The Söderström Bridge

COST Action TU1402 – Case study proposal

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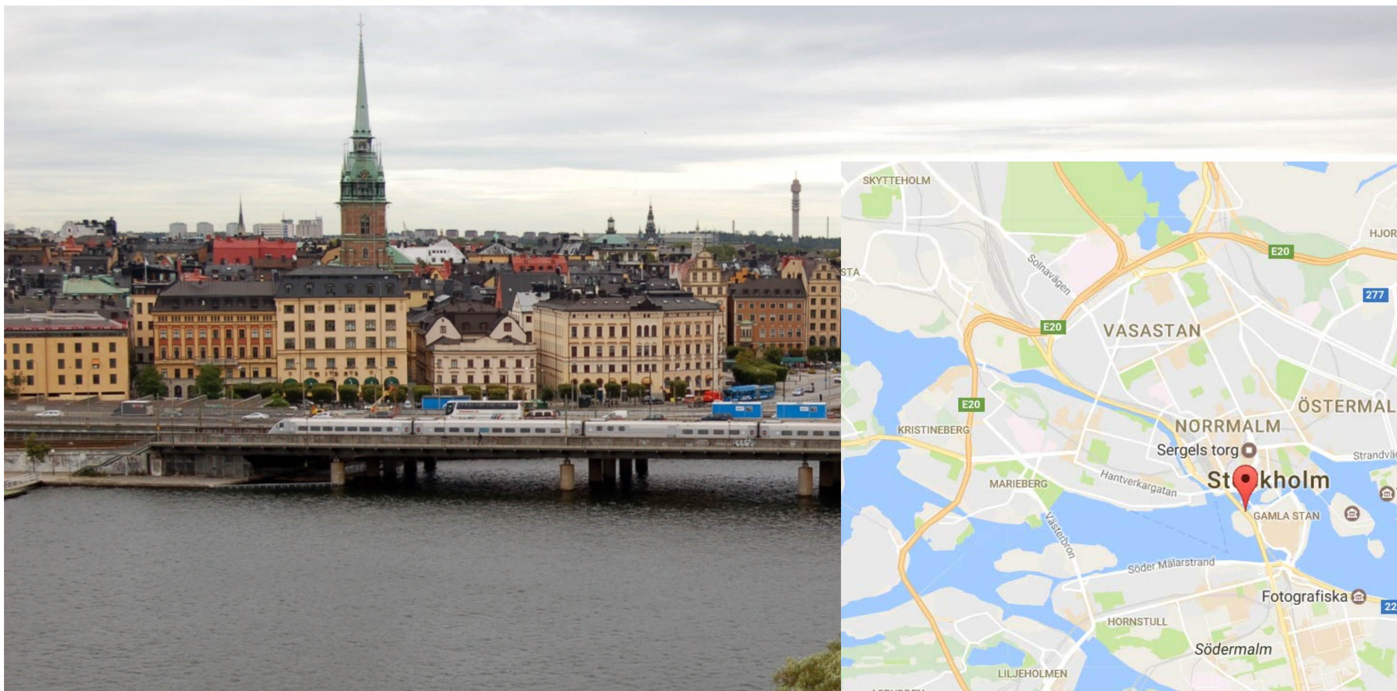
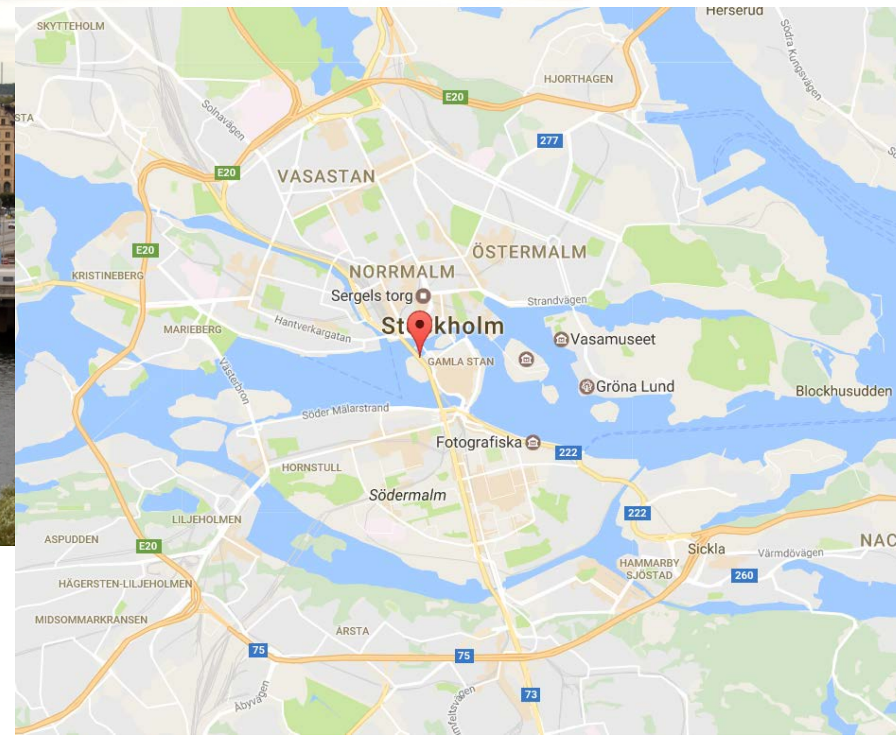
The Söderström Bridge



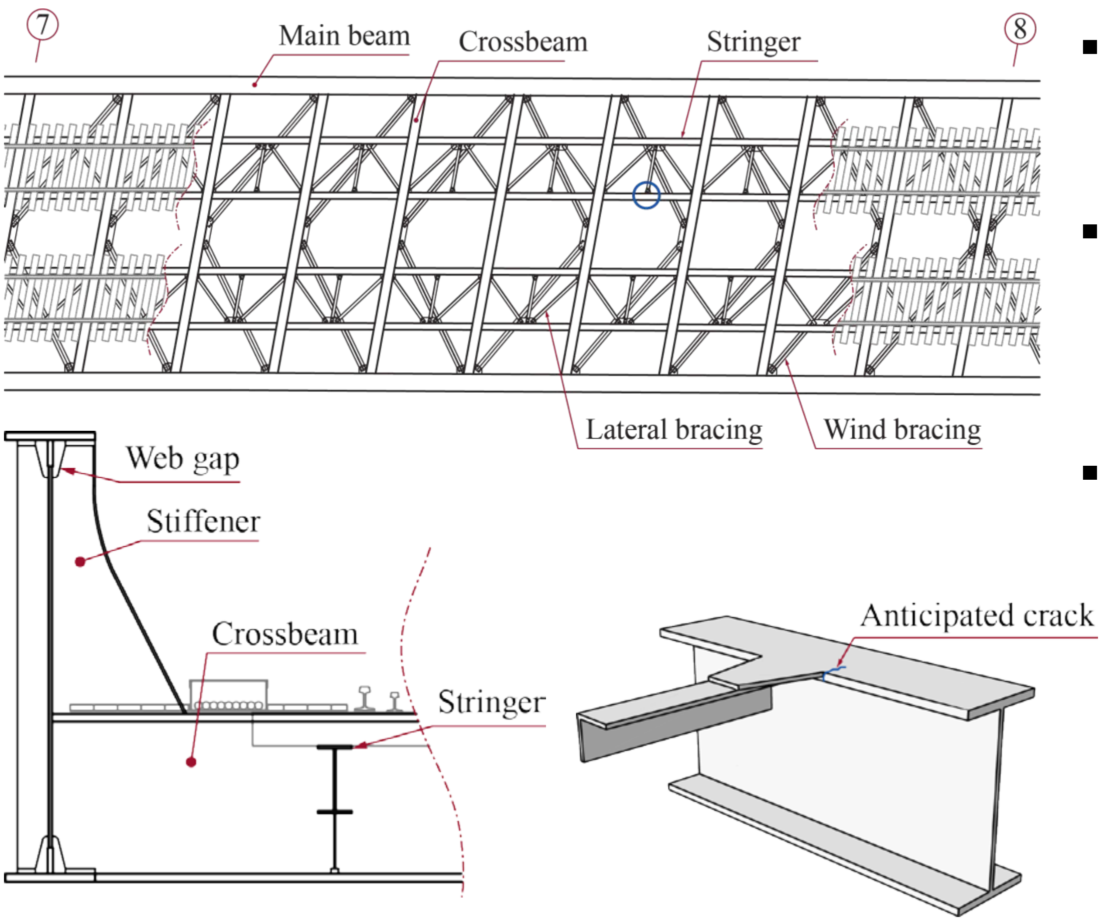


The Söderström Bridge

Some properties:

- A steel girder bridge continuous in 6 spans.
- A total length of 190 m.
- Built 1950.
- Carries the railway traffic through the so-called wasp waist in Stockholm.
- About 550 trains pass the bridge every day.
- Long term measurements of strains for fatigue assessment (56 strain gauges).

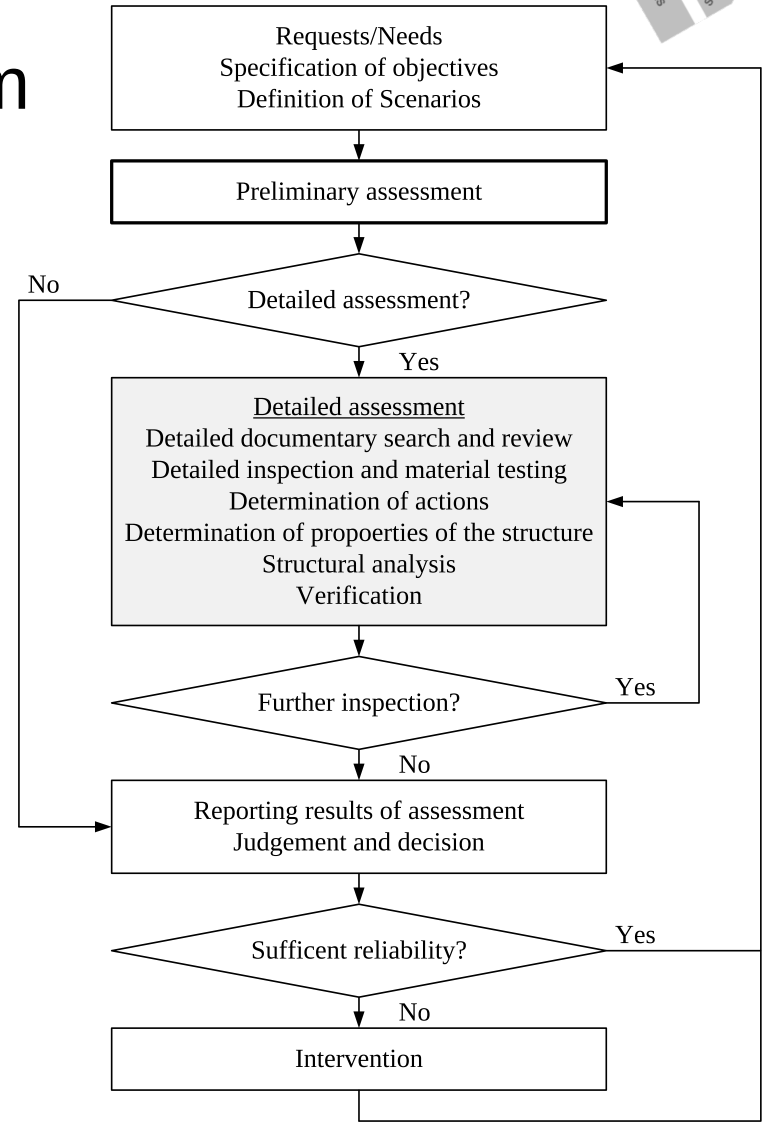
The Söderström Bridge



- The bridge contains numerous fatigue critical details.
- This case study is focused on the connection between the lateral bracing and the stringer beams.
- Previous assessments (conventional and enhanced) have shown an exhausted fatigue life.

Condition assessment problem

- What methods should be used, linear damage accumulation or fracture mechanics, how can measured response be utilized to the most?
- What further actions should be taken regarding inspections, monitoring, and repair actions to lengthen the service life of the bridge?
- Worth to do further assessment?
- How?
  - Inspect more/better?
  - Improve structural analysis?
  - Improve consideration of uncertainties?
  - Etc.



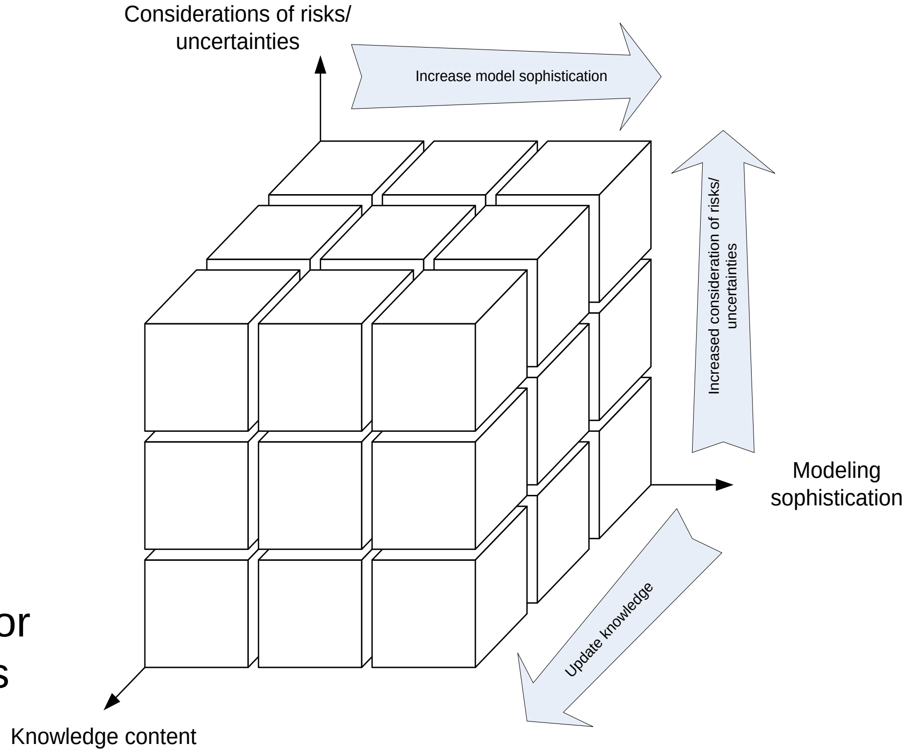
ISO 13822

Levels of assessment (examples)

	Assessment level				
Ref.	1	2	3	4	5
BRIME, 2001	Partial factors method, loads and resistances from records and standards, simple structural model	Partial factors method, loads and resistances from records and standards, refined structural model	Partial factor method, material properties and loads based on in-situ observations	Modification of partial factors, material properties and loads based on in-situ observations	Full probabilistic assessment
SAMCO, 2006	Direct assessment of serviceability values from measurements (no structural analysis)	Assessment of safety and serviceability using simple model based methods (data from documents)	Assessment using refined model based methods (data from tests, monitoring, etc.)	Adaptation of target reliability measures and assessment with modified structure-specific values.	Full probabilistic assessment (data from tests, monitoring, etc.).
Wenzel, 2009	Condition assessment (simple instrumentation and simple decision support)	Performance assessment (more detailed then the previous level, more indicators)	Detail assessment and rating (includes analytical model representing the structure)	Lifetime prediction (data from at least 3 years and simulations, special software for decision support)	
Skokandic et al., 2016	a) Linear analysis b) + updated loads from measurements	a) Non-linear analysis with global safety factor b) + updated loads from measuerements	a) Probabilistic approach b) + Bayesian updating		
Plos et. al, 2017	Simplified analysis methods	3D linear shell (FE) analysis	3D non-linear shell FE analysis elements and fully bonded reinforcement	3D non-linear FE analysis with continuum elements and fully bonded reinforcement	3D non-linear FE analysis with continuum elements including reinforcement slip

Levels of condition assessment

- Consolidate approaches considering three aspects of assessment:
  - Modeling sophistication
  - Considerations of risk/uncertainty
  - Knowledge/information content
- Improved assessment entails moving away from origin
- Central question:
  - How can this representation aid with decisions?
- More specifically:
  - Determine suitability of methods for specified case; are some methods less appropriate?
  - Provide guidance for ’navigating the cube’



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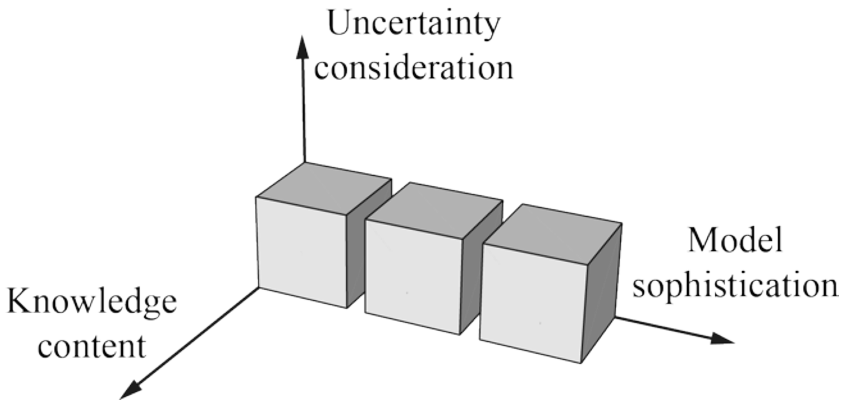
Model sophistication

1. Initial assessment
   - Conventional assessment following the governing regulations.
   - Based on theoretical load models and a verification of stress levels.
2. Linear damage accumulation
   - Palmgren–Miner rule.
   - Load models based on “realistic trains”.
   - Consideration of historic loads.
3. Linear elastic fracture mechanics
   - Nonlinear damage accumulation.
   - Consideration of a physical crack.
   - Consideration of load sequence.



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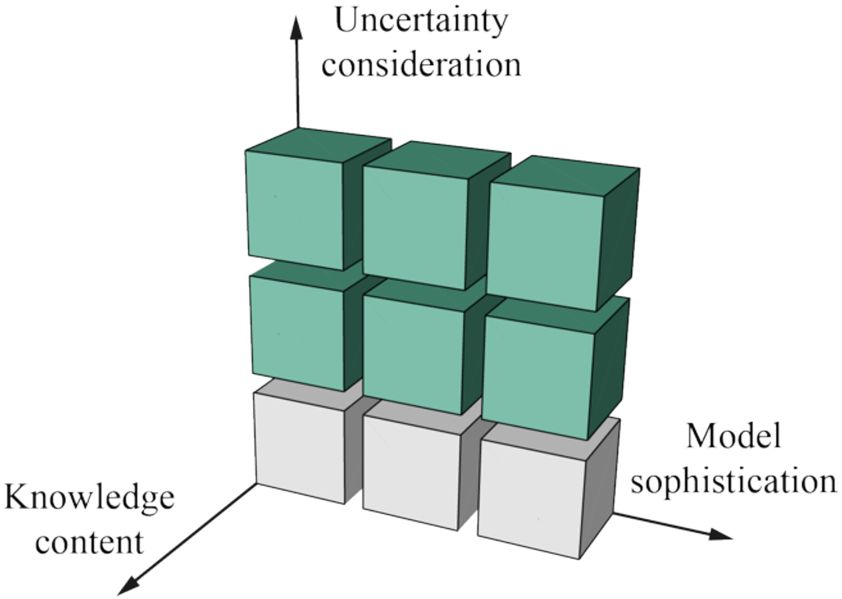
Uncertainty consideration

1. Deterministic assessment
   - Conventional assessment following the governing regulations.
2. Reliability-based assessment
   - Limit state function.
   - Uncertain data considered by stochastic variables.
   - Model uncertainties.
   - An estimated probability of failure.
3. Risk-based assessment
   - Risks and benefits.
   - Enables decision support.



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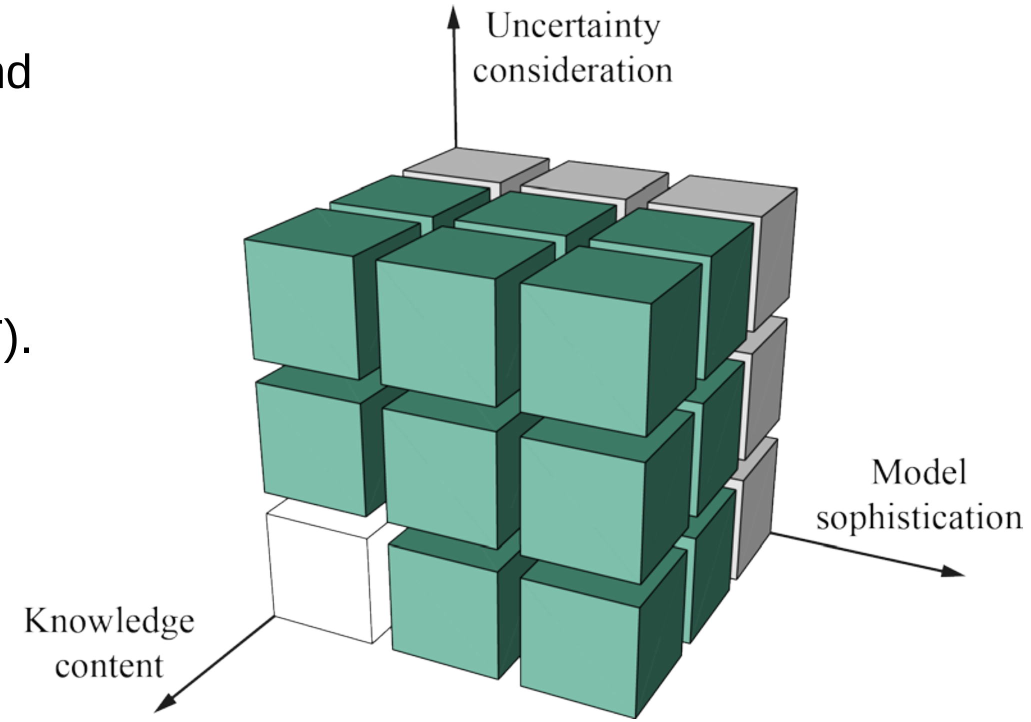
Knowledge content

1. Desktop assessment
   - Information from drawings and regulations.
2. Inspections and testing
   - Damage prognosis.
   - Non-destructive testing (NDT).
   - Material samples.
3. Monitoring
   - Response measurements.



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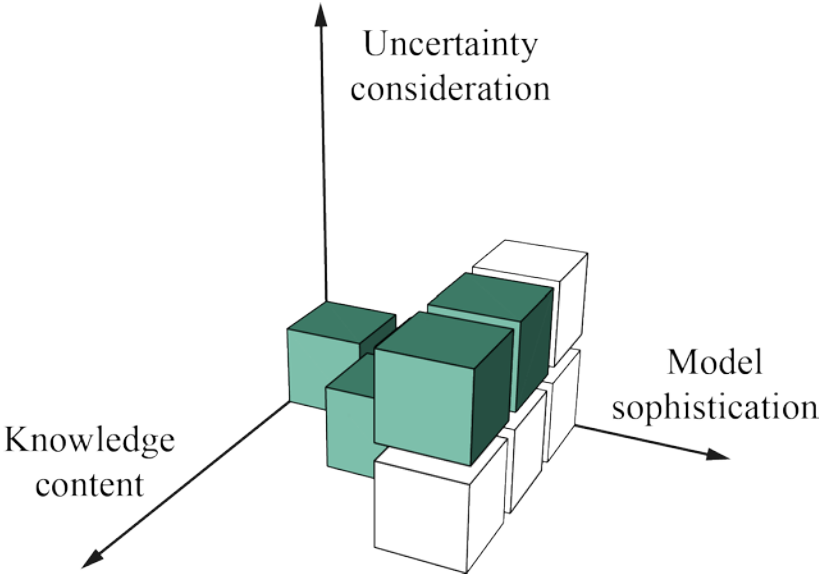
Some numerical results…

Assessment level	Fatigue life/number of cycles
Initial assessment	Insufficient
Linear damage accumulation Reliability-based Measured response	8.6×10^6
Linear elastic fracture mechanics Reliability-based Measured response	20×10^6
Linear elastic fracture mechanics Reliability based Measured response NDT results (magnetic particle testing)	42×10^6



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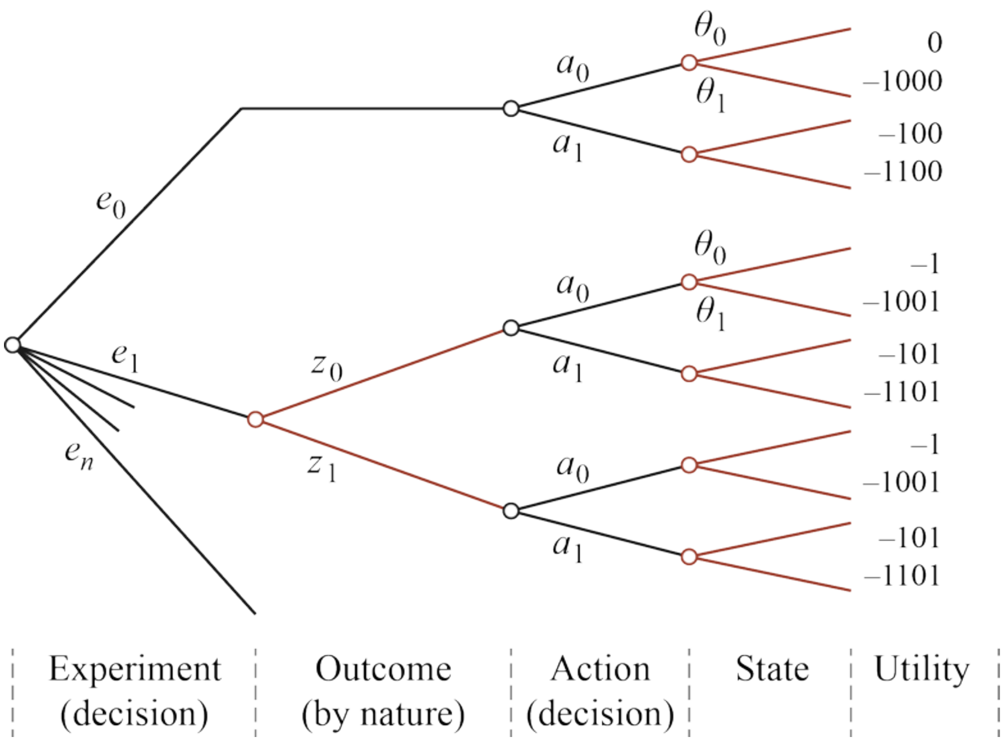
Pre-posterior analysis



e_0	– No inspection
e_1	– Inspect
z_0	– Sufficient reliability
z_1	– Insufficient reliability
a_0	– Do nothing (0)
a_1	– Repair (-100)
θ_0	– Nothing happens (0)
θ_1	– Failure of the detail (-1000)

Utility – Cost of experiments + actions + final state.

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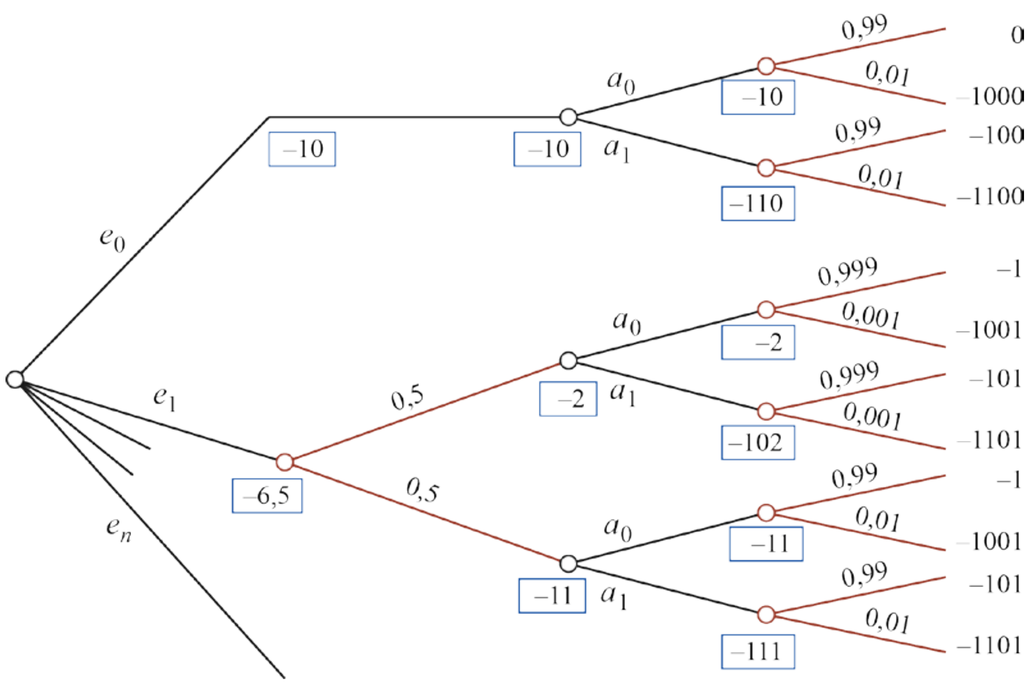
Pre-posterior analysis



Result with tentative values:

- $E[u(e_0)] = –10$
- $E[u(e_1)] = –6.5$

Best decision: e_1

Some references

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Thank you for your attention!