Value of information of static and modal data for a concrete bridge exposed to reinforcement corrosion

Eline Vereecken (Hasselt University), Wouter Botte and Robby Caspeele (Ghent University), Geert Lombaert (KU Leuven)

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Introduction

"The most sustainable building is the building you don't have to build."

Carl Elefante

→Rising interest in assessment of existing structures

→Measurements to improve estimates

→Worth the investment?

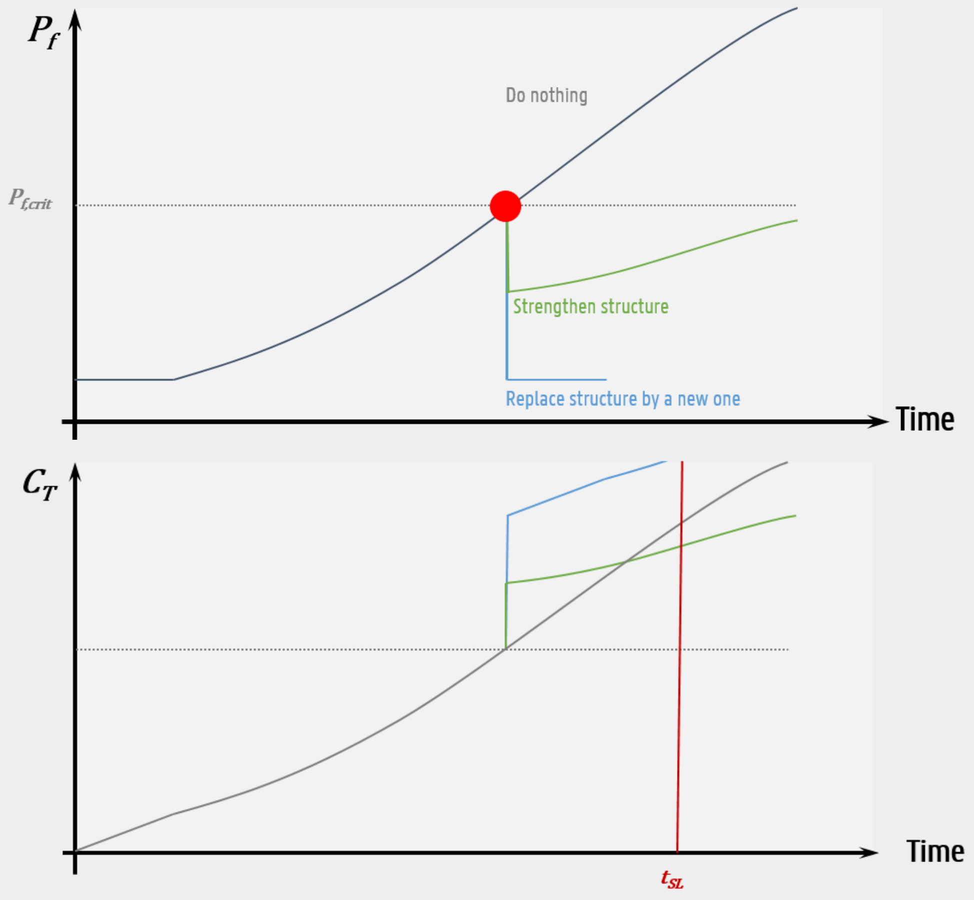
→Value of information (VoI) taking into account time-dependent and spatial character of degradation

Value of Information (VoI)

Taking into account time-dependent and spatial character of degradation

$$E[VoI] = C_{prior} - E[C_{posterior}]$$

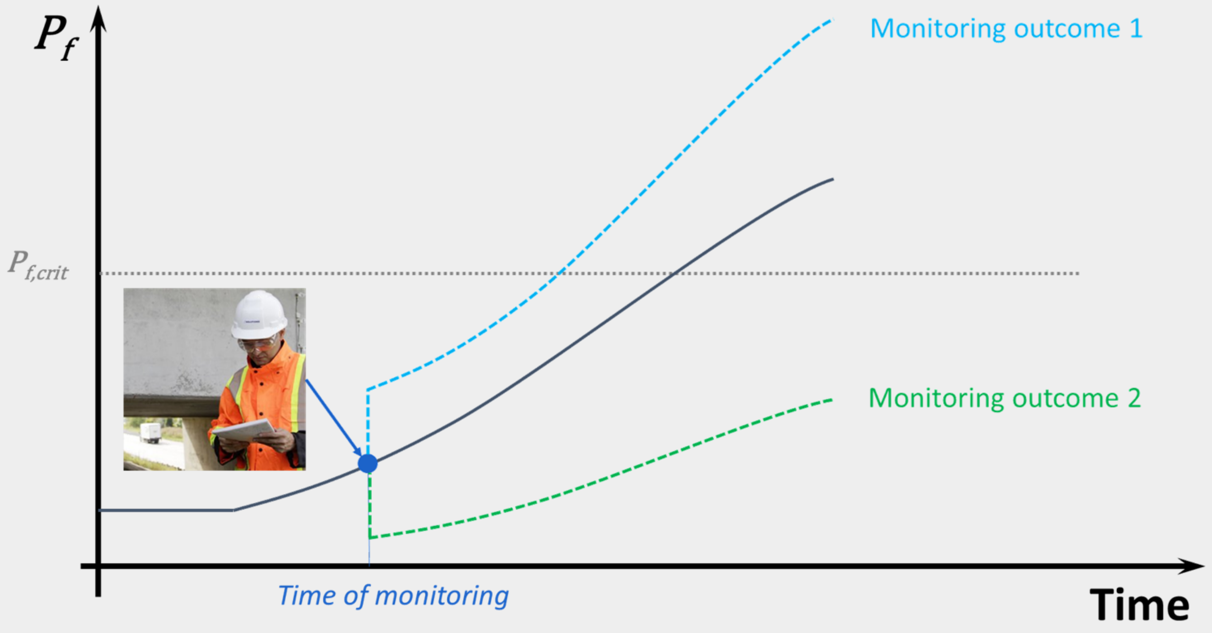
→ **Life-cycle costs**



Value of Information (VoI)

Taking into account time-dependent and spatial character of degradation

Incorporate unknown results of monitoring



Case study bridge

- 14 RC girders
- L = 13 m
- Analysis: each girder subdivided in 4 elements

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Input VoI analysis

- **Two situations**:
  1. Carbonation-induced corrosion
  2. Chloride-induced corrosion

- **Different monitoring strategies and data-types:**
  - Static strain measurements (error 3 με)
  - Ambient acceleration measurements
    - Natural frequencies (error $0.001\overline{\lambda_r}$)
    - Displacement mode shapes (error $0.01\|\overline{\boldsymbol{\phi}_r}\|$)
  - Ambient strain measurements
    - Natural frequencies (error $0.001\overline{\lambda_r}$)
    - Strain mode shapes (error 0.5 με)

Input for the VoI analysis

Degradation of the bridge

- Corrosion according to fib bulletin 34 and Duracrete

- Carbonation-induced corrosion:
  - T_i = LN(51 years; 21 years) for c = 40 mm
  - V_{corr} = LN(0.0075 mm/year; 0.005 mm/year)

- Chloride-induced corrosion:
  - T_i = LN(33 years; 26 years) for c = 40 mm
  - V_{corr} = LN(0.21 mm/year; 0.18 mm/year)

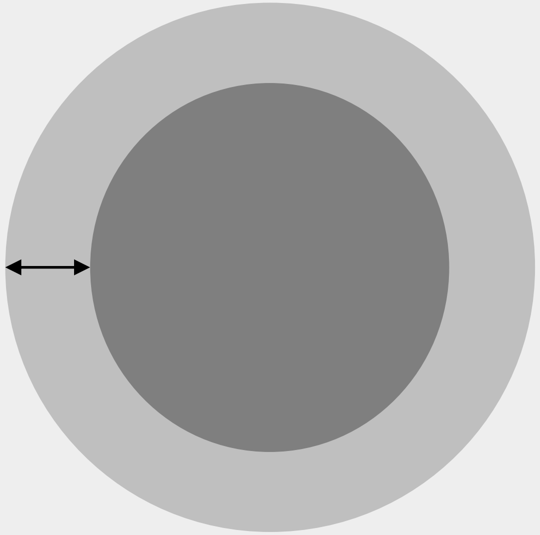
Input for the VoI analysis

Limit states to evaluate probability of failure

- Bending and shear failure of longitudinal girders

- Corrosion modelled by reduction in steel section

$$x(t) = V_{corr}(t - T_i)$$



Input for the VoI analysis

Costs in the VoI analysis

- Cost of failure C_F: € 10 million (cost of bridge itself and indirect (economic) costs)

- Repairs:
  - New bridge: € 1 700 000
  - Upgrading: € 340 000 (repairs and economic damage)

- Measurements:
  - Triaxial acceleration measurements: € 10 000
  - Modal strain with optic fibres: € 20 000
  - Static strain measurements: € 20 000 (20 sensors) to € 28 000 (52 sensors)
  - Installation cost (roadblock): € 30 000

Input for the VoI analysis

Decision alternatives

- **Action alternatives:**
  1. Do nothing
  2. Upgrade to β_{up} (4.2) if $\beta < \beta_{crit}$ (3.57)
  3. Replace the structure if $\beta < \beta_{crit}$ (3.57)

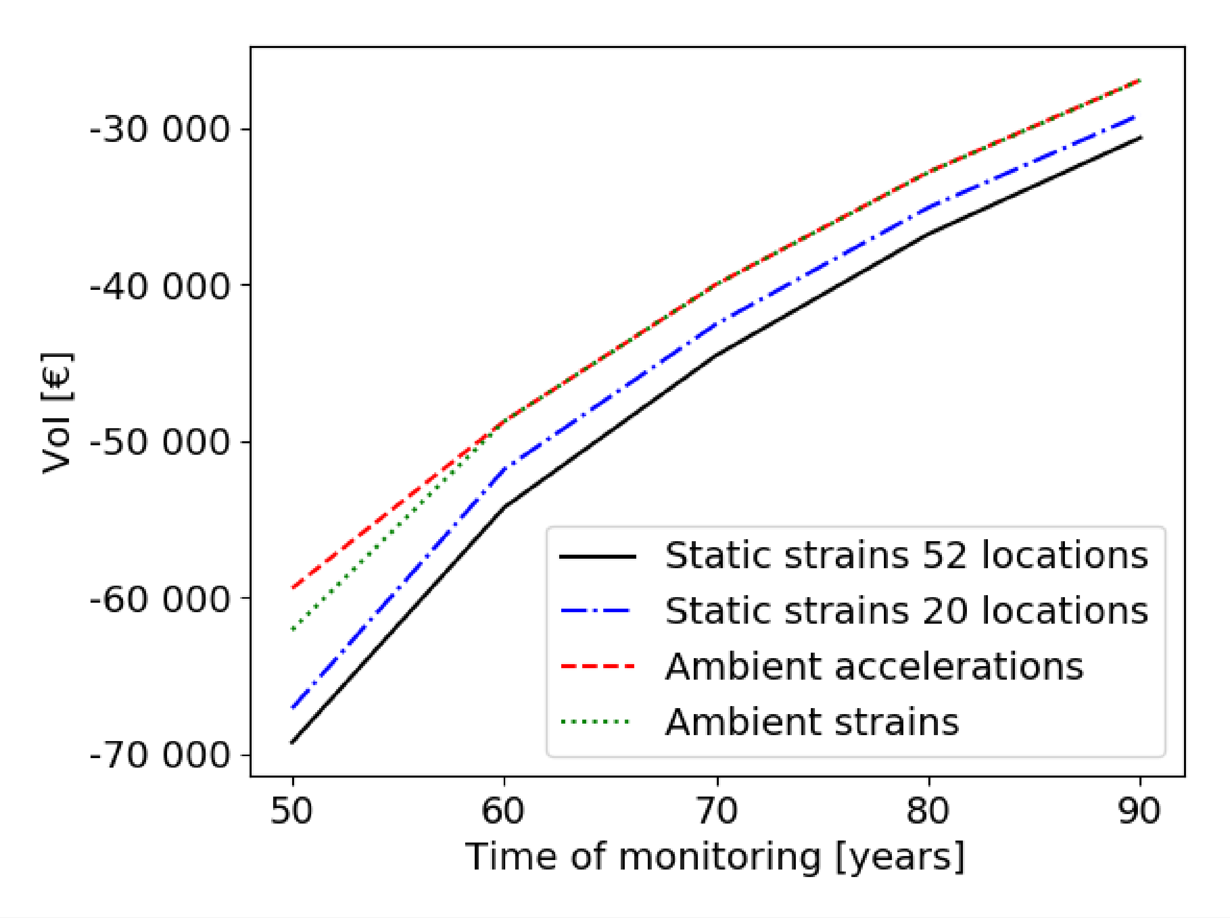
- **Actions triggered by measurements:**
  - Cathodic protection if $P[x(t) > x_{crit}] \geq P_{crit}$
  - Cathodic protection + strengthening if $P[\alpha > \alpha_{crit}] \geq P_{crit}$

Results of the VoI analysis

Negative VoI due to slow corrosion process

→ Measurements do not trigger intervention

Carbonation-induced corrosion

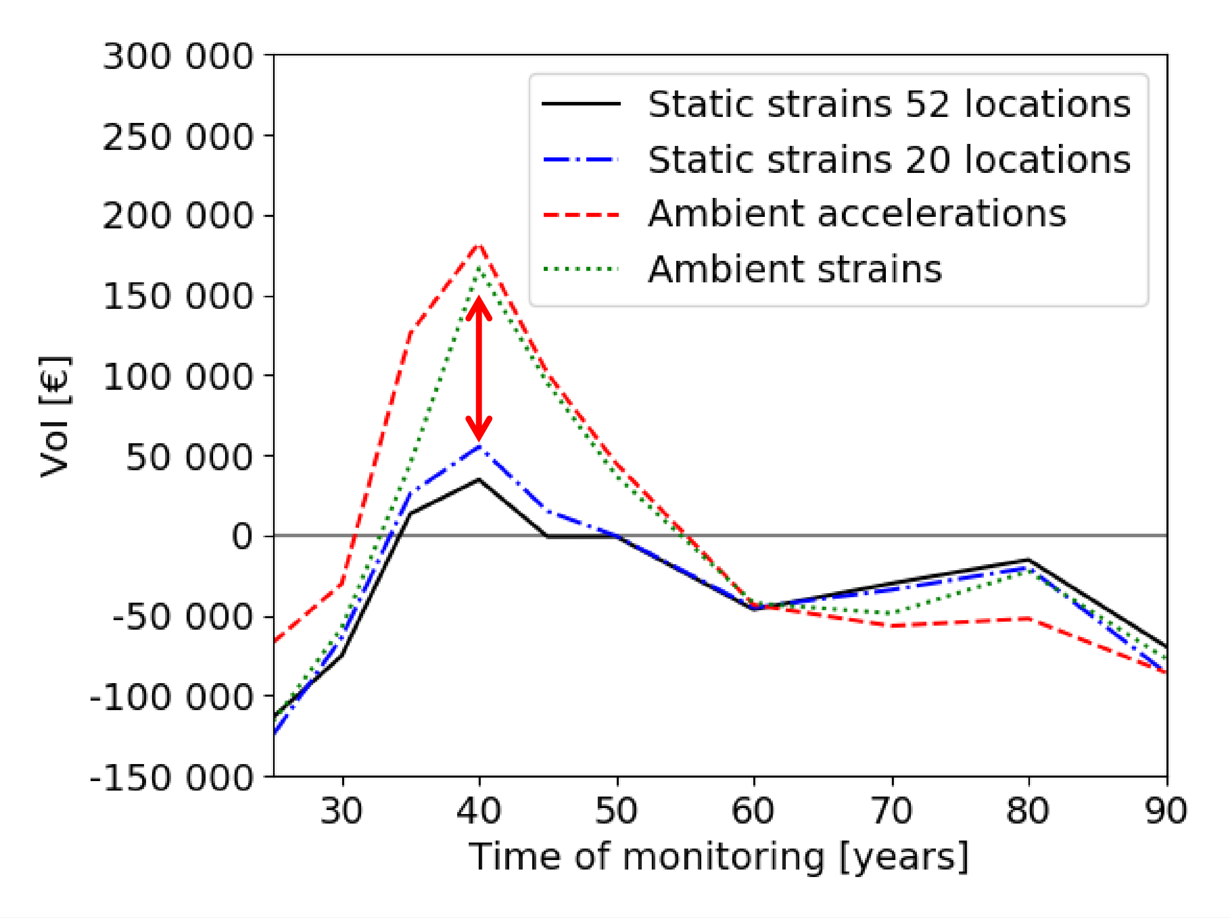


Results of the VoI analysis

Critical β reached earlier

Dynamic data triggers more repair + actions differ from prior choice (upgrade)

Chloride-induced corrosion



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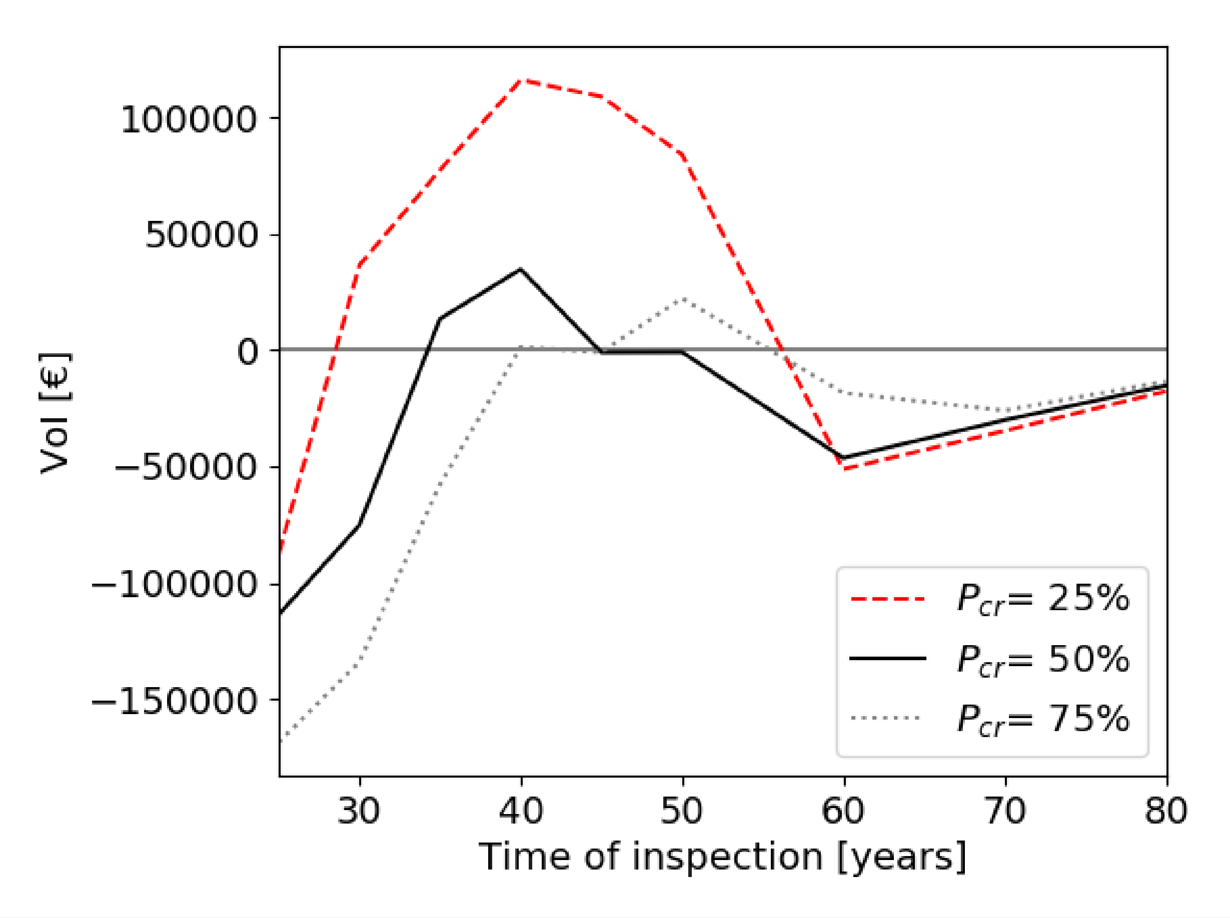
Results of the VoI analysis

P_{crit} = 25%: optimal action often changes to 'do nothing'
→ Higher VoI

P_{crit} = 75%: less elements repaired or maintained
→ Lower VoI

Influence P_{crit}



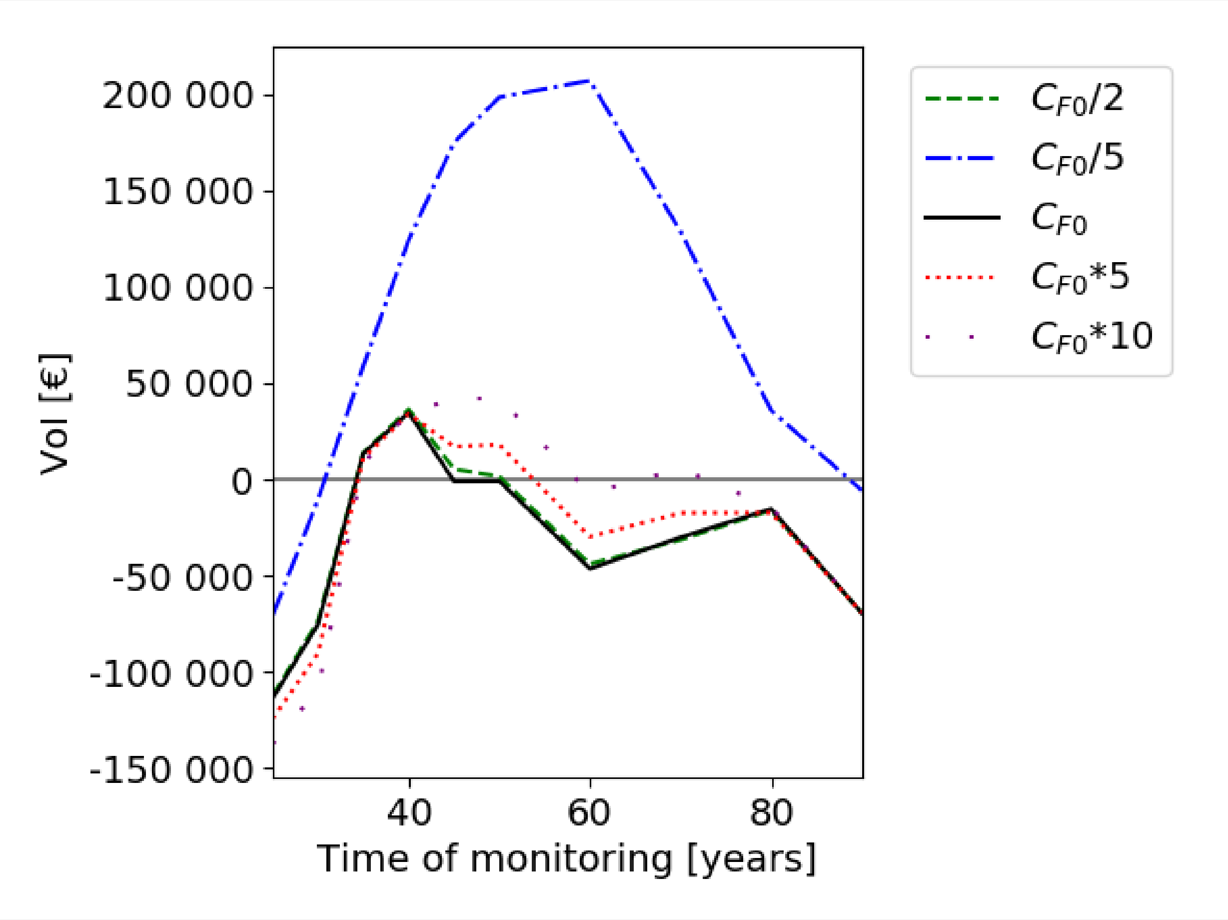
Results of the VoI analysis

*5, *10, /2 → Small influence

/5 → Large influence → Posterior most optimal action in all cases = ‘do nothing’ (prior: ‘upgrade’)

General behaviour not impacted
- Too early: no action triggered
- Too late: repair already performed

Influence failure cost



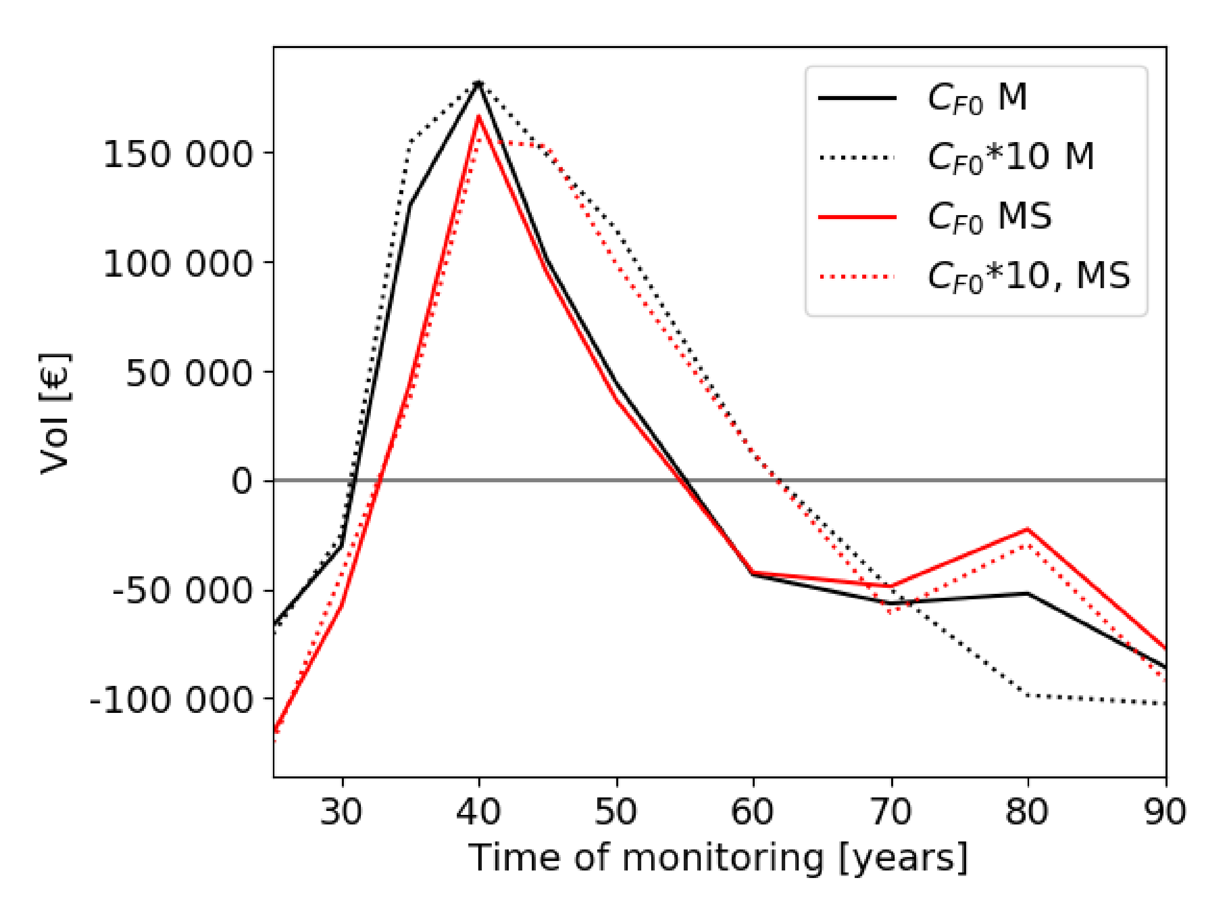
Results of the VoI analysis

Limited influence untill t = 40 years

Later: higher VoI for higher C_F

Optimal strategy unaltered

Influence failure cost



Conclusions

- Small degradation rate → No repairs required → Negative VoI
- Higher degradation rate → Monitoring triggers intervention → Positive VoI with optimum
- Value of P_{crit} influences absolute value of VoI, not general behaviour
- Influence of C_F depends on assumed value and can be limited

→ Sensitivity analysis might be required