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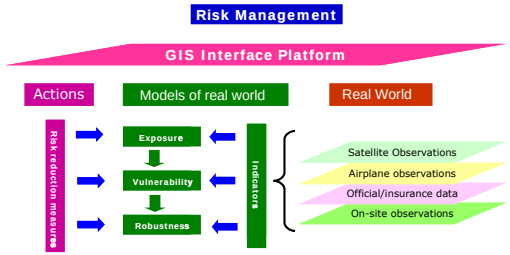
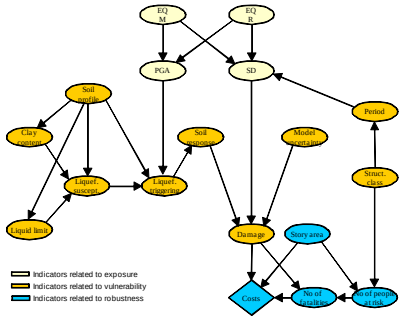
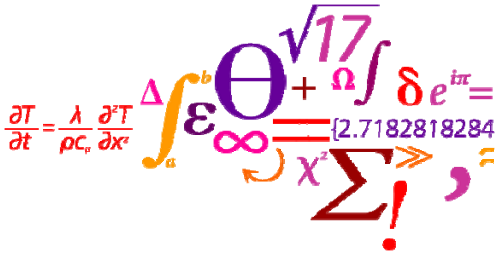




Decision Support for Sustainable Developments Based on Risk



M & M - DTU Management Engineering

Contents of presentation

- The Grand Challenge
- Overall Approach
- Decision Analysis and Risk
- LCA and Quantitative Sustainability
- The DTU Global Decision Support Initiative
- Questions and Answers

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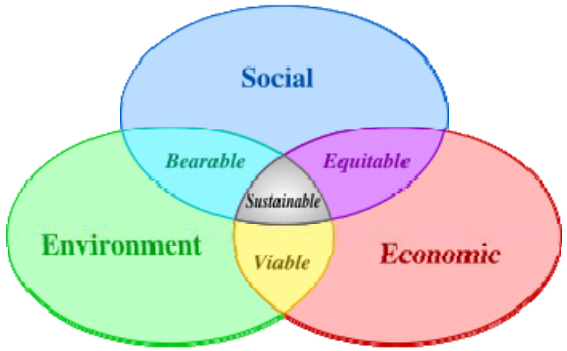
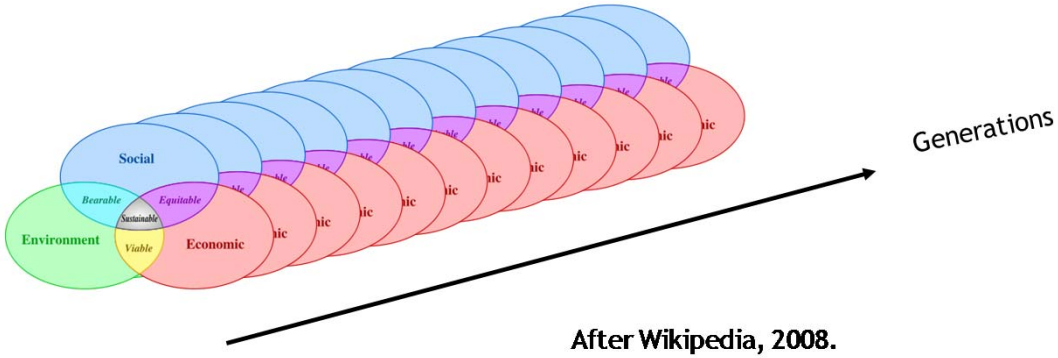
The Grand Challenge

Need for sustainable societal developments



Brundtland Report:

Meets the needs of the present without compromising the ability of future generations to meet their own needs



After Wikipedia, 2008.

At all scales - from individual stakeholders, over industries, regions, nations to the Earth systems scale

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The Grand Challenge

Situation analysis (abridged)

Society "household" at all scales must be managed much more efficiently:

- Resources
- Livelihoods
- Industry
- Infrastructures
- Environment
- Food
- Health
- Safety/security

…

This is appreciated by UN, WEF, OECD, etc. and is high on the agenda at national governmental and executive levels throughout the world – lately with UN's 17 World goals for sustainable development

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The Grand Challenge

Situation analysis (abridged)

- Over the later years there has been a strong focus in society that risk management is key in the management of societal resources, safeguarding of societal services as well as the qualities of the environment

- At the same time the research field of sustainability has emerged – and significantly improved insights on the effect of human activities on the environment

- **Hypothesis**
  Sustainable societal developments at all scales would be greatly enhanced through the availability of a fully holistic and consistent basis and associated tools for decision support

The Grand Challenge

Situation analysis (abridged)

- Several activities must be undertaken

  - Establish a common framework for risk management and assessment across application areas

  - Join information on quantitative sustainability and risk in support of decision making

  - Provide teaching and training to students and professional

  - Provide services and tools for decision support to all stakeholders in society

The Grand Challenge

Situation analysis (abridged)

- Several activities must be undertaken

  - Establish a common framework for risk management and assessment across application areas

  - Join information on quantitative sustainability and risk in support of decision making

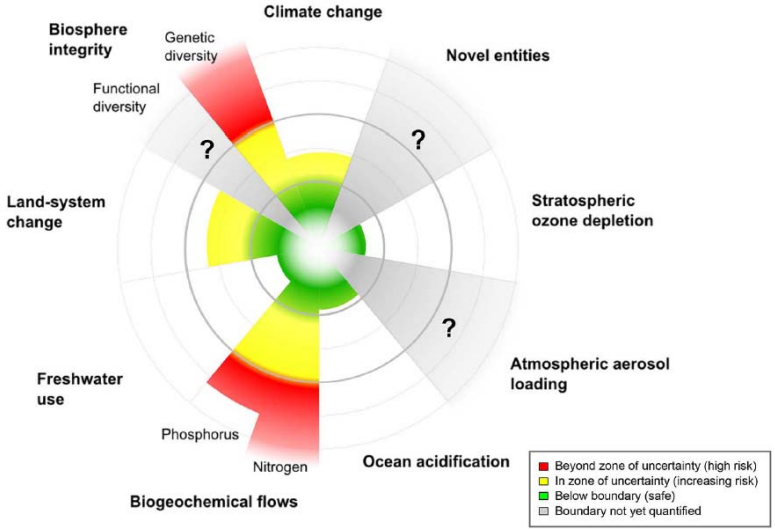
  - Provide teaching and training to students and professional

  - Provide services and tools for decision support to all stakeholders in society

Overall Approach

The perspective

- Human activities initiate from decisions
- Decisions may have impact on all aspects related to societal performance as well as boundary conditions for human existence
- To the best of our understanding both the "resources" and the "capacity" of Earth with respect to their "rearrangement" (pressures) are limited (Planetary Boundaries)



Daly:

1. Limit use of all resources to rates that ultimately result in levels of waste that can be absorbed by the ecosystem.
2. Exploit renewable resources at rates that do not exceed the ability of the ecosystem to regenerate the resources.
3. Deplete nonrenewable resources at rates that, as far as possible, do not exceed the rate of development of renewable substitutes.

Steffen *et al.* 2015[1]

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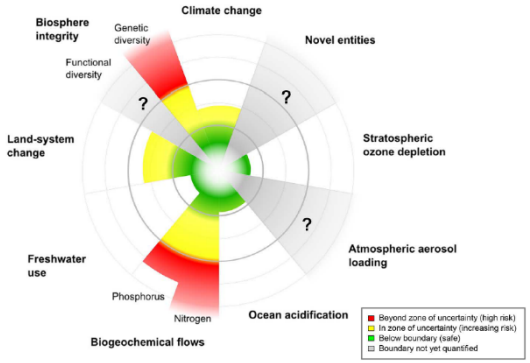
Overall Approach

The perspective



Steffen *et al.* 2015[1]

- Ultimately there are no tradeoffs possible with respect to decision making affecting the pressures at global scale – besides the risk of extinction

- At any lower scale than global there are of course any choice of tradeoff possible – this is a matter of optimization

- **Optimization of decisions is key in the process of "household" management**

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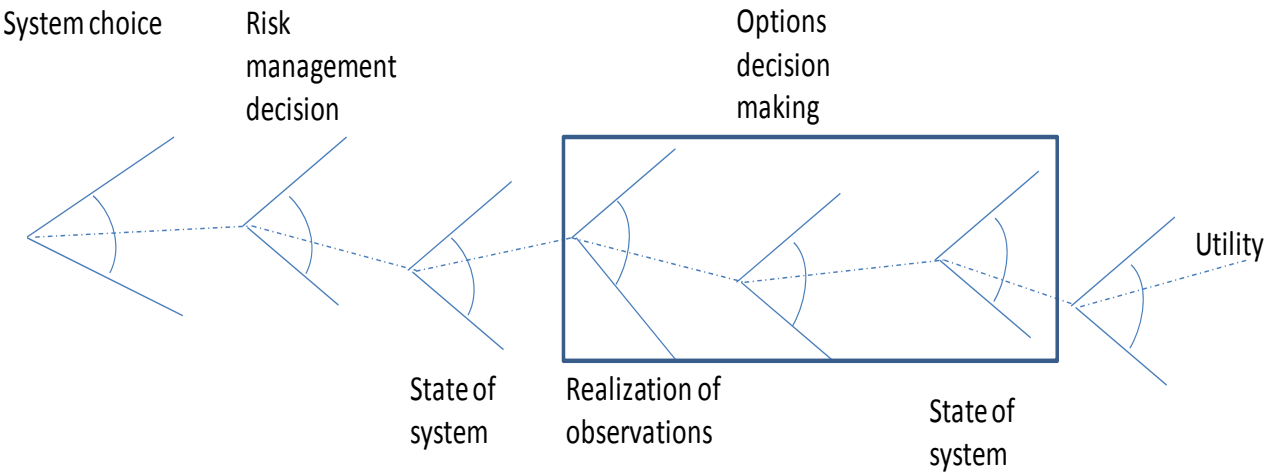
Decision Analysis and Risk

Good news – the basis for optimization is available

- The decision theory has been available since mid last century
- Decision theory accounting consistently for uncertainty – also subjective – is available through Bayesian decision analysis
- The Bayesian decision analysis provides the framework for risk informed decision support



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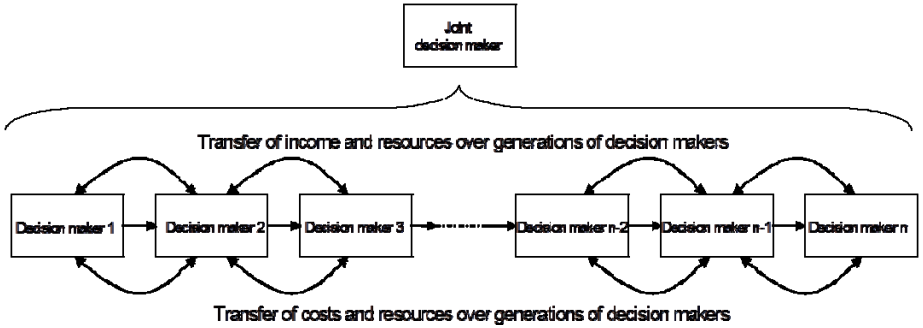
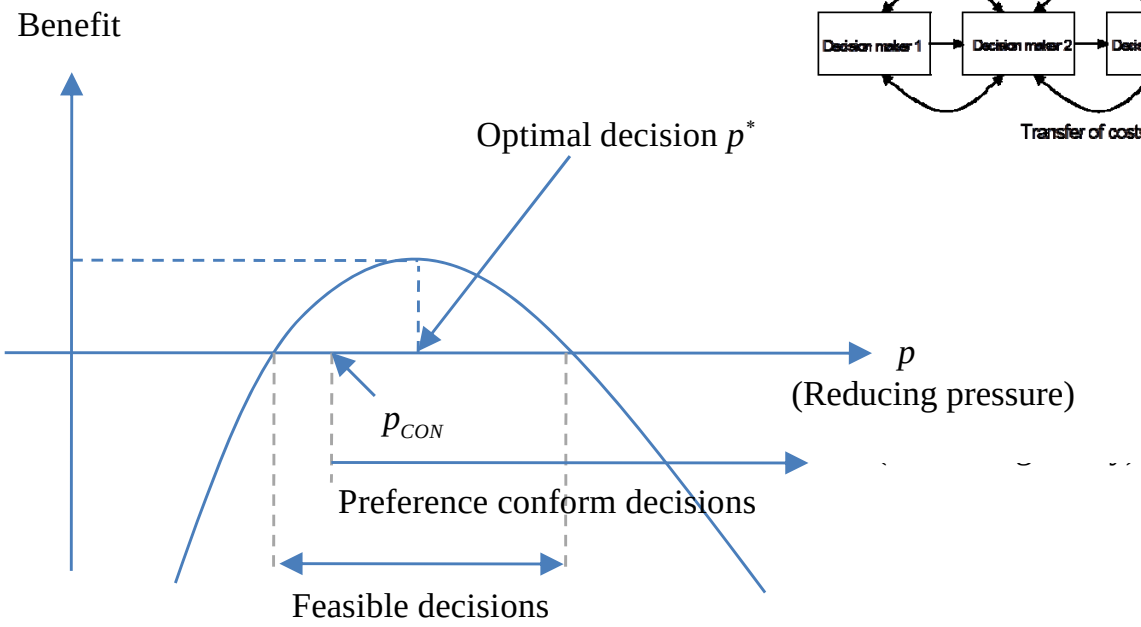
Decision Analysis and Risk

Optimization subject to constraints





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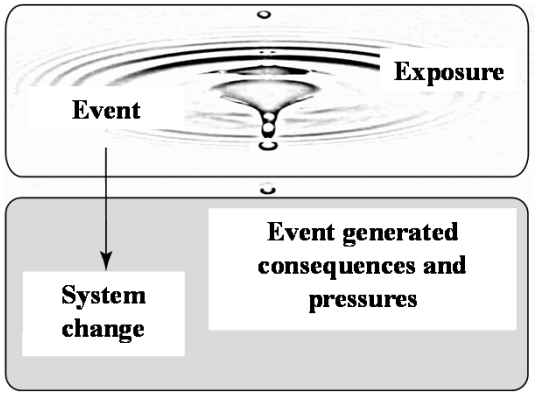
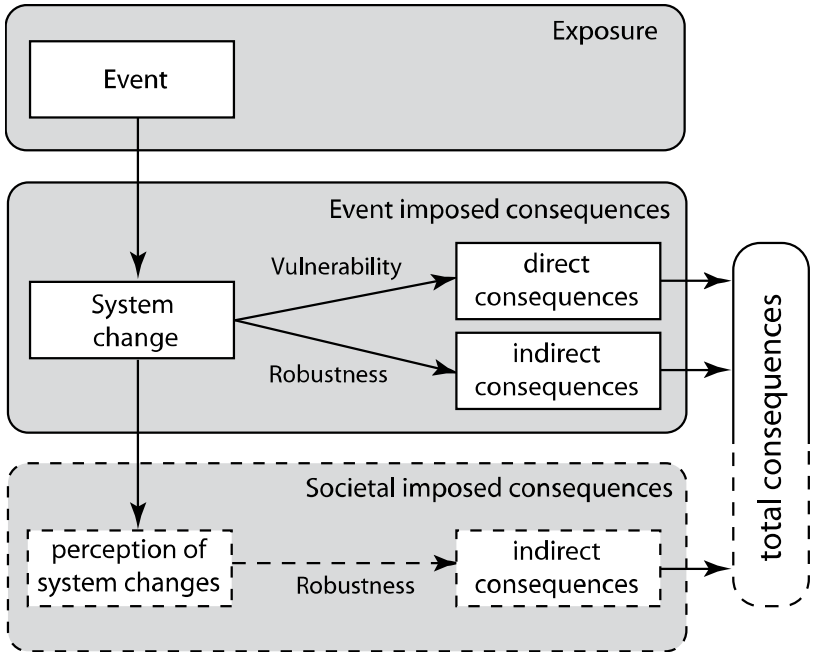
Decision Analysis and Risk

Generic decision models for systems





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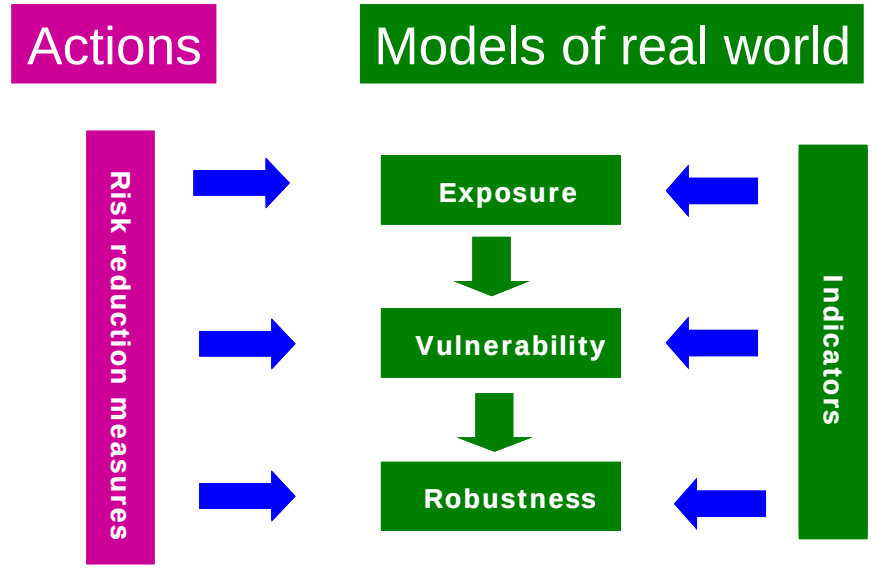
Decision Analysis and Risk

Generic decision models for systems



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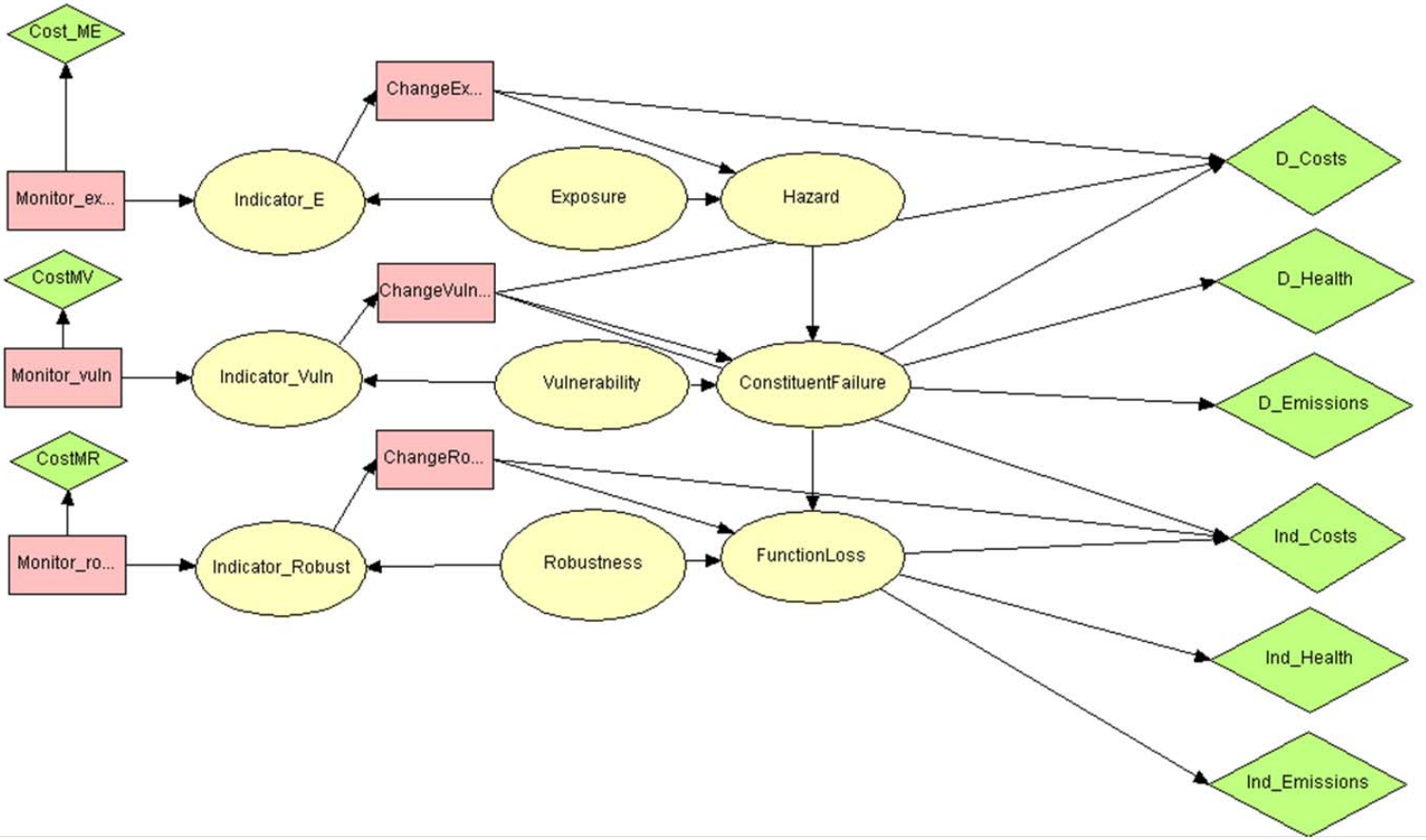
Decision Analysis and Risk

Generic decision models for systems



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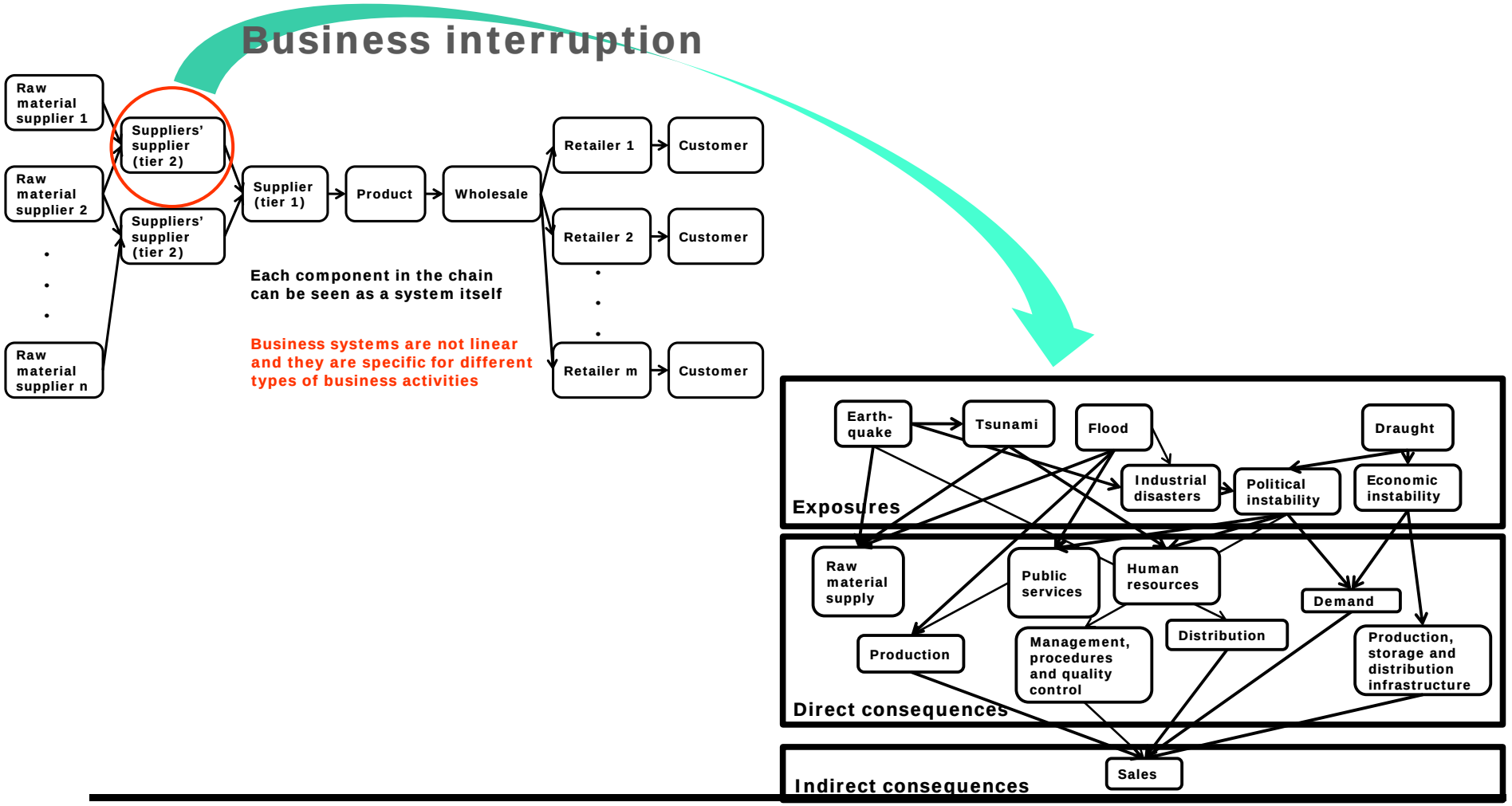
Examples



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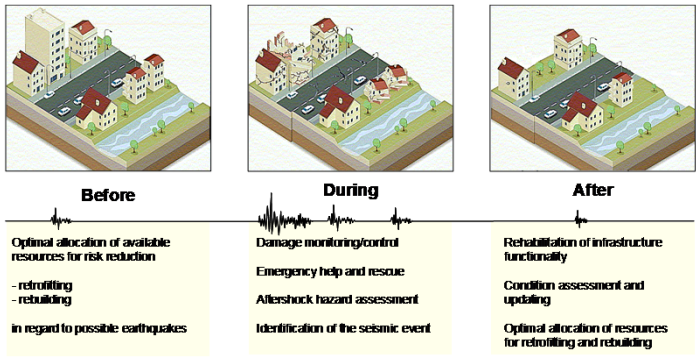
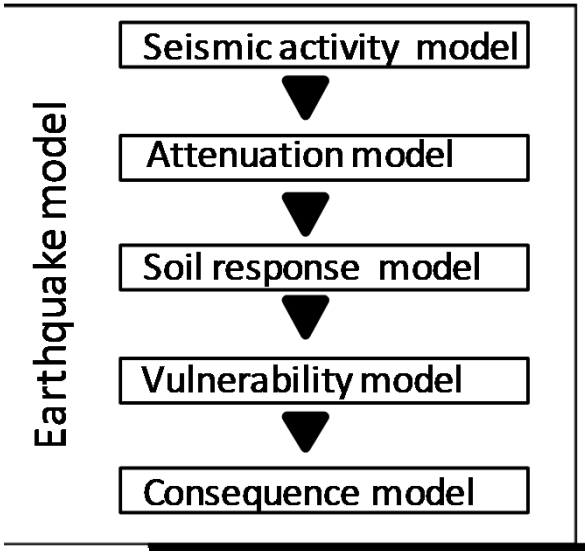
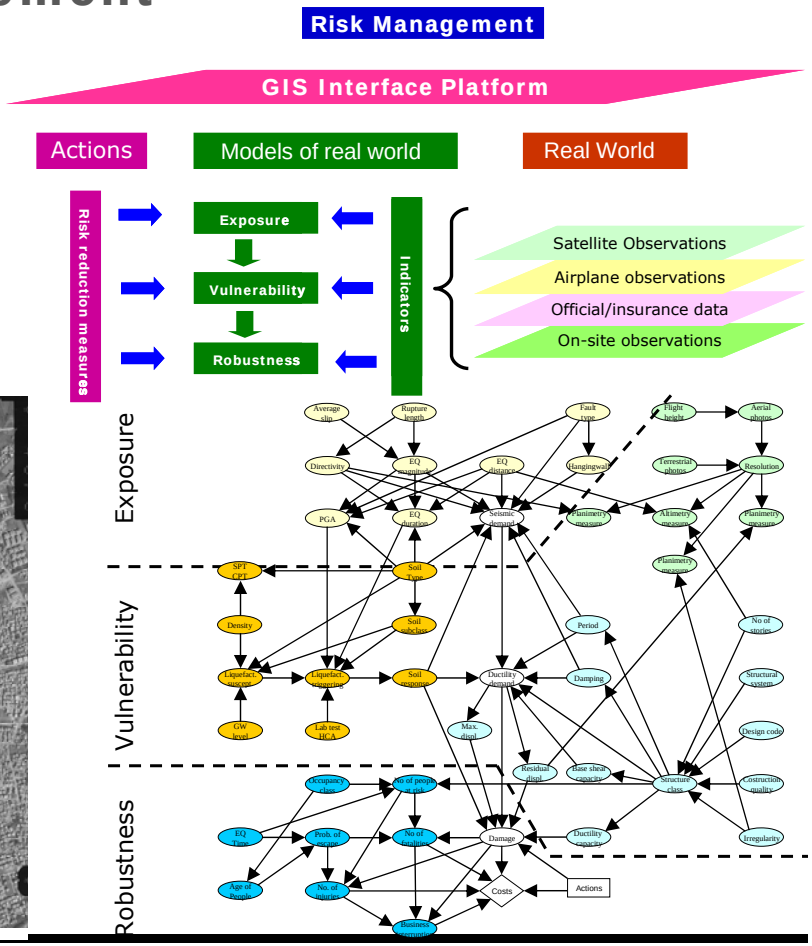
Examples

Large scale eq hazards risk management







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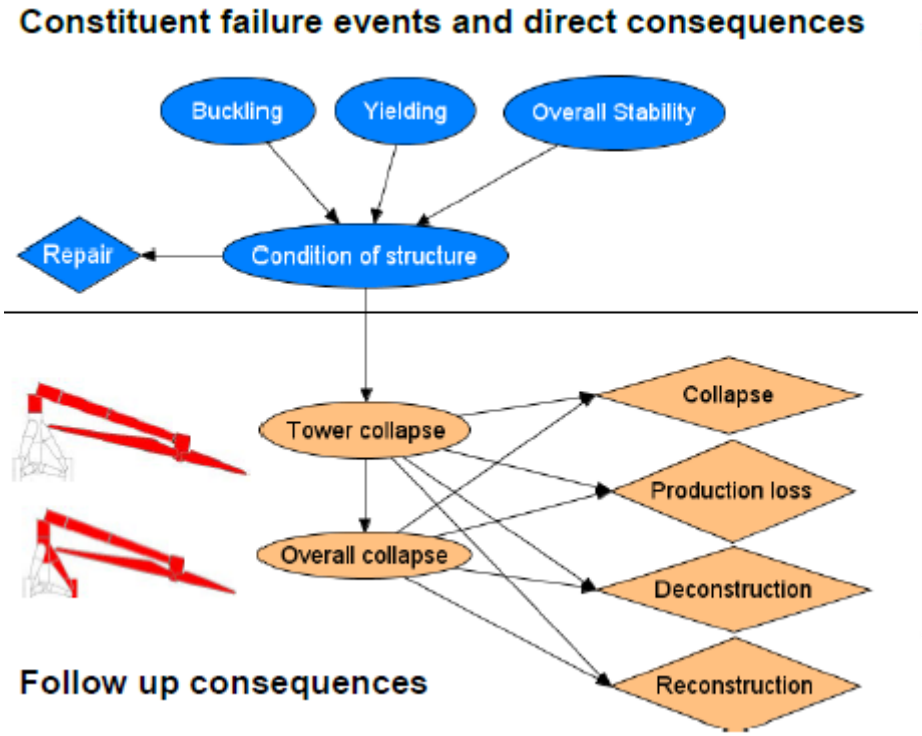
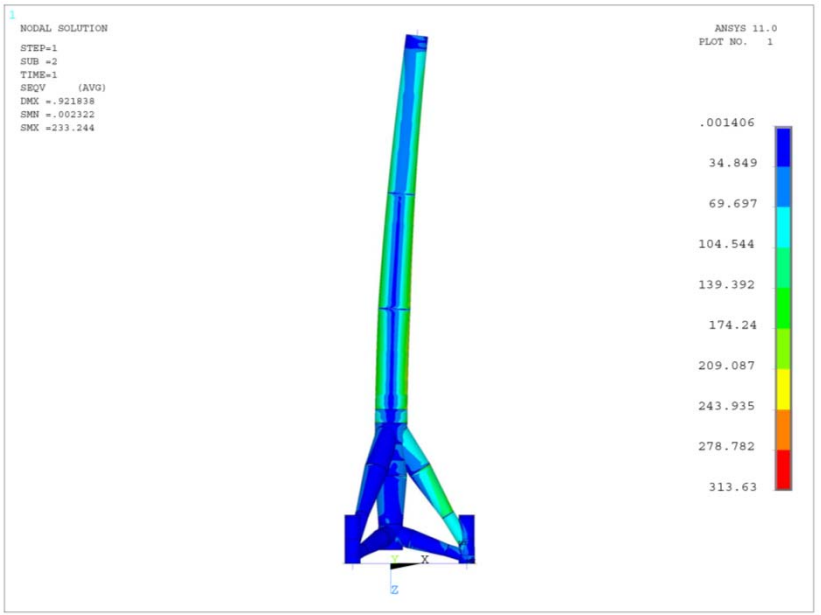
Examples

Optimal wind turbine design





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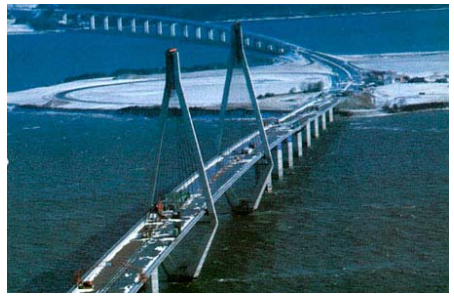
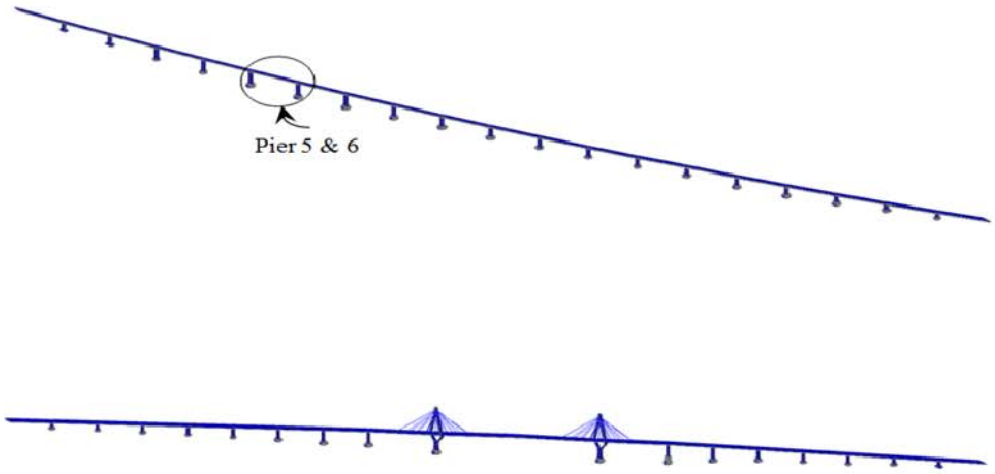
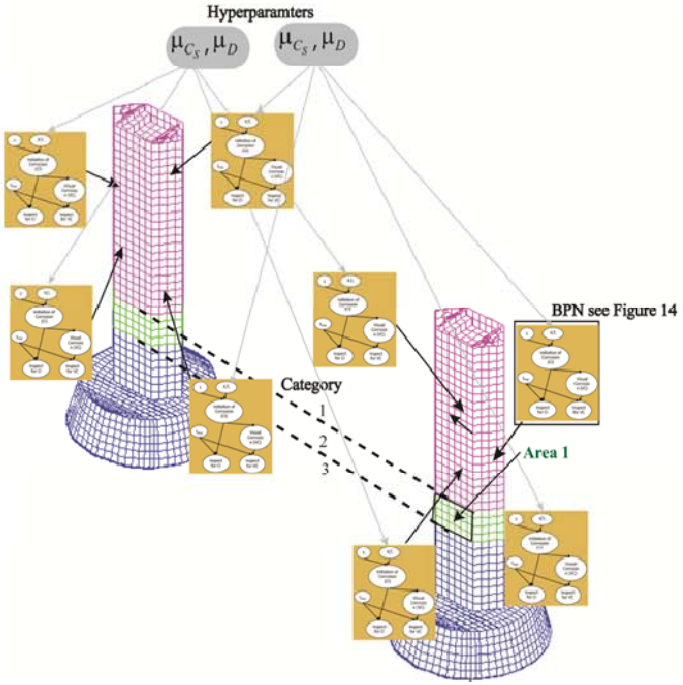
Examples



Life Cycle Cost Optimization for the Farø Bridge





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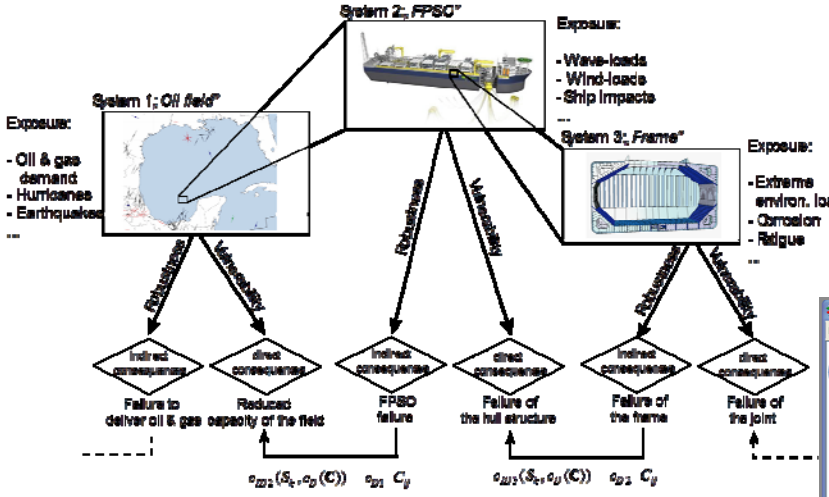
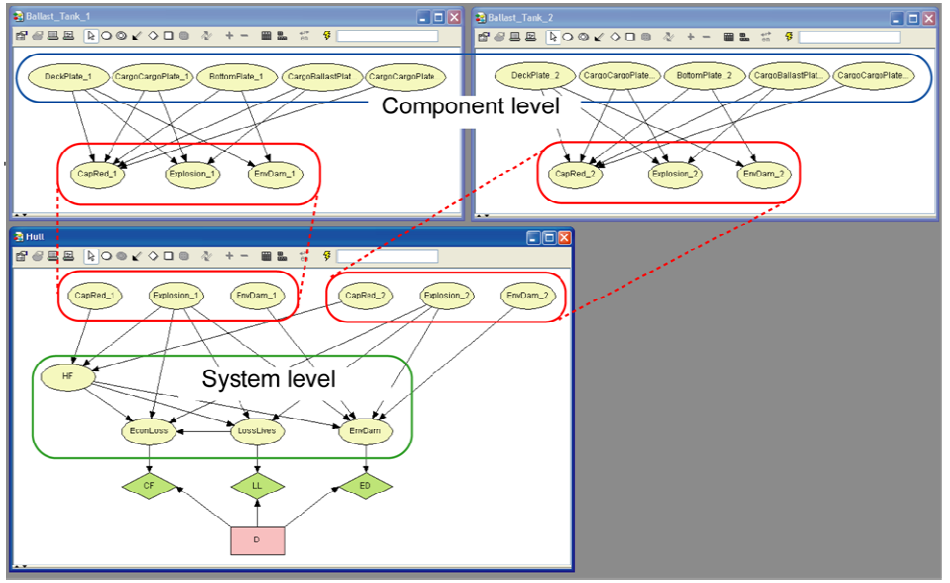
Examples

Design basis optimization for FPSO´s in the GoM





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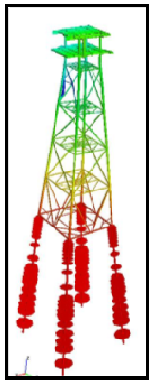
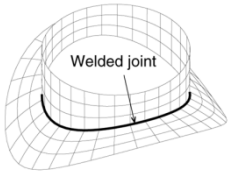
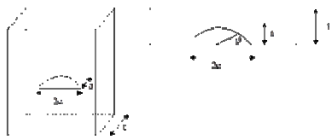
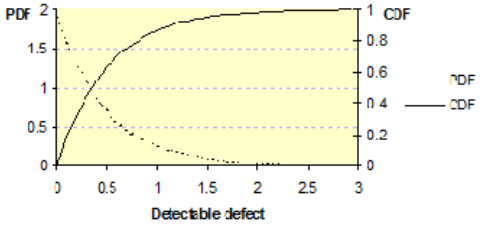
Examples

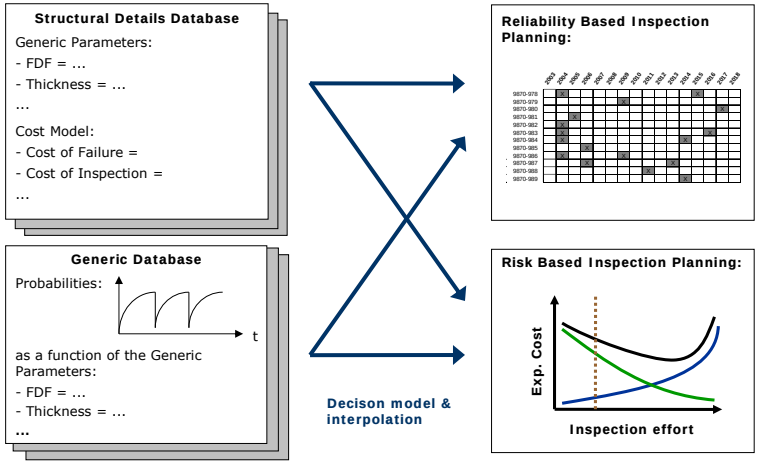
RBI for Jacket Steel Offshore Structures











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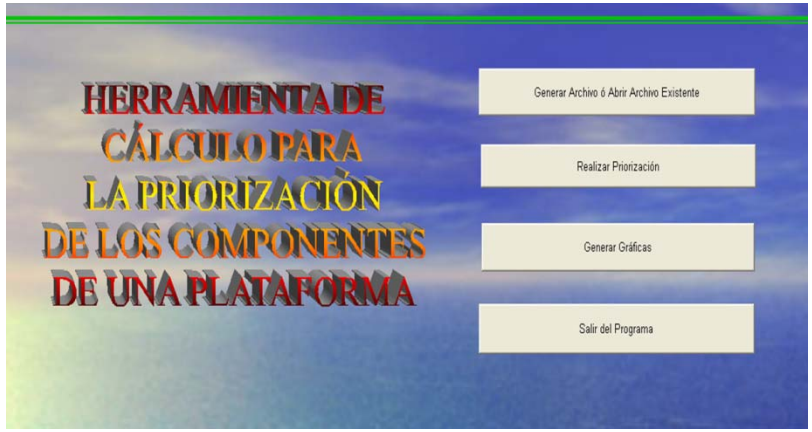
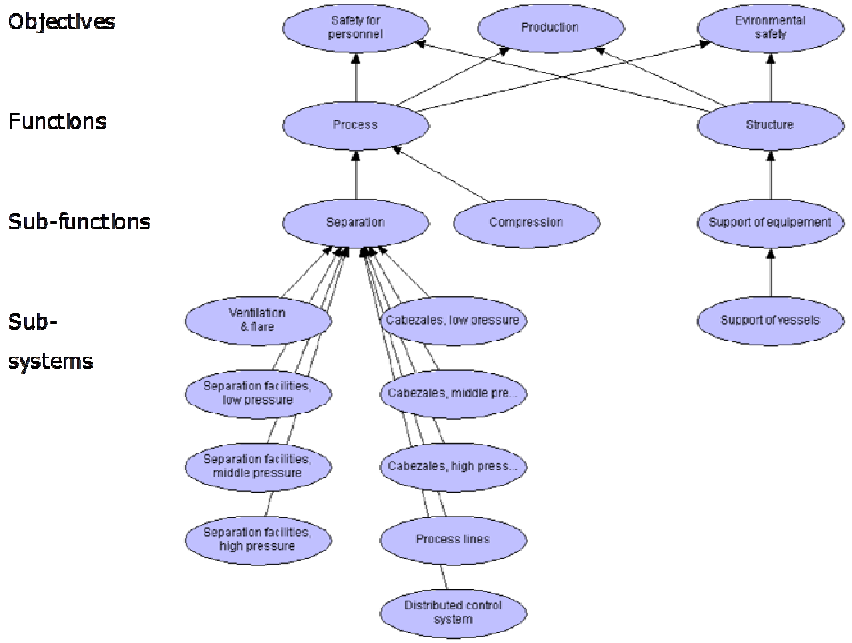
Examples

Maintenance optimization for offshore facilities





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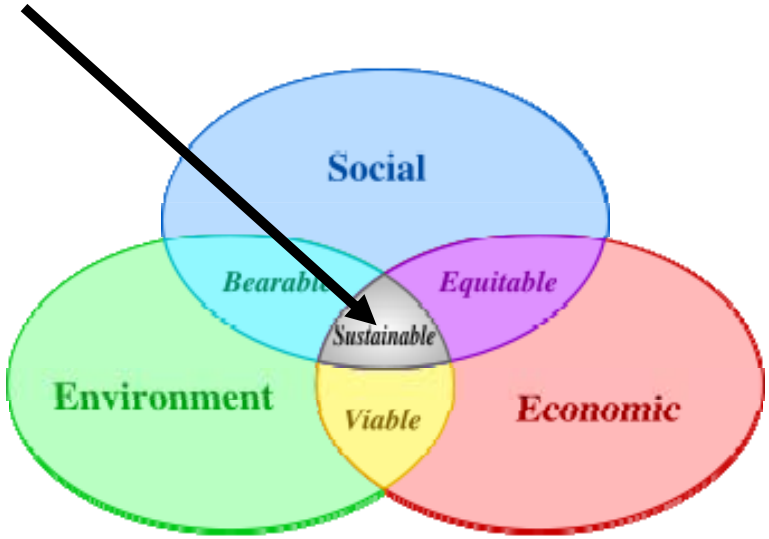
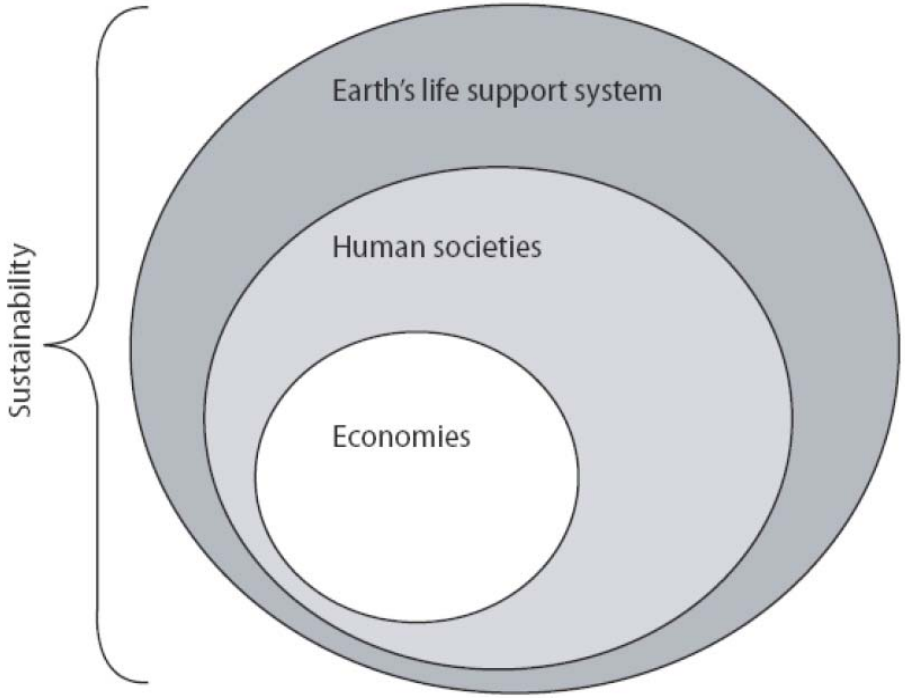
Intentional Blank

LCA and Quantitative Sustainability





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Which social impacts?

- Human health
  - basic needs fulfilment
  - live a healthy and naturally long life
- Human dignity and well-being
  - live a decent life
  - enjoy social respect
- Development and productivity of society
  - social capital and human capital
  - social networks

- How to quantify them?

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Economic sustainability definition

- Utility generation must not decrease over time

$$V(t) = \int_{s=t}^{\infty} U[C(s)]e^{-\delta(s-t)}ds$$

  - U[C(s)] is the utility from society's total consumption at time s
  - δ is the discount rate (Arrow et al., 2004)

Economic sustainability definition

- Means that real per capita welfare must not decrease
- Real investment must be positive, i.e. the sum of the values of all capitals must not be negative
  - Produced capital
  - Human capital
  - Natural capital
- Trade-offs between capitals allowed - growth in one capital can justify decrease in another

Economic sustainability definition

- Compensation between capitals (World 2010)

National accounting aggregates	
Gross savings (% of GNI)	20.9
Consumption of fixed capital (% of GNI)	13.0
Education expenditure (% of GNI)	4.2
Energy depletion (% of GNI)	3.9
Mineral depletion (% of GNI)	0.5
Net forest depletion (% of GNI)	0.0
CO_2 damage (% of GNI)	0.4
Particulate emissions damage (% of GNI)	0.2
Adjusted net savings (% of GNI)	7.2

(World Bank 2010)

- ”Soft sustainability”
- Can a society without nature be sustainable?

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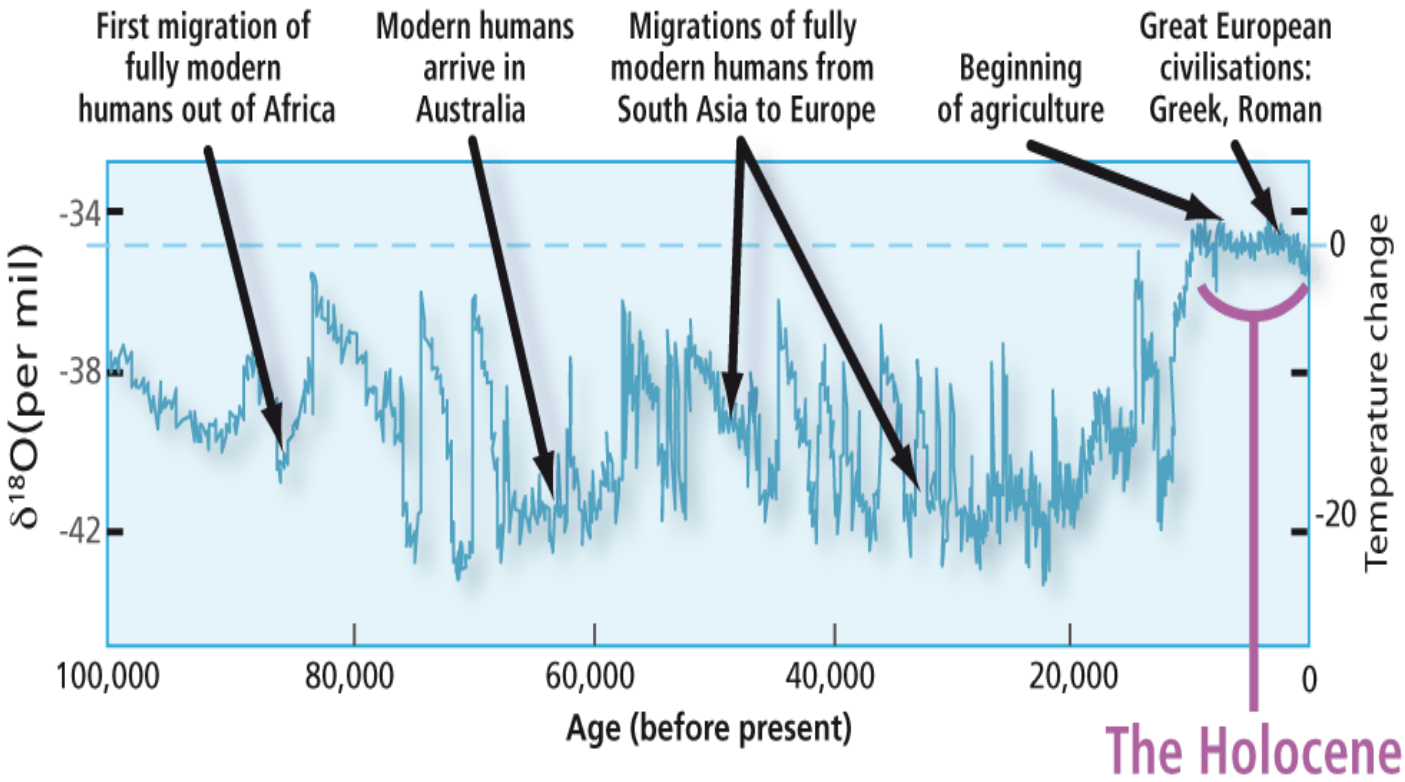
Planetary boundaries

Keeping the planet in the holocene



International Geosphere Biosphere Programme (2015)

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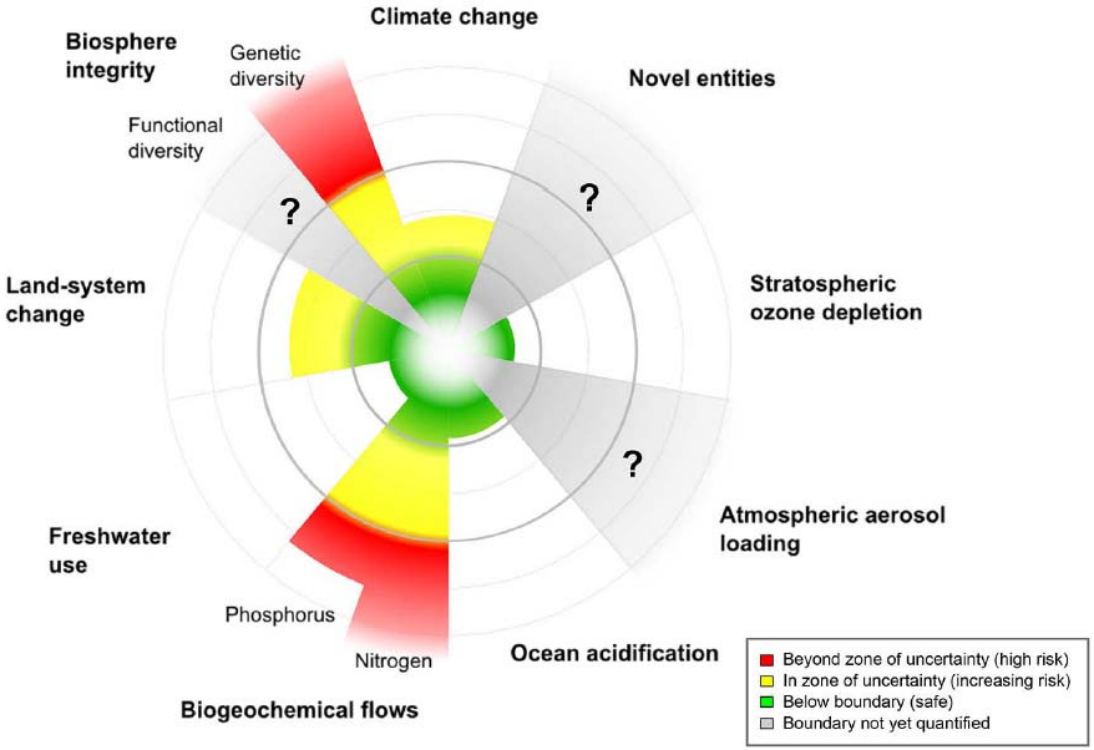
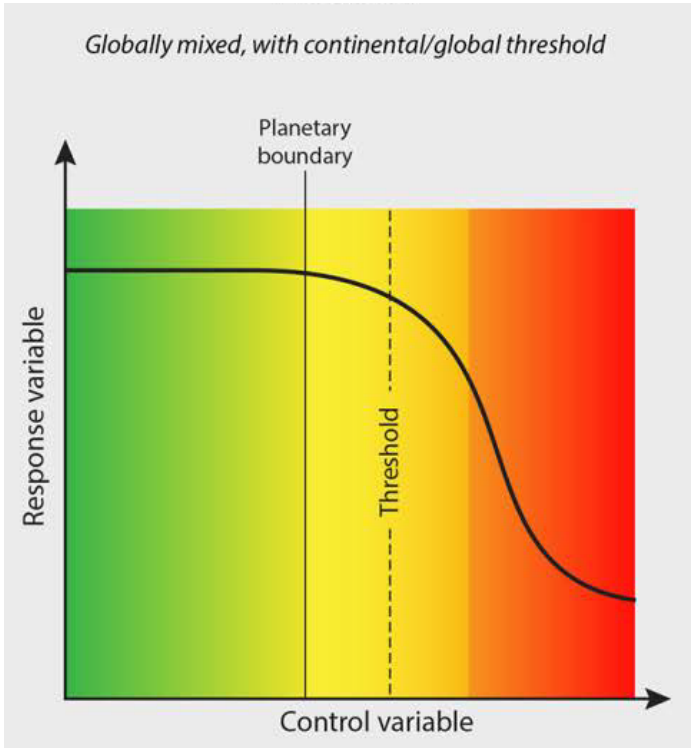
Planetary boundaries





Steffen et al. (2015)

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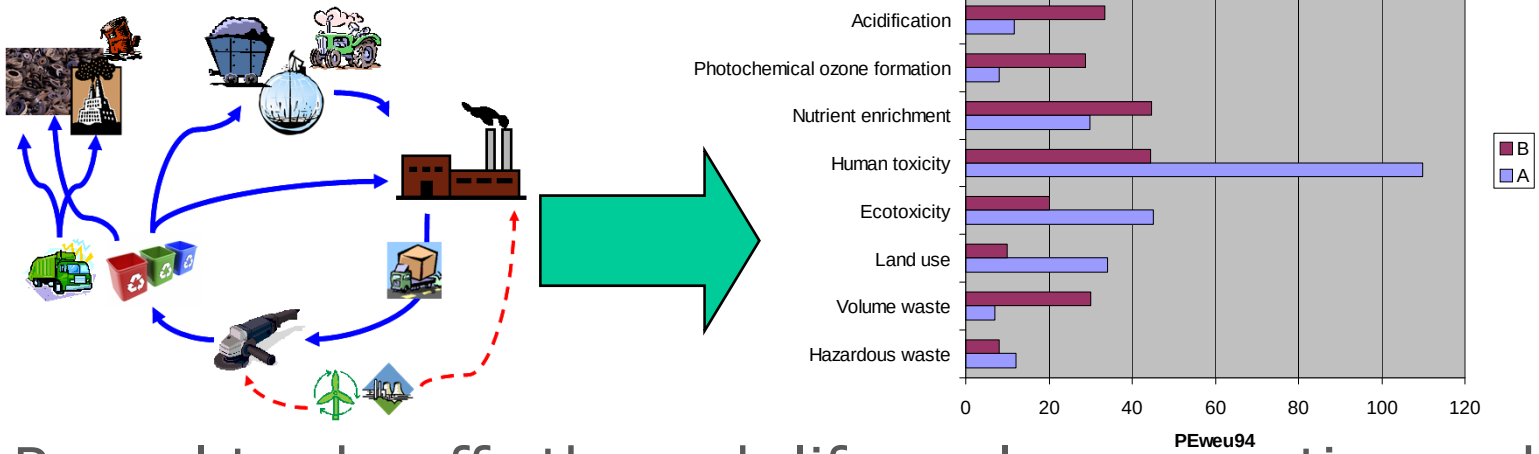
Life cycle assessment

- Modelling the whole life cycle and all relevant environmental impacts



- Reveal trade-offs through life cycle perspective and broad coverage of impacts
- Used to assess and optimize the eco-efficiency of a product or service: $\frac{Delivered\ service}{Caused\ environmental\ impact}$
- But is the activity environmentally *sustainable?*

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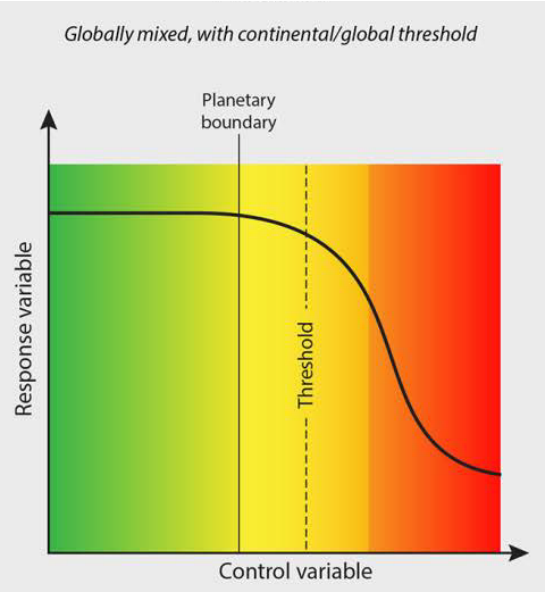
What is a sustainable level of environmental impact?

- Sustainability: Fulfilment of needs
  - Today and in the future
  - Which needs?
  - How to fulfil them?
  - For how many?



- Carrying capacity: *The maximum impact that an ecosystem can sustain without experiencing permanent changes in its structure or central functionalities*
  - ”No” effect
  - For all categories of environmental impact

Sustainable annual impacts of a Person

Impact category	Sustainable impact (person.year)	Carrying capacity approach (indicator based on)
Climate change	0.98 ton CO_2-eq	Resilience (2° target)
Climate change, alternative	0.52 ton CO_2-eq	Resilience (350 ppm CO_2)
Ozone depletion	0.078 kg CFC-11-eq	Resilience (7.5% decrease in average ozone conc.)
Photochemical ozone formation	2.5 kg NMVOC-eq	Protection of sensitive species (3 ppm.h AOT40)
Terrestrial acidification	$1.4 \cdot 10^3$ mole H+ eq	Buffer flow (1080 mole H^+ eq/ha/year)
Terrestrial eutrophication	$1.8 \cdot 10^3$ mole N eq	Buffer flow (1270 mole N eq/ha/year)
Freshwater eutrophication	0.46 kg P eq	Resilience (0.3 mg P/L)
Marine eutrophication	31 kg N eq	Resilience (1.75 mg N/L)
Freshwater ecotoxicity	$1.0 \cdot 10^4$ [PAF].m^3.day	Protection of sensitive species (HC5(NOEC))
Land use, soil quality	1.2 tons eroded soil	Buffer flow (0.85 tons/(ha.year))
Land use, biodiversity loss	$9.5 \cdot 10^3$ m^2.year	Resilience (31% un-conserved land area)
Water depletion	490 m^3	Buffer flow (2100 km^3/year)

Bjørn & Hauschild, 2015

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Societal and company perspective

How do we allocate the space?

- Per capita (the person equivalent)
- Per area
- Per created value (GDP, turnover)
- Per satisfied need (where in the pyramid?)
- Per generated employment
- What about the historical justice (climate change)?
- …

The DTU Global Decision Support Initiative

Aims

1. Systematize and integrate **methods for system identification and representation**, and **decision support methodologies** across different application fields.
2. Improve scientific methods for **sustainability assessment** and **risk assessment** in support of decision – and policy making.
3. Propose **common principles and methods** for use across the different technological sectors covered by DTU.
4. **Apply** the developed methods and models **to selected application domains**.
5. Collect and share knowledge for **cross-fertilization** and development of new and more accurate insights.
6. **Support the implementation** of quantitative sustainability- and risk assessment as well as their use in engineering decision making in all education profiles offered at DTU.
7. ***Strengthen DTU's profile*** *in international consulting*

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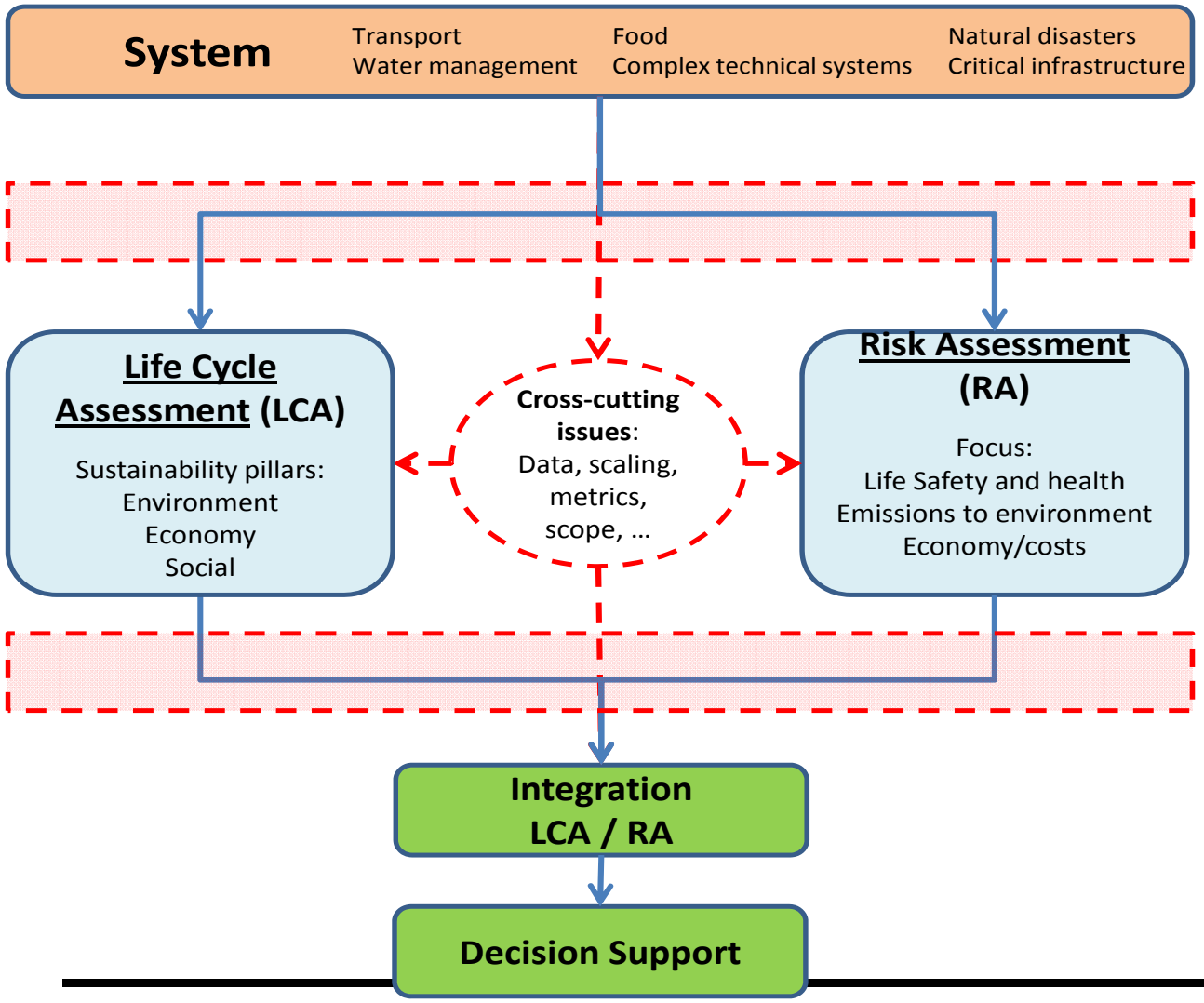
The DTU Global Decision Support Initiative



Harmonisation I:

- Basic research
- Data
- Methodologies
- Scope/boundaries
- Scenarios

Harmonisation II:

- Uncertainty
- Results
- Reporting
- Applicability

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The DTU Global Decision Support Initiative

Initial Package of Post Doc Projects

- Probabilistic Modeling and Assessment of Complex Systems
- Metrics and Criteria for Sustainability and Risk management
- Decision Theory and Decision Support Tools
- Open Platform Design, Data and Risk Mapping Tools
- Natural Hazards Risk Modeling and Management

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