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# Cost Benefit Analysis for water network resilience assessment

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# RESIWATER

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EUROPEAN WATER ASSOCIATION

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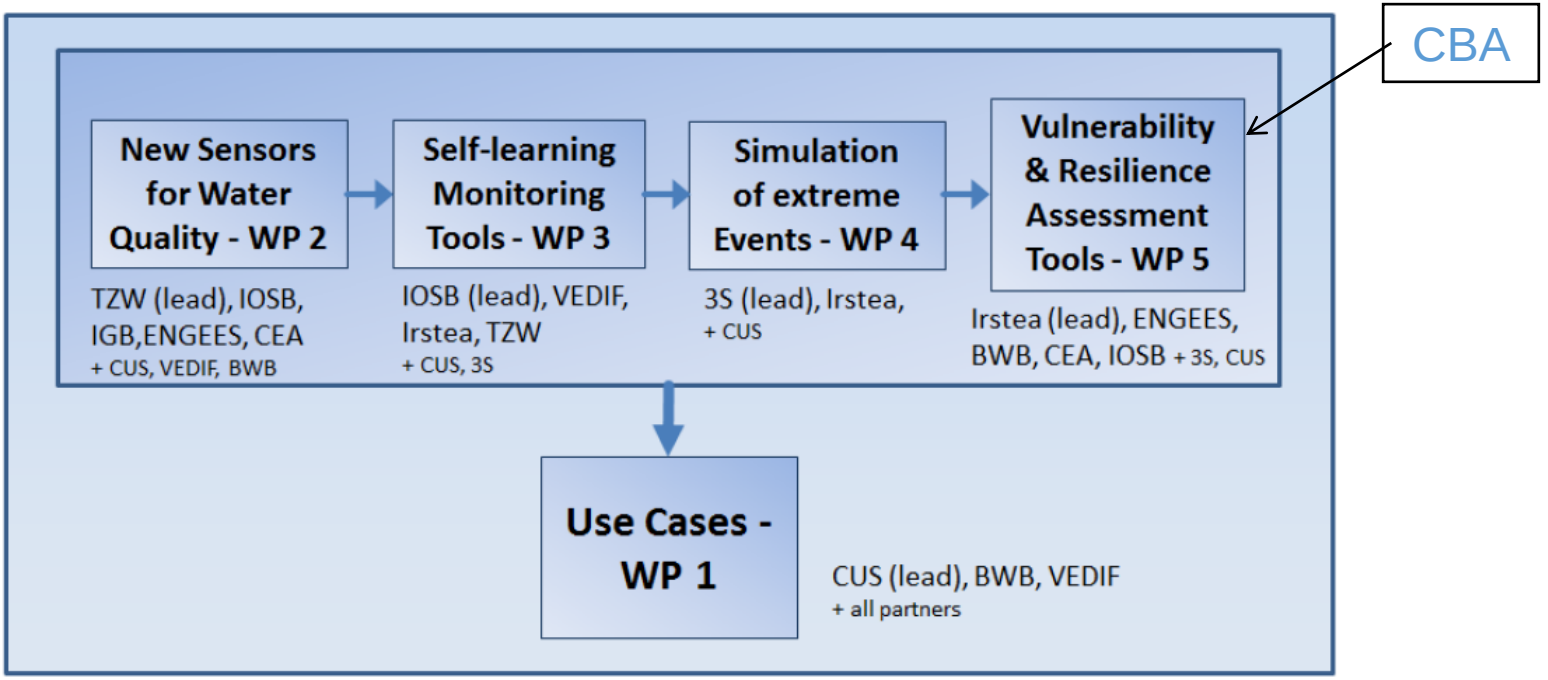
# INNOVATIVE SECURE SENSOR NETWORKS AND MODEL-BASED ASSESSMENT TOOLS FOR INCREASED RESILIENCE OF WATER INFRASTRUCTURES




Overall project structure

PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR

SPONSORED BY THE

Federal Ministry of Education and Research

Fraunhofer IGB

Fraunhofer IOSB

ENGEES National School for Water and Environmental Engineering

DVGW

TZW Technologiezentrum Wasser

VEOLIA Eau d'Île-de-France Délégataire du SEDIF

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# Context and research question

Water Utilities increasingly interested in the issue of the security of water supply, both in terms of quantity and of quality

Aim of this study = implementation of a cost-benefit analysis (CBA) of resilience scenarios in the face of a threat (crisis)

First application of its kind

# Cost Benefit Analysis (CBA)

Objective = assessment tool to **measure the negative (*i.e.* costly) and the positive (*i.e.* beneficial) consequences of a policy or a program in monetary values** linked with a cost accounting analysis as a decision-making tool

➡ **Compare the negative and positive effects of resilience programs regarding a crisis scenario established for 1 water utility on**

-the utility Profit & Loss (P&L) account

-the consumers preferences and their Willingness To Pay (WTP)

**Resilience programs**

-prevention programs with different levels of efficiency and rationality

★**3 resilience programs: BAU Business-as-usual (SQ), R+, R++**

-taking into account both operating and investment measures

-comparison is done regarding always the BAU situation

-implementing costs methods that will bring assessment of operating and investment values

-resilience programs are then studied from the consumer point of view using Choice Experiment method

# Cost Benefit Analysis (CBA)

## Steps:

- ✓ Describe the crisis scenario
- ✓ Define the resilience programs

} Going to the activities and investment measures description details

- ✓ Establish a generic framework of operating activities and reactions in response to a particular crisis type (previous study of crisis cases)
- ✓ Assess the operating and investment values through cost accounting methods
- ✓ Assess the consumers preferences through Choice Experiment method
- ✓ Assess the costs and benefits of each resilience program

  -in terms of externalities for the consumers
  -in terms of impacts on the P&L account for the utility

- ✓ Put the costs and benefits together and apply NPV

$$VNA = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t}$$

## Objectives:

find the resilience program the most interesting in terms of economic efficiency for the utility and the consumers

# Study area

## Eurométropole of Strasbourg

Water utility provides water service to 423,600 inhabitants within 12 municipalities/28 at all

1,083 km of network, 4 waterworks, with a balancing tank

89,980 $m^3$ produced/day

## Crisis scenario: Cyberattack

Physical attack+ cyber attack (replication of normal data series)

No compensation of the loss of pressure by the main plant

Detection of the problem when users call saying they experience water cuts = when the water distribution fails

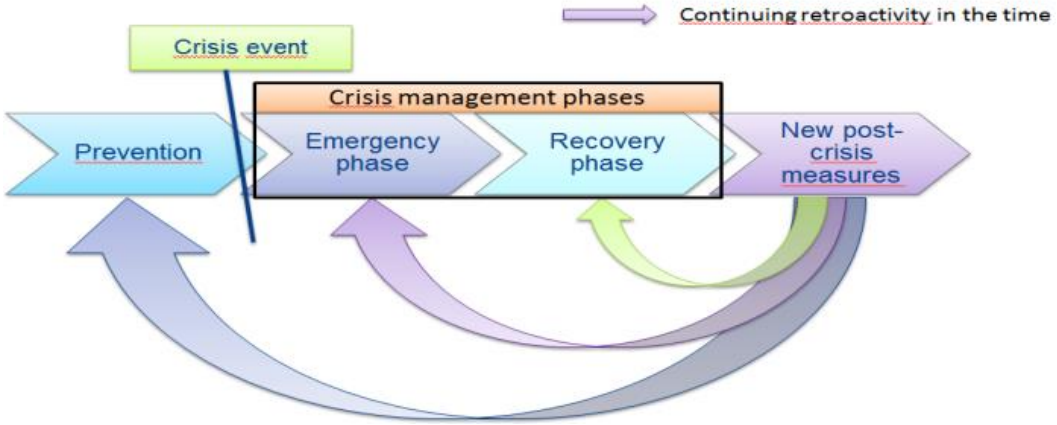
# Resilience programs

- ✓ **Statut Quo (SQ / BAU)➔** reference situation, current resilience at EMS
- ✓ **Resilience + (R+)➔** resilience improved thanks to RESIWATER best practice tools
- ✓ **Resilience ++ (R++)➔** resilience improved thanks to a better knowledge of the crisis situation (*learning effect* more important) and use of cyberattack detection tool (IT tool & internal training)

| Characteristics | BAU | R+ | R++ |
|---|---|---|---|
| **Sensitive domestic consumers support** | No information on where they are located | Localisation known | Knowledge on how to recognize sensitive consumers and how to react rapidly and appropriately |
| **Water cut** | **4h** | **3h** | **2h** |
| **Water use restriction** | **6 days** | **5 days** | **4 days** |
| **Number of people affected** | 400,000 inhabitants | 100,000 inhabitants | 1,000 inhabitants |
| **Communication** | On paper at the bottom of the buildings | Also in the streets | Also by individualised SMS<br>Consumers educated to be alarm raiser |
| ***New investment and operating measures*** | - | *Applying ResiWater tools* | *Cyberattack protection by tools and staff* |

# Generic cost framework establishment

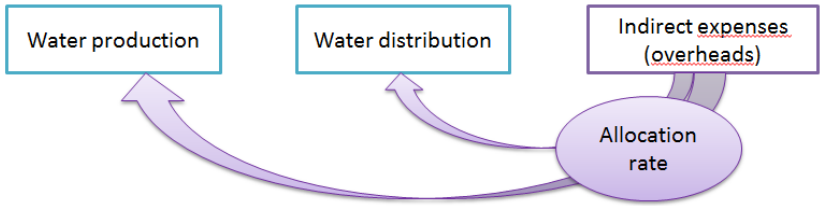
- Resilience process



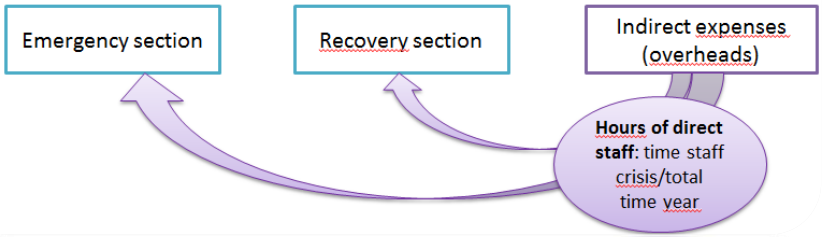

- Cost accounting methods
  - Full costing: direct + indirect expenses
  - Homogeneous sections: classify expenses and define an allocation tool to take into account indirect expenses
  - Hidden costing: take into account costs that are not in the accountancy or not directly visible in the accounting information system

# Generic cost framework establishment on real crisis

- Homogeneous sections by water utilities




- Homogeneous sections: simplified implementation




| Fullcost recovery phase Pipe-burst EMS | Unit | Quantity | Unit cost average (in €) | Total cost (in €) |
|---|---|---|---|---|
| Using material | piece | 221 | 6,53 | 1 442,19 |
| Motorized machines, vehicles: truck and excavator | hours | 1 | 67,75 | 135,5 |
| Costs for staff | hours | 148,5 | 39,5 | 5 858,54 |
| Costs for staff (overtimes) | hours | 100 | 27,4 | 2740 |
| Total | | | | 10 176,23 |
| Water losses (flushing) | m3 | 7410 | 0,2 | 1482 |
| Total direct costs | | | | 11 658,23 |
| Allocation rate | Hours of direct staff | | | 0,00025 |
| Overheads | € | | | 10 000 000 |
| Total indirect costs | € | | | 2 483 |
| Full cost recovery phase (in €) | € | | | 14 142 |

Table 14: Full costs recovery phase EMS

Table 13: Work order extract

| Work Order n°81563 (OT): pipes repair | Hours registered | Unit cost (hourly rate in €) | Total cost (in €) |
|---|---|---|---|
| Task execution (Job-category C: technicians) | 65,5 | 21,9 | 1 434,45 |
| Excavator | 4 | 34,86 | 139,44 |
| Truck | 5 | 45,73 | 228,65 |
| Total | 74,5 | | 1 802,54 |

**Allocation rate**: expressing indirect costs in staff time

| Other costs | Non registered time (estimated) | among overtimes | Unit cost (hourly rate in €) | Total costs (in €) |
|---|---|---|---|---|
| *Job category A: managers* | 65 | 26 | 35,61 | 2 315 |
| *Job category B: senior technician* | 65 | 30 | 26,79 | 1 741 |
| Total | 130 | 56 | | 4 056 |

Table 15: Costs for other staff categories

| Selected overheads of the utility | Total costs extracted from the administrative account (in €) |
|---|---|
| Maintenance on movable goods (movable material) | 41905,34 |
| Maintenance on movable goods (other material) | 18033,51 |
| Maintenance on property assets (network) | 818595,05 |
| Maintenance on property assets (streets excavation) | 313655,65 |
| Depreciation charge (motorized machines) | 1356,43 |
| Depreciation charge (vehicles) | 257566,25 |
| Maintenance and little equipment supplies (others) | 7427,68 |
| Office supplies | 8454,31 |
| Non storable supplies (fuel) | 9173,49 |
| Other material and supplies (road network) | 125527,94 |
| Other material and supplies (repairs) | 322442,23 |
| Gas | 132357,34 |
| ..... | ..... |
| Total overheads (in €) | 10025257 |

# Assessing the operating and investment values on the resilience program through cost accounting methods

**Recovery phase operating costs**

| Expenses € | Quantity (staff, m³) | Time (h) | Unit standard cost plus additional over times € | On call allowance | Overheads € | Full cost € |
|---|---|---|---|---|---|---|
| Rehabilitation of the information system of the supervisor from Polygone water station | 2 | 18 | 35,61 | - | 141 | 1423 |
| Manually filling of the water tank during the IS rehabilitation time | 2 | 10+8 | 45,94+ 22,97 | 16,071 | 71 | 714 |
| Other samples and water analysis | 40 | | 70 | - | 308 | 3108 |
| ..... | | | | | | |
| Total € | | | | | | 5245 |

**Cost assessment examples of the recovery phase for R++**

**Post-crisis phase operating costs**

| Expenses € | Quantity (staff, m³) | Time (h) | Unit standard cost plus additional over times € | Overheads € | Full cost € |
|---|---|---|---|---|---|
| Cold debriefing | 15 (3 ING+ 1 senior TECH +11 TECH) | 4 | 35,61+26, 79+22,97 | 170,0 | 1715,1 |
| RETEX redaction | 1 | 14 | 35,61 | 55 | 553 |
| Crisis management planning updating | 1 | 14 | 35,61 | 55 | 553 |
| Delays in daily staff works due to their involvement during the crisis | 37 | | | | 1 869,82 |
| Total € | | | | | 4 691,7 |

Hidden costs

**Cost assessment examples of the post-crisis phase for R+**

Total time spend by each expert during crisis period

# Assessment of the internal costs/benefits linked to the impacts of resilience programs on the utility

In R+ and R++, operating costs decrease but investment costs increase and we know that resilience is better which proves that an increase in investment tools go to pair with a resilience improvement

➔R++: internal benefit
➔R+: internal benefit also

Calculation examples

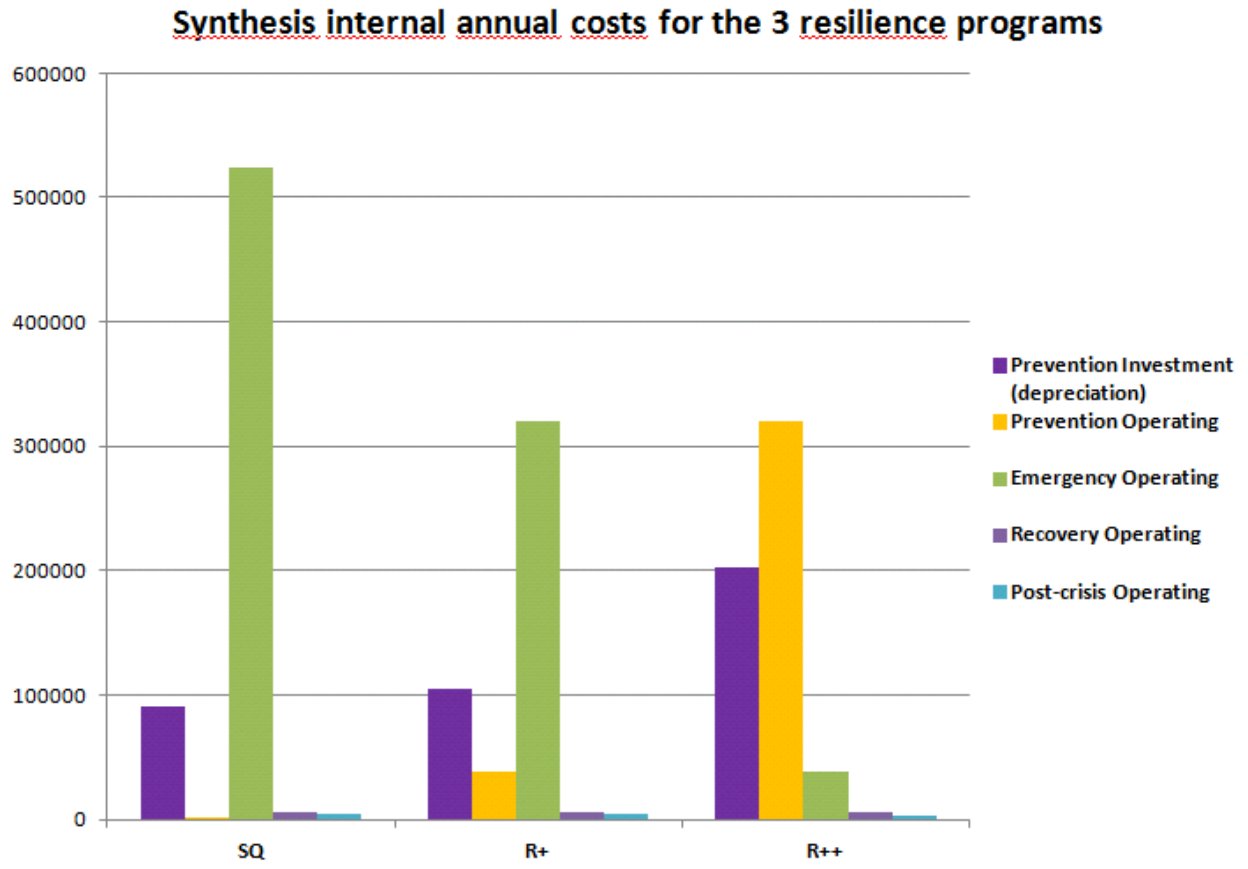
Total costs and benefits for R+

| Resilience phase | | SQ | R+ | R+ // SQ | |
|---|---|---|---|---|---|
| Prevention | Investment (depreciation value) | 90 440 | 105 440 | 15 000 | Increase in cost |
| | Operating | 1 000 | 37 785 | 36 785 | |
| Emergency | Water losses | 2 933 | 2 200 | -733 | Decrease in cost |
| | Cyberattack time detection | 400 | 358 | -41 | Decrease in cost |
| | Water use restriction | 520 547 | 318 247 | -202 300 | Decrease in cost |
| | *Total operating* | 523 880 | 320 805 | -203 075 | Decrease in cost |
| Recovery | Operating | 5 245 | 5 245 | 0 | |
| Post-crisis | Operating | 3 770 | 4 692 | 921 | Increase in cost |
| Total | *Total investment* | 90 440 | 105 440 | 15 000 | Increase in cost |
| | *Total operating* | 533 895 | 368 527 | -165 368 | Decrease in cost |
| | Benefit/cost TOTAL € | | | -150 368 | Benefit |

Total costs and benefits for R++

| Resilience phase | | SQ | R++ | R++ // SQ | |
|---|---|---|---|---|---|
| Totaux | *Total Investissement* | 90 440 | 202 143 | 111 703 | Increase in cost |
| | *Total fonctionnement* | 533 895 | 367 239 | -166 657 | Decrease in cost |
| | Gain/surcoût TOTAL € | | | -54 954 | Benefit |

# Assessment of internal costs/benefits linked to the impacts of resilience programs on the utility



# Assess the externalities linked to the resilience programs on the consumers

➢Assessment of residents' preferences and estimation of their willingness to pay for the resilience measures using the **Choice Experiment Method**

- Theoretical framework: consumers derive satisfaction not from a good in itself but from its "*attributes*" which are defined as the objective features of the good considered relevant by the consumers

⇨ Considering the *attributes* of each resilience program ie their characteristics

- Survey Questionnaire

| Characteristics | BAU | R+ | R++ |
|---|---|---|---|
| Care of sensitive domestic consumers | Partial | Exhaustive | Exhaustive and appropriate to the needs of those concerned |
| Duration of water cuts | 4h | 3h | 2h |
| Water use restriction | 6 days | 5 days | 4 days |
| Number of people impacted | 400,000 inhabitants | 100,000 inhabitants | 1,000 inhabitants |
| Contribution | 0 € | X € | XX € |

# Steps of the Choice Experiment method

1. Define attributes and assign them levels
   - Relevant attributes: (1) the number of people affected; (2) the duration of the water cut as a result of the attack; (3) the duration of the water-use restrictions; ...
   - Monetary attribute in order to estimate welfare changes: the cost expressed as a contribution
2. Combine the attributes in hypothetical scenarios
3. Construct the valuation questions (called “choice sets”) combined with a questionnaire
   - The reference situation: the utility addresses impacts of the cyber-attack on an *ad hoc* basis (current situation)
   - 2 alternative scenarios: implementation of measures intended to improve the system resilience
4. Present the choice sets to the respondents inquired in order to disclose their preferences
   - Fixed number of choice sets: 5 per respondent
5. Ask them to choose the alternative they prefer and the one they like least
6. Conduct an econometric analysis of answers

# Example of a choice set

Alternative scenarios

Reference situation

Characteristics of the options

| | Option A | Option B | Option C (without additional prevention measure) |
|---|---|---|---|
| Number of people impacted | 400,000 | 200,000 | 400,000 |
| Duration of water cuts | 3 hours | 4 hours | 4 hours |
| Duration of water use restriction (for drinking and cooking) | 6 days | 5 days | 6 days |
| Sensitive domestic consumers support | Partial | Exhaustive | Partial |
| Cost per household (paid at once) | €10 | €50 | €0 |

| | Option A | Option B | Option C |
|---|---|---|---|
| What do you like the most? | o | o | o |
| What do you like the least? | o | o | o |

Respondents' choices

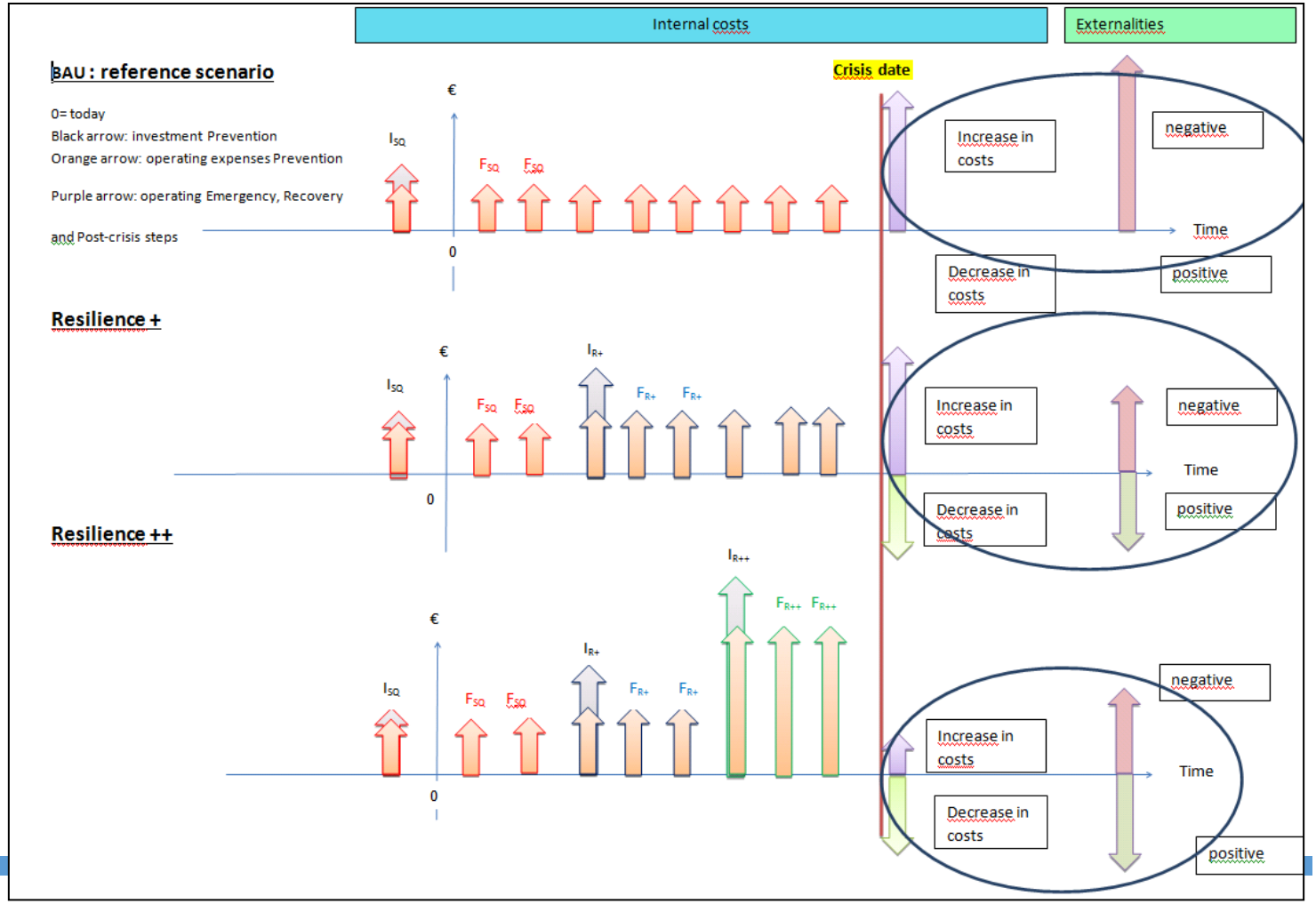
# Outline of the questionnaire

Questionnaire made up of 6 parts:

1. Environment generally speaking
2. Water consumption
3. Perception of the water quality in EMS and health risk associated;
4. Perception of the water Utility performance and risks
5. Valuation questions and follow-up questions which are designed to explore the reasons for responses
   - Before the choice sets, presentation of a scenario which reminds of the current situation, description the concrete resilience measures, reminds of the budget constraint, etc.
6. Socio-economic questions

**Has been tested and finally version is currently implemented**

# Espected results



# Conclusion

## Scientific challenge

First CBA on water networks resilience

- Handful of studies dealing the valuation of benefits of infrastructure resilience
- Methodological improvements in the comprehension and appreciation of consumers' preferences

Mixing an accounting full-costing approach for the assessment of internal costs and an economic valuation of consumers' willingness to pay

- Very informative

## Operational issue

Add a very useful decision tool to the existing approaches

*”Cost Benefit Analysis for water network resilience assessment”*

# Thank you for your attention

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