# INTERVENTION PLANNING AND OPTIMIZATION OF INTERCONNECTED INFRASTRUCTURES

## AN INTEGRATIVE MULTI-SYSTEM AND MULTI-STAKEHOLDER APPROACH

**Omar Kammouh**

Delft University of Technology
O.Kammouh@tudelft.nl

NGinfra Next Generation Infrastructures

TU Delft

# INTRODUCTION

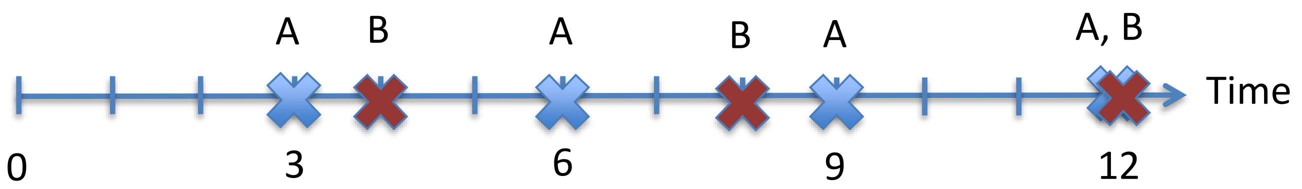
## Motivation

- Different infrastructure networks are **managed by different operators**
- Every operator plans their intervention activities separately with **little coordination** with other operators
- The lack of integrated approach to **manage all networks as one system** is preventing them to obtain the highest possible benefits

# PROBLEM STATEMENT

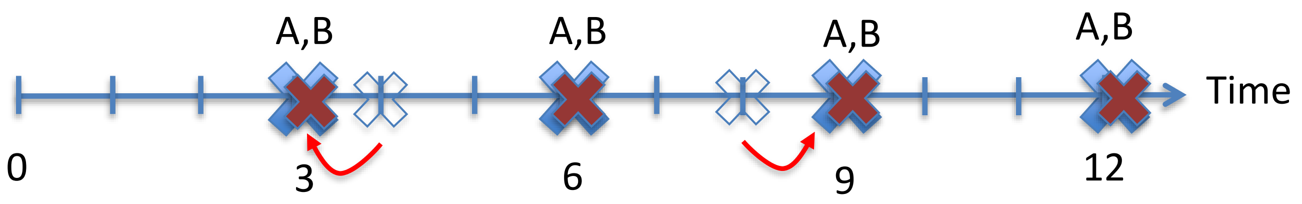
## Intervention planning

- Intervention planning **without** coordination/optimization




  - Operator A: maintenance every 3 time units
  - Operator B: Maintenance every 4 time units
  - System closure: 6 times

- What if

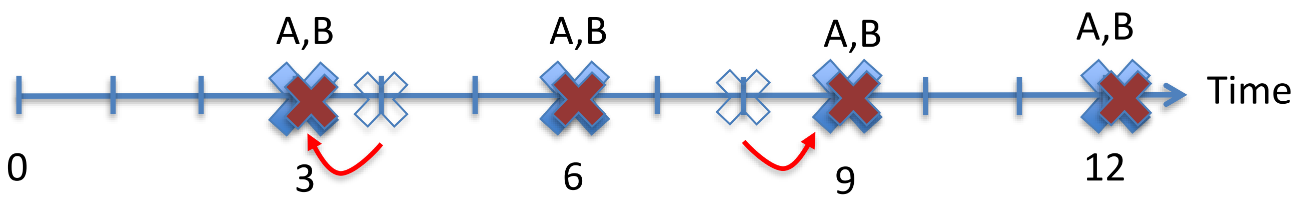



  - Operator A: maintenance every 3 time units
  - Operator B: Maintenance every 3 time units
  - System closure: 4 times

# OBJECTIVE

## Interdependent Infrastructure Interventions Optimization

- Introduce an **integrative optimization approach for intervention planning of interconnected infrastructure**.
- The optimization problem **must be scalable**



# MODELING AND OPTIMIZATION

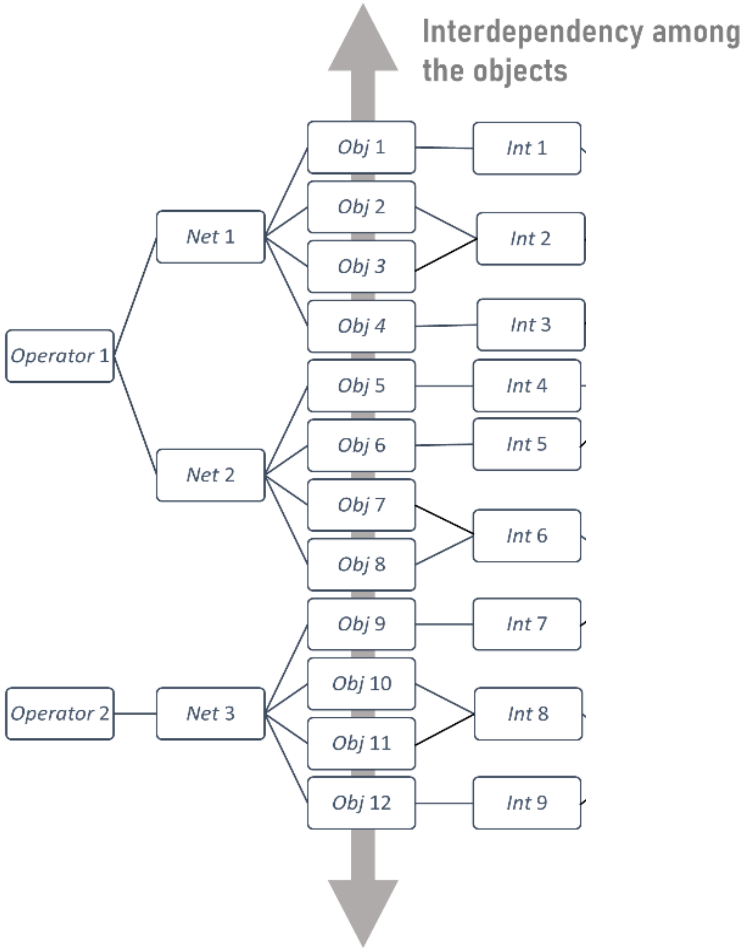
## Multisystem and Multistakeholder modeling approach

Operator

Network (*Net*)

Object (*obj*)

Intervention (*int*)

# MODELING AND OPTIMIZATION

## Mathematical formulation of the optimization problem

- Objective function: Minimize the net cost

$$Min \ (NetCost)$$

$$NetCost = C_{tot}^{prev} + S_{tot} + U_{tot}$$

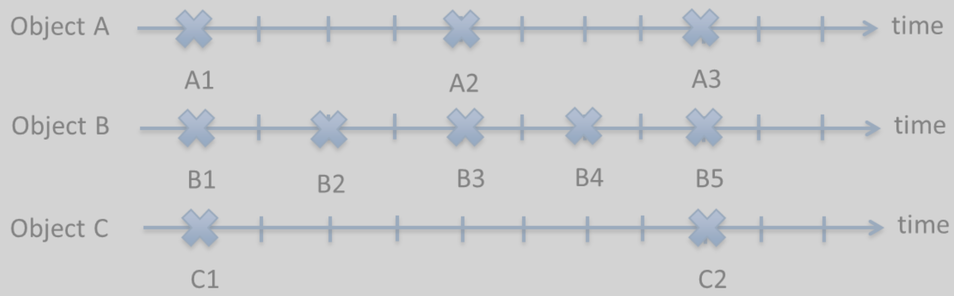
  - where $C_{tot}^{prev}$ is the total cost of intervention activities:
  - where $U_{tot}$ is the total service interruption cost caused by the interventions:
  - where $S_{tot}$ is the total set-up costs of the interventions:

$$C_{tot}^{prev} = \sum_{t=1}^{T} C_{1\times K}^{prev} \times M_{K\times T}^{t}$$

$$S_{tot} = \sum_{t=1}^{T} C_{1\times E}^{setup} \times V_{E\times T}$$

$$U_{tot} = \sum_{t=1}^{T} C_{1\times N}^{shut} \times U_{N\times T}$$

**Decision variables** $\mathbf{M}_{K\times T}$



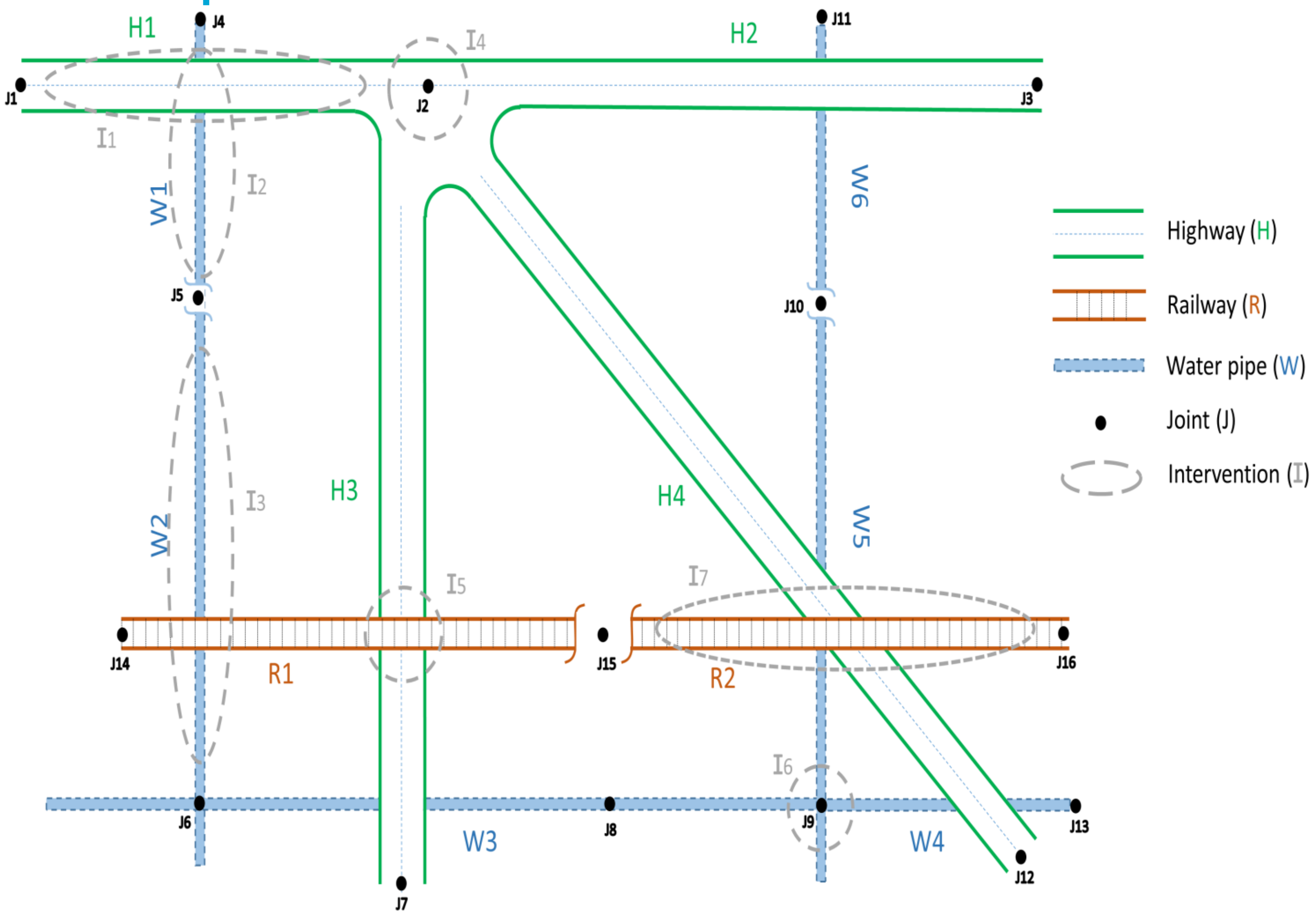

$$= \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix} \begin{matrix} A \\ B \\ C \end{matrix}$$

- Binary problem
- Linear optimization

→ Computational effort: low
→ Quality of solution: high

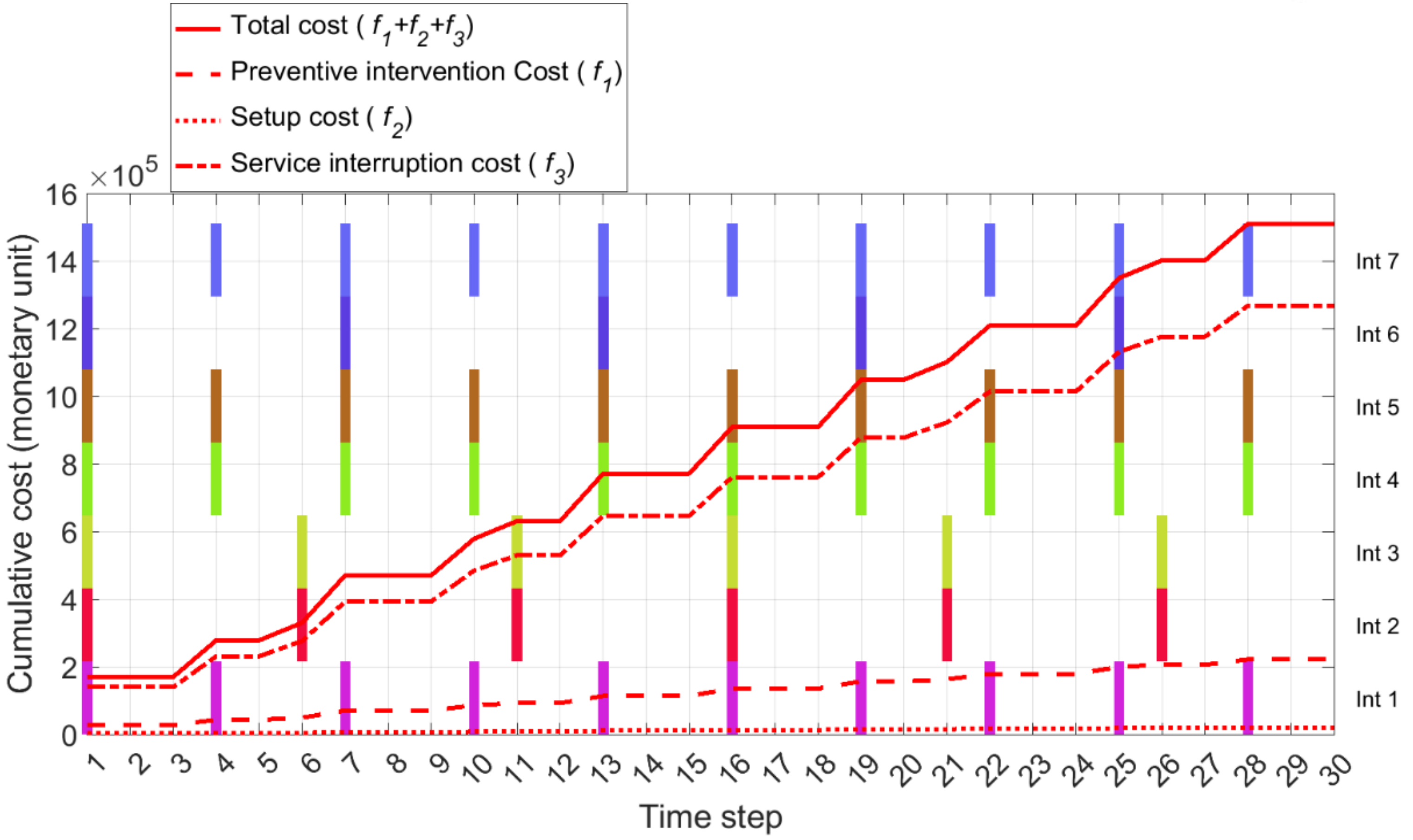
# CASE STUDY AND RESULTS

## Numerical example



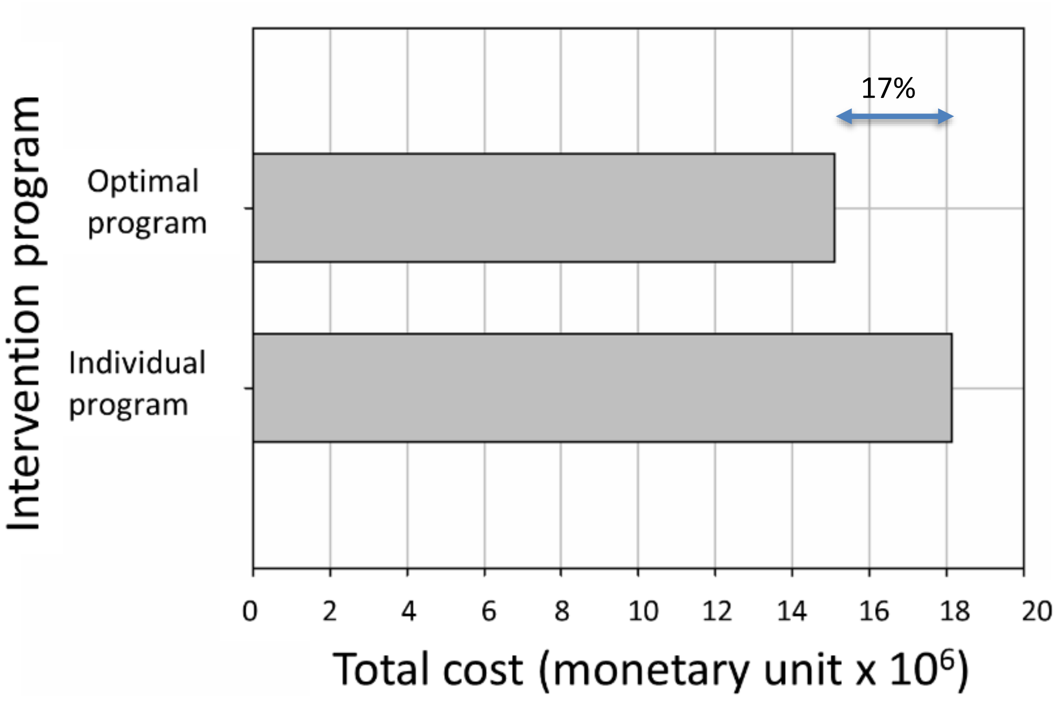
# CASE STUDY AND RESULTS

## Results: optimal intervention program



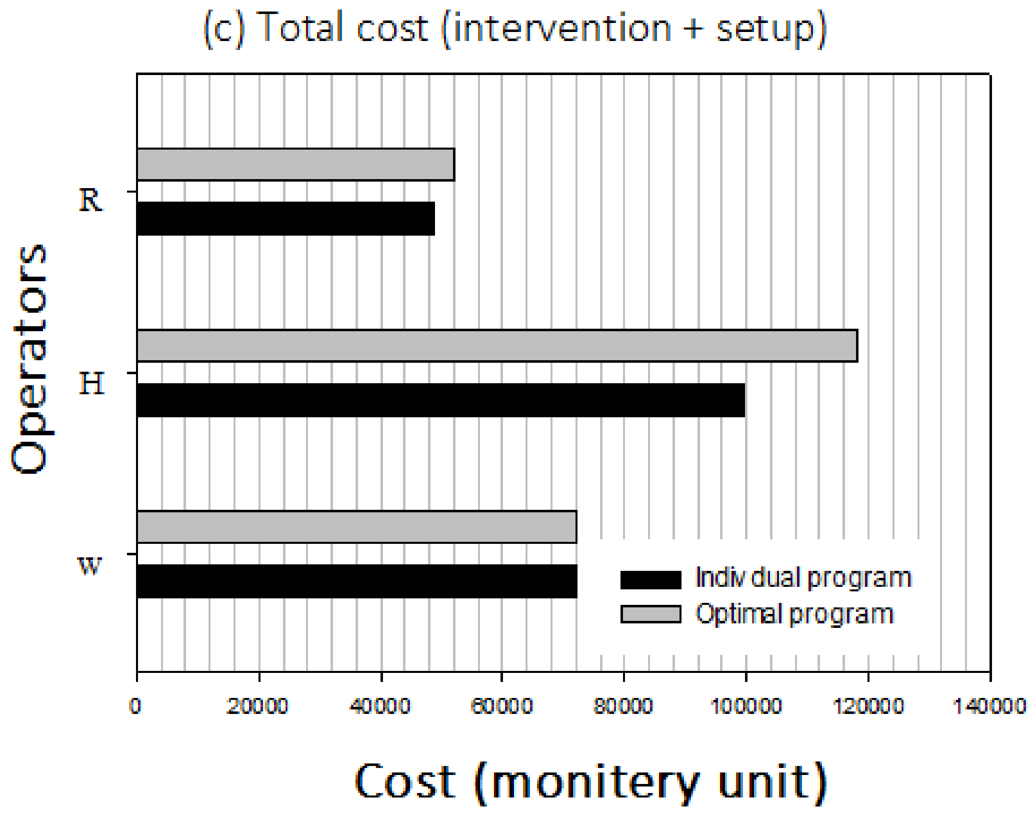
# CASE STUDY AND RESULTS

## Results: minimum cost (optimal vs individual)



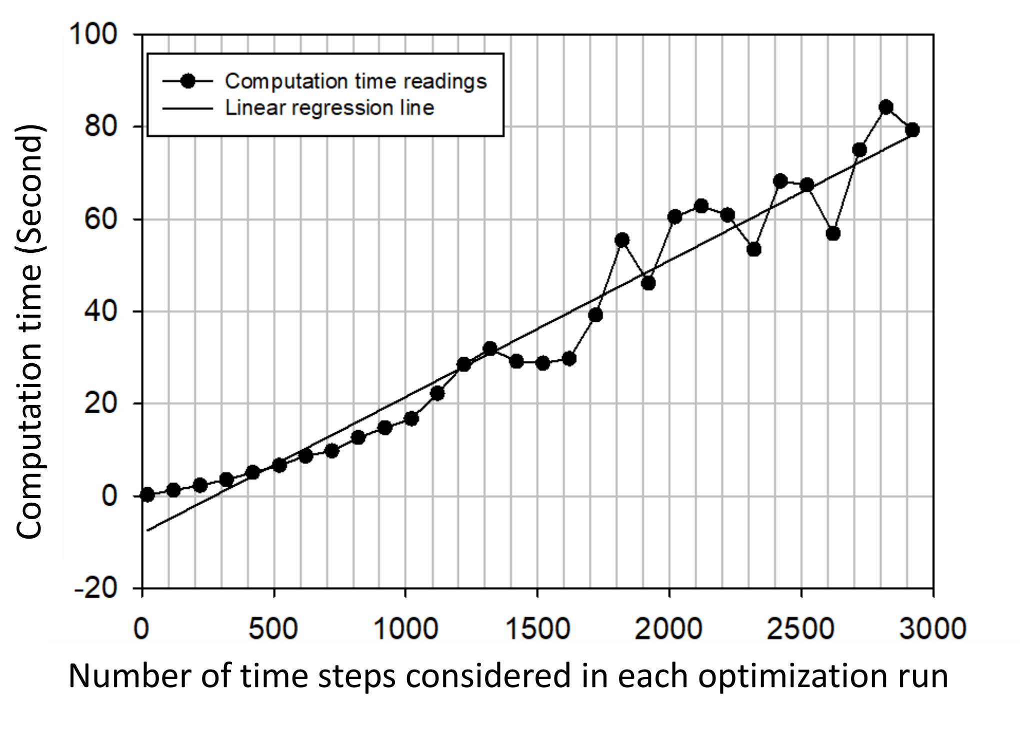
# CASE STUDY AND RESULTS

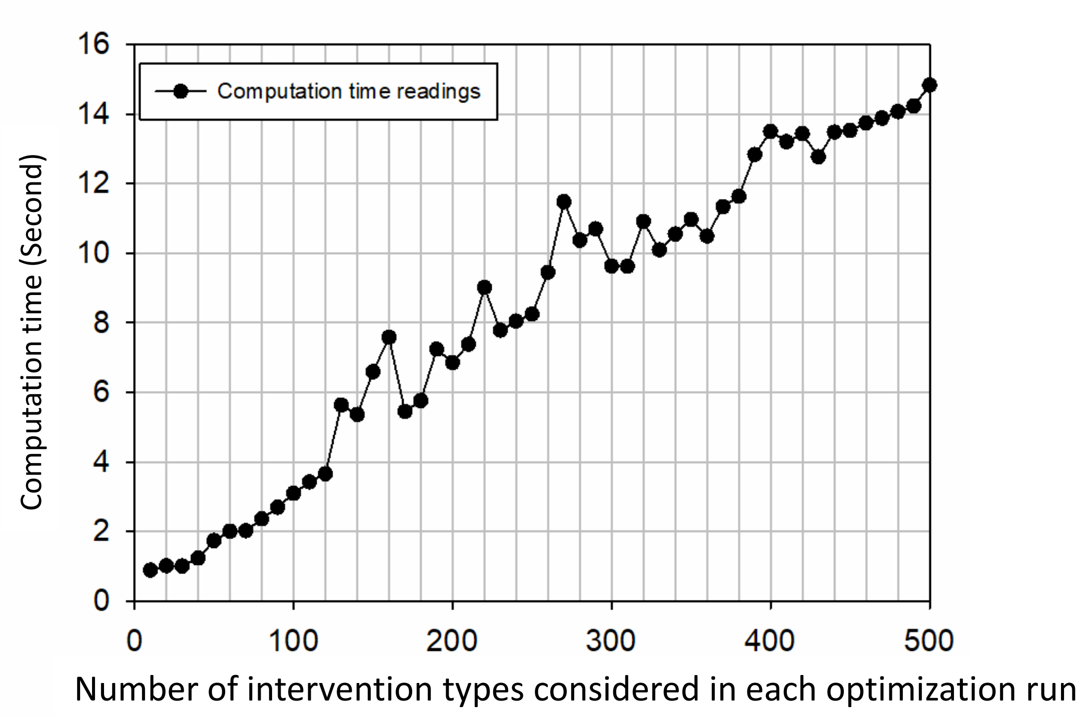
## Results: Stakeholder cost analysis



# CASE STUDY AND RESULTS

## Results: Algorithm performance



# CONCLUSIONS

## Take-aways

01 Identifying the optimal arrangement of interventions may significantly reduce the net intervention costs.

02 The decrease in cost is mainly caused by the reduction in service unavailability

03 There will be extra direct costs for the operators

THANK YOU

# INTERVENTION PLANNING OPTIMIZATION OF INTERCONNECTED INFRASTRUCTURES

**Omar Kammouh**

Delft University of Technology
O.Kammouh@tudelft.nl

NGinfra Next Generation Infrastructures

TU Delft