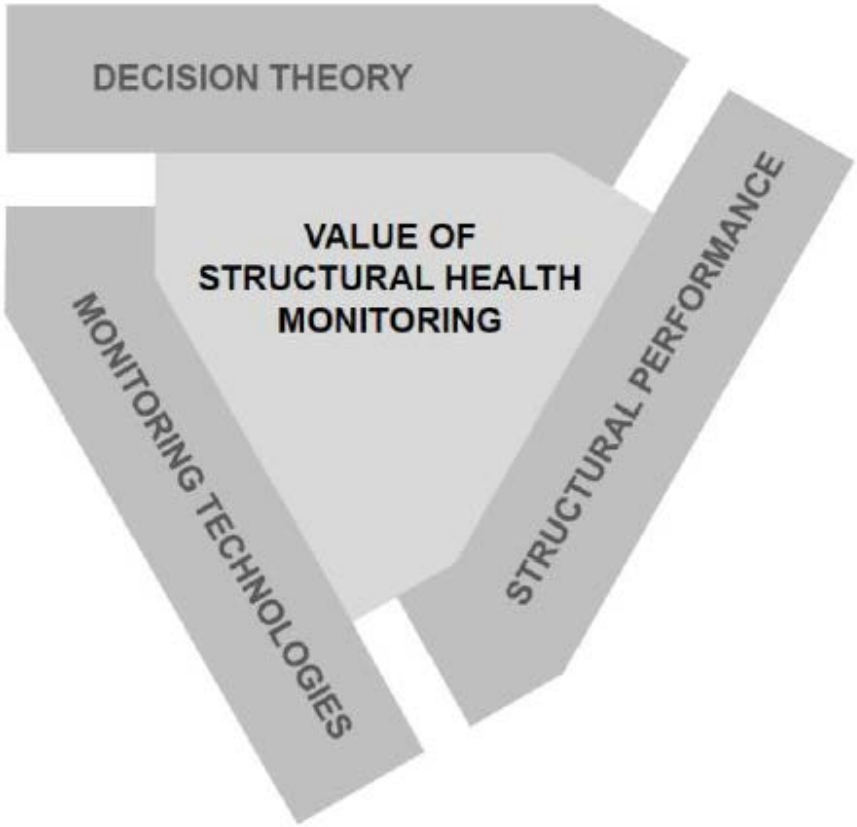
COST Action TU1402
Quantifying the value of Structural Health Monitoring

2nd Workshop
September 28-29, 2015
Istanbul



Joint Session on
WG2: SHM Strategies and Structural Performance
WG3: Methods and Tools

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Daniel Straub, Eleni Chatzi

Objectives of WG2 and WG3

- Categorise available **SHM technologies** with regard to the **measured quantity** and the related **structural performance** – collect and represent “best practice”
- Quantify links between measured quantities and structural performance of interest with consistent treatment of **uncertainties**.

➢ **Milestone:** Report on SHM categorisation and SHM information modelling by the end of year 2

- Provide a systematic overview of **methods and tools** for estimating **Value of Information** (VoI), and set up a repository of openly available tools.
- Use example applications to steer research on **computationally efficient algorithms** needed for VoI analysis

➢ **Milestone:** Report on databases and toolboxes for assessing the value of SHM by the end of year 2

DTU workshop: Participant comments

Main challenges regarding performance assessment of different structural types

- Situation within the whole value chain
- Find correct performance indicators and link with performance thresholds
- Step between indicators and actual performance
- Work with matrices – have several lists (e.g. by structural type, material, etc)
- Link to COST Action on bridges

Needs/opportunities for SHM in performance assessment

- Owners want to reduce costs but it is often unclear what they want exactly (bearings, corrosion, foundations, …) - what are the major problems?
- To enhance confidence in performance assessment, we must set “good” thresholds
- Budget and knowhow constraints can be crucial

Categorization of SHM technologies

- SHM technologies can be categorized in many different ways:
  - Type of structural application
  - Type of data or features extracted
  - Global or local nature of the methods
  - Model-based versus data-based methods
- In order to guide owners in the selection of appropriate SHM technologies, it seems natural to depart from the **type of structure**
- The structure then defines relevant **types of performance**, e.g. for a bridge:
  - Ultimate limit state
  - Serviceability limit state
  - Durability
  - Fatigue
- The type of performance can be assessed through **indicators,** e.g. for durability:
  - Appearance (rust stains)
  - Ingress of deterioration agents (chlorides, CO_2)
  - Crack width
  - Loss of material
- **Threshold values** may be set to define the onset of further action. This requires monitoring and interpretation of these indicators through an appropriate **SHM strategy.**

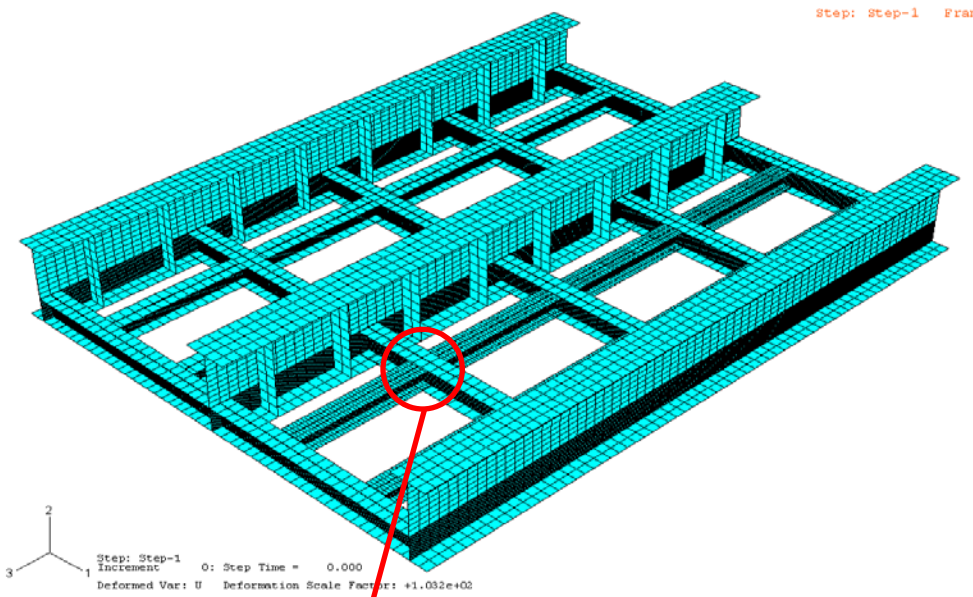
SHM Strategies

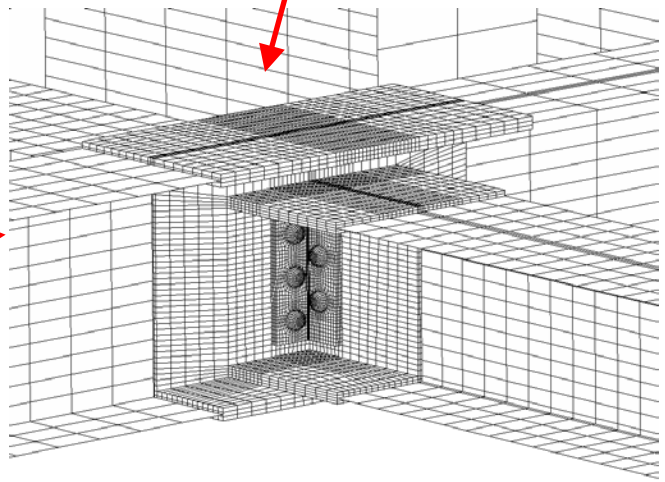
strategy /ˈstratɪdʒi/: *plan of action designed to achieve a long-term/overall aim*

- An SHM strategy is an organized collection of **engineering knowhow**, **sensor technologies** and **methods/tools for data processing**, jointly implemented in order to assist owners in making **asset management decisions**
- SHM is underpinned by **observations** on the behaviour of the structure or the actions to which the structure is exposed (environmental, loading, …).
- For a given type of structure and performance requirement, a selection of suitable SHM strategies can be made by qualitatively screening alternatives through **knowledge** and **experience**.
- A final selection and design of the SHM strategy can be facilitated by quantitative analysis, e.g. relying upon the concept of the **Value of Information**.
- A **framework** is proposed to structure the different concepts involved.

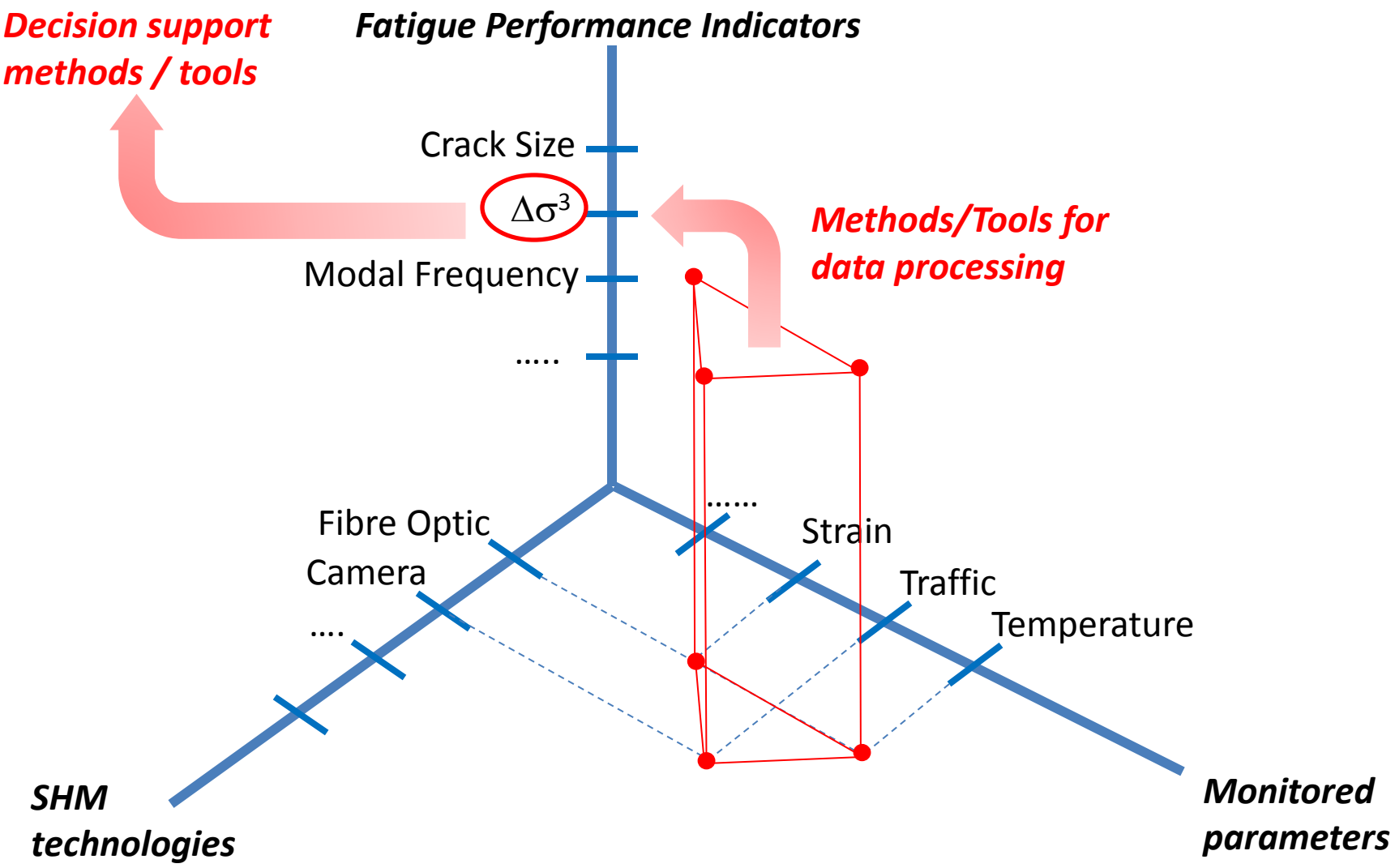
…from observations to decisions…

A railway bridge with fatigue problems

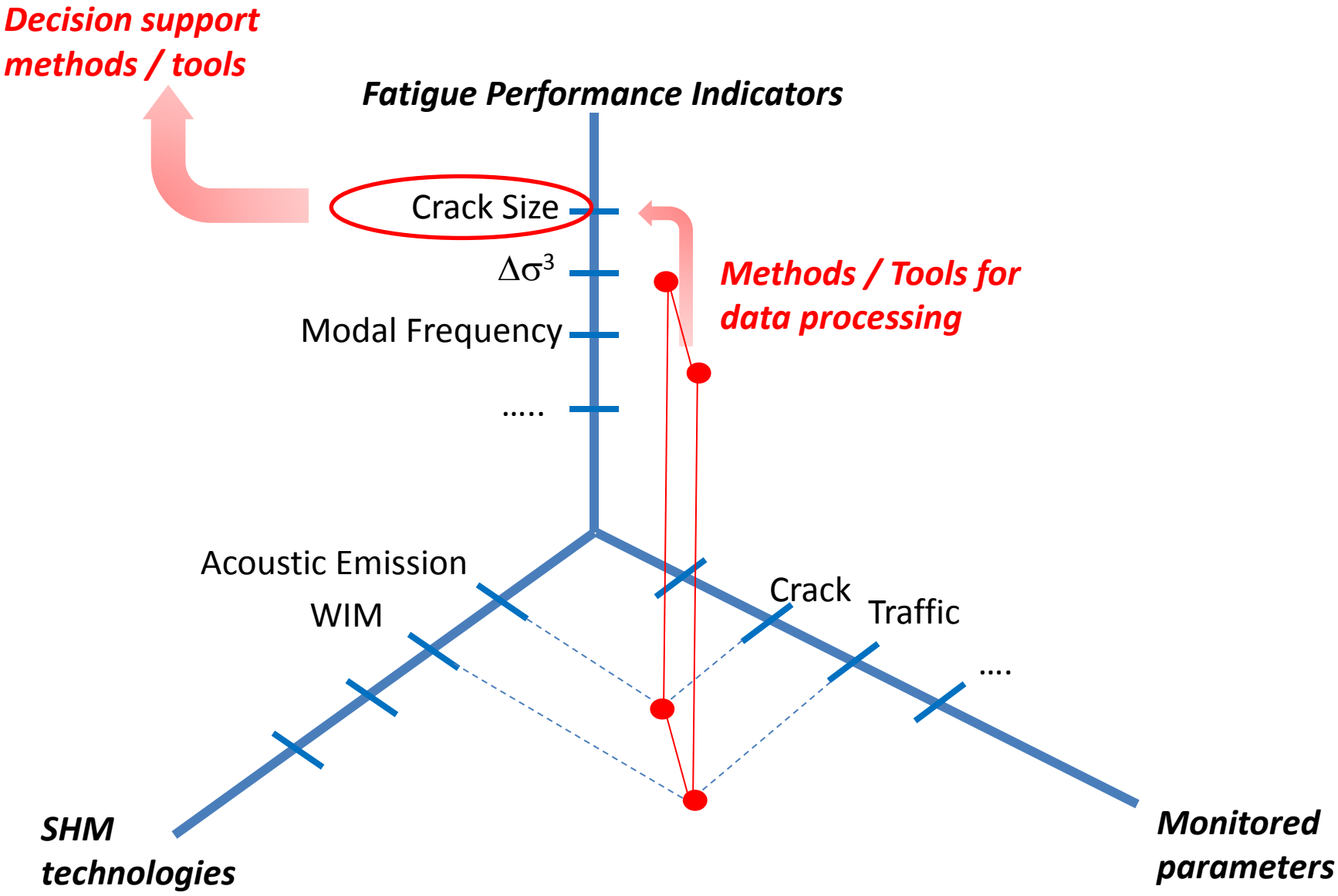


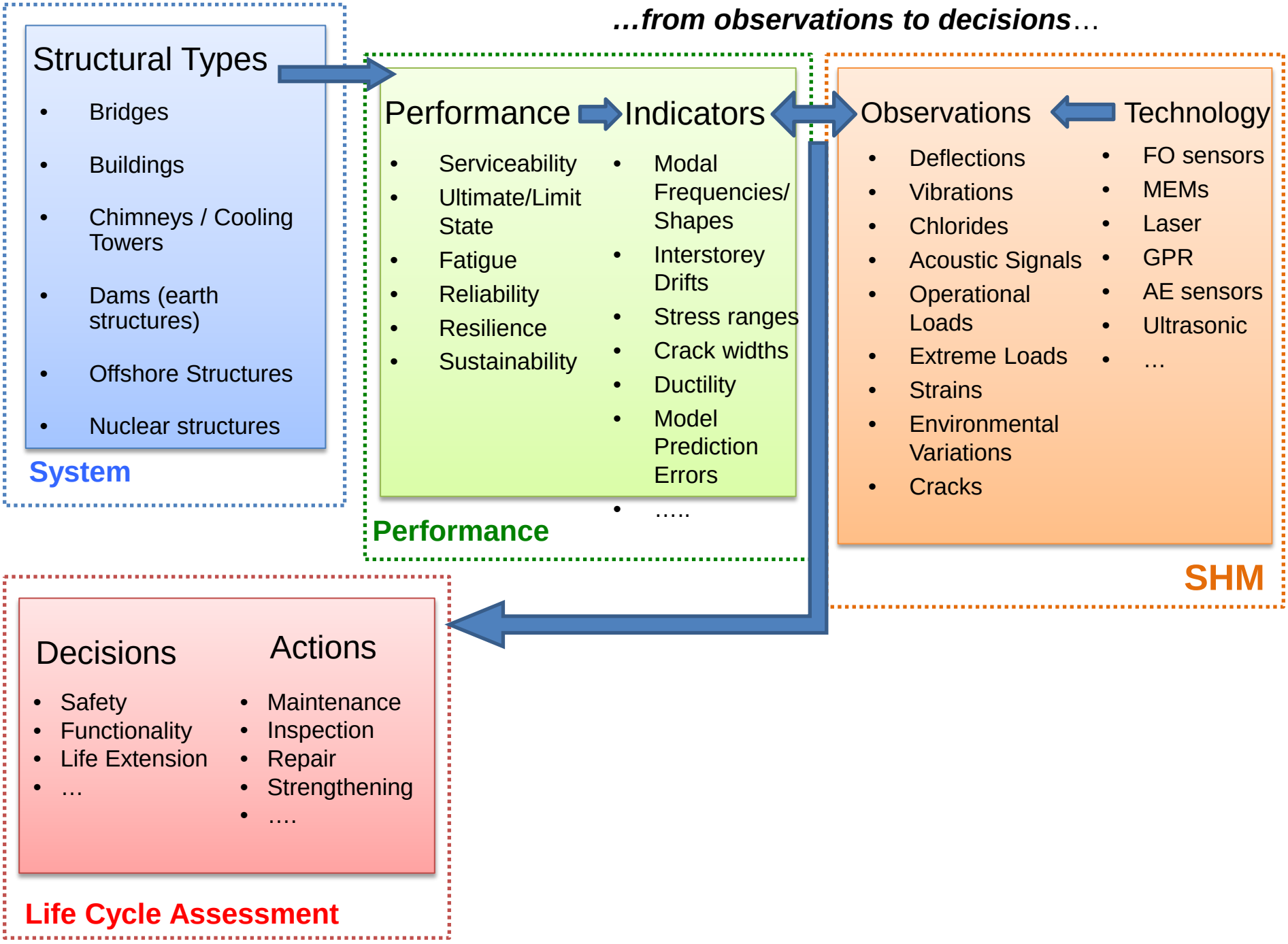


A possible SHM strategy



An alternative SHM strategy




...from observations to decisions...
Structural Types
Bridges
Buildings
Chimneys / Cooling Towers
Dams (earth structures)
Offshore Structures
Nuclear structures
System
Performance
Indicators
Serviceability
Ultimate/Limit State
Fatigue
Reliability
Resilience
Sustainability
Modal Frequencies/ Shapes
Interstorey Drifts
Stress ranges
Crack widths
Ductility
Model Prediction Errors
.....
Performance
Observations
Technology
Deflections
Vibrations
Chlorides
Acoustic Signals
Operational Loads
Extreme Loads
Strains
Environmental Variations
Cracks
FO sensors
MEMs
Laser
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AE sensors
Ultrasonic
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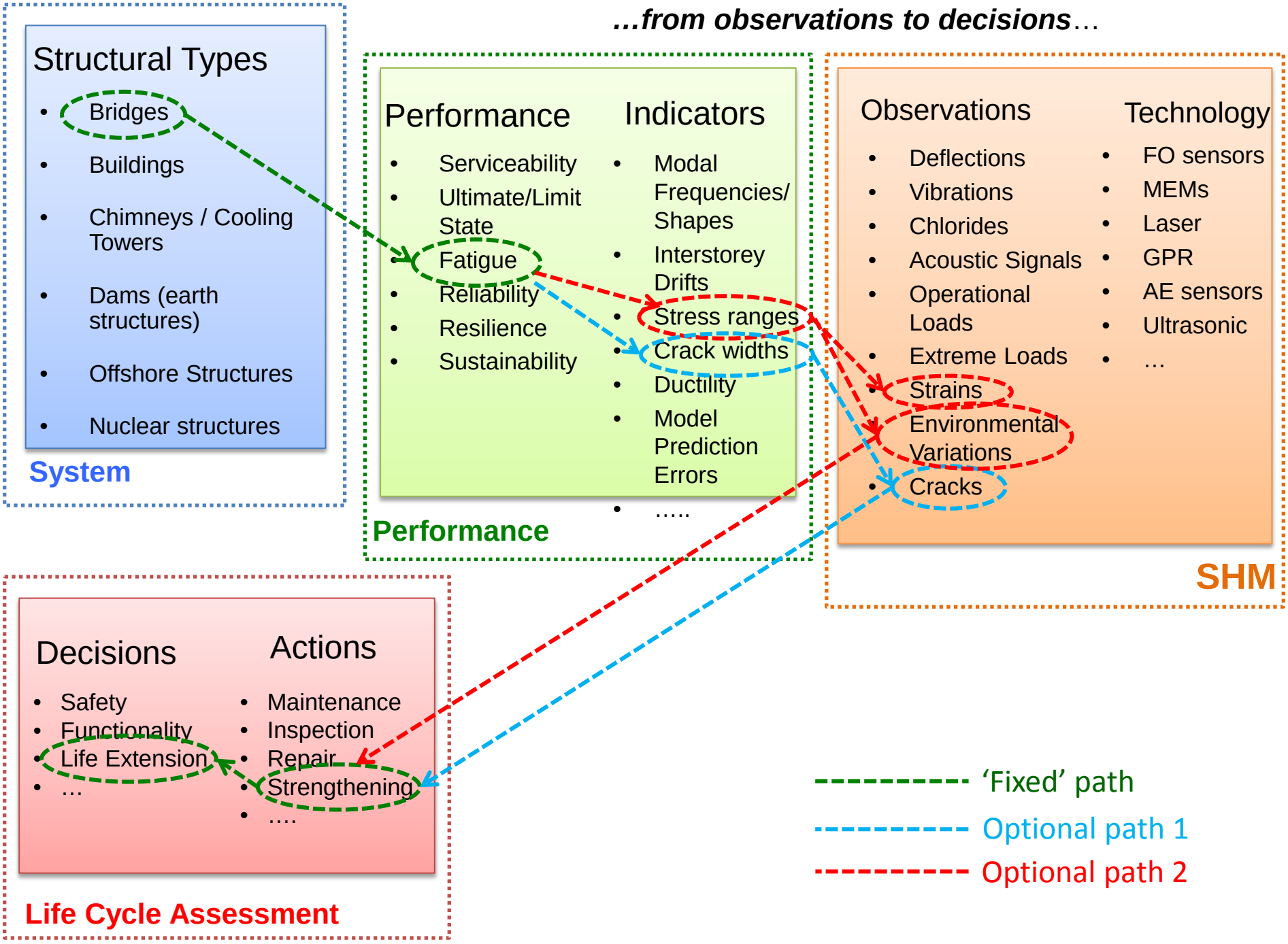
SHM
Decisions
Safety
Functionality
Life Extension
...
Actions
Maintenance
Inspection
Repair
Strengthening
....
Life Cycle Assessment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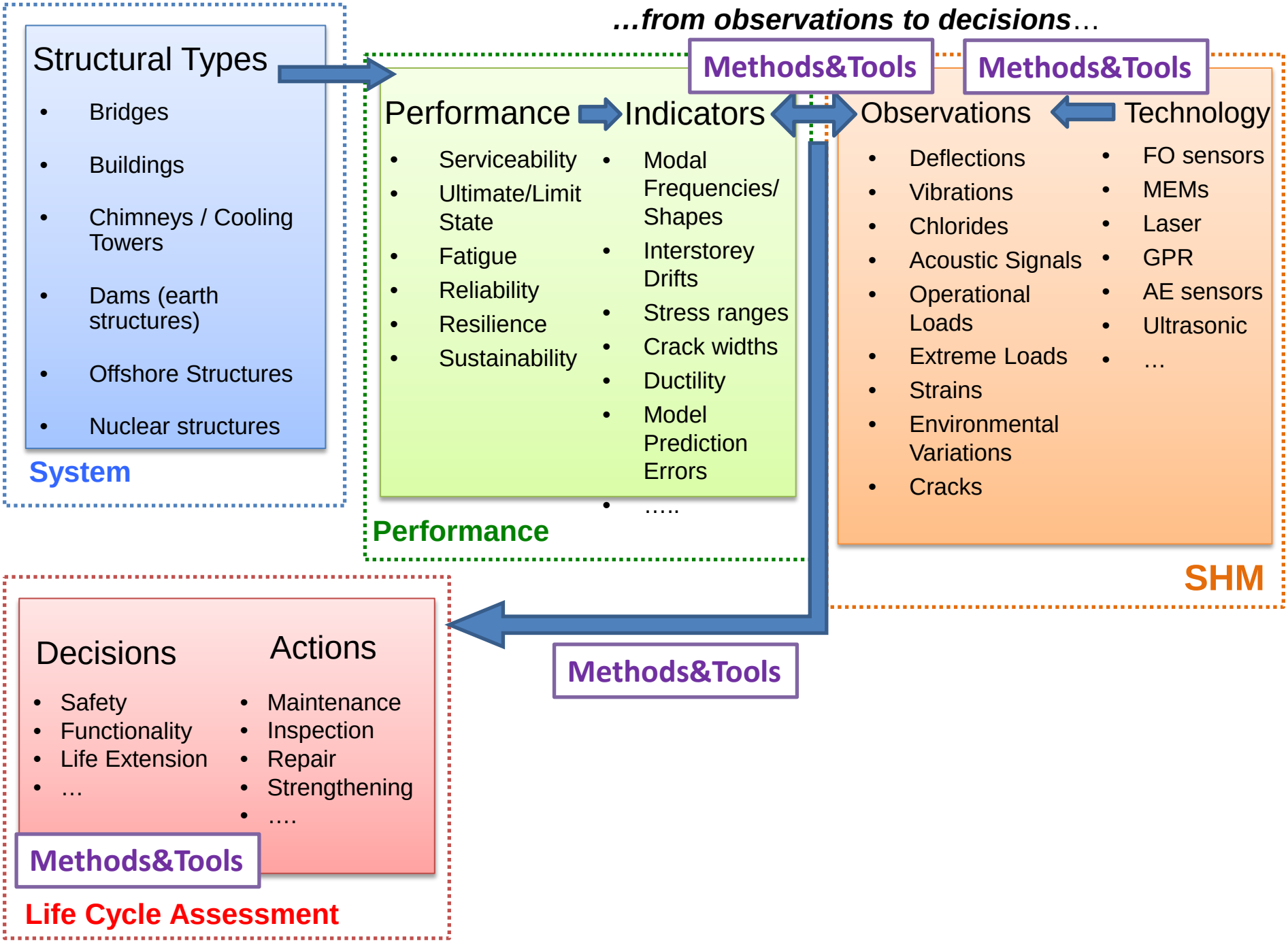
Life Cycle Assessment
'Fixed' path
Optional path 1
Optional path 2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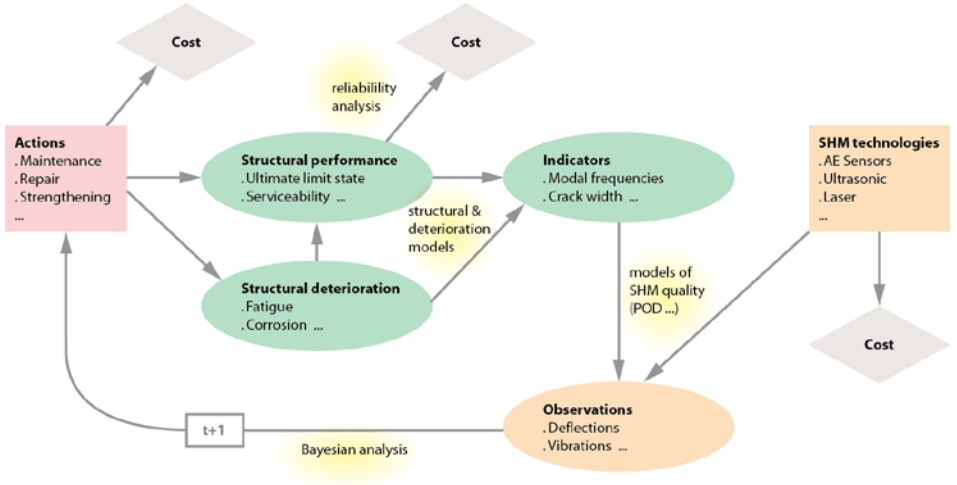
Life Cycle Assessment

Methods and tools

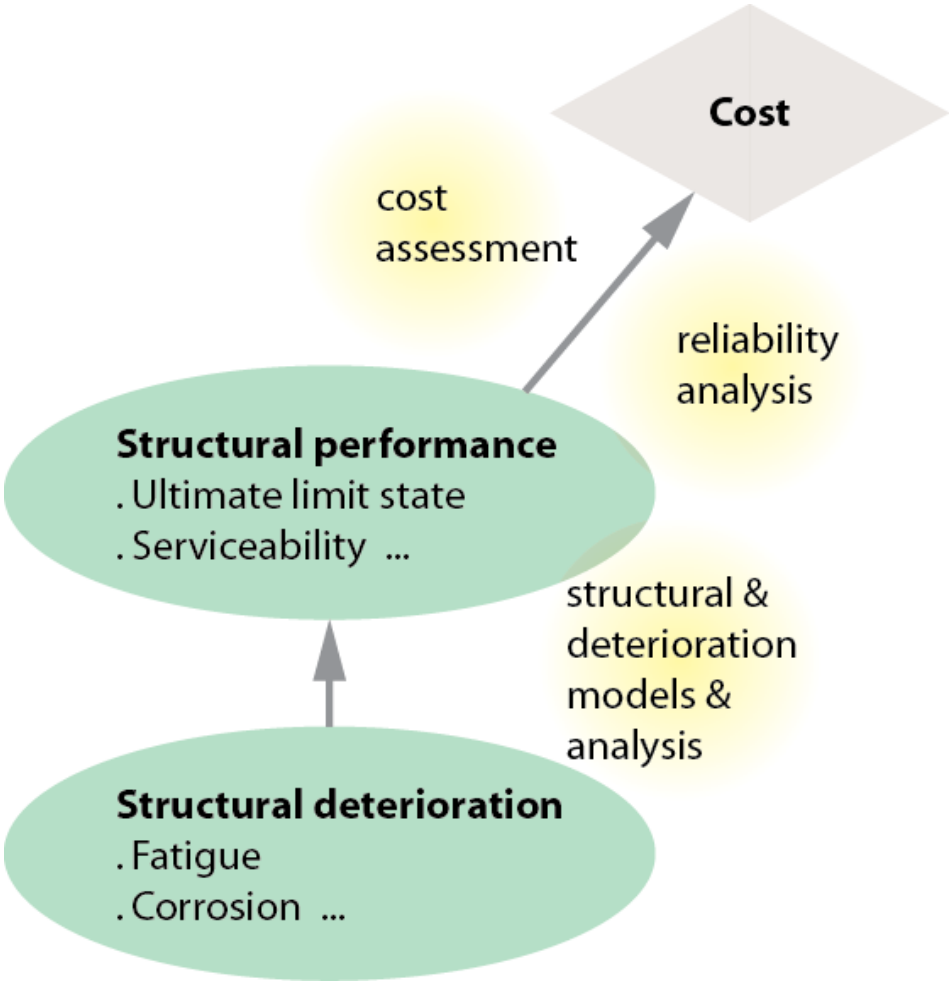
Goals:

- Providing an overview on computational models, methods and tools for supporting the SHM value chain and computing VoI
- Establish database of methods and tool

Structuring through an influence diagram



Influence diagram of the SHM process



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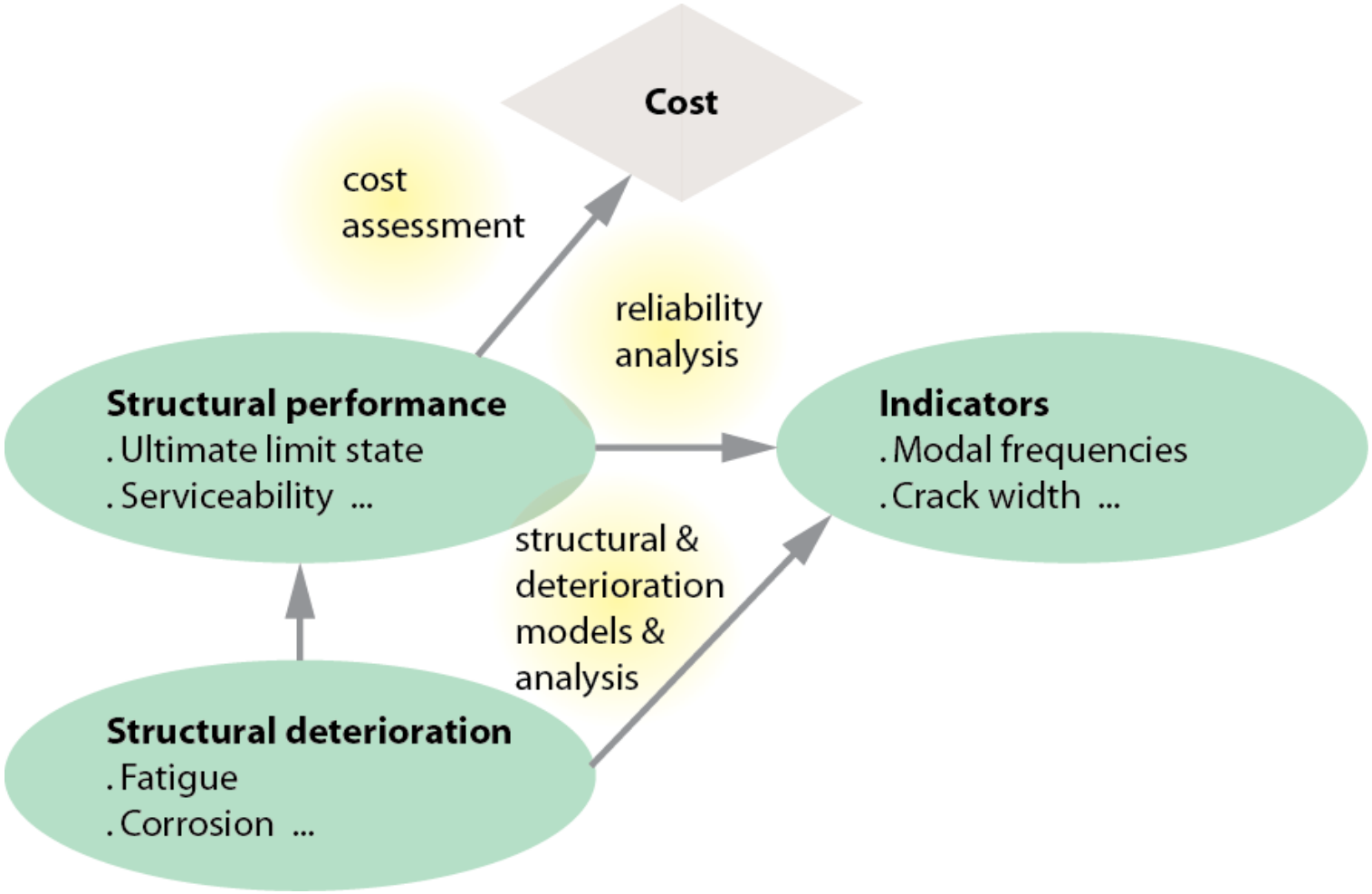

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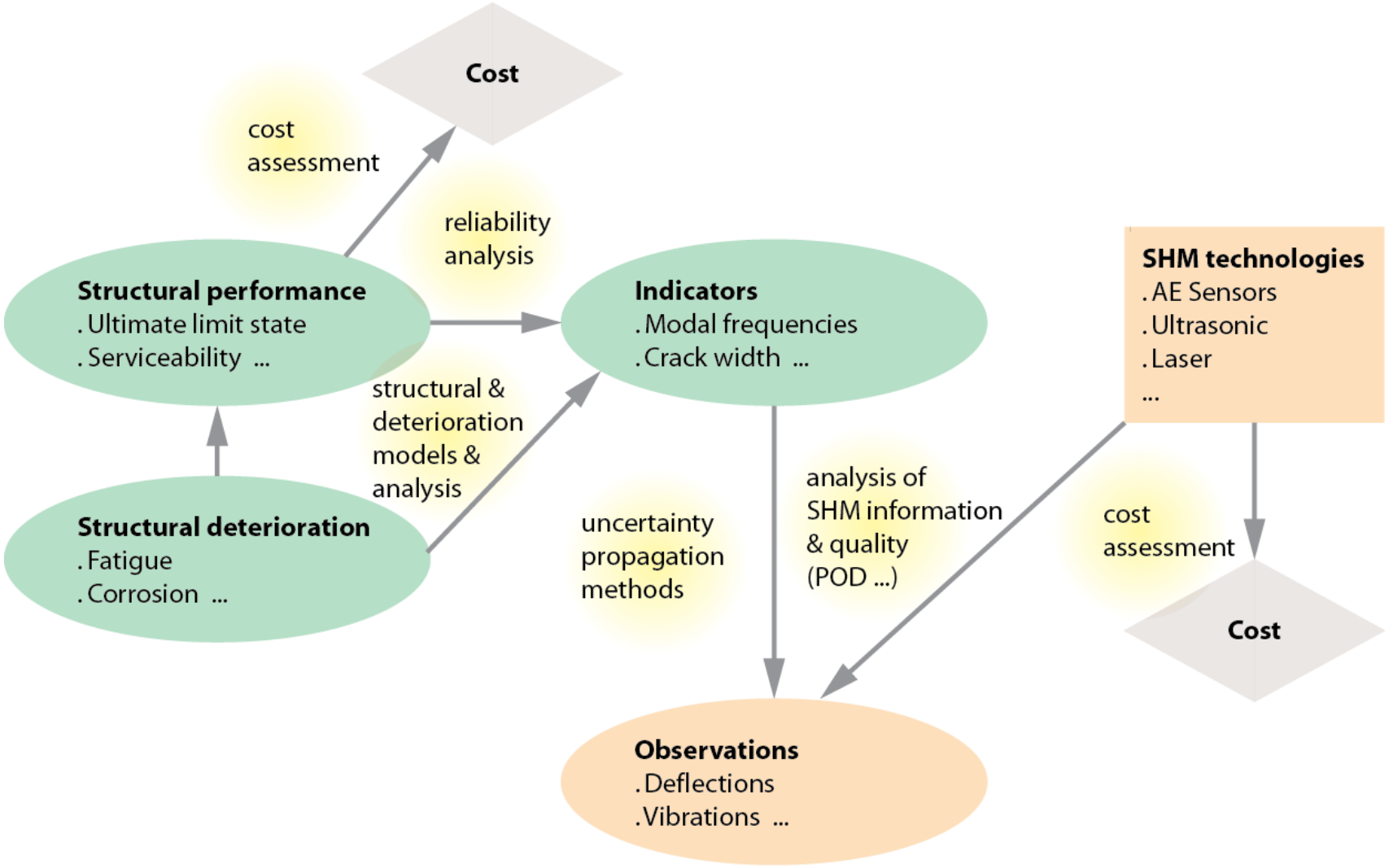

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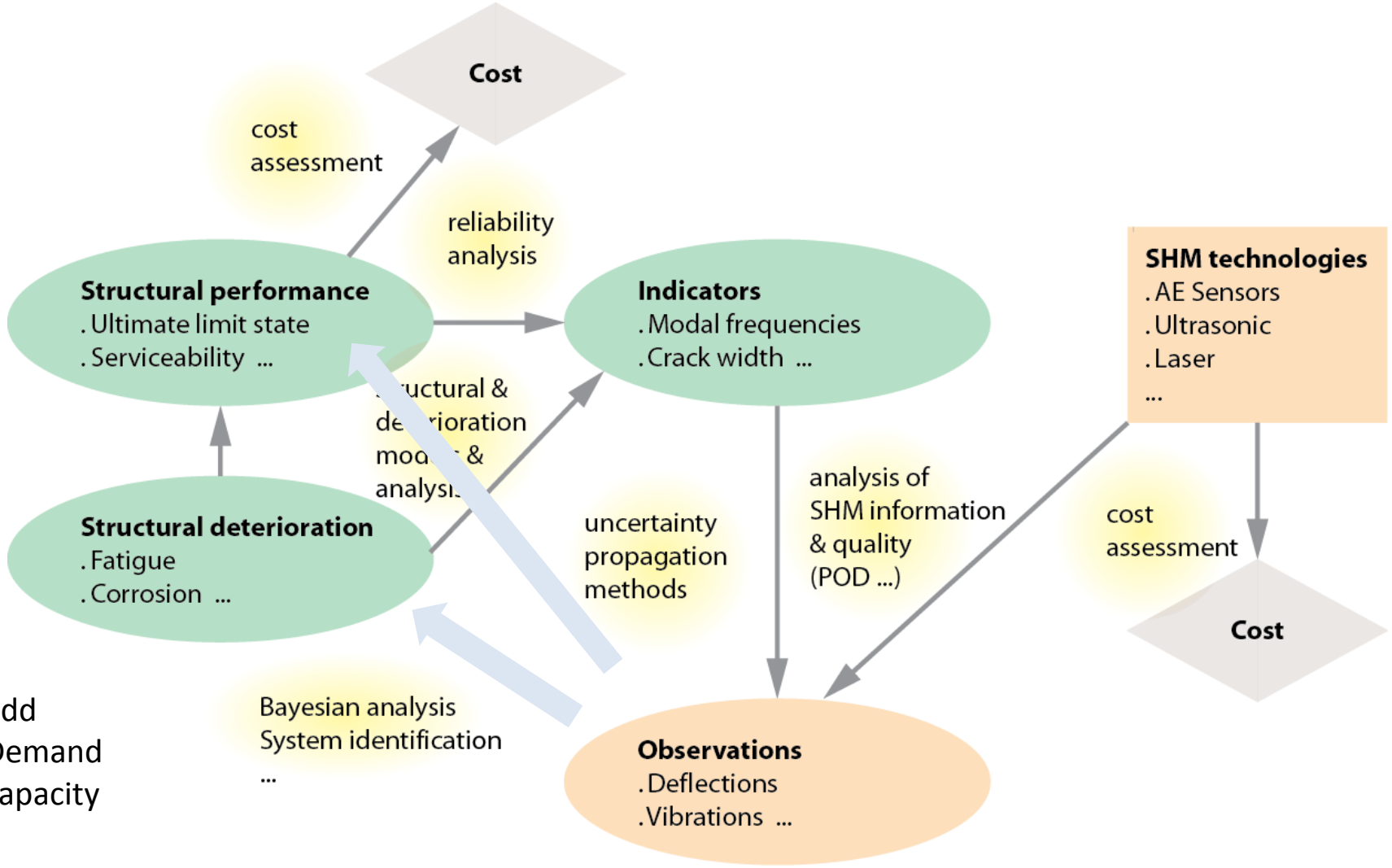
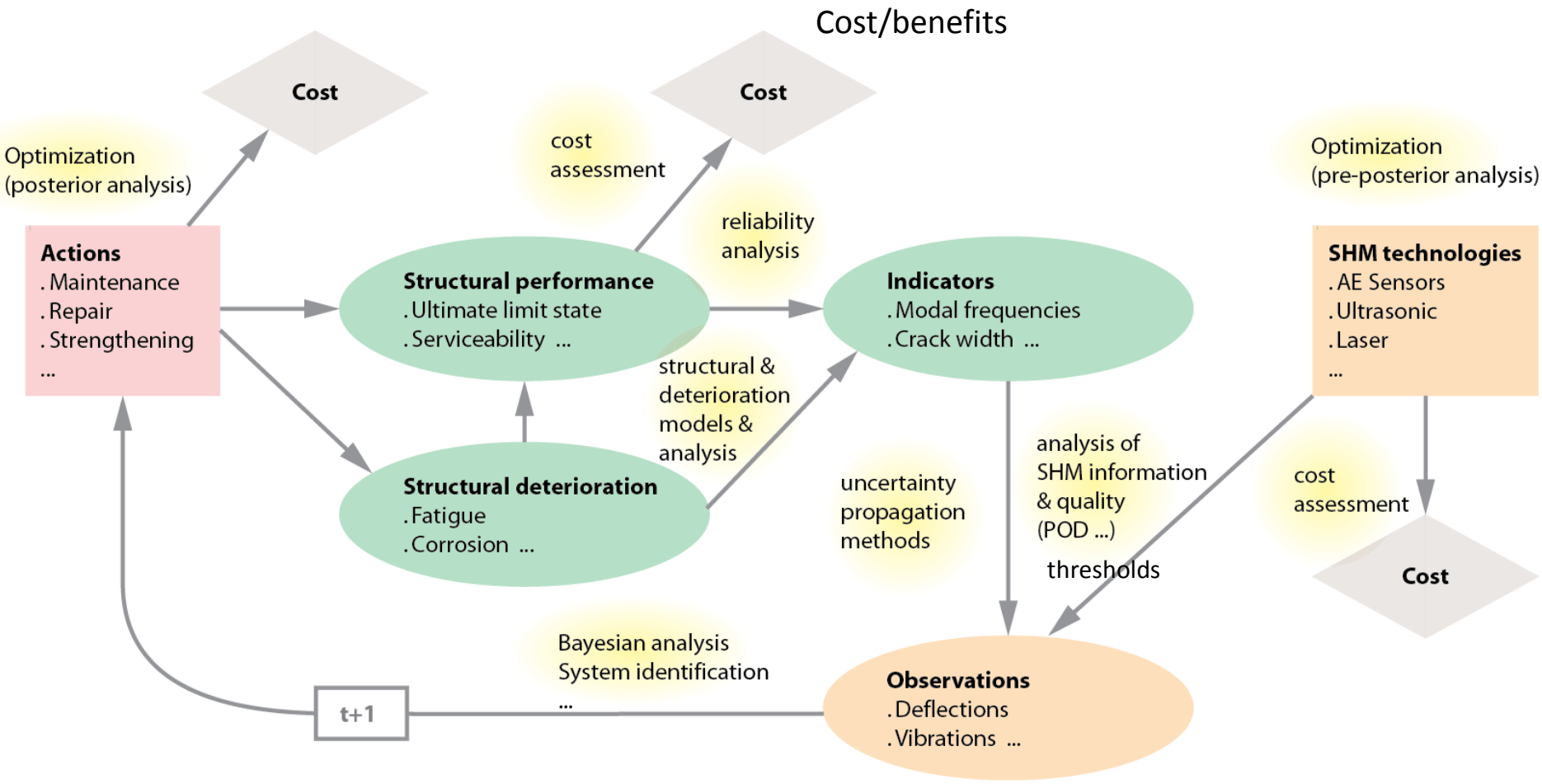


add
Demand
capacity

Influence diagram of the SHM process



add component or network level

Address within context of specific example & test cases

Methods and tools

Factors relevant for selection of appropriate methods and tools:

- local vs global damage
- spatially discrete (hotspots) vs distributed damage
- known vs unknown damage mechanisms
- model-driven vs. data-driven approch
- component vs system performance
- static vs dynamic system behaviour
- …

Finally: VoI analysis, as well as all the steps involved in the SHM value chain can be performed at different levels of detailing

A bit of homework

Outlook and discussion

- Discussion and development of proposed framework:
  - Is the proposed framework sufficiently general and informative?
  - Can we use the framework to define future fact sheets in WG2 and WG3?
  - What is the link with ‘ test cases’?

- Parallel working group sessions:
  - Please complete the questionnaire by end of week!
  - Tomorrow we will ask for individual contributions to the WG work – please be prepared to commit yourselves!