COST Action
TU 1402

Quantifying the Value of Structural Health Monitoring

Concrete Bridge

Reinforcement Corrosion Sensor Alternatives

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TNO innovation for life

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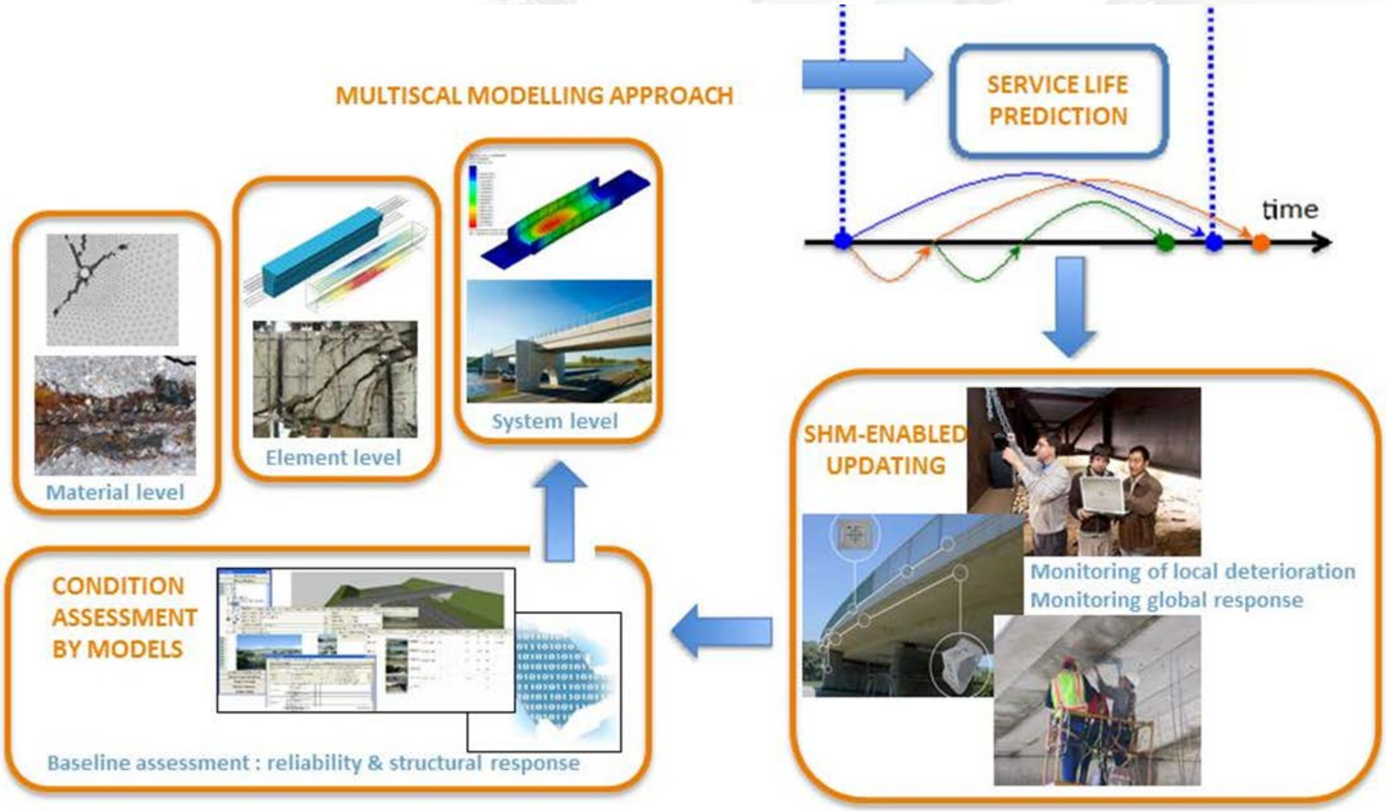
INDEX

1. Early Research Program ERP_SI_BRIDGE : Scope & focus

- **Advanced assessment of existing RC structures**

- **Accounting for multiple sources of uncertainty, i.e.:**
  - randomness in intrinsic material properties,
  - randomness in defects due to load history,
  - (FEM) modelling uncertainty,
  - randomness in defects due to deterioration mechanisms : **CORROSION**

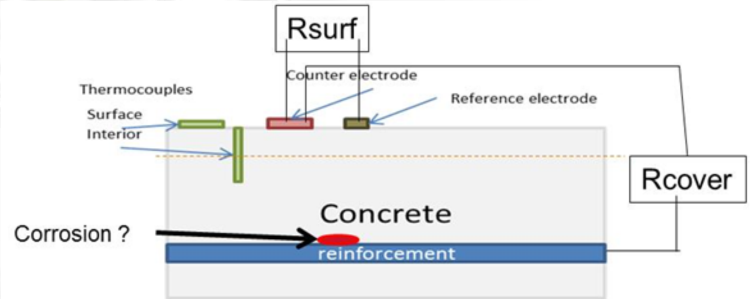
1. Early Research Program ERP_SI_BRIDGE : Assessment & prediction



1. Early Research Program ERP_SI_BRIDGE : MSDF

MSDF: reliable corrosion detection

- measuring system is based on multiple sensors and interpretation model
- additional data come from intake testing and sampling
- physical and the statistical model captures the relations between the measurable corrosion-relevant parameters



Measured parameters
Corrosion potential - Ecor
Corrosion rate – icor – LPR
Corrosion rate – icor – EN
Concrete cover resistivity – Rho_co
Concrete surface resisitivity – Rho_s
Air humidity – RH
Air Temperature – T_air
Concrete cover temperature T_cover

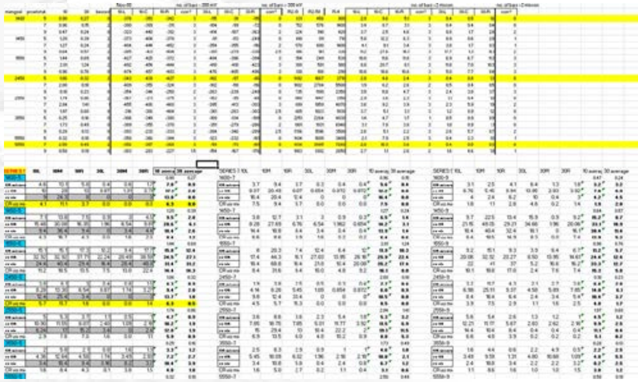
1. Early Research Program ERP_SI_BRIDGE : MSDF

MSDF: reliable corrosion detection

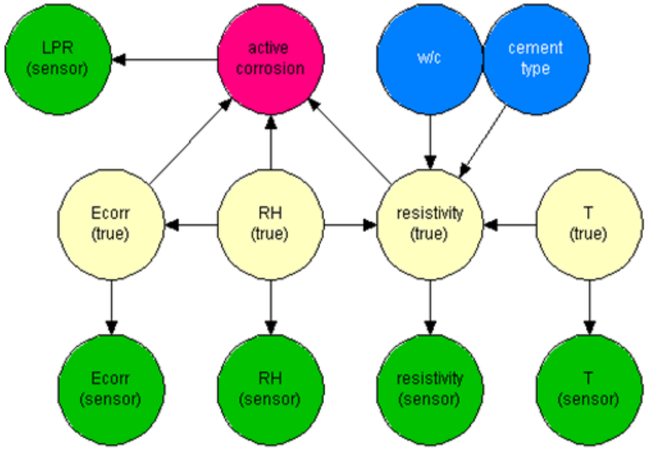
- Data, physics and Expert Opinions captured in Bayesian Net
- Autonomous interpretation model

→ Likelihood of Corrosion based on indicators

data



Bayesian Net



2. Decision scenario

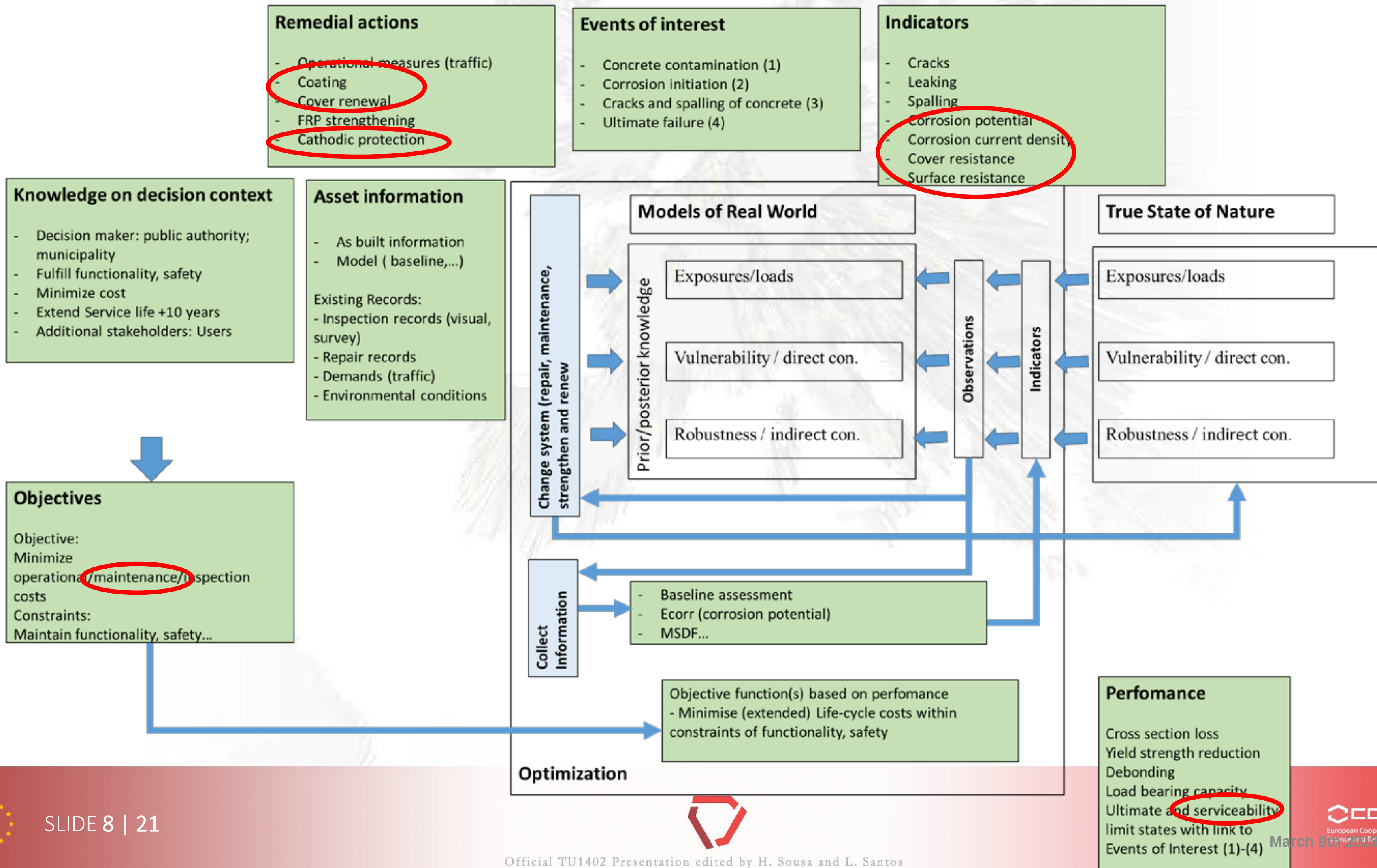
Which SHM technique should the owner apply which results in the minimization of the remaining service life cost?

Answer depends on:

- the **cost** related to each of the measuring techniques;
- the **accuracies** of each of the measuring techniques;
- the possible **actions** resulting from the outcomes of the measuring techniques;
- the **actual state** of the structure;
- the **cost and benefits** related to the failure or existence of the structure.

2. Decision scenario

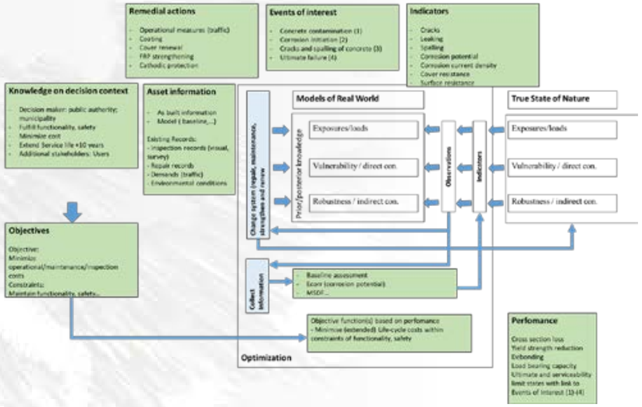
SHM (MSDF) : VoI Categorization & Flowchart



2. Decision scenario

Sensor Alternatives

(1) Half-cell potential measurements
Probability of active corrosion.
Sensitive to environmental influences.
Interpretation by means of American Standard ASTM C876.



(2) MSDF
Probability of active corrosion.
Embedded sensors
Environmental data
Multiple Electrochemical data
Knowledge based (expert) system for data interpretation.
Autonomous interpretation.

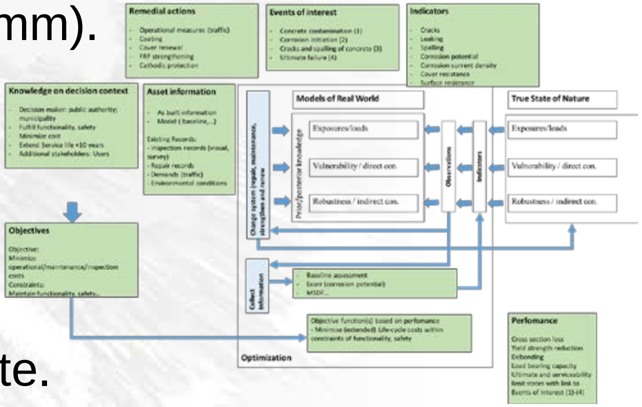
2. Decision scenario

Case study

Fictitious, reinforced concrete slab bridge located in Rotterdam.

Focus on crack width near middle support (w_{lim} = 2mm).
Two SHM techniques:
- MSDF
- Potential measurements

Two possible actions:
- No action
- Cathodic protection (limit corrosion rate.



Results from file-survey (nominal / characteristic values):
- The design lifetime: 50 years; Concrete cover: 30 mm; Curing time: 28 days
- Water cement ratio: 0.5 [-]; Cement type: CEMI; Rebar diameter: 12 mm
- Tensile splitting str.: 2.2 Mpa; Environmental class: XS3;
- Average relative humidity: 80%; Average temperature: 20 ^{o}C

2. Decision scenario

Case study

Assumptions

Both measuring techniques equally expensive while compiling first models.
MSDF better information than half-cell potential measurements.

MSDF

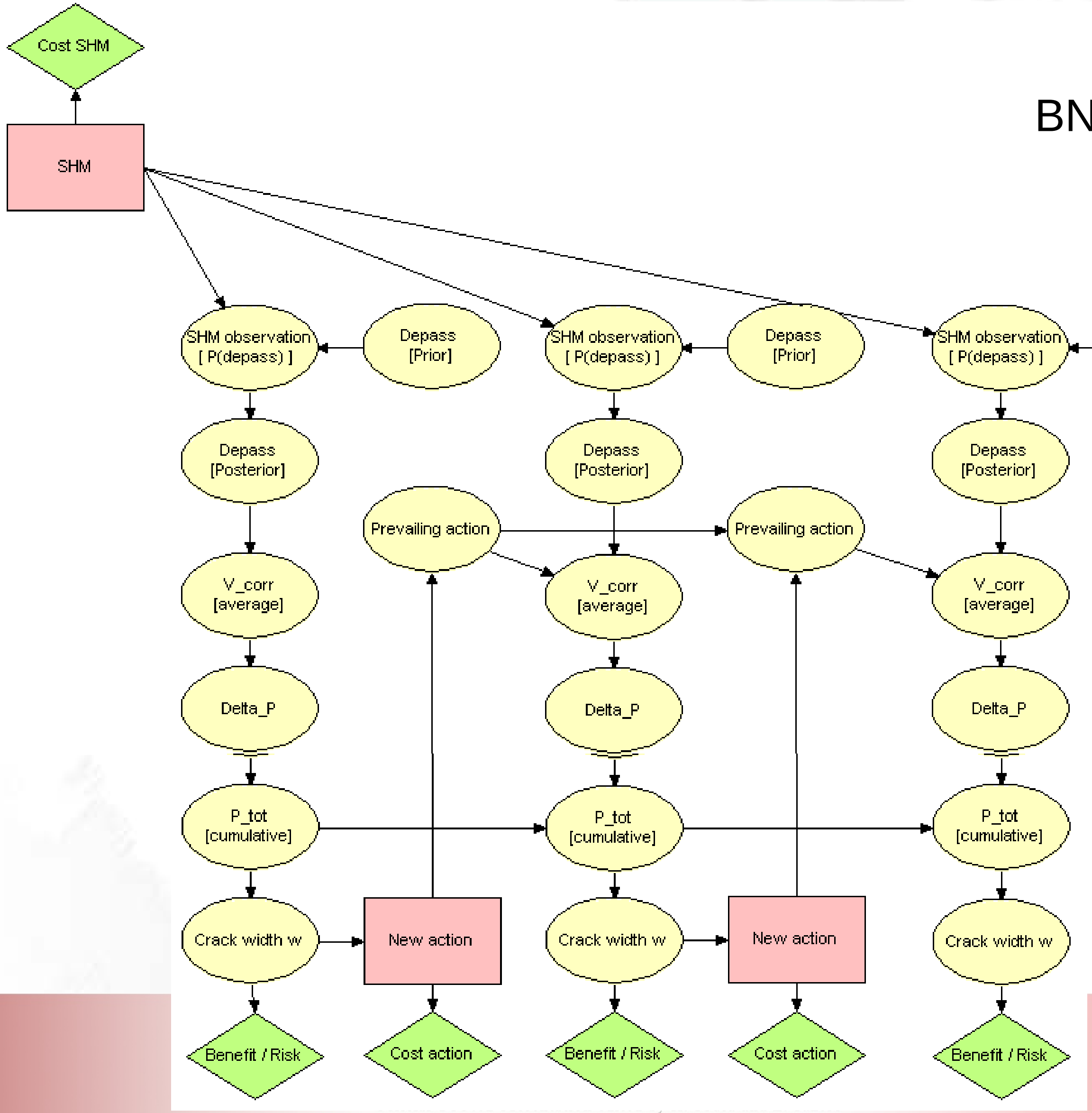
P(depass)	depass	no depass
0-10 %	0.05	0.9
10-90%	0.05	0.05
90-100%	0.9	0.05

Epot + ASTM C876

P(depass)	depass	no depass
0-10 %	0.2	0.6
10-90%	0.2	0.2
90-100%	0.6	0.2

3. Methods applied

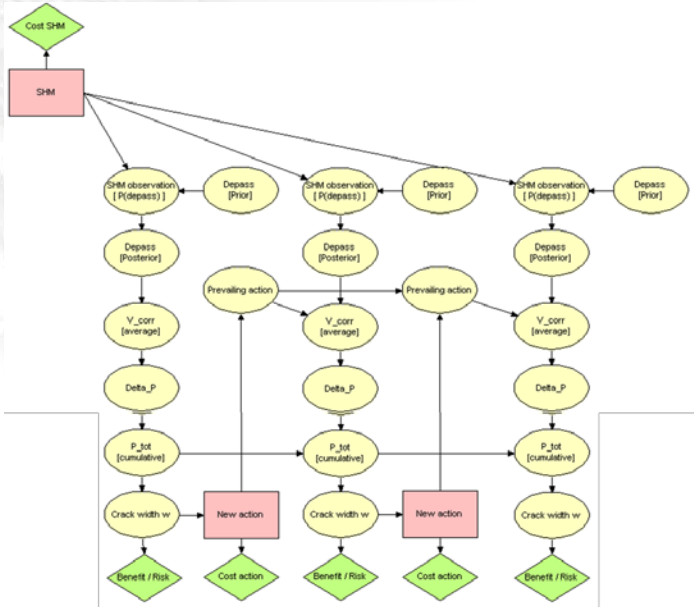
BN & LIMID



3. Methods applied

Ongoing:

- Hierarchical prior model for depassivation to be added
- Developments w.r.t. MSDF sensor to be taken into account
- Costs to be quantified
- Time as parameter in model to be included
- Other actions to be included
- Spatial variability



4. Results (to be) obtained

		Description
Structure	Type	Concrete bridge
	Life cycle phase	operation
	Performance	deterioration
Decision scenario	Decision maker	municipality as bridge owner
	Decision point in time	operational
	Objective	Minimize total maintenance costs
Decision variables	Actions	maintenance: cathodic protection, coating or cover renewal
	Action parameters	type of action
	Information acquirement strategies	MSDF sensor; potential sensor
	Strategy parameters	tpe of sensor
Results	Value of Information	## Euro
	Decision rules	Type of sensor in combination with maintenance policy

5. Value of the SHM information for the owner/concessionaire

Owner	Minimized total maintenance costs
	Optimal SHM method
	Optimal Maintenance policy
	Maintenance policy is adaptive/dynamic
Sensor	Insight in sensor VoI
	Business case for sensor
	Innovation development incentives

Thank you for your attention

http://www.cost-tu1402.eu/