Resilience of water infrastructures

Olivier Piller, Jochen Deuerlein

RESIWATER

INNOVATIVE SECURE SENSOR NETWORKS AND MODEL-BASED ASSESSMENT TOOLS FOR INCREASED RESILIENCE OF WATER INFRASTRUCTURES

Resilience of water infrastructures

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Dr. Olivier Piller & Dr.-ing Jochen Deuerlein

French-German project funded by ANR/BMBF

Critical Infrastructure Protection Call

PICS 2014 – Final meeting

Lyon, the 16th October 2018

Water Distribution Systems

LARGE INTERCONNECTED CRITICAL INFRASTRUCTURES

potential hazards


Extreme weather


Accidents or technical failures

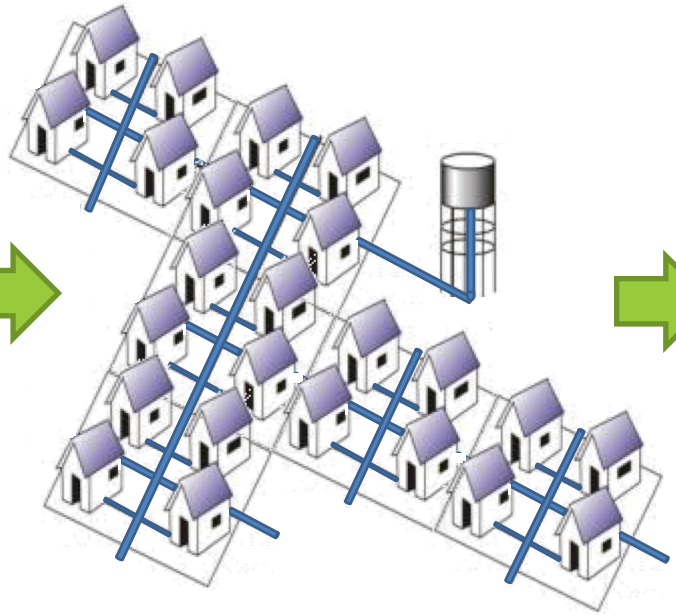

Cyber threats


Acts of terrorism


Chemical contamination


Cascading events

others
- Aging
- Components degradation



potential consequences or potential impacts

- Pipe break
- Other infrastructure (damage/failure)
- Power outage
- Service disruption (source water treatment, distribution or storage)
- Loss of pressure/Leaks
- Change in water quality
- Environmental impacts
- Financial impacts (e.g. loss of revenue, repair cost)
- Social impacts (e.g. Loss of public confidence, reduce workforce)
- Others

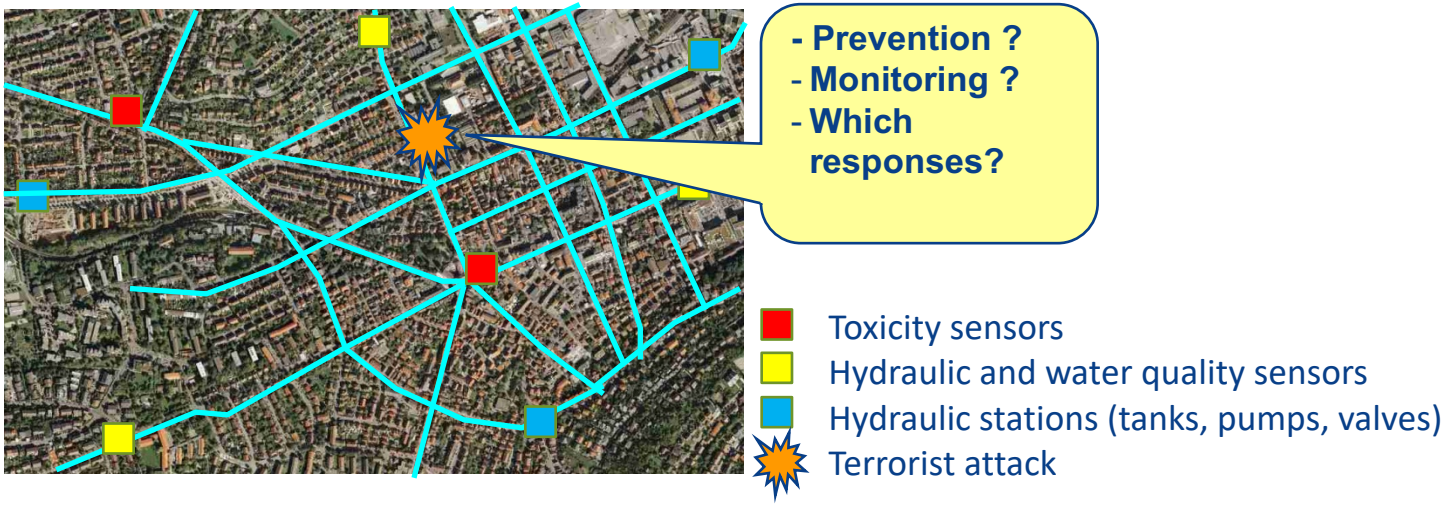
Introduction

CRITICAL INFRASTRUCTURE PROTECTION

Drinking water distribution networks are exposed to natural or human-made disasters

Not only are contaminant warning systems important, but so is water utility preparation, maintenance, training…

The detection of faults and the capacity to return quickly to a normal state after failures and interruption of services are essential for water utilities.



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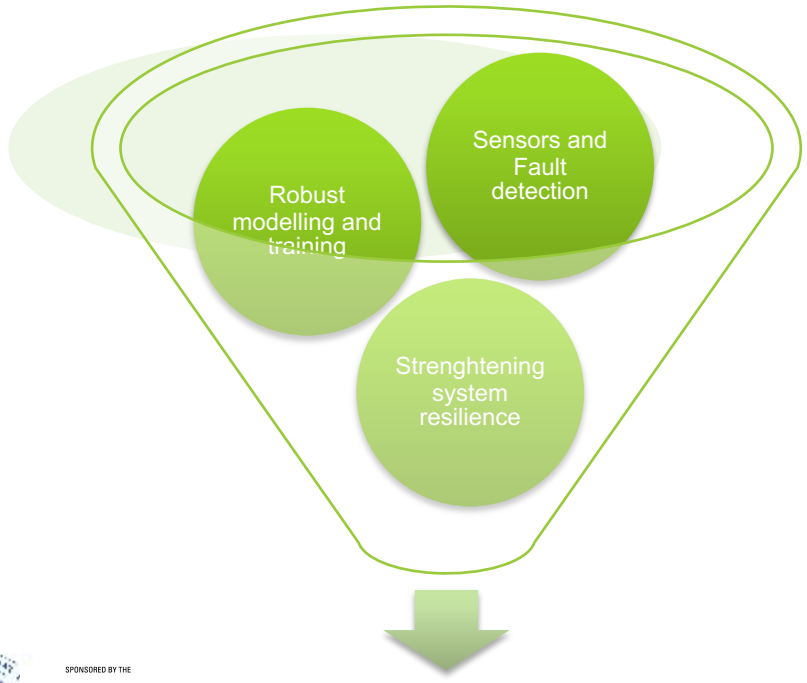
Introduction

OBJECTIVE

Prepare water utilities to crisis management by improving the system resilience with respect to 2 specific case studies: system failure and water quality deterioration.



1. Project consortium & work plan
2. The resilience framework
3. Simulation and resilience training
4. Conclusions and outlook

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Project consortium

PARTNERS (JULY 2015 – JUNE 2018)

End-users

Berliner Wasserbetriebe (BWB, Germany)

Eurométropole de Strasbourg (EMS, France)

Veolia Eau d'Ile-de-France (VEDIF, France)

Engineering Consulting Company

3S Consult GmbH (Germany)

Laboratories and Research Centers

Irstea (France)

Engees GESTE and ICUBE (France)

DVGW-Technologiezentrum Wasser TZW (Germany)

Fraunhofer Institute IOSB (Germany)

Fraunhofer institute IGB (Germany)

CEA DAM (France)

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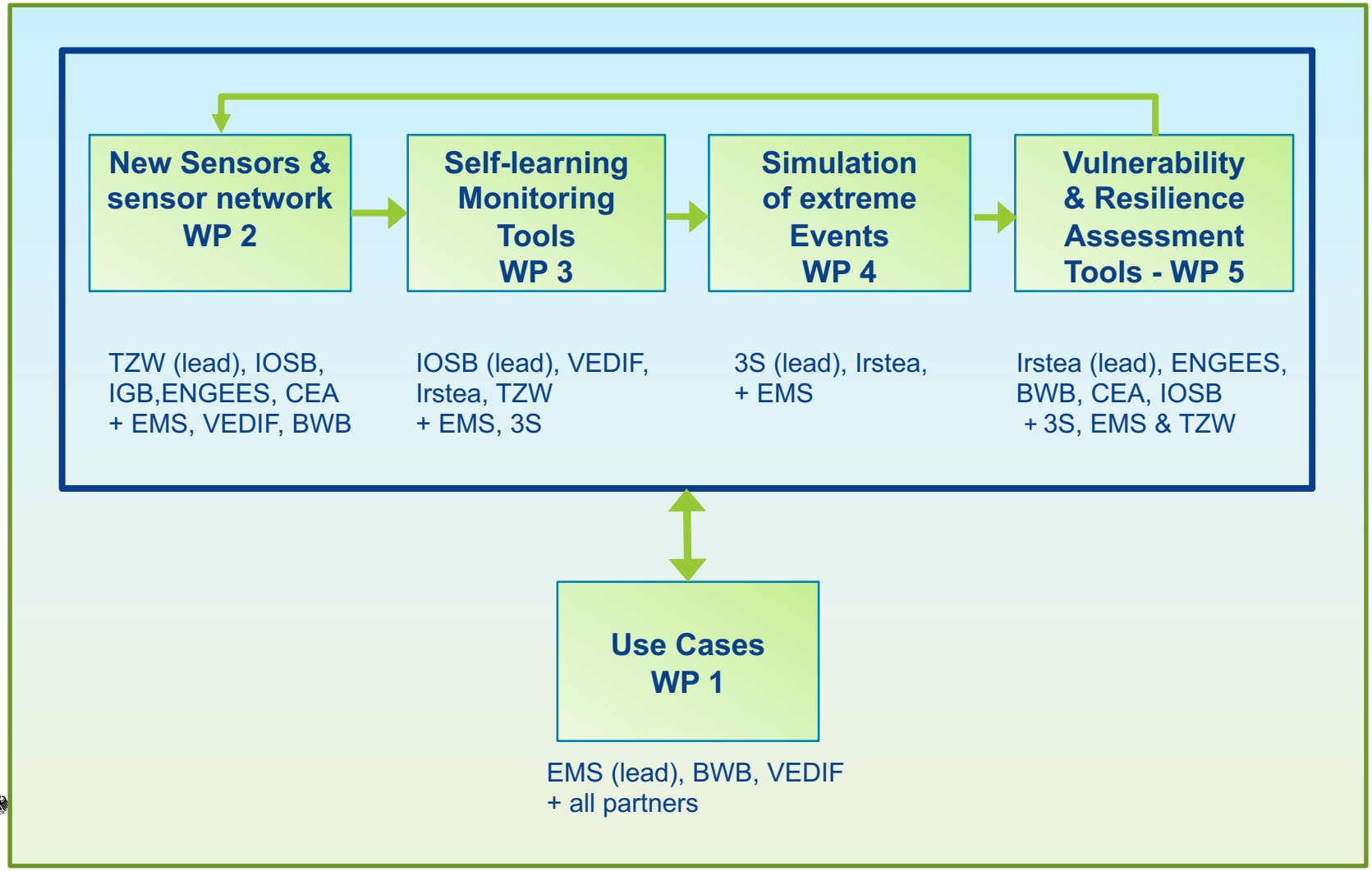
Work plan

SCIENTIFIC AND TECHNICAL PROGRAM



The resilience framework

DEFINITIONS

The resilience is the inverse of a time for driving back the system into its desirable properties ; the theory of viability is a good mathematical framework that focuses on desired use of a system

More general definitions with technical, social and organisational facets:

- The four R's of resilience and multi-hazard engineering, Bruneau *et al.*, 2003, Redundancy, Robustness, Rapidity and Resourcefulness
- Resilience is the ability of the system to absorb, adapt, and rapidly recover from a potential disruptive event NIAC, 2009

Simulation and analysis tools can help water utilities explore how their network will respond to expected, and unexpected events

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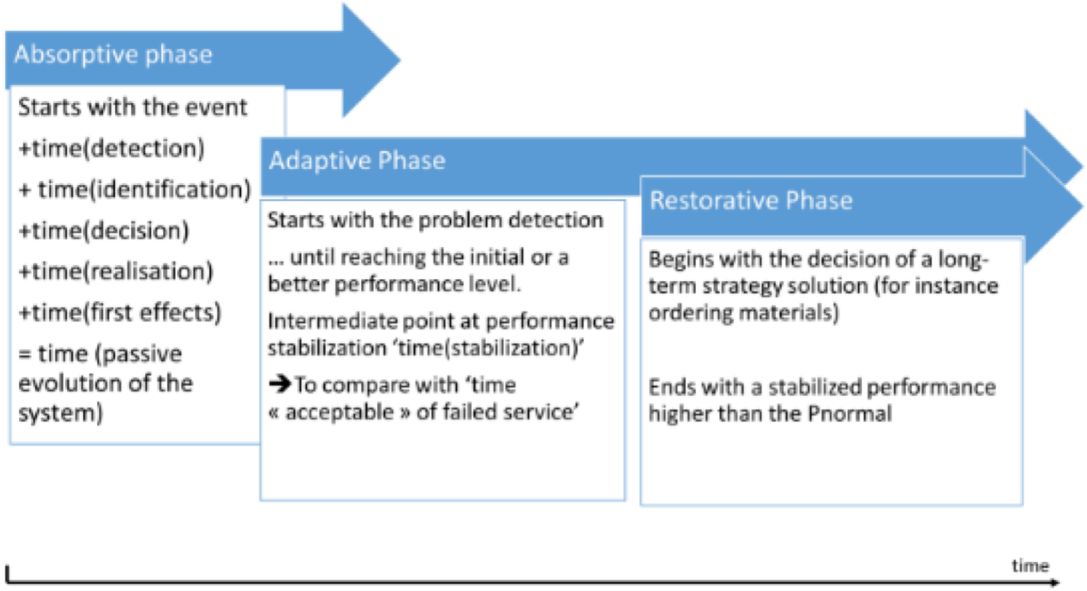
The resilience framework

THE RESIWATER THREE RESILIENCE COMPONENTS



Timeline for the three resilience phases in the ResiWater project

VULNERABILITY and RESILIENCE signatures are assessed on a simple three-level scale:

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The resilience framework

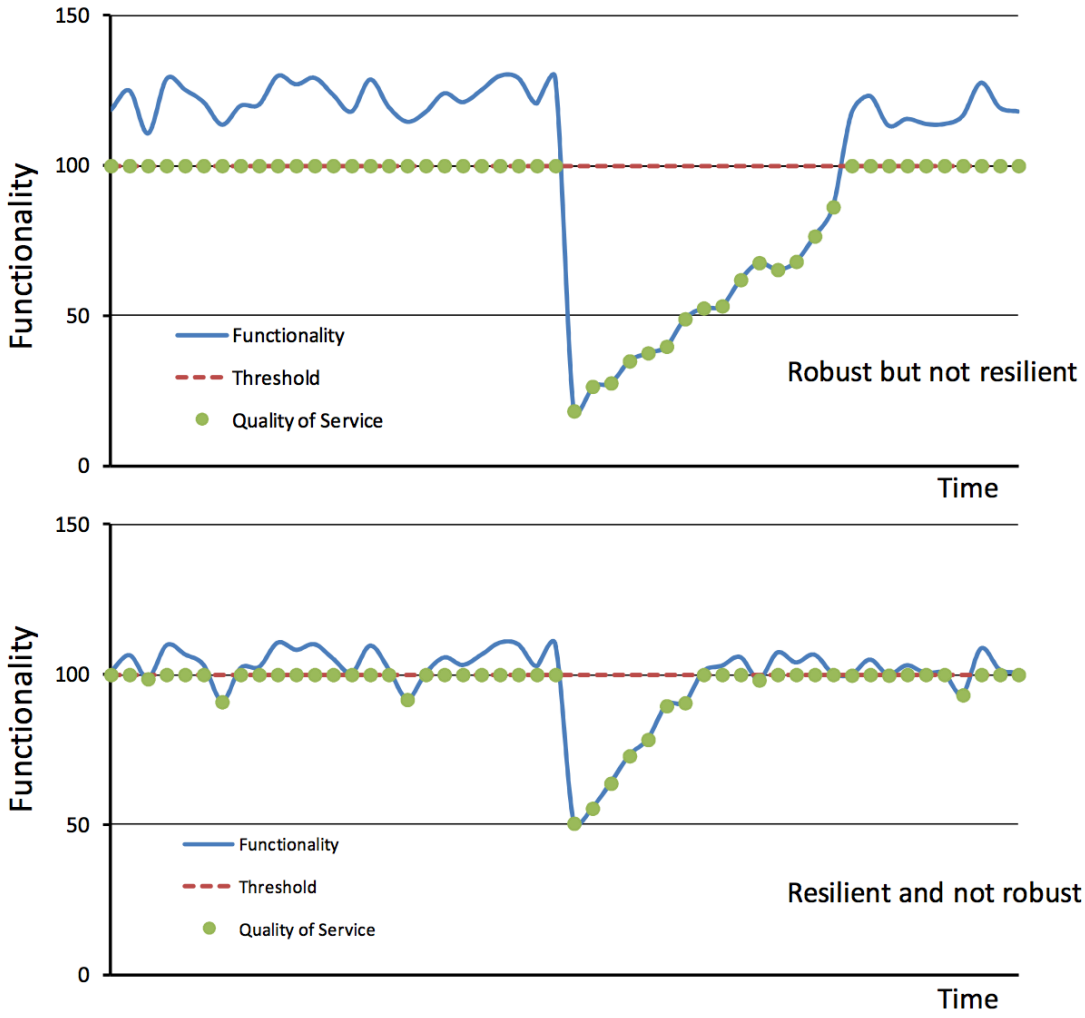
VULNERABILITY, RESILIENCE AND ROBUSTNESS

Kevin Lansey (2013)

Infrastructure resilience is the ability to gracefully degrade and subsequently recover from a potentially catastrophic disturbance that is internal or external in origin

The **robustness** of a system to a given class of disturbances is defined as the ability to maintain its function when it is subject to a set of disturbances of this class

Resourcefulness + rapidity



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Simulation and resilience training

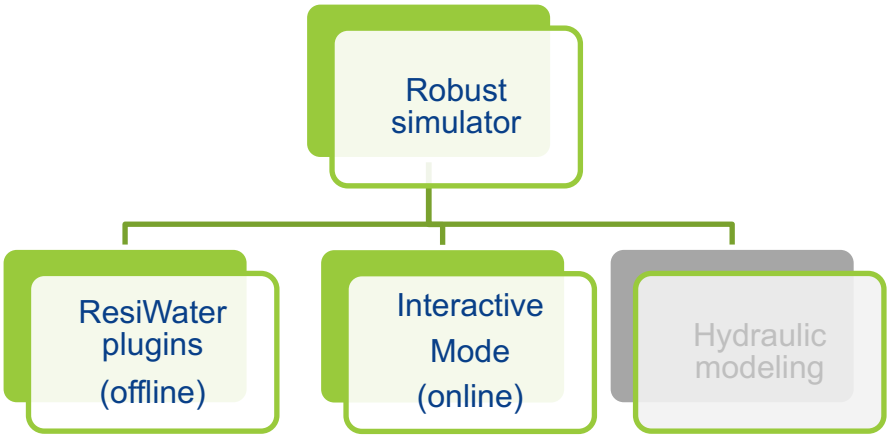
DESIGN

Objective: Managing disruptive events by

- Improved system design
- Improved operations and response

Decision was made to split into two application modes:

- Offline training -> planning and preparedness
- Online training -> network operation and management



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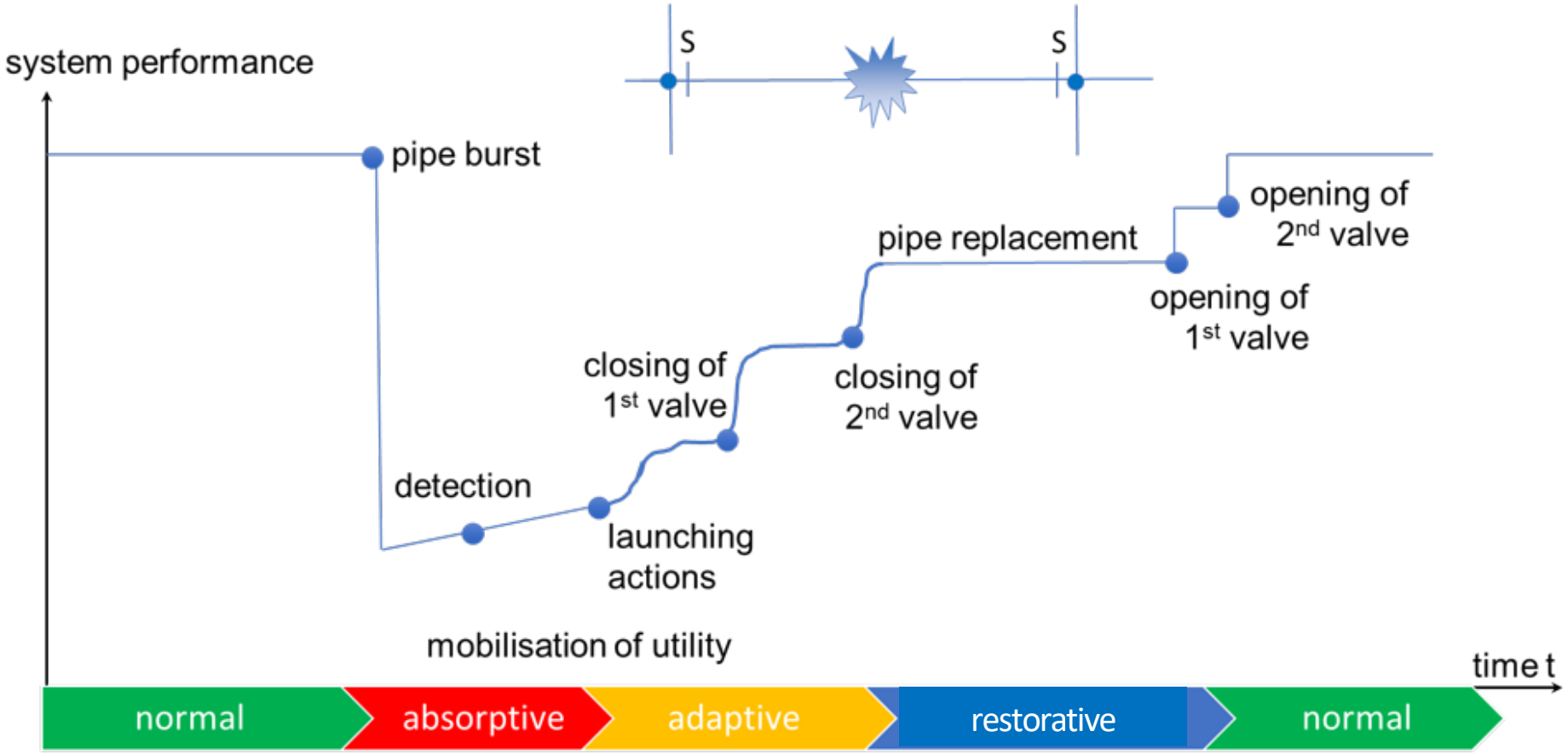
Phases of resilience

SIMPLE EXAMPLE: PIPE BURST



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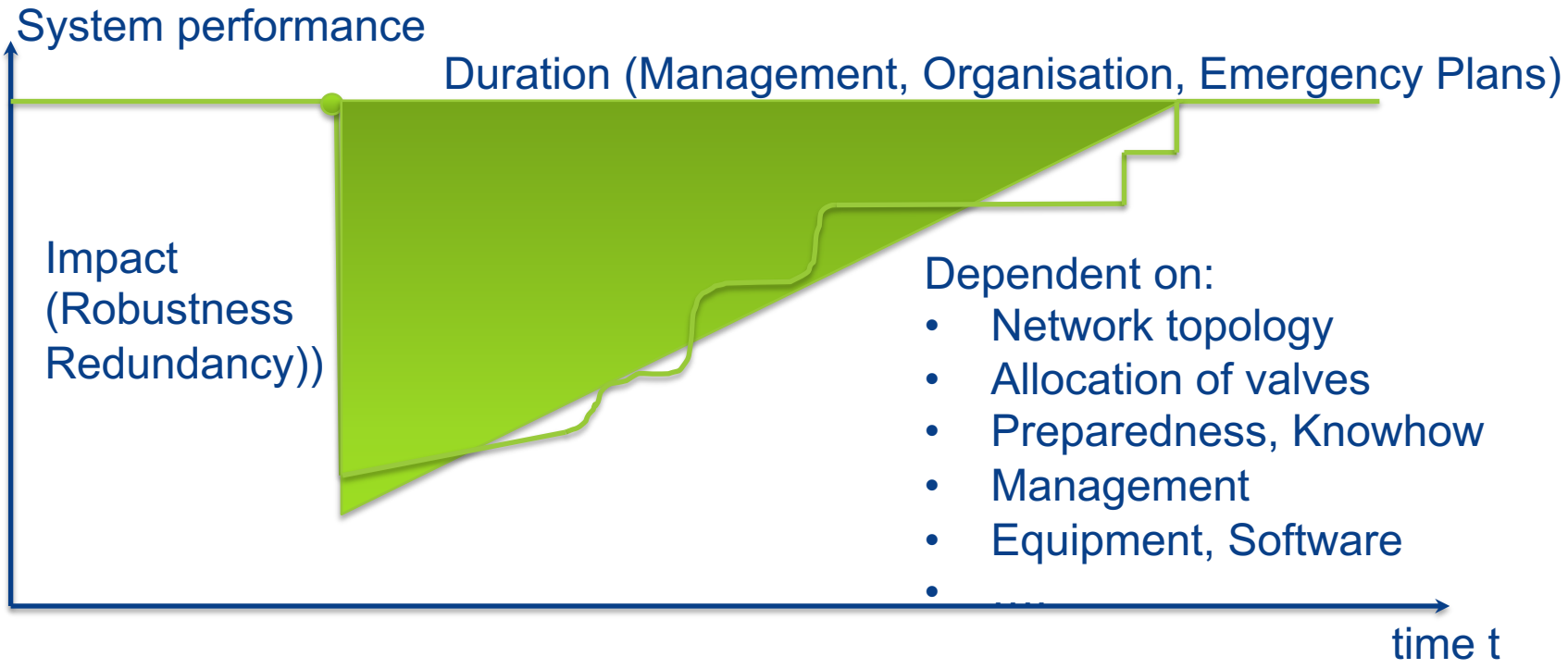
Resilience triangle



Objective: Area of triangle should be as small as possible.

Decrease area in vertical direction → static Resilience

Decrease area in horizontal direction → dynamic Resilience

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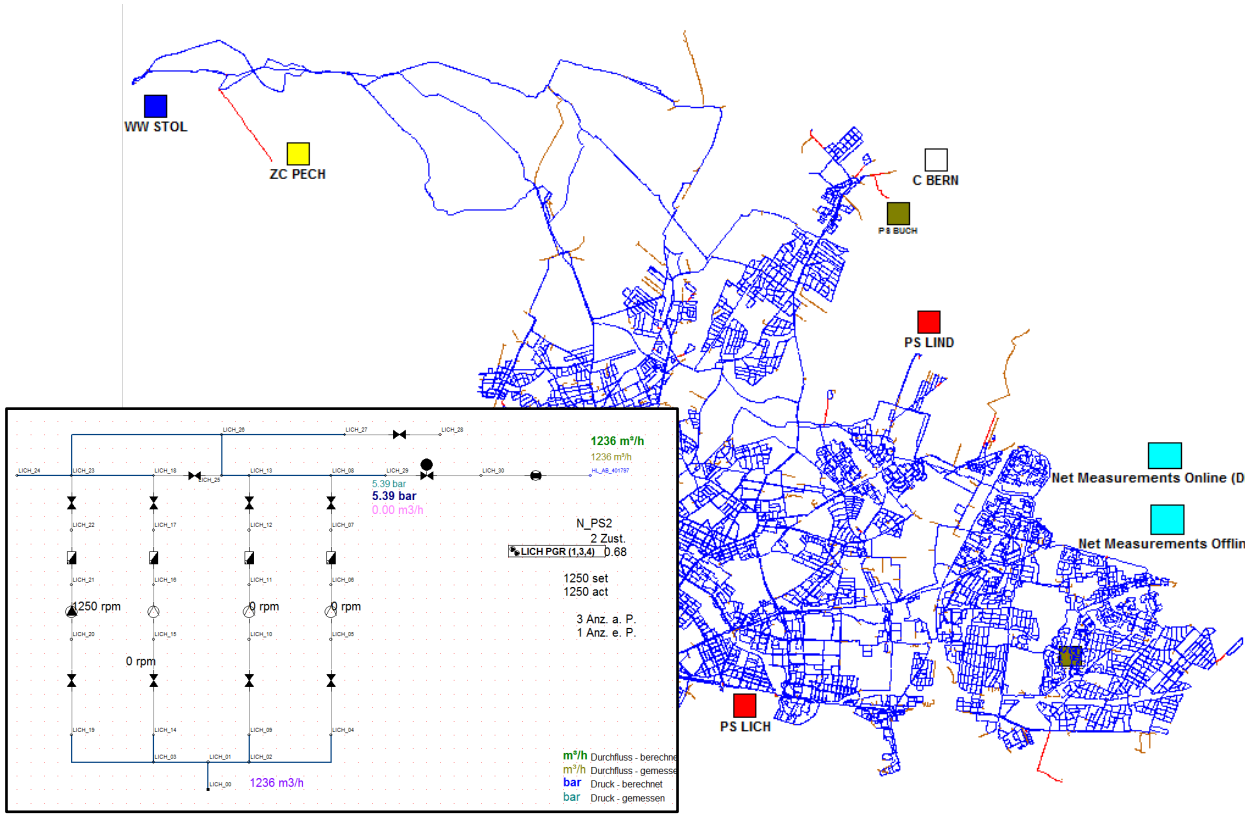
Training Simulator

MODEL OF PILOT ZONE



model data:
21.500 nodes
26.300 links

min. supply pressure for PDM: 3,0 bar

base (average) demand:4.500 m^3/h

calculation mode:
fast transient solver (water hammer) with 1 sec time step

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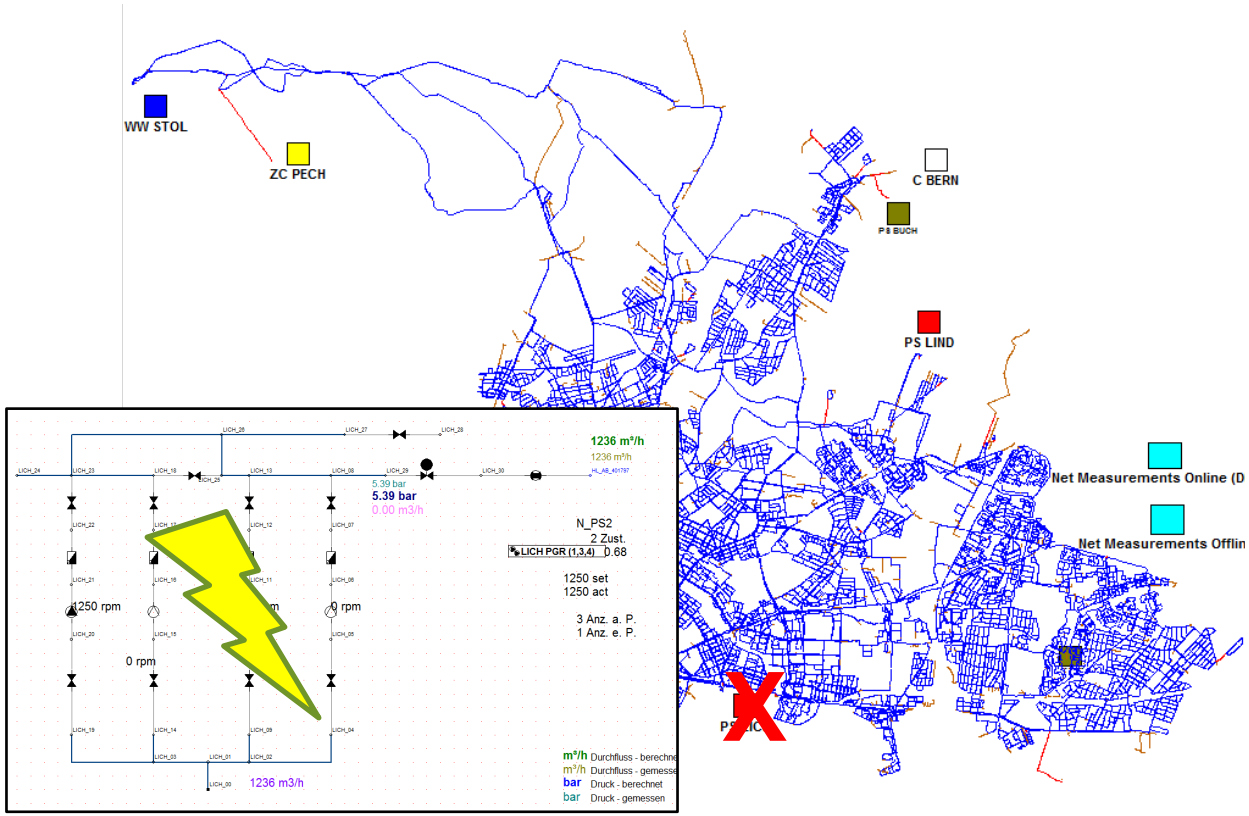
Training Simulator

SCENARIO



pumping station failure and …

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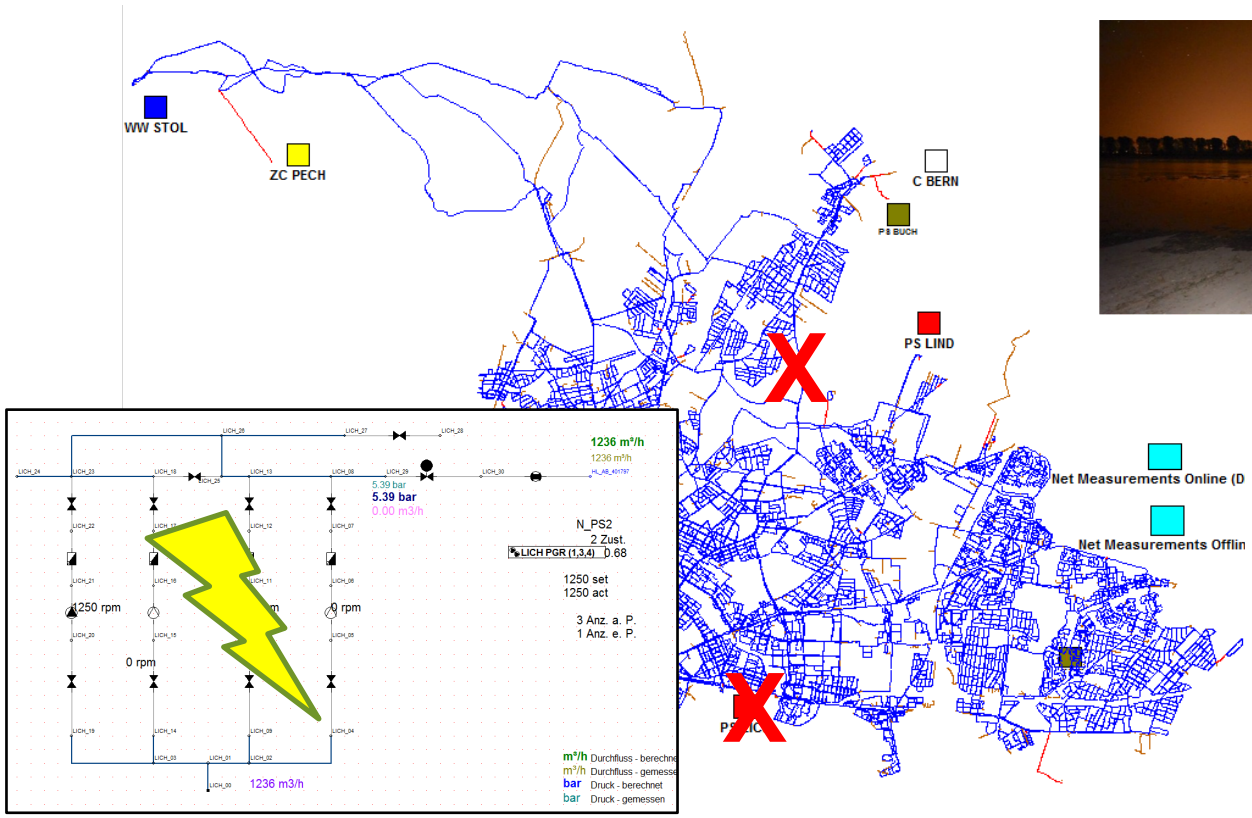
Training Simulator

SCENARIO

… pipe burst of trunk main at the same time



pumping station failure and …

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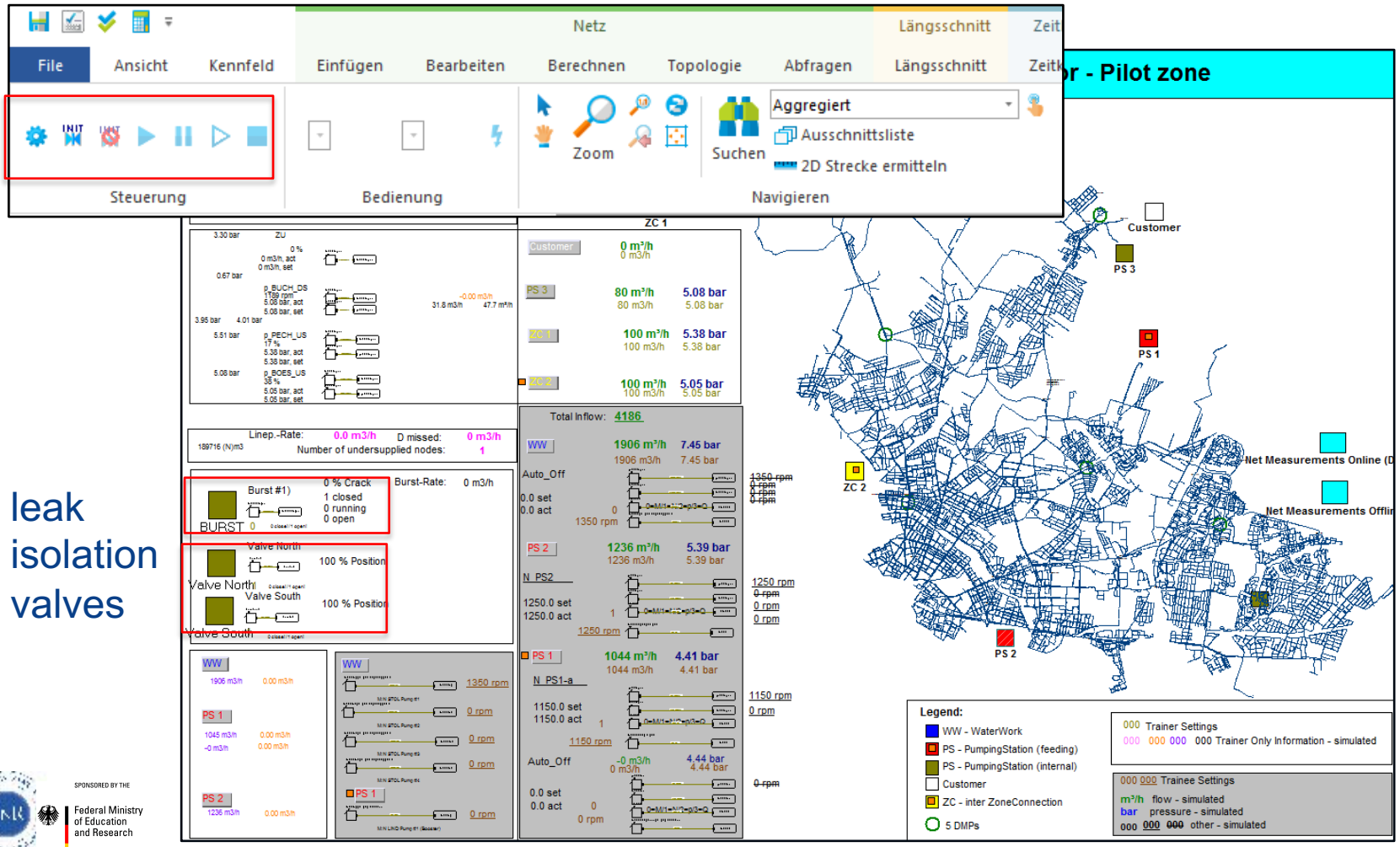
Trainees possibilities to control the network

OVERVIEW

leak isolation valves



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Trainees possibilities to control the network

PUMP STATIONS: AUTOMATIC VS. MANUAL CONTROL

Automatic Off

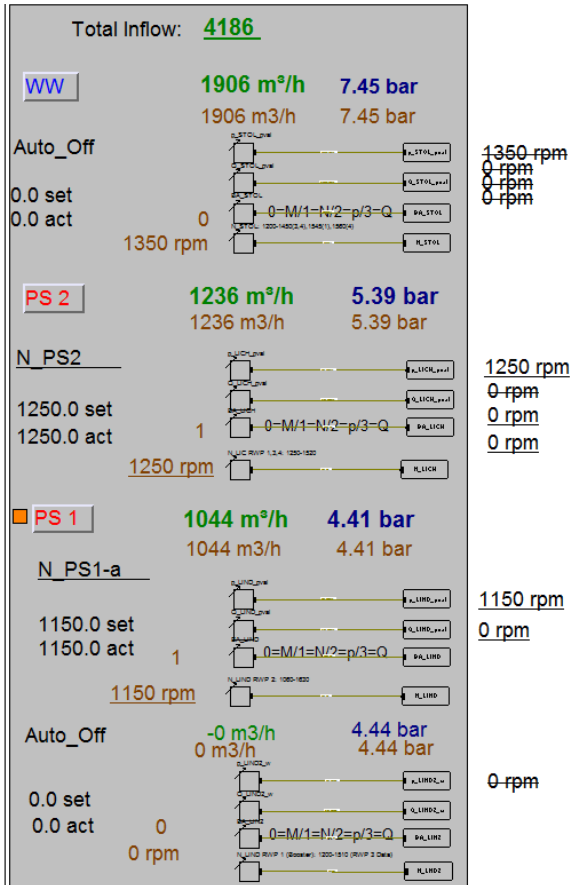
On/N (speed)

On/N (speed)

PS1 pumps 2,3

Automatic Off

PS1 Booster



Automatic On/Off:

Automatic Off: pump speed has to be set by the Trainee for each single pump

Automatic On:

Trainee sets Mode

N (speed), p or Q

and setpoint – automatic drives the whole group

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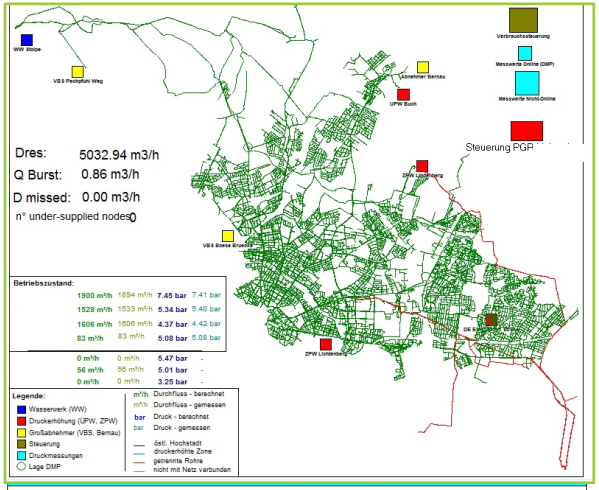
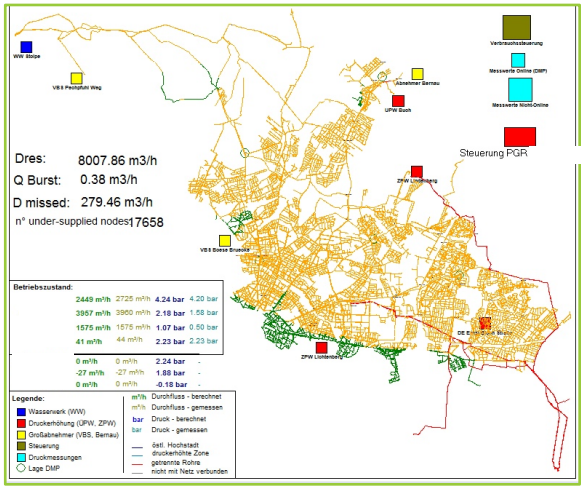
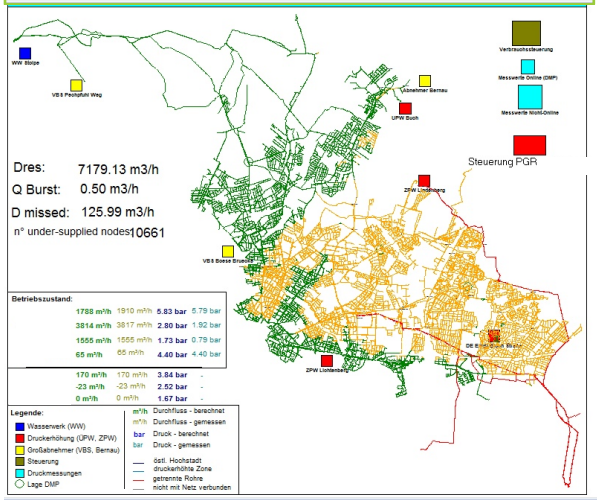
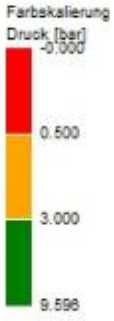
Real-time visualization of calculation results

EXAMPLE: SYSTEM PRESSURE









Traffic light colours (easily and quickly to determine)

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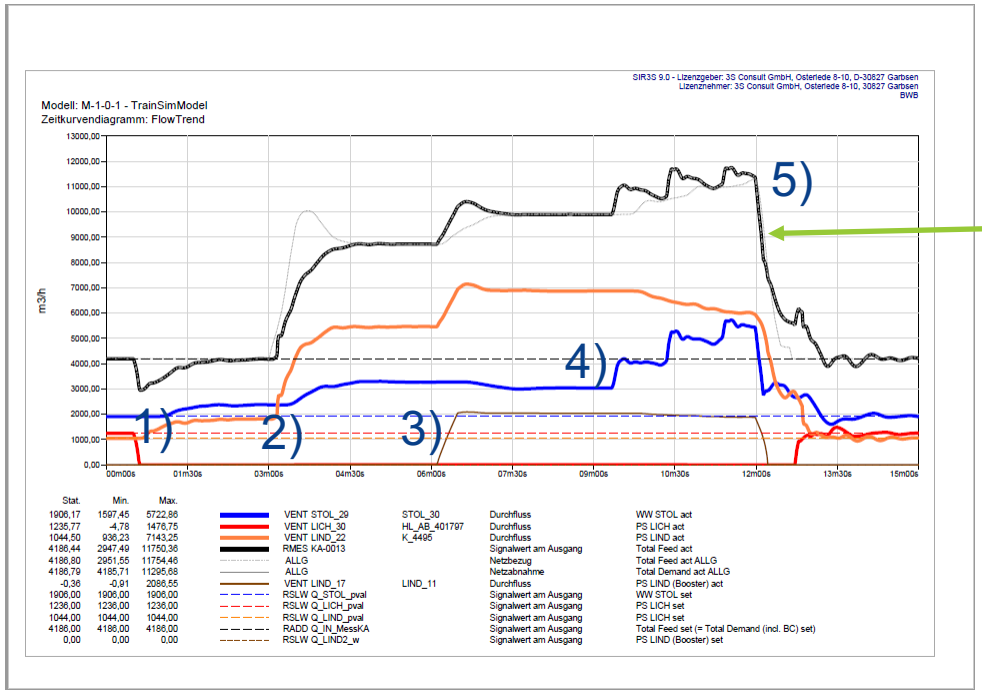
Training Scenario - Results

TIME CURVES FOR FLOWS



Demand is constant

Total inflow
- due to leakage
- and linepack

1) PS2 Off! 2) Leakage! 3) Trainee runs PS1 Booster!

4) Trainee runs WW pumps 2>3>4!

5) Trainer closes Leakage &Trainee stops PS1 Booster, WW 2,3,4 and starts PS 2 again

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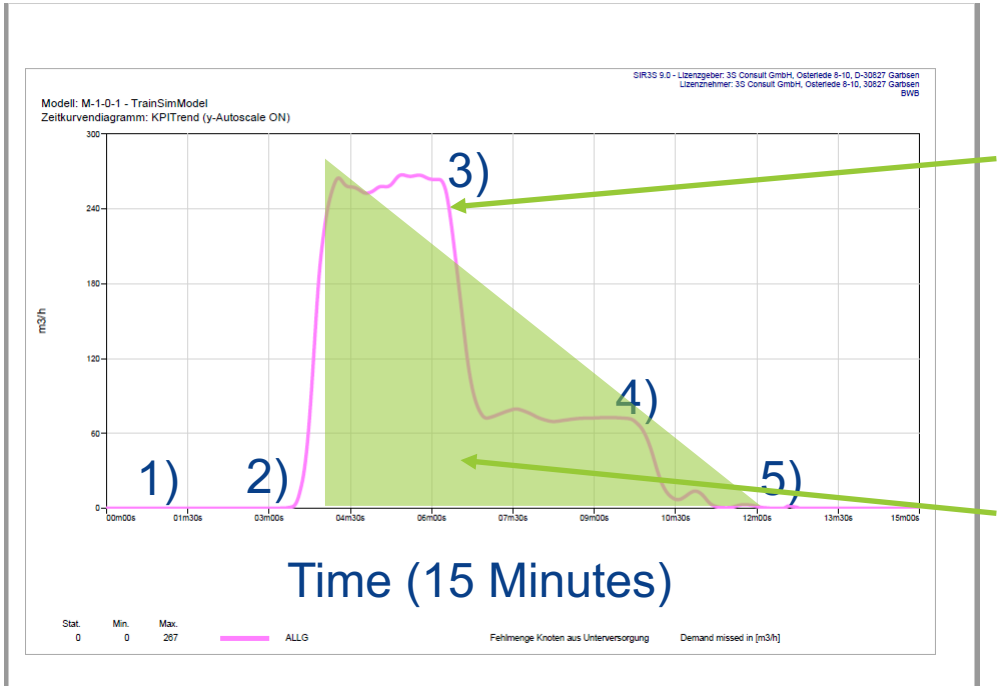
Training Scenario - Results

KPI: SUPPLY RATE



Demand missed due to Leakage (negative performance curve)

Resilience triangle

1) PS2 Off! 2) Leakage! 3) Trainee runs PS1 Booster!

4) Trainee runs WW pumps 2>3>4!

5) Trainer closes Leakage &Trainee stops PS1 Booster, WW 2,3,4 and starts PS 2 again

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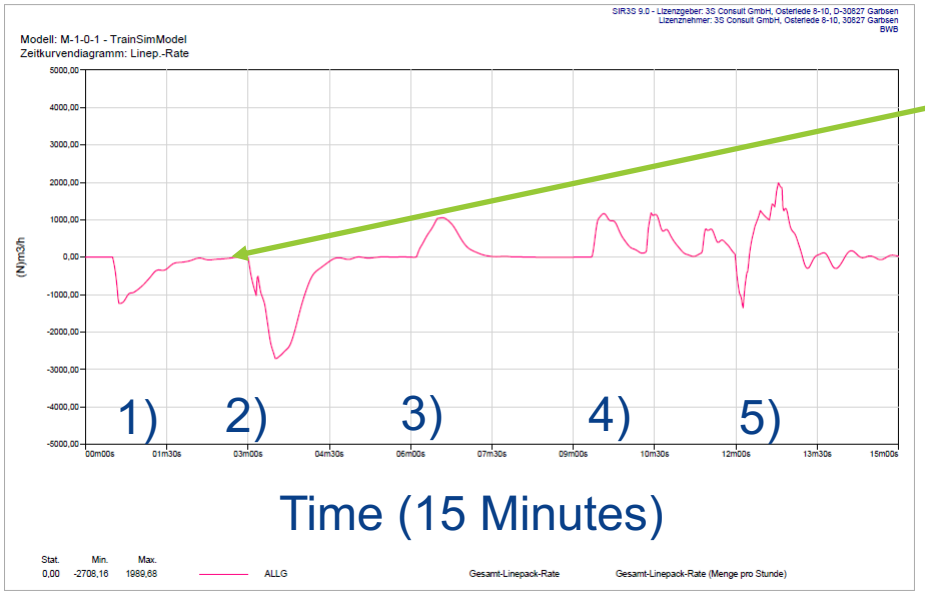
Training Scenario explained

LINEPACK-RATE

m3/h



Linepack-rate

understanding Linepack is key for understanding dynamic resilience

1) PS2 Off! 2) Leakage! 3) Trainee runs PS1 Booster!

4) Trainee runs WW pumps 2>3>4!

5) Trainer closes Leakage &Trainee stops PS1 Booster, WW 2,3,4 and starts PS 2 again

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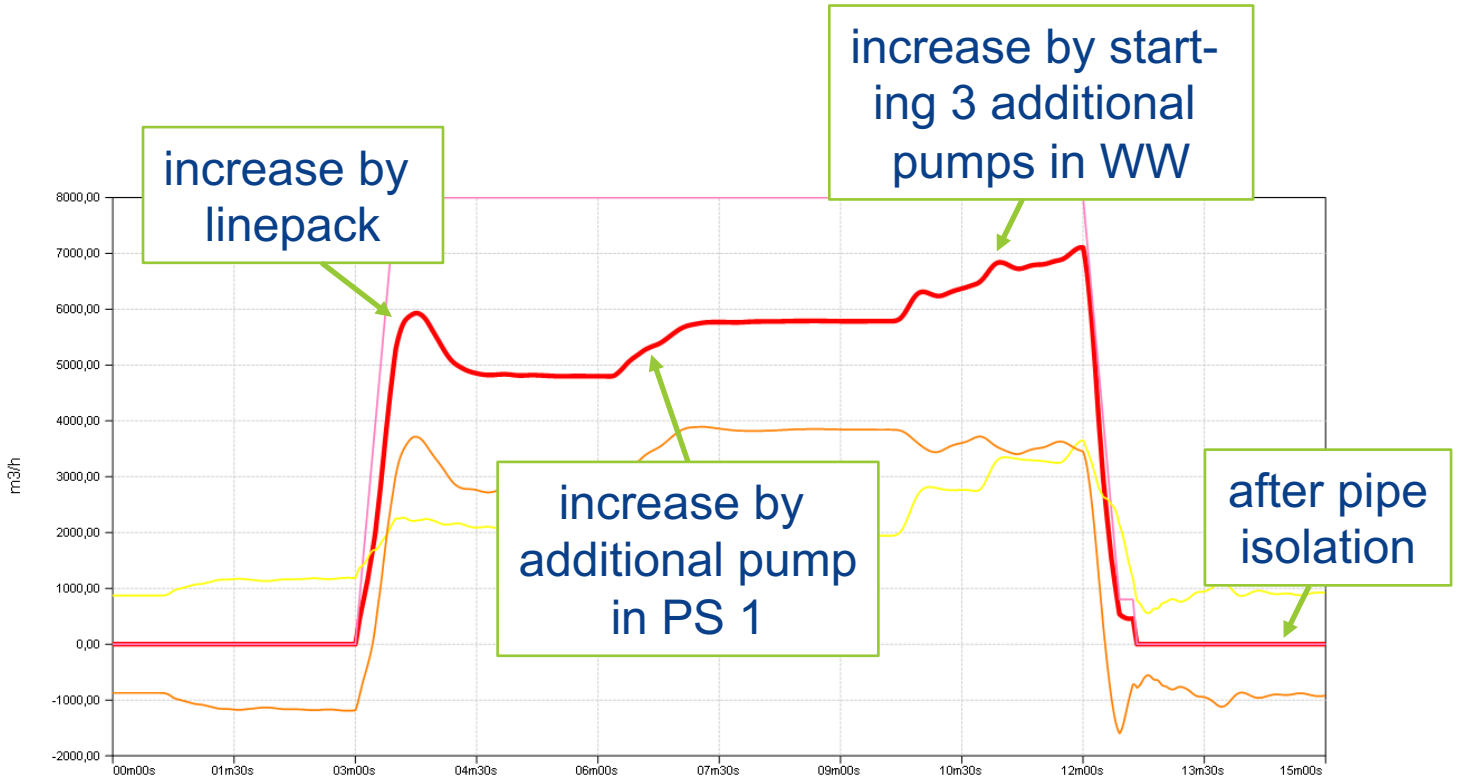
Training Scenario - Results

LEAKAGE LOSS



-> Trade-off between system performance and leakage loss

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Summary and Conclusion

- ✓ Water supply system is a critical infrastructure
- ✓ 3 Resiliences absorptive, adaptive and restorative
- ✓ Robust Modelling
- ✓ Sensors, detection and Cost benefit Analysis
- ✓ Simulation and resilience training
- ✓ Event Case studies with end users
  - Berlin BWB
  - Strasbourg CUS
  - VEDIF

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Outlooks

- ✓ Resilience by design and adaptive improved control system
- ✓ New technologies or types of critical infrastructures (IoT, robotics, cybersecurity)
- ✓ Holistic and integrated approaches considering interactions between different CIs (communication, cascading effects, etc.)
- ✓ Development of operational metrics and practical approaches to support decision making
- ✓ Model-based decision making (optimisation, sensor and actuator placement)
- ✓ Use of new technologies for the protection of critical infrastructures (big data, artificial intelligence, remote control actuators in the network)
- ✓ Improvement of training on decision-making through proposal of procedures, serious games

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Thank you for your attention
Any questions?

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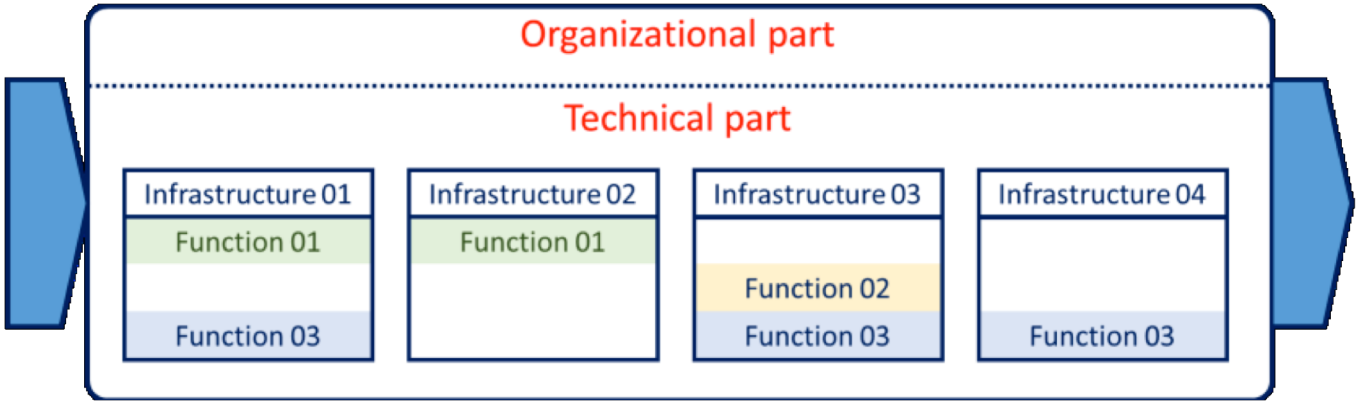
The resilience framework

VULNERABILITY AND RESILIENCE ASSESSMENT

a WDS is composed of :

- A technical part, described through infrastructures and functions.
- An organizational part (WD utility).



For the present study:

- VULNERABILITY concerns the technical part of the system only.
- RESILIENCE concerns both the technical and the organizational parts of the system.

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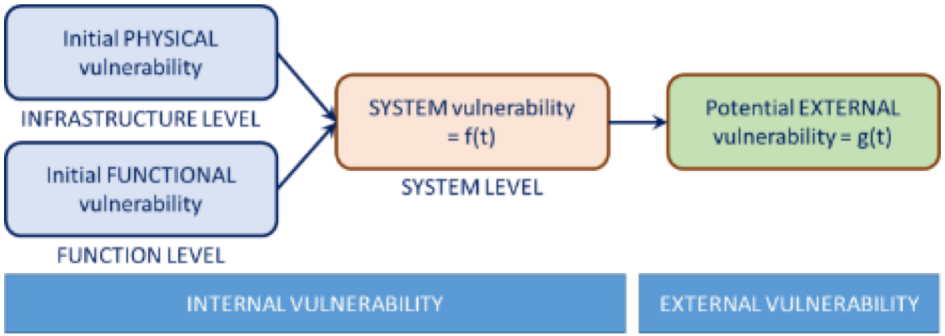
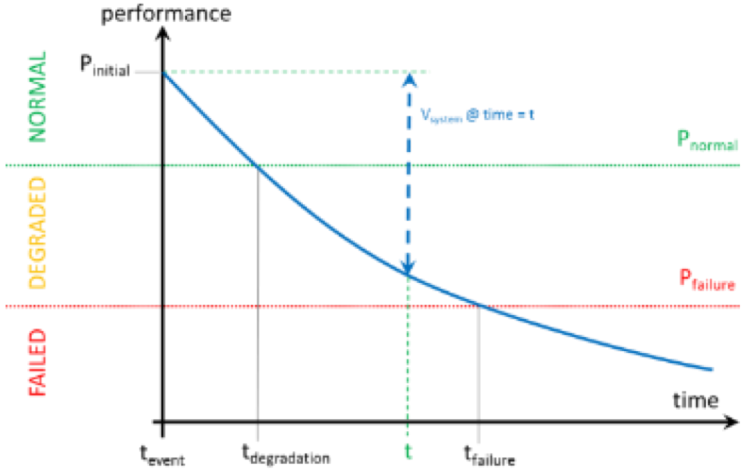
The resilience framework

FOUR VULNERABILITY & 3 RESILIENCE COMPONENTS



The 4 vulnerability components in the ResiWater project



Residual performance at time t

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