



TNO CASE STUDY CONCRETE BRIDGE

COST TU1402, Como | Courage, W.M.G. (Wim)

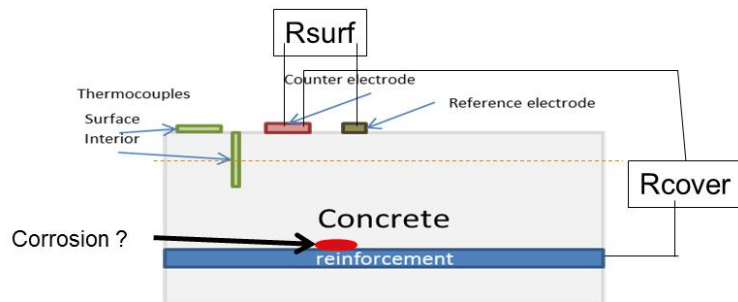
TNO innovation
for life

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) modeling uncertainty,
 - **randomness in defects due to deterioration mechanisms : CORROSION**



SHM (MSDF) : MultiSensorDataFusion

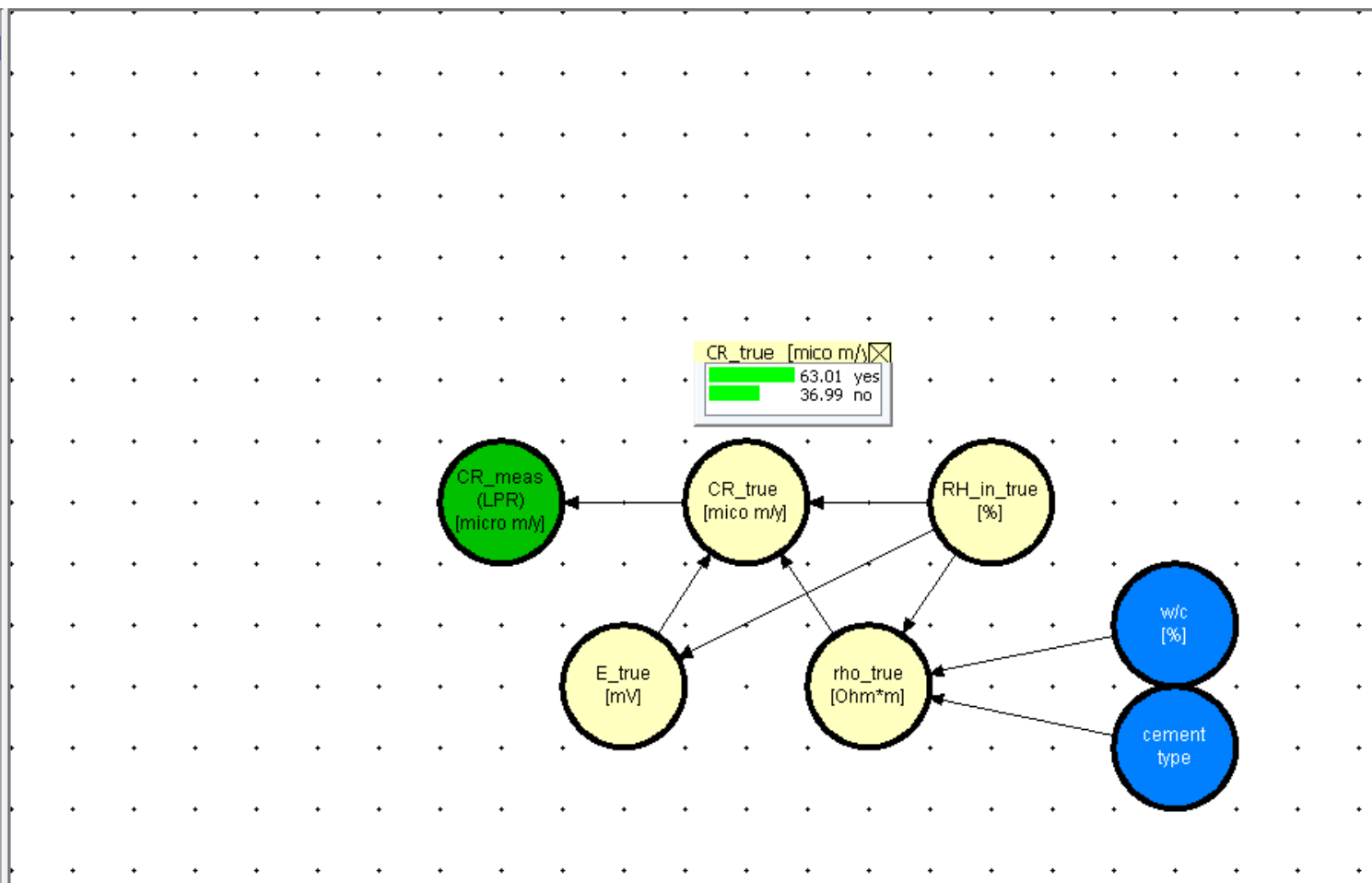
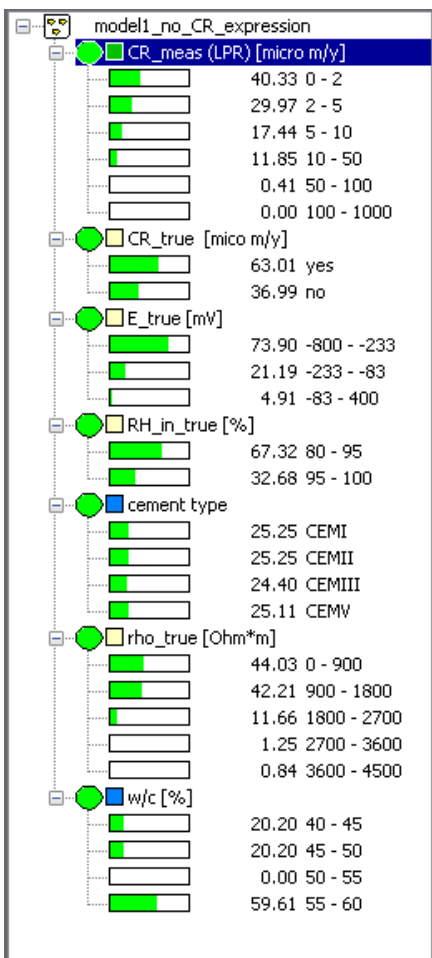


Measured parameters
Corrosion potential - E_{cor}
Corrosion rate - i_{cor} - LPR
Corrosion rate - i_{cor} - EN
Concrete cover resistivity - Rho_{co}
Concrete surface resistivity - Rho_s
Air humidity - RH
Air Temperature - T_{air}
Concrete cover temperature T_{cover}

➤ 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

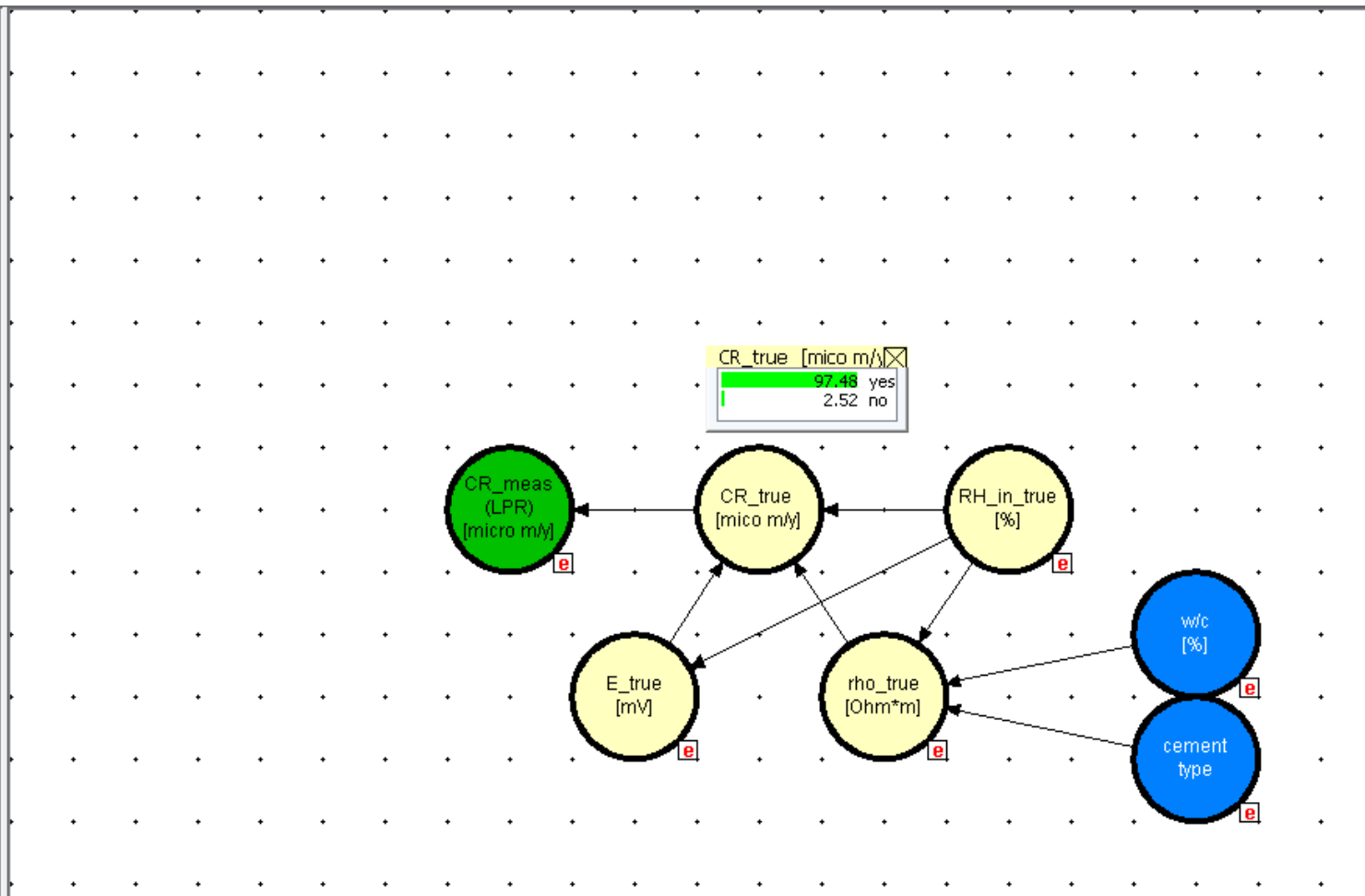
SHM (MSDF) : MultiSensorDataFusion



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model1_no_CR_expression

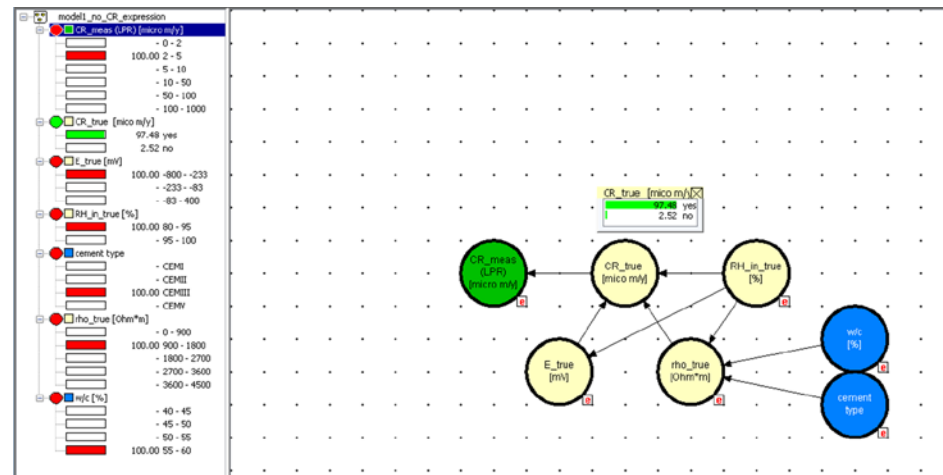
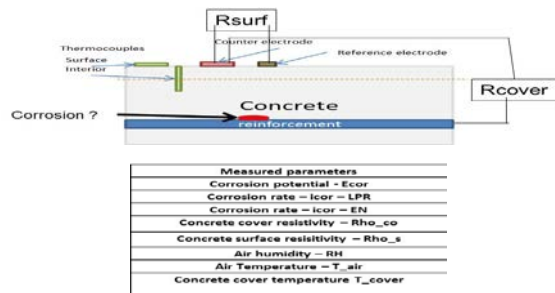
- CR_meas (LPR) [micro m/y]
 - 0 - 2
 - 100.00 2 - 5
 - 5 - 10
 - 10 - 50
 - 50 - 100
 - 100 - 1000
- CR_true [mico m/y]
 - 97.48 yes
 - 2.52 no
- E_true [mV]
 - 100.00 -800 - -233
 - -233 - -83
 - -83 - 400
- RH_in_true [%]
 - 100.00 80 - 95
 - 95 - 100
- cement type
 - CEMI
 - CEMII
 - 100.00 CEMIII
 - CEMV
- rho_true [Ohm*m]
 - 0 - 900
 - 100.00 900 - 1800
 - 1800 - 2700
 - 2700 - 3600
 - 3600 - 4500
- w/c [%]
 - 40 - 45
 - 45 - 50
 - 50 - 55
 - 100.00 55 - 60



SHM (MSDF) : Value of Information

› Vol

- › Compare the added value of the MSDF measurements to more traditional corrosion state measurements based on one indicator, e.g. electrical current.

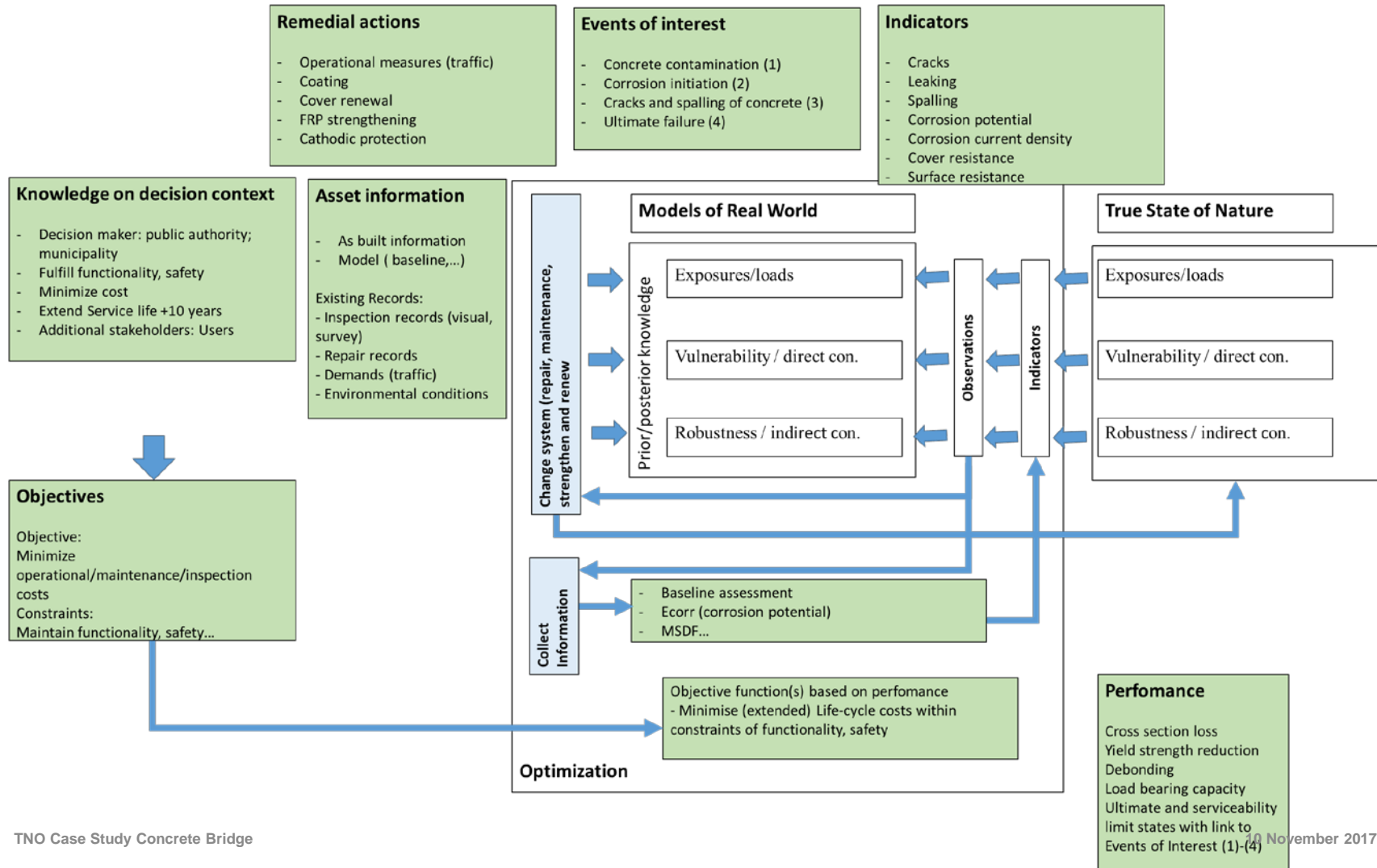


SHM (MSDF) : Possible Structures

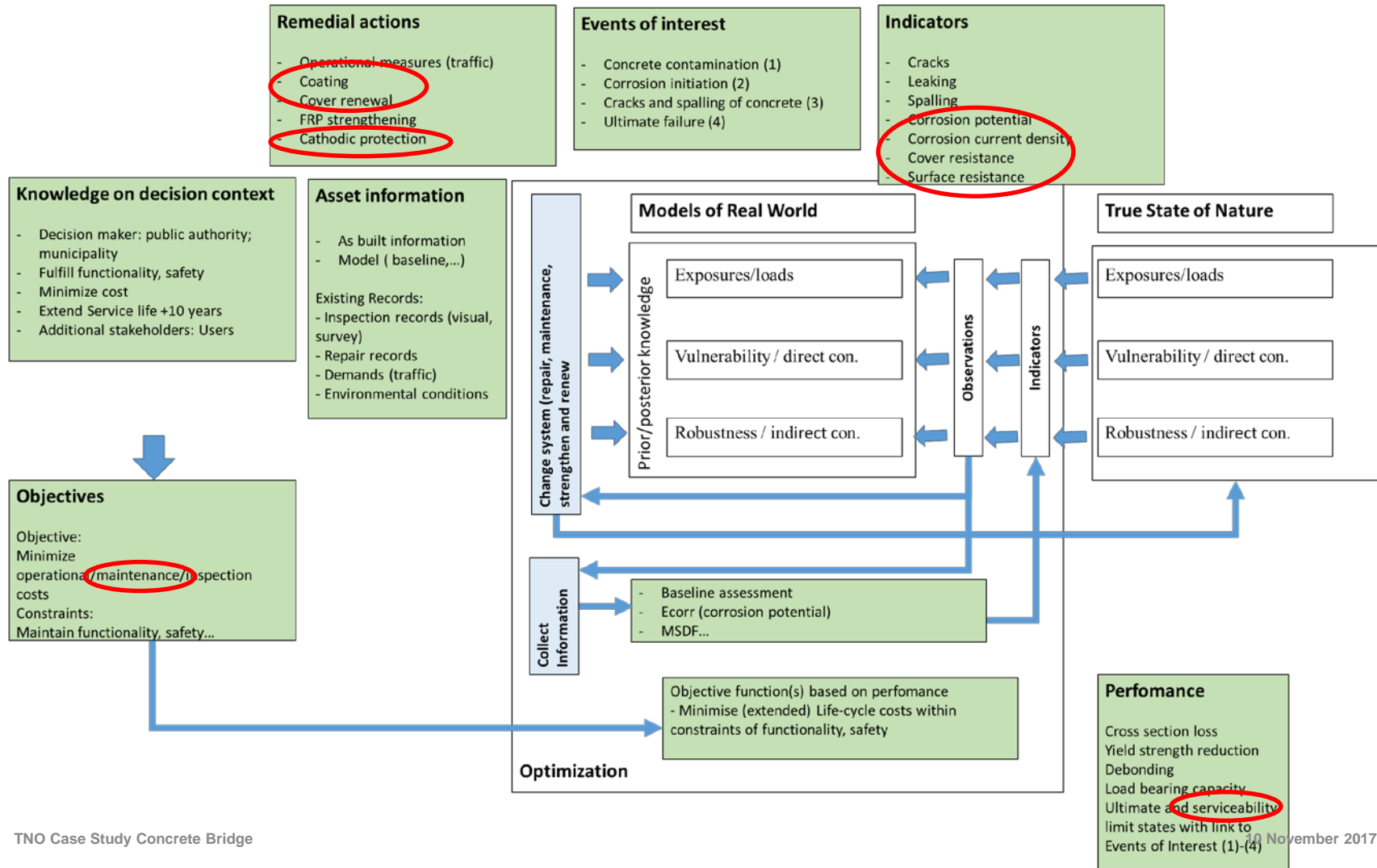
➤ **Amsterdam City Bridges**



SHM (MSDF) : Vol Categorization & Flowchart



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- Remedial actions**
- Operational measures (traffic)
 - Coating
 - Cover renewal
 - FRP strengthening
 - Cathodic protection

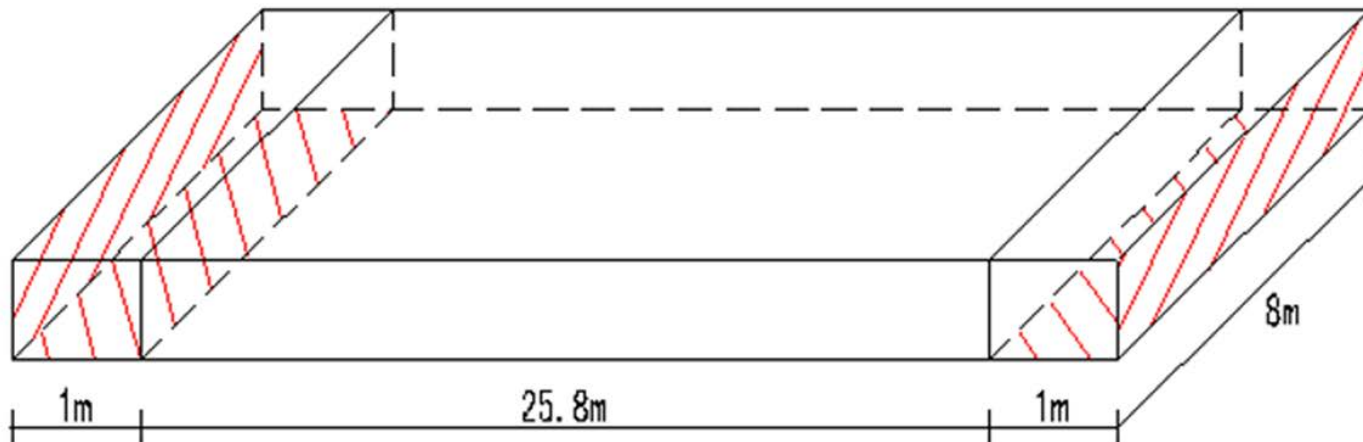
- Events of interest**
- Concrete contamination (1)
 - Corrosion initiation (2)
 - Cracks and spalling of concrete (3)
 - Ultimate failure (4)

- Indicators**
- Cracks
 - Leaking
 - Spalling
 - Corrosion potential
 - Corrosion current density
 - Cover resistance
 - Surface resistance

Knowledge on decision context

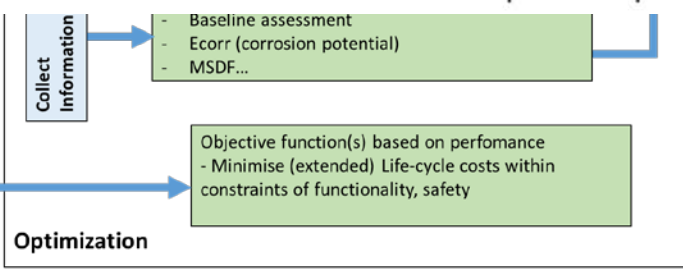
- Decis
- muni
- Fulfill
- Minin
- Exten
- Addit

Asset information



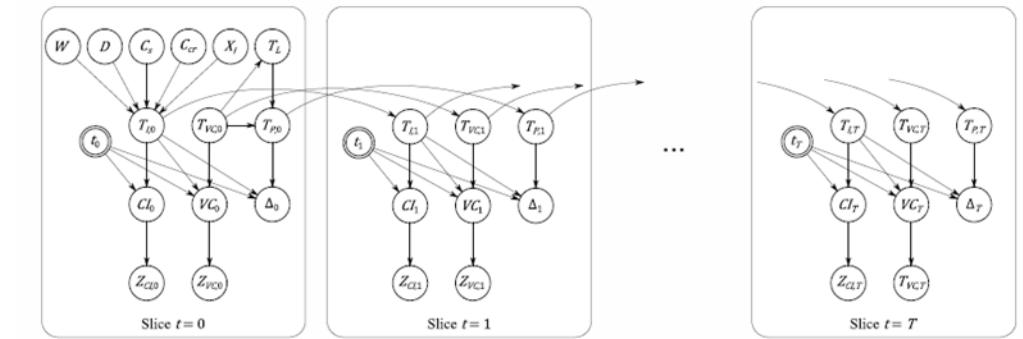
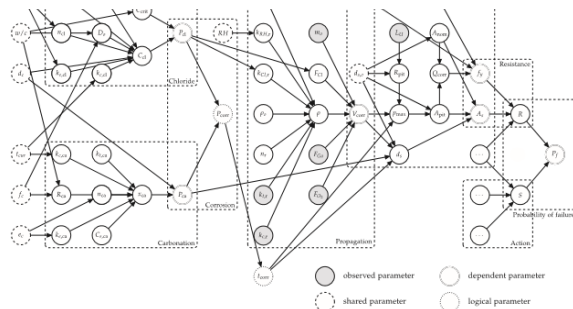
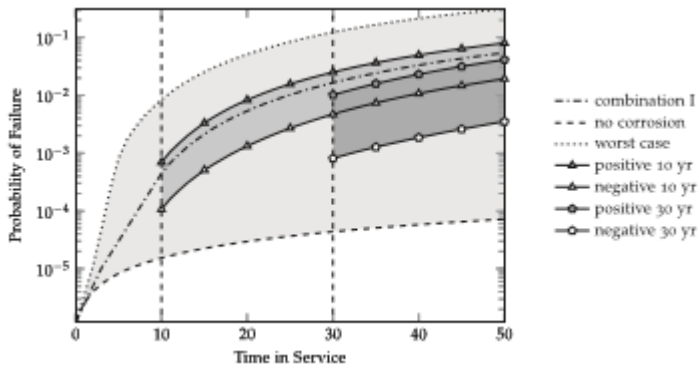
Objecti

- Objective
Minimize operation costs
Constraints: Maintain functionality, safety...



- Performance**
- Cross section loss
 - Yield strength reduction
 - Debonding
 - Load bearing capacity
 - Ultimate and serviceability limit states with link to Events of Interest (1)-(4)

SHM (MSDF) : Vol Approach



Reliability assessment of deteriorating reinforced concrete structures by representing the coupled effect of corrosion initiation and progression by Bayesian networks

J. Hackl^{a,*}, J. Kohler^b

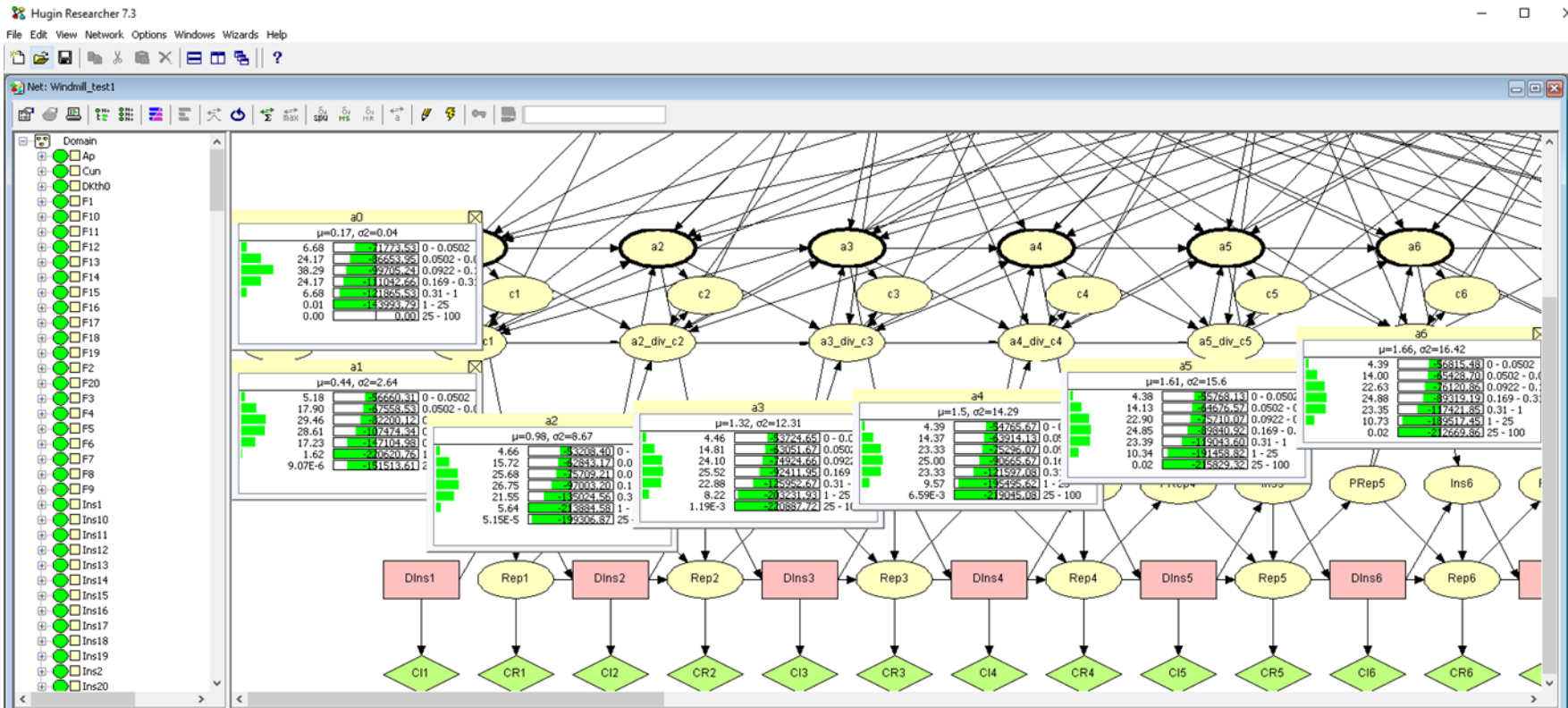
A software prototype for assessing the reliability of a concrete bridge superstructure subjected to chloride-induced reinforcement corrosion

Ronald Schneider
BAM Federal Institute for Materials Research and Testing, Berlin, Germany

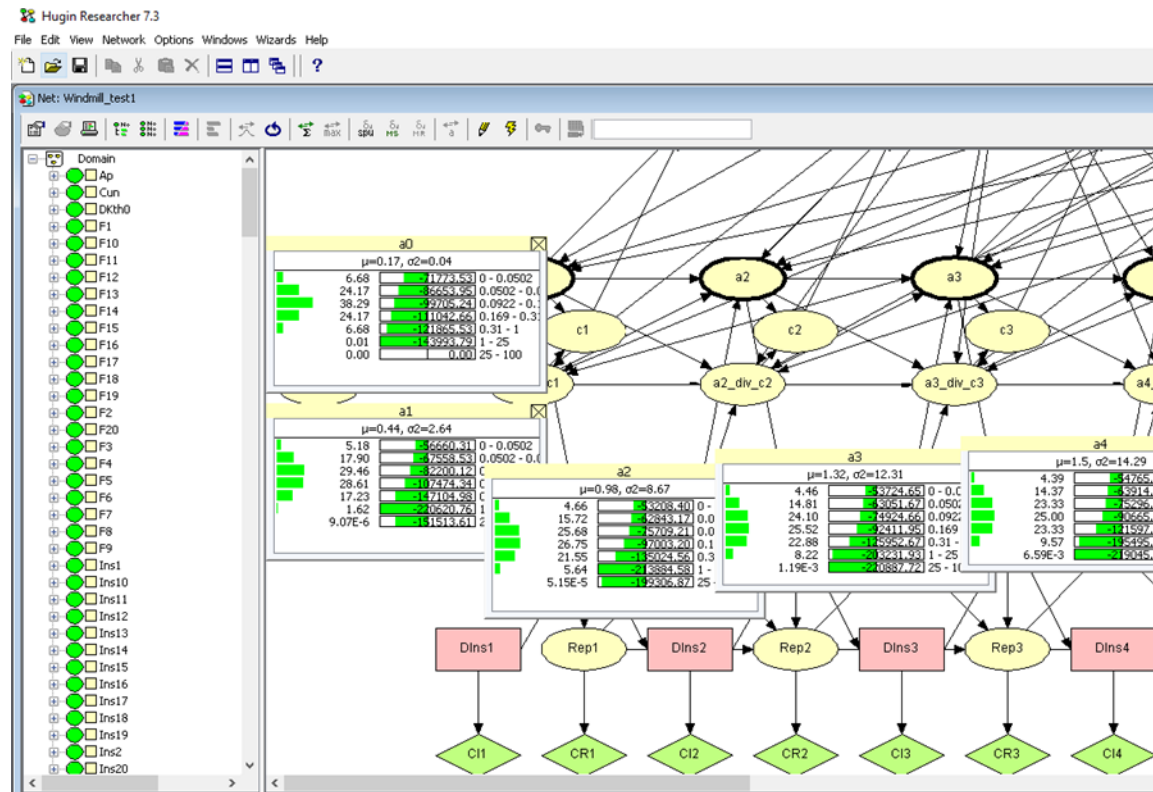
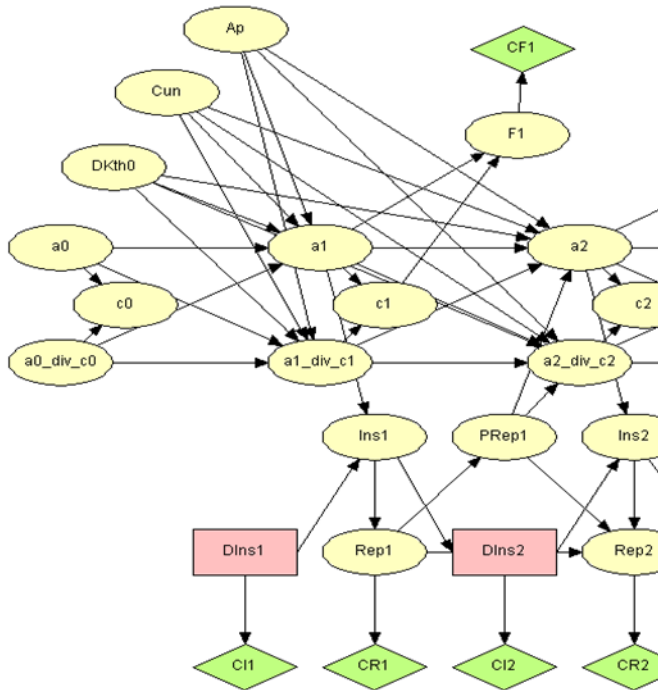
Sebastian Thöns
Technical University of Denmark, Lyngby, Denmark

Johannes Fischer, Maximilian Bügler, André Borrmann & Daniel Straub
Technische Universität München, Germany

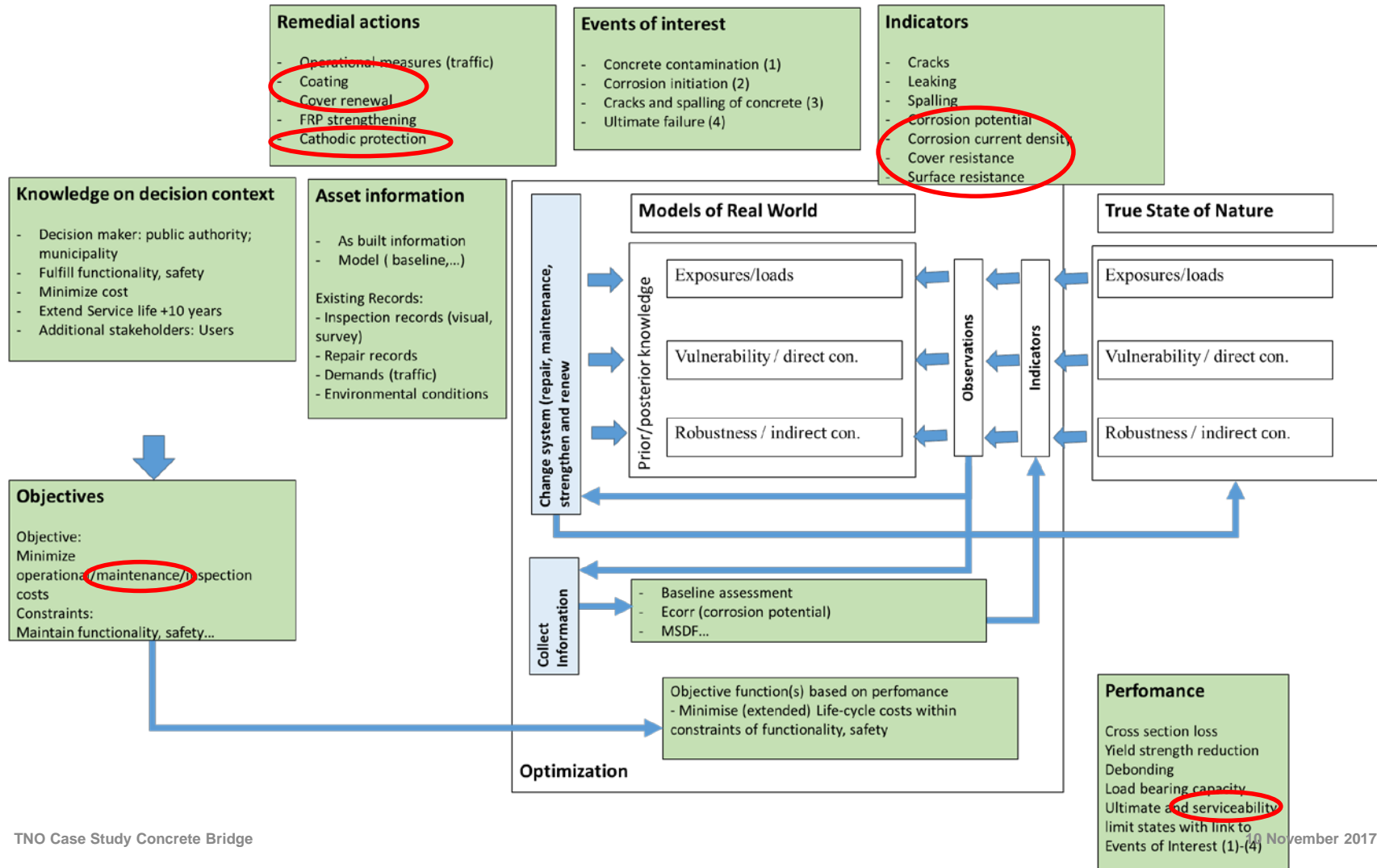
SHM (MSDF) : Vol Approach DBN (example)



SHM (MSDF) : Vol Approach DBN (example)



SHM (MSDF) : Vol Categorization & Flowchart



› THANK YOU FOR YOUR ATTENTION

Take a look:
TIME.TNO.NL

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