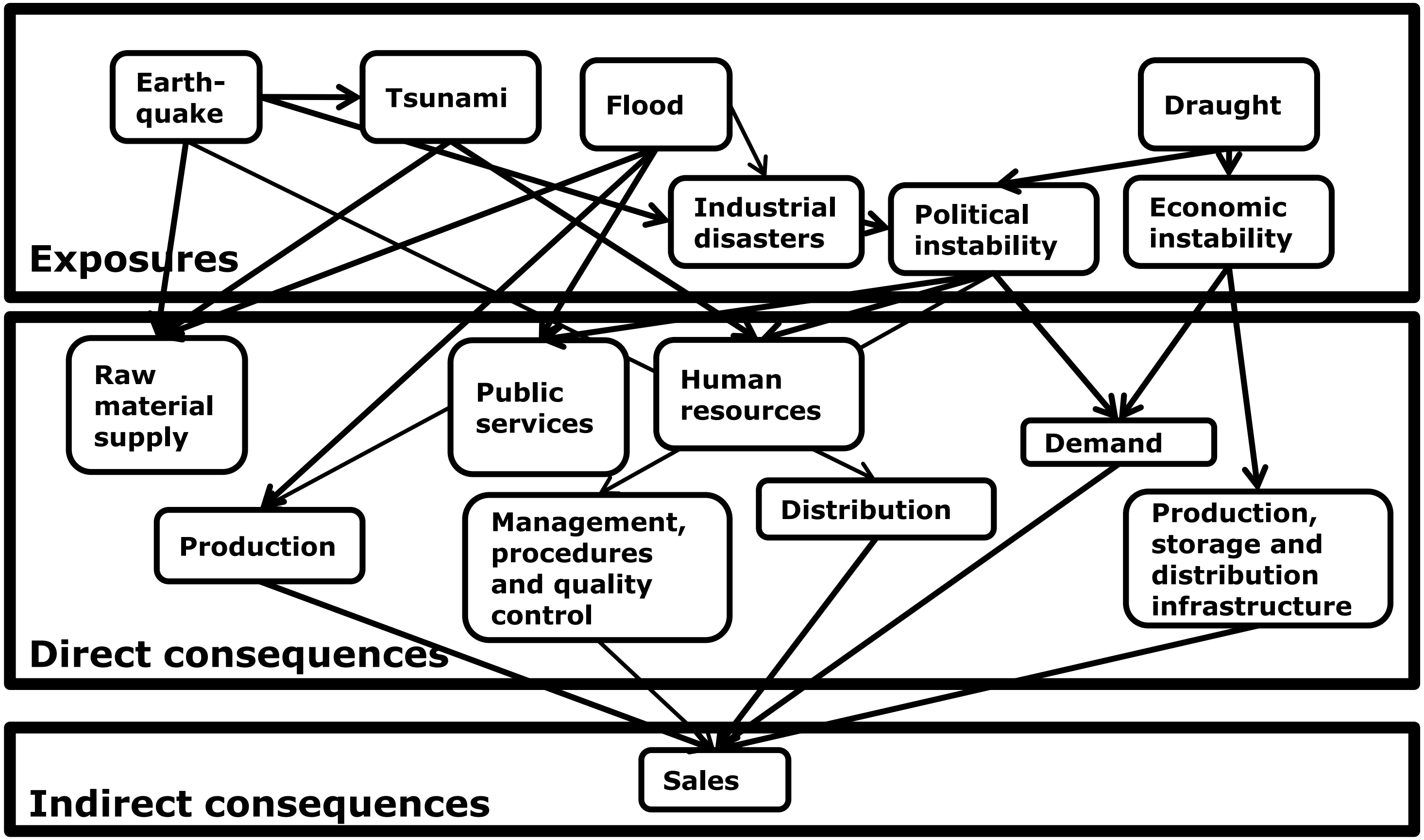
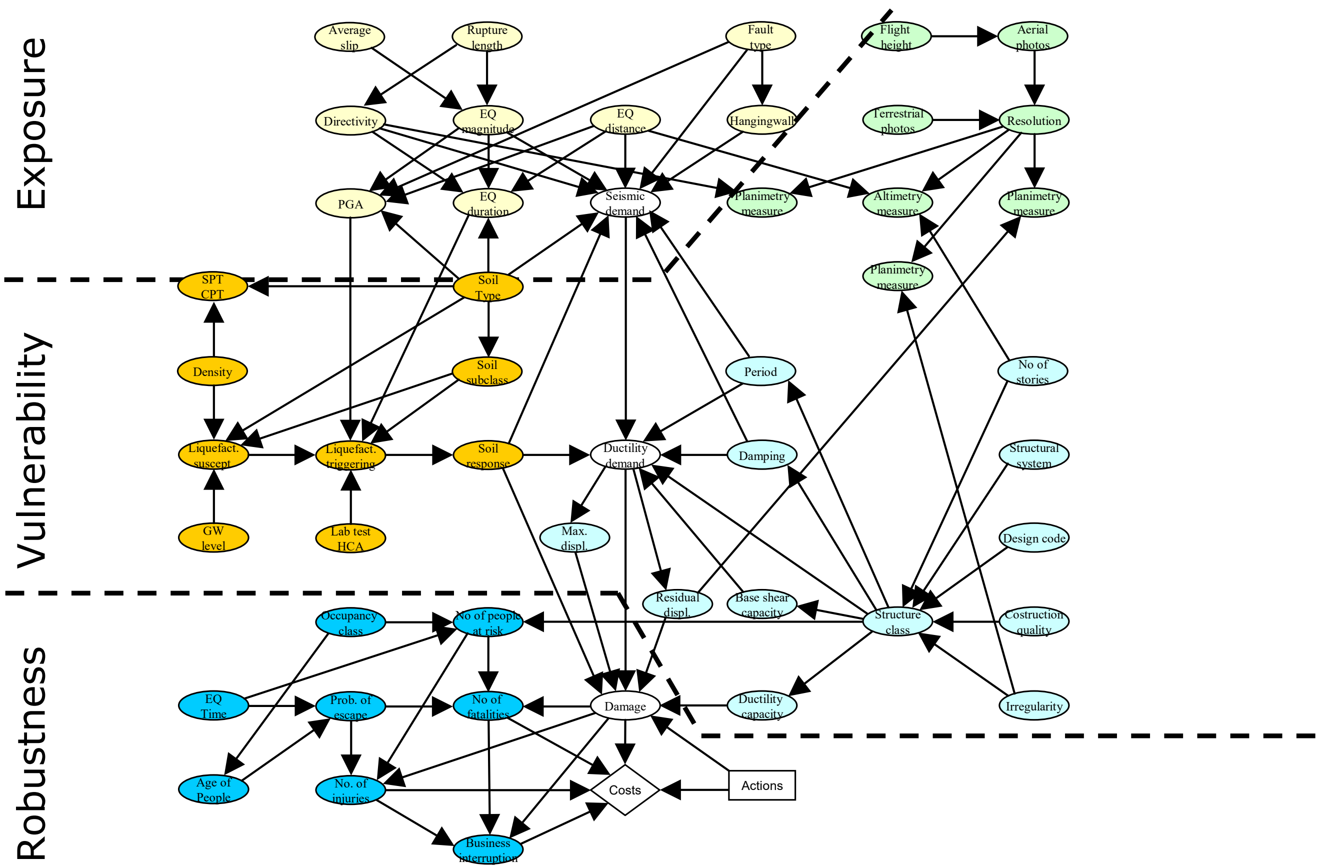
Models for individual sub-systems



Resilience and Business Interruption

Tools for risk modeling – Bayesian Probabilistic Nets



General Insights on Complex Systems Risks

Systems risk management rules of thumb

Common cause effects may severely reduce redundancy properties of systems, and should thus be a major concern in systems risk management.

Common causes may include various characteristics of natural and societal hazards, of which lack of knowledge and systematic human errors e.g. associated with bad best practices and cognitive biases are central.

In some cases risks due to common cause effects may be reduced by (spatial) separation of the constituents of the system. In other cases it is more relevant to pursue to contain the damages caused by common cause effects by segmentation.

General Insights on Complex Systems Risks

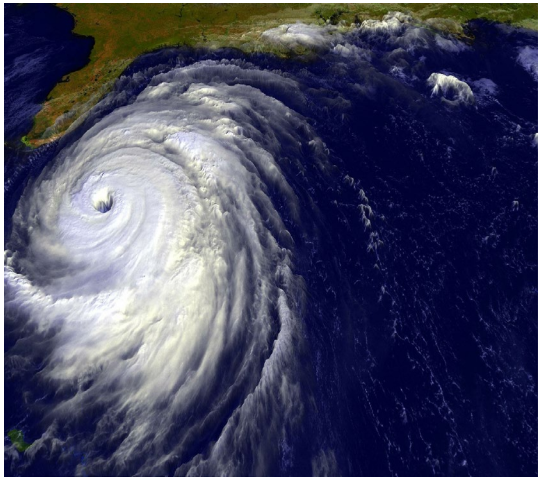
Systems risk management rules of thumb

When possible system constituent failures are highly dependent due to common cause effects of some sort, it is generally a good idea to segment the system. Thereby, the risk of cascading events and overall system functionality loss may be reduced considerably.

When possible system constituent failures are close to independent it is a good idea if relevant for the considered system to "tie up" the constituents of the system in such a manner that the functionality of failed constituents are transferred to other non-failed constituents.

Closing Remarks

- Business interruption poses a challenge for risk modeling and assessment
- Efforts must be focused on establishing “standardized” modeling approaches – which are holistic and integral
- Systems resilience modelling appears very relevant in the context of insurance risk assessments/management
- Generic Bayesian modeling approaches would seem feasible - from natural hazard event to business interruption loss
- BPN’s facilitate “standardization” and practical use



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Thanks for your attention ☺

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Risk
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