COST Action
TU 1402

Quantifying the Value of Structural Health Monitoring

WG3: Methods & Tools

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Final TU1402 Workshop

Contents

Introduction

WG3 Motivation (Reminder)

WG3 has initiated its activities with active participation in Workshops 3 and 4 of the action, albeit intensifying its working in the second reporting period. A number of synergies are identified with WG2, which focuses on SHM strategies and structural performance, which explains the close collaboration of the two WGs throughout the first reporting period, manifested in joint session during the action meeting.

WG3 aims to provide an overview on the different analyses and computations that are involved in the VoI process, as this is defined within the context of SHM.

Introduction

WG3 Motivation (Reminder)

The concept of the ***Value of Information*** (VoI) concept enables a quantification of the benefits provided via adoption ***of Structural Health Monitoring*** (SHM) systems – *in principle*.

Its implementation is challenging, as it requires explicit modelling of the structural system's life cycle, and in particular of the type and level of decisions that are taken based on the SHM information.

In **WG3**, we approach the VoI analysis through definition of **an influence diagram** (ID), which supports the modelling process.

based on Straub, Chatzi, Bismut et al. ICOSSAR 2017

1. Aims

The following objectives should be addressed

(i) While many methods and tools exist for the individual components of the VoI analysis*, these have seldom been put together for a complete VoI analysis*.

(ii) The objectives of the third working group lie in *identifying, developing and critically overviewing methods and tools* required for the utilization of the theoretical VoI framework in practice.

(iii) Considering the multiplicity of methods involved, successful incorporation into actual Operation and Maintenance schemes necessitates *standardization of the vocabulary, models and methods undertaken*.

2. Achievements

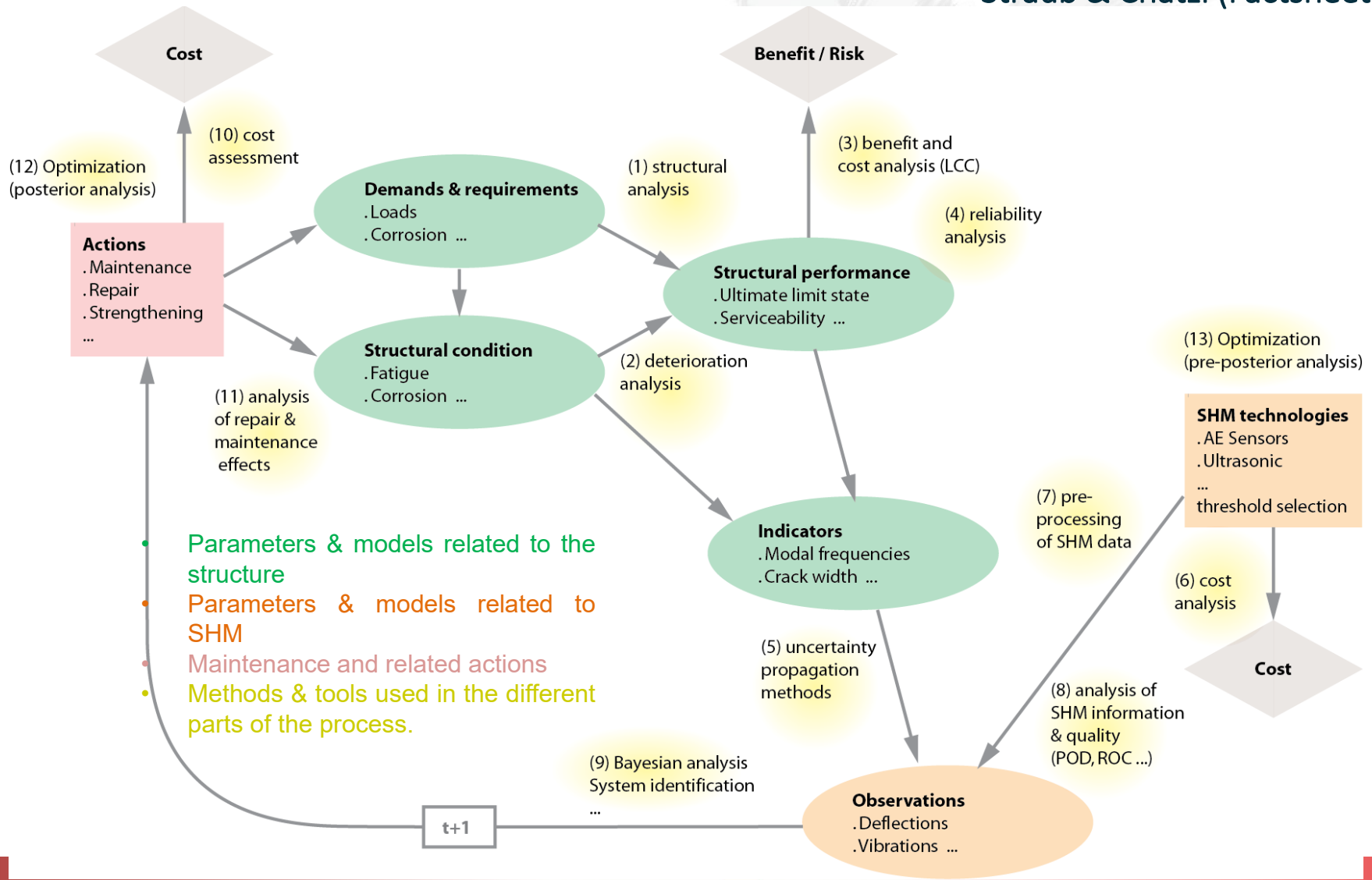
dissemination

- The overview provided in the WG3-related factsheets contributes toward realization of the specified objectives.

- The scientific content of **WG3 related conference-papers** contribute to development of new methods.
- The "*Software Database on VoI & UQ*" document, available for download in the members download area (WG3 subfolder), summarizes existing tools that may be used in the context of a VoI analysis.
- The *toy case-study -"benchmark"* - to be made available to the scientific community will offer a common platform for V&V of the VoI tools.

The VoI Inluence Diagram of the SHM analysis process

Straub & Chatzi (Factsheet)



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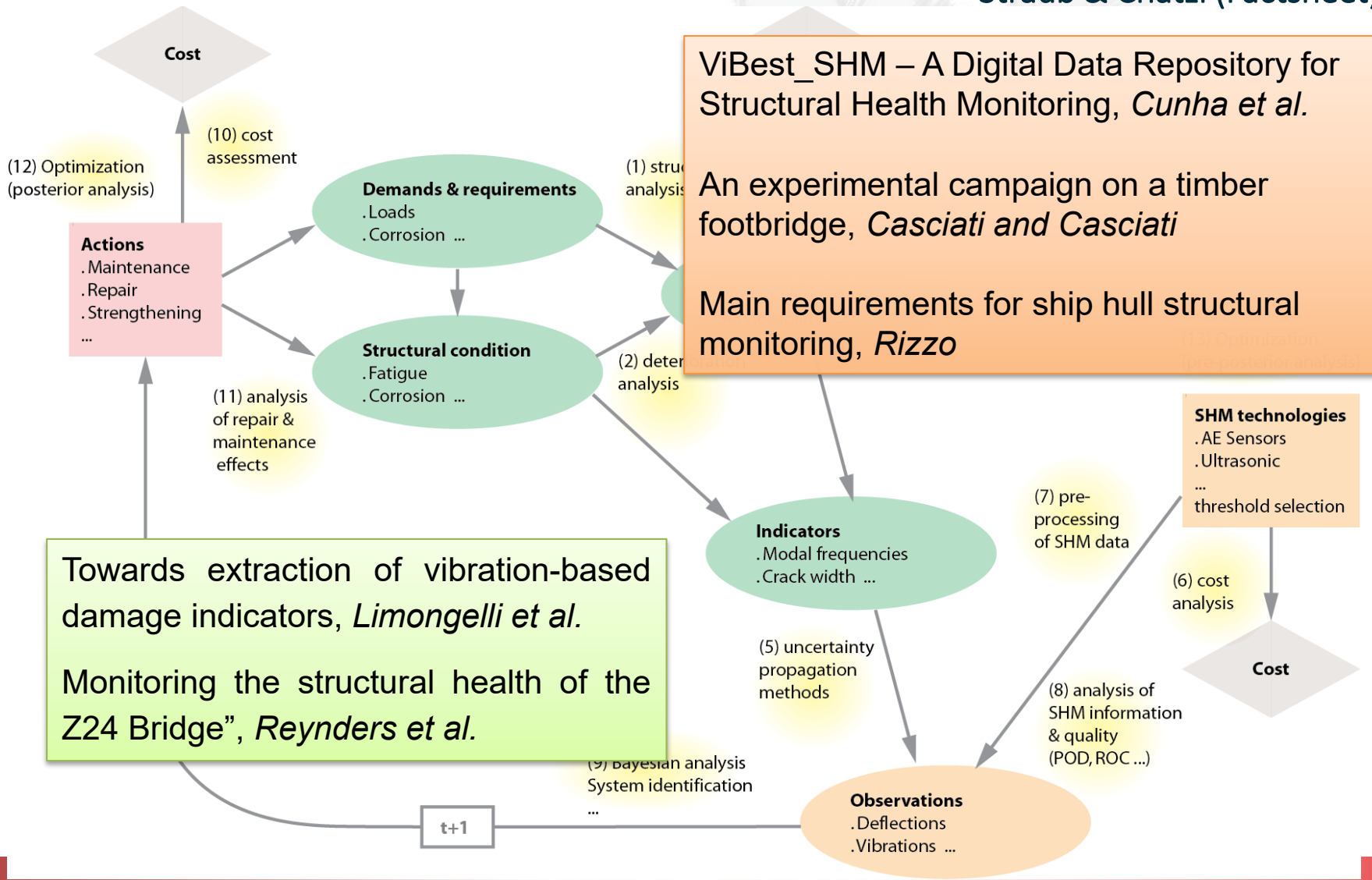

ViBest_SHM – A Digital Data Repository for Structural Health Monitoring, *Cunha et al.*

An experimental campaign on a timber footbridge, *Casciati and Casciati*

Main requirements for ship hull structural monitoring, *Rizzo*

Towards extraction of vibration-based damage indicators, *Limongelli et al.*

Monitoring the structural health of the Z24 Bridge", *Reynders et al.*

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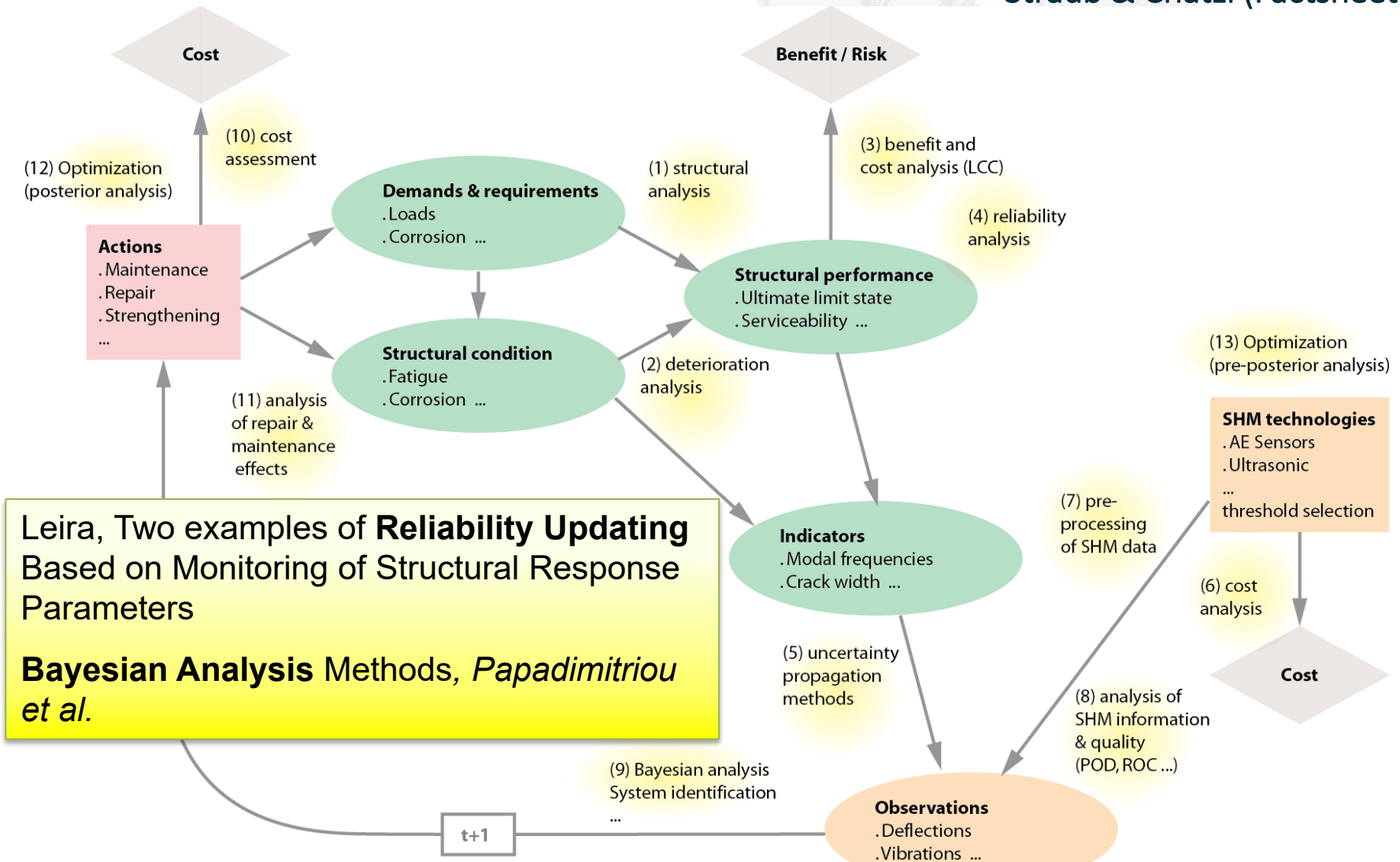

Leira, Two examples of **Reliability Updating** Based on Monitoring of Structural Response Parameters

Bayesian Analysis Methods, *Papadimitriou et al.*

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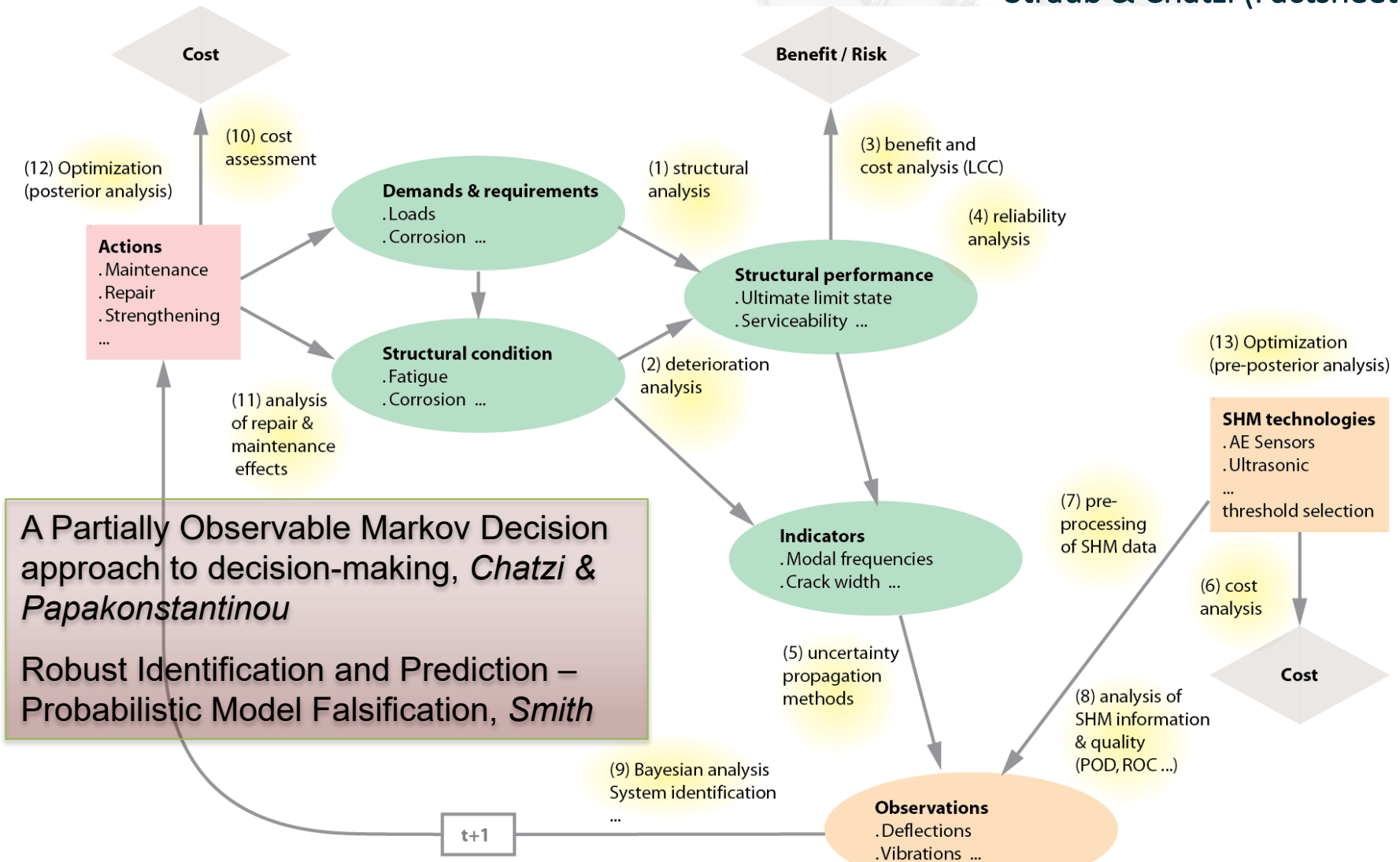
Straub & Chatzi (Factsheet)



A Partially Observable Markov Decision approach to decision-making, *Chatzi & Papakonstantinou*

Robust Identification and Prediction – Probabilistic Model Falsification, *Smith*

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Dissemination - WG3 related conference-papers

- D. Straub, E. Chatzi, E. Bismut, W.M.G. Courage, M. Döhler, M.H. Faber, J. Köhler, G. Lombaert, P. Omenzetter, M. Pozzi, S. Thöns, D. Val, H. Wenzel and D. Zonta, "Value of Information: A roadmap to quantifying the benefit of structural health monitoring", 2th international conference on Structural Safety & Reliability (ICOSSAR2017), August 6-10, 2017, Vienna, Austria.
- E. Chatzi, K. G. Papakonstantinou, D. Straub and R. Hajdin. '' Observation-based Decision-making for Infrastructure''. In Proceedings of the Joint COST TU1402 - TU1406 - IABSE WC1 WORKSHOP: The Value of Structural Health Monitoring for the Reliable Bridge Management, March, 02 and 03, 2017, Zagreb, Croatia. DOI: https://doi.org/10.5592/CO/BSHM2017.4.1
- R. Schneider, S. Thöns and D. Straub. ,''Reliability analysis and updating of deteriorating systems with subset simulation''. Structural Safety 64: 20-36. DOI: 10.1016/j.strusafe.2016.09.002.
- B.J. Leira, S. Thöns. ''System reliability of concrete structures subjected to chloride ingress''. European Safety and Reliability Conference (ESREL 2017); Portoroz, Croatia.
- P. Omenzetter, M.P. Limongelli, U. Yazgan and S. Soyoz, ''Quantifying the value of SHM for emergency management of bridges at-risk from seismic damage based on their performance indicators''. In Proceedings of the JOINT COST TU1402 - COST TU1406 - IABSE WC1 WORKSHOP: The Value of Structural Health Monitoring for the Reliable Bridge Management. March, 02 and 03, 2017, Zagreb, Croatia. DOI: https://doi.org/10.5592/CO/BSHM2017.4.5
- C. Malings, M. Pozzi, "Optimal Sensor Placement and Scheduling with Value of Information for Spatio-Temporal Infrastructure System Management", 12th international conference on Structural Safety & Reliability (ICOSSAR2017), August 6-10, 2017, Vienna, Austria.
- M. Pozzi, C. Malings and A. Minca, "Negative value of information in systems' maintenance", 12th international conference on Structural Safety & Reliability (ICOSSAR2017), August 6-10, 2017, Vienna, Austria.
- A. A. Irman, S. Thöns and B. J. Leira. ''Value of information-based inspection planning for offshore structures''. 36th International Conference on Ocean, Offshore and Artic Engineering (OMAE), Trondheim, Norway, 25-30 June, 2017.

and more found on the ***TU1402 webpage***: https://www.cost-tu1402.eu/resources-downloads/journal-and-conference-papers

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Methods & tools library

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verification

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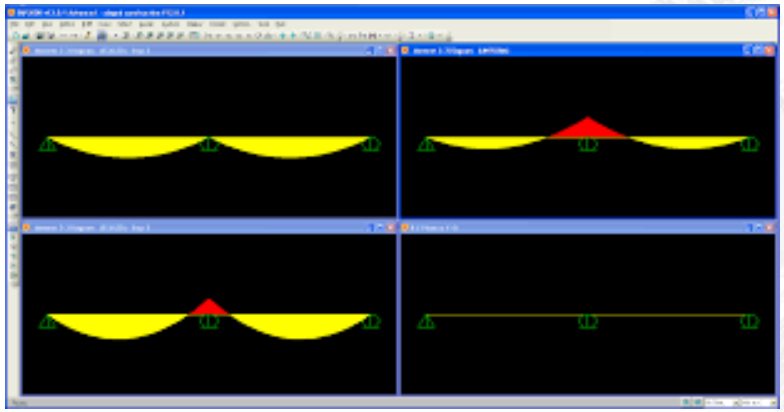
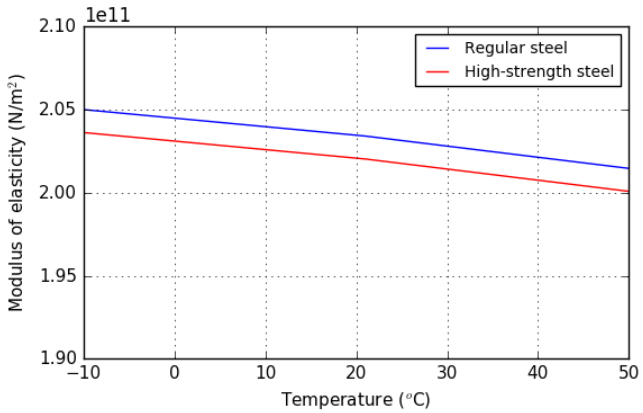
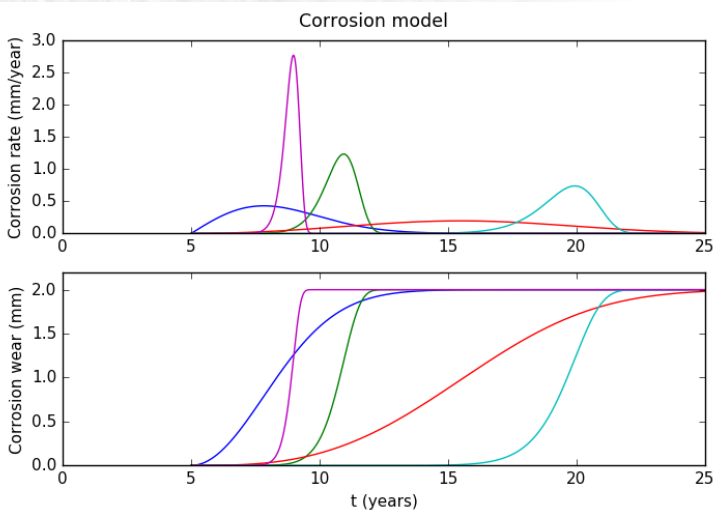
Verification Tools – The TU1402 Benchmark



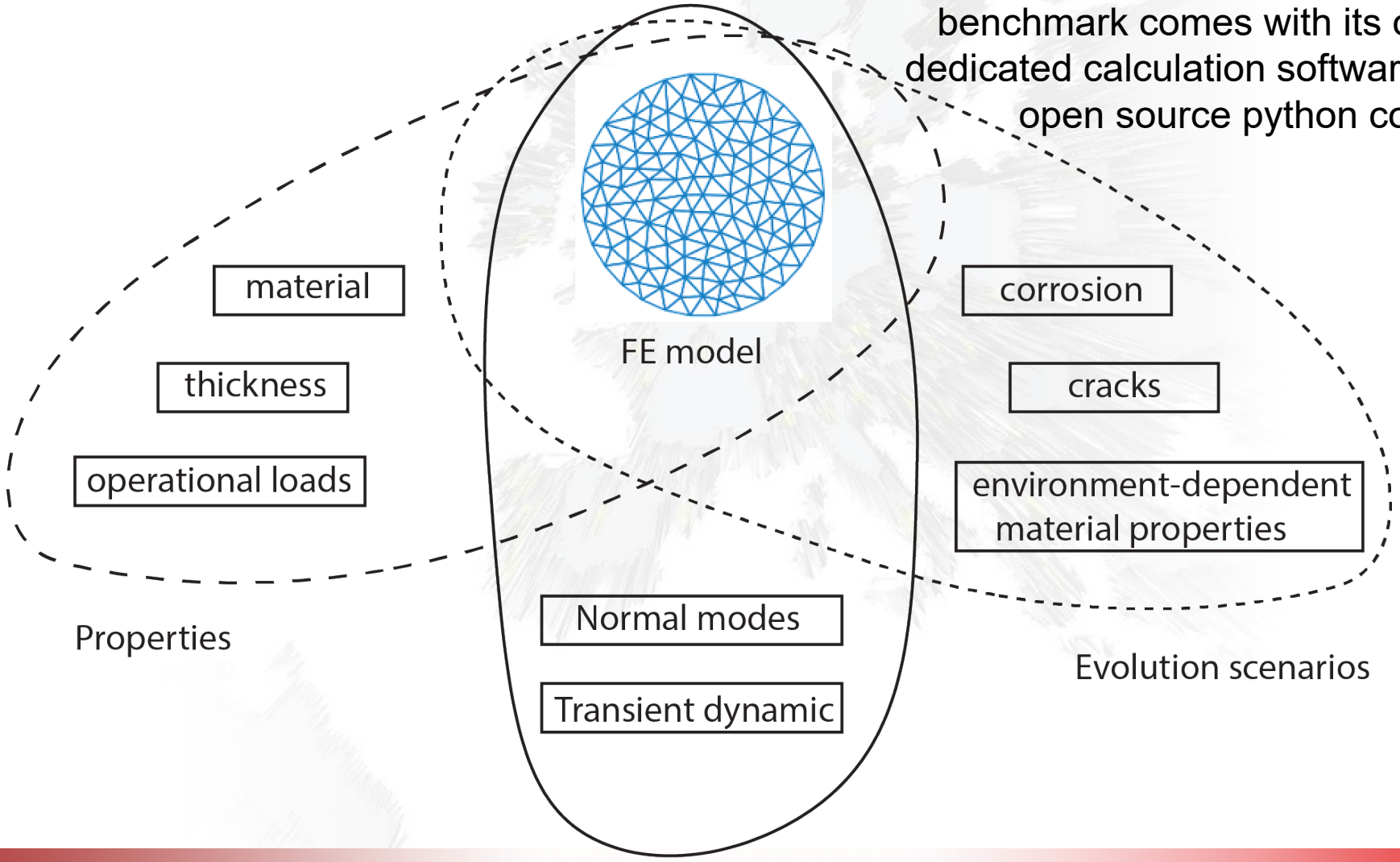
2-span beam, modeled via 2D plane stress elements, under various **deterioration effects**



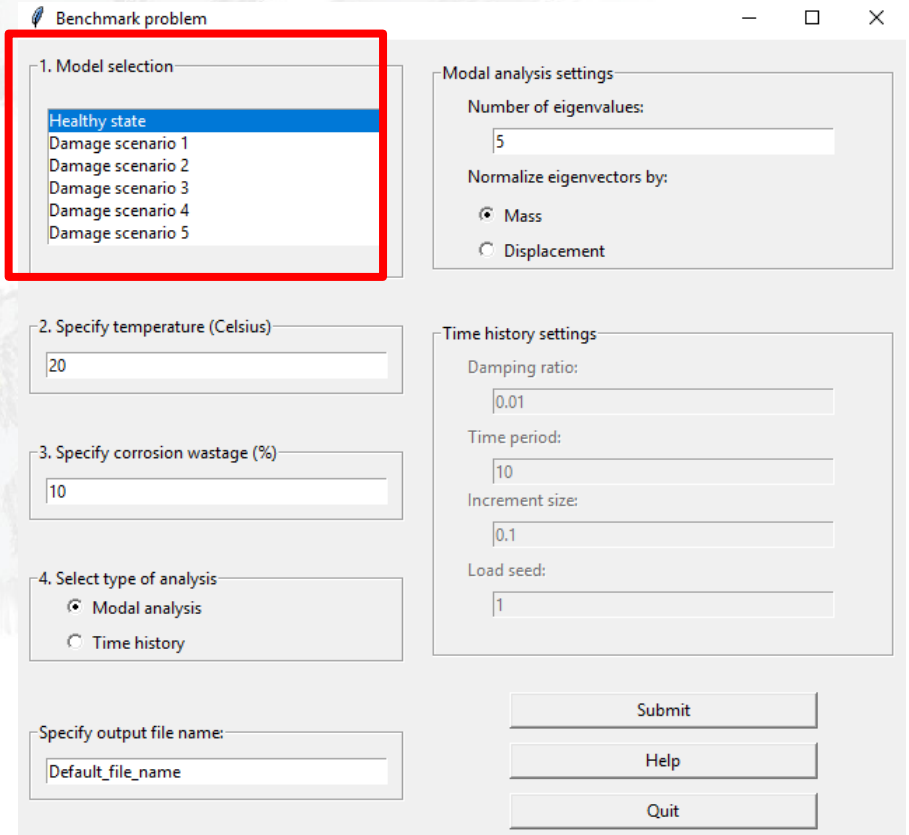


Operational framework

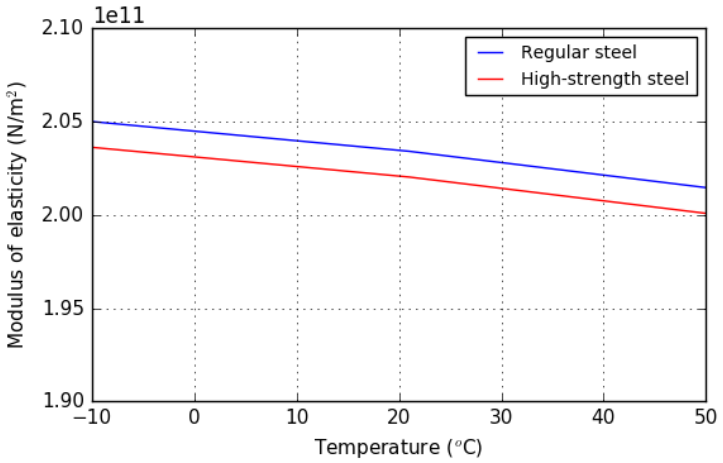
As its ASCE SHM benchmark counterpart, the TU1402 benchmark comes with its own dedicated calculation software in open source python code.

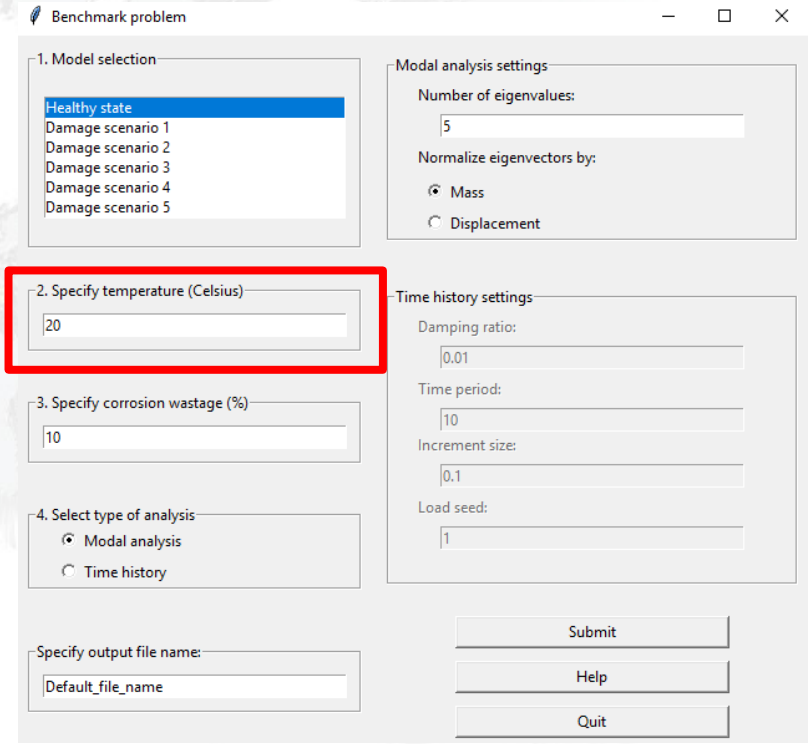


Damage scenarios

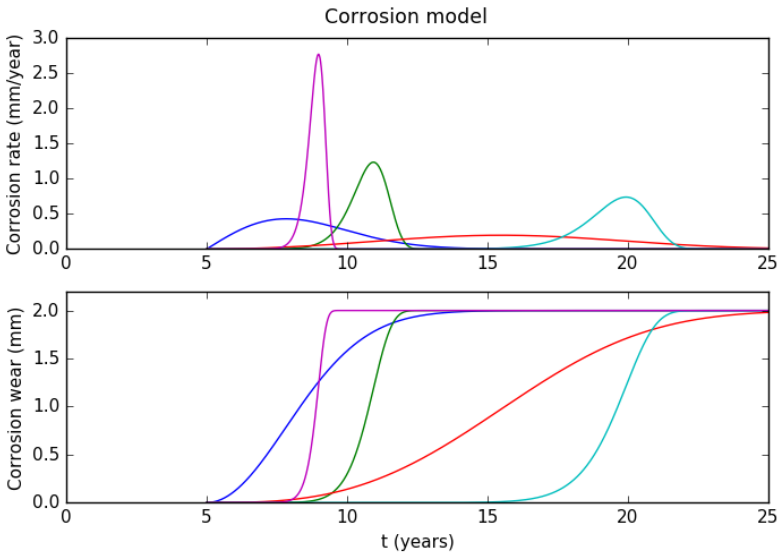


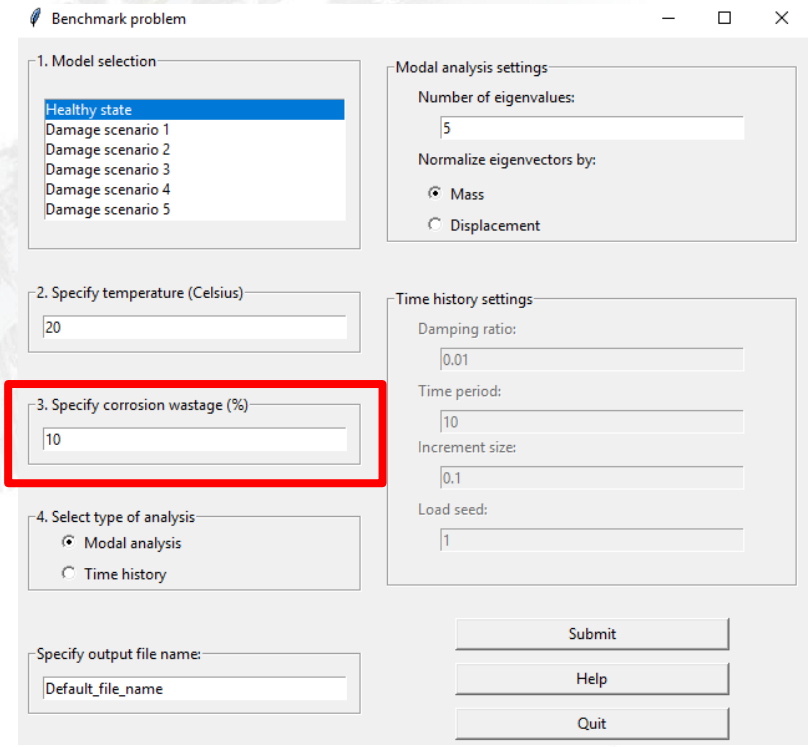
Temperature-dependent material properties



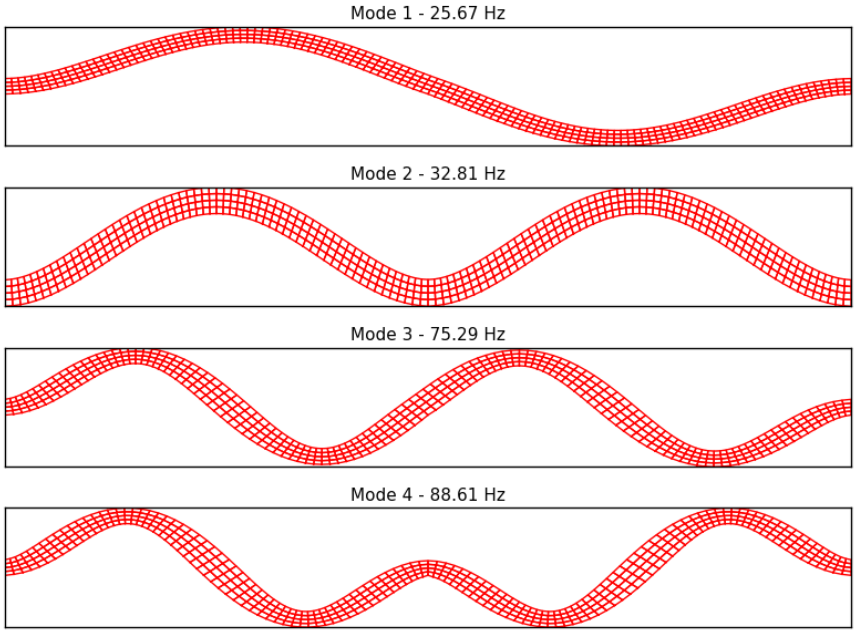


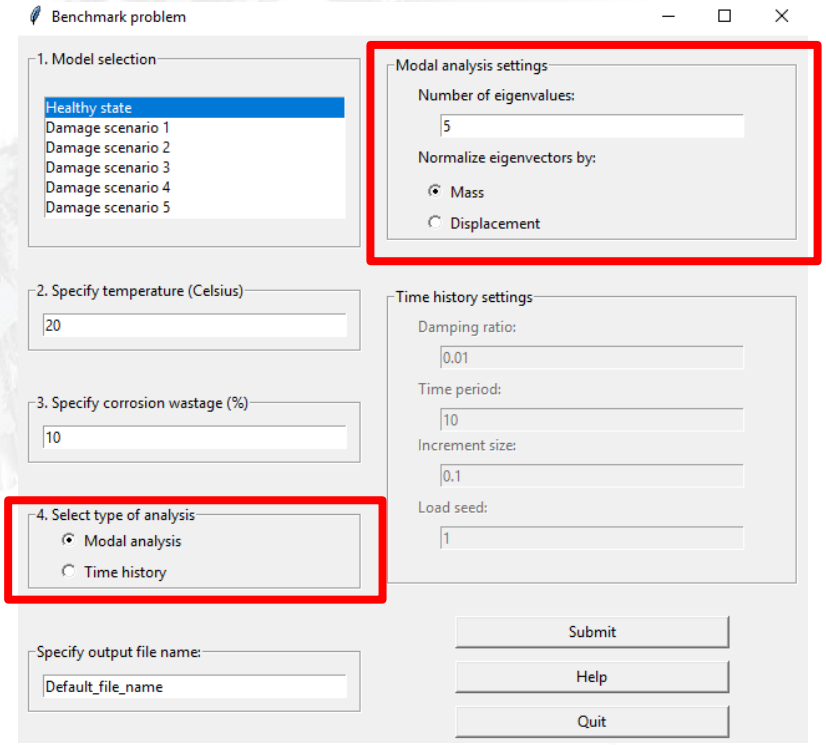
Corrosion-induced degradation



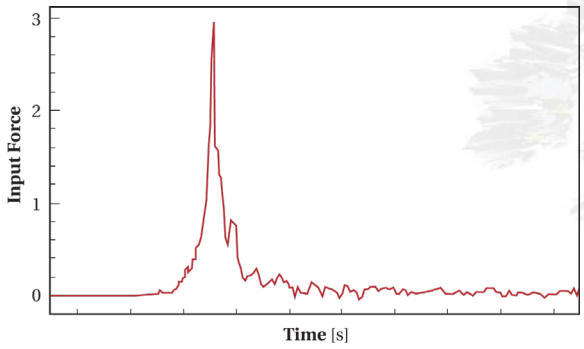


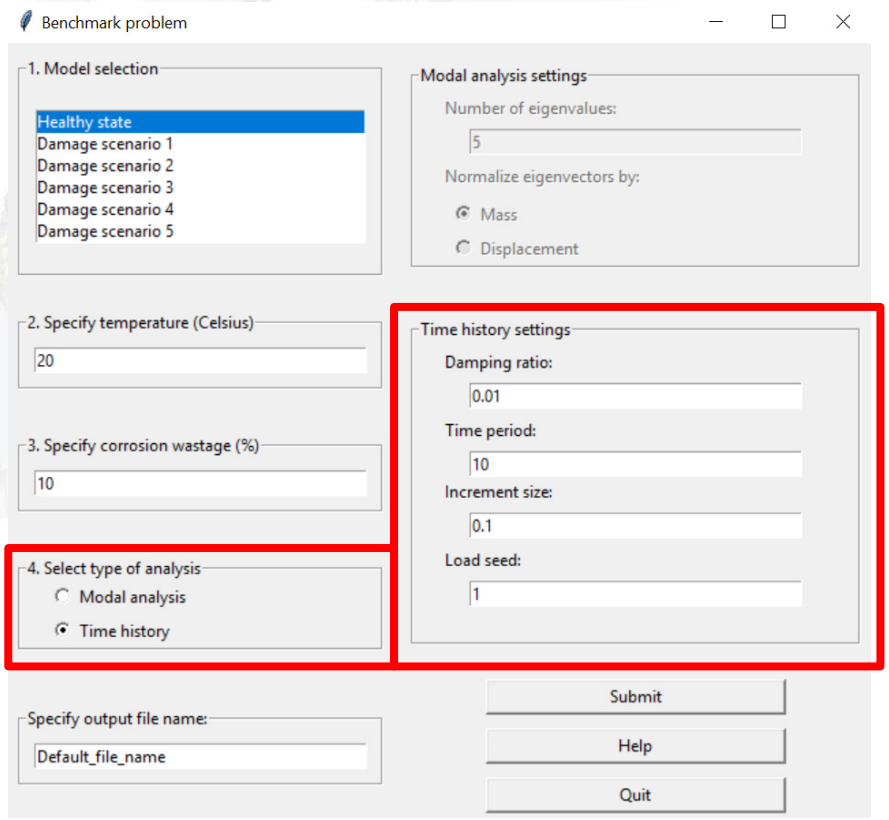
Modal analysis



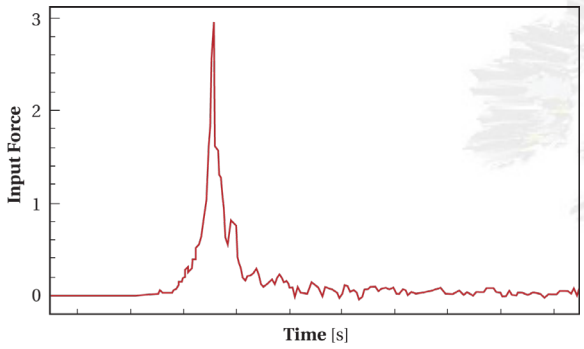


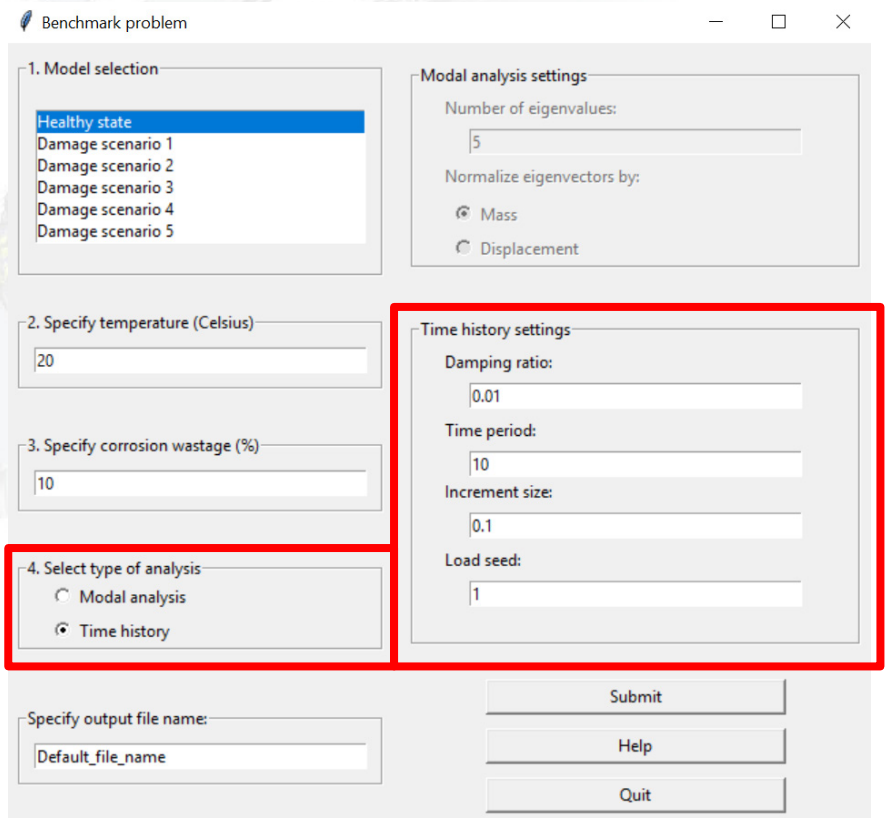
Time history



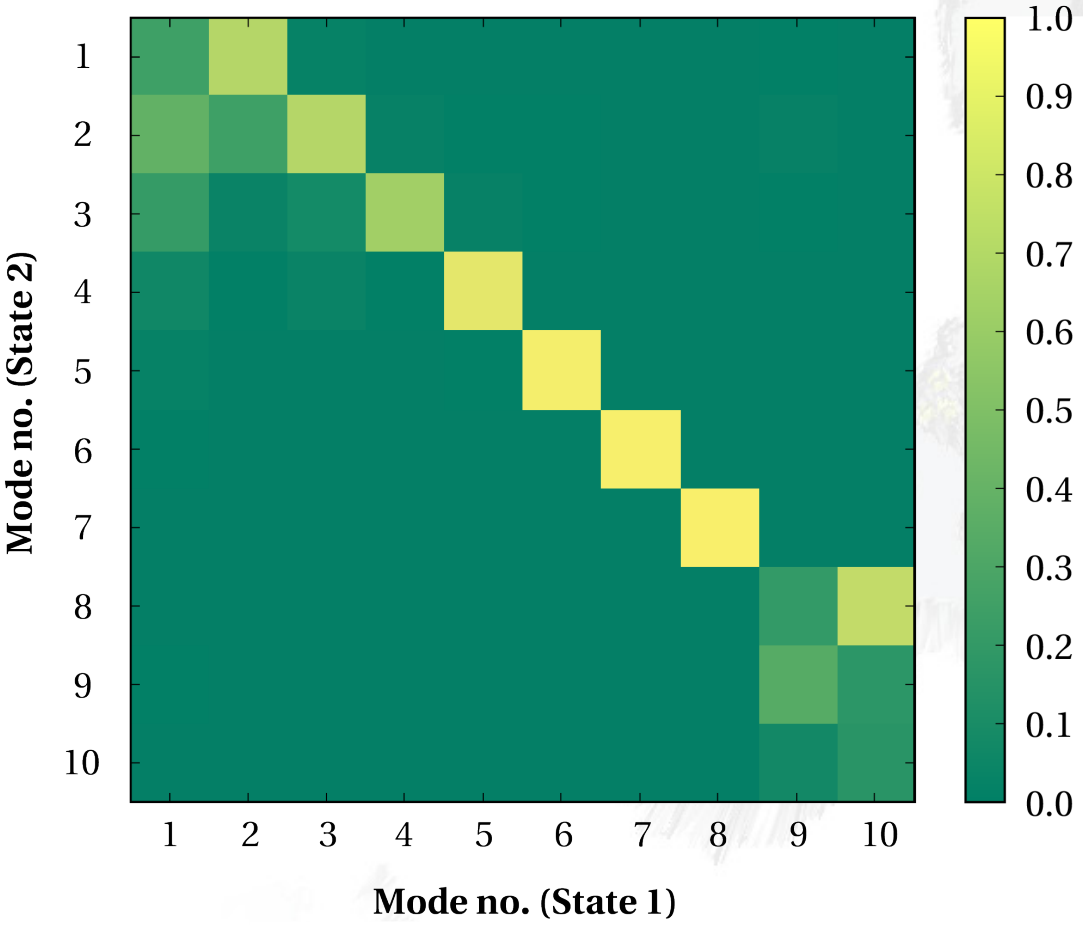


Time history





Example – Degradation scenario



Mode shape Comparison

Modal Assurance Criterion (MAC) for the comparison of mode shapes:

$$\mathbf{MAC}\left(\boldsymbol{\phi}_k, \boldsymbol{\phi}_l\right) = \frac{\left|\boldsymbol{\phi}_k^{\mathrm{H}} \boldsymbol{\phi}_l\right|^2}{\left(\boldsymbol{\phi}_k^{\mathrm{H}} \boldsymbol{\phi}_k\right)\left(\boldsymbol{\phi}_l^{\mathrm{H}} \boldsymbol{\phi}_l\right)}$$

- **MAC** ≈ 1 for mode shapes of the same mode
- **MAC** ≈ 0 for mode shapes of different modes
- **MAC** matrix $\approx \mathbf{I}$ for identical modal bases

3. Open Discussion & finalization

- The benchmark beta version is to be released soon, available on the Action Webpage
- Additional Features:
  - Scheduling of deterioration, damage scenaria
  - Inclusion of “interventions”, i.e., possibility to intervene for locally or globally repairing damage
- We need your feedback as testers, as well as input on more features to be included in the benchmark
  - Ideas ….
- The benchmark should serve as common verification platform for different methods of the VoI framework.

6. Conclusions

- We need your contribution now to proceed!

Looking for volunteers for

- Building demonstrators using the **methods & tools** summarized in the library, or additional tools we need to add onto the library

- Verifying these methods on the TU1402 "**benchmark**"

6. Lessons Learnt

- The process of understanding each other through VoI discussions helps improve current understanding and state of knowledge.-> helps augment the VoI!
- It is not easy to establish a uniform Vocabulary among experts for concept that are still abstract.
- It is still worth doing so!

Thank you for your attention

www.cost-tu1402.eu