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2nd IWA Leading-Edge Conference & Exhibition on

Strategic Asset Management

A GIS based approach to assess the vulnerability of water distribution systems

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Objective

- Water distribution systems in most European cities are reaching the end of their lifetime;
- Efforts are recently being undertaken in order to establish a rational framework maintenance for decision-making in water distribution systems, based on pro-active approach;
- The experience demonstrated that System knowledge is a pre-requisite for obtaining an efficient system management.
- Under the present Italian national legislation (Law n°36, 1994), water distribution systems are required to achieve higher management efficiency;

From our experience…

- European projects developed during the 5th Framework Programme, focused on water asset management, have been looking at risk in terms of economic, social and environmental probability of failure;
- Tools and practice have been successfully applied in many countries, but in Italy the results have been sometimes disappointing…;
- The application of advanced management approaches seems unfeasible because of the lack of a long term planning/thinking strategy;
- Information about the asset and the surrounding environment is in some cases available at the municipality/utility archive, but not recorded in order to be directly applied for AM.

A GIS based approach to assess the vulnerability of water distribution systems

Objective:

⟶ Evaluate what results would be possible to provide the utility with *data driven* selected tools;

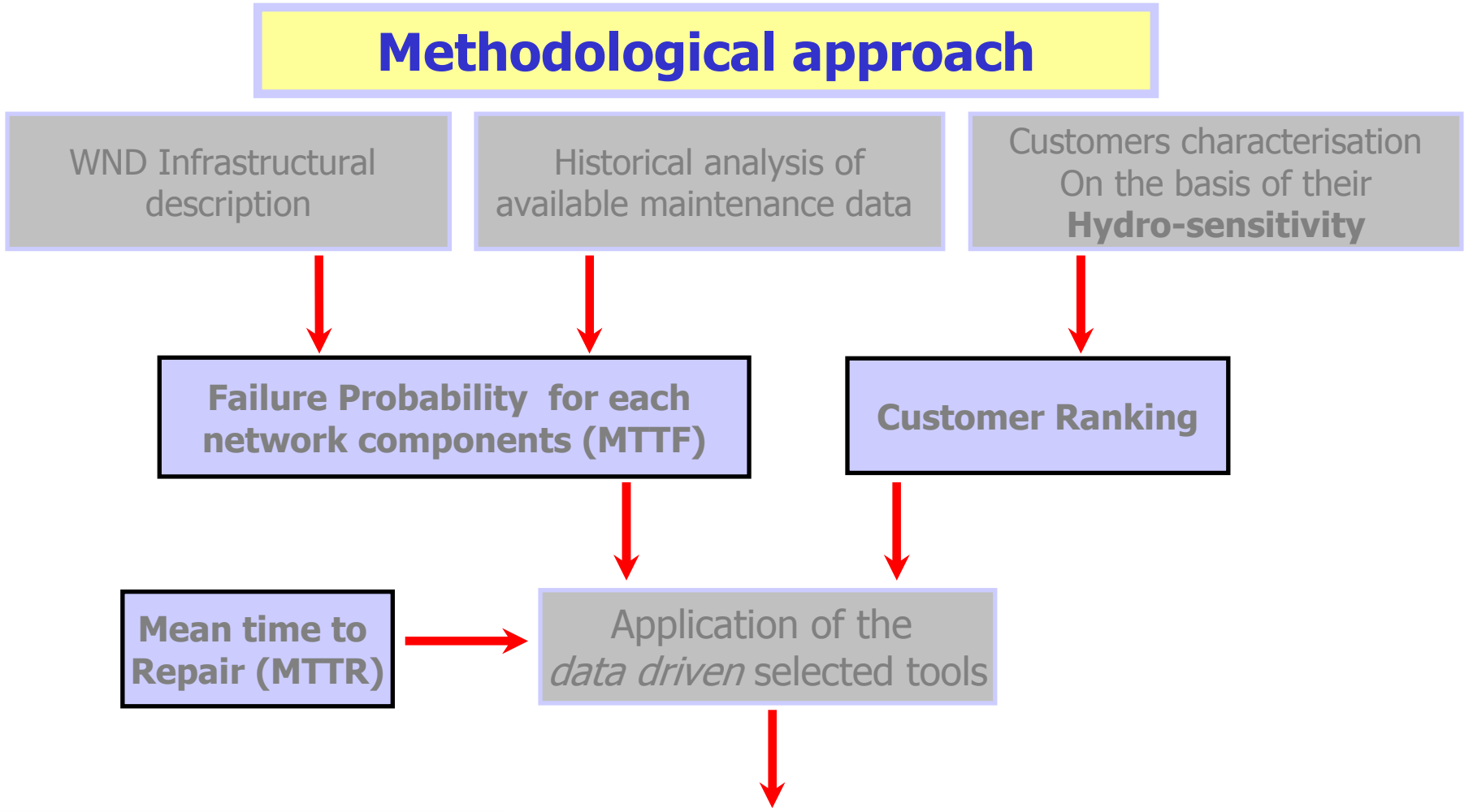
⟶ Suggest feasible improvements in data collection and in their format;

Procedure:

⟶ Data availability evaluation;

⟶ Selection of tools able to provide reliable results with the available data.

A GIS based approach to assess the vulnerability of water distribution systems



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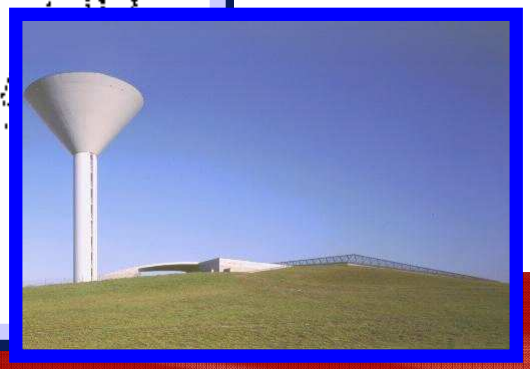
Case study: Reggio Emilia's drinking water system

General WDN Infrastructural Description



Area: 232 km²

Inhabitants : 140.000

Hourly Consumption: 2200 m³/h

Total Lenght: 700 km

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WDN Infrastructural Description

Area: 1.3 km^2

Pipe length: 23 km

Inhabitants: 30.000

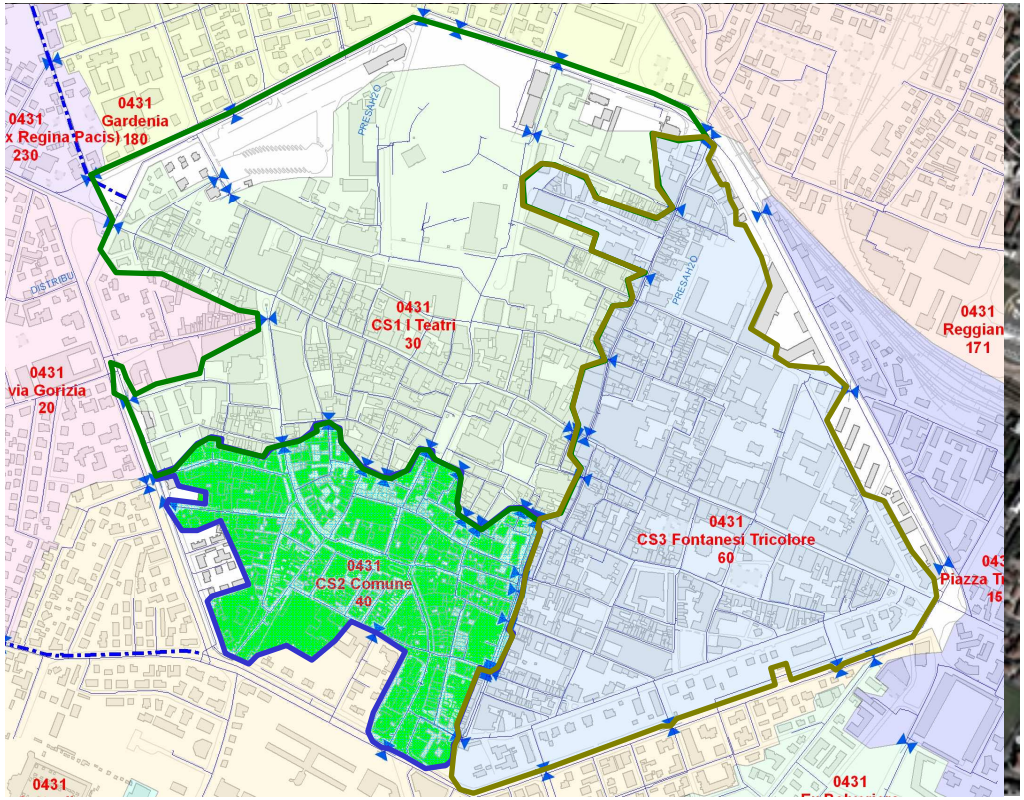
Case study: Reggio Emilia's drinking water system

WDN Infrastructural Description

Available Data:

3 WDN Epanet model (1 for each DMA)

Pipe length
Pipe Diameter
Pipe Material
Nodal Demand
Minimum Nodal Pressure



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WDN Infrastructural Description

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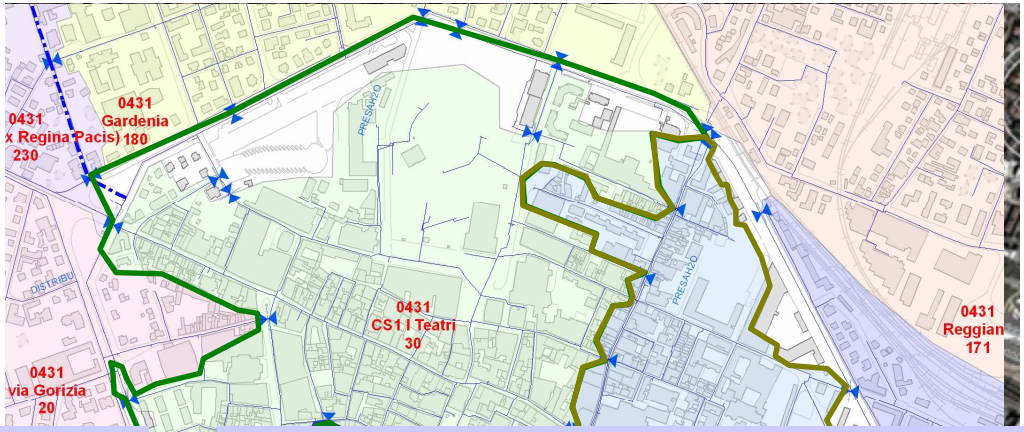

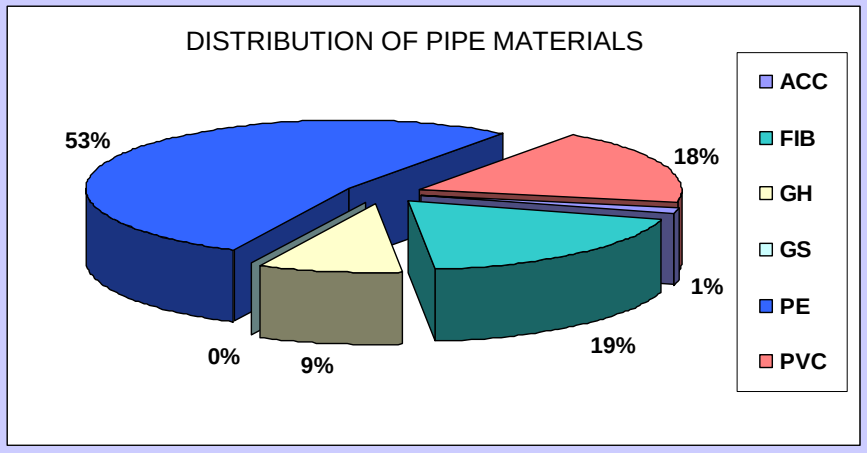

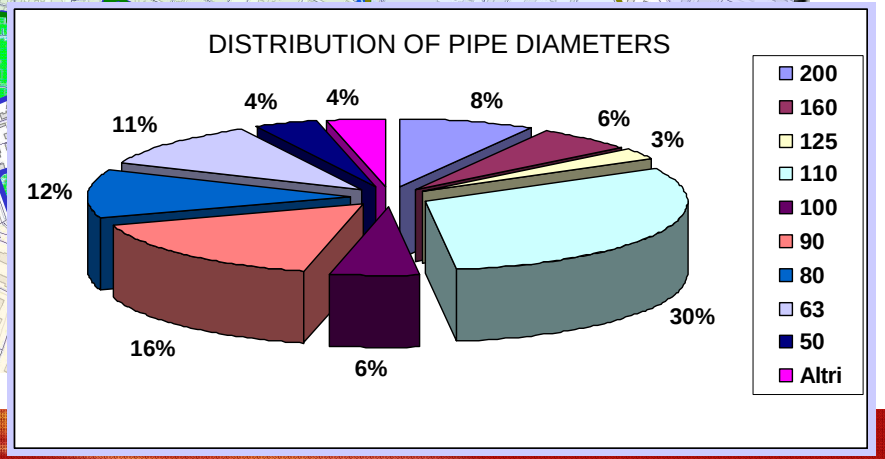

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Case study: Reggio Emilia's drinking water system

Historical analysis of available maintenance data

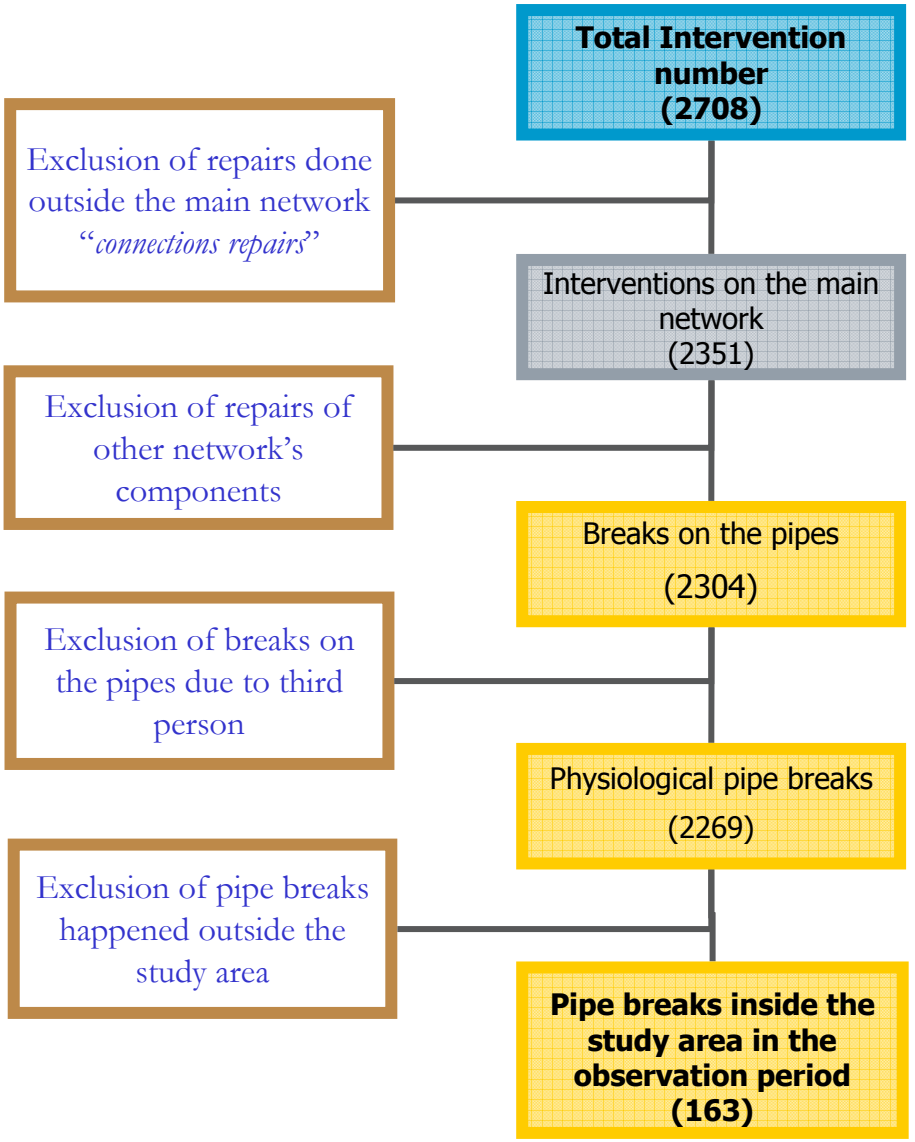
Available Data:

Database of service order for the entire municipality of Reggio Emilia for an observation period of 13 years (1994 – 2006)

year	ID Call	Municipality	Street	N°	Type of problem	Dig	Observations
…	…	…	…	…	…	…	…
1994	1118	REGGIO EMILIA	VIA MONTAGNANI MARELLI PIERO	23	Burst	True	Pipe repair
1994	1136	REGGIO EMILIA	VIA DEI GONZAGA	0	Burst	True	Pipe Repair
1994	1243	REGGIO EMILIA	VIA GIACOSA G.	2	Burst	False	Connection Renewal
…	…	…	…	…	…	…	…

Case study: Reggio Emilia's drinking water system

Followed procedure for database "filtering" in order to select acceptable breaks data



Case study: Reggio Emilia's drinking water system

Historical analysis of available maintenance data

Pipe Failure Rate and MTTF

Material →	PE	FIB	PVC
Diameter ↓	Bursts	Bursts	Burst
200	6	2	-

CLASS DIAMETERS	
1 (125 ÷ 250)	4182 *m*
2 (75 ÷ 110)	14952 *m*
3 (25 ÷ 65)	3904 *m*

Pipe Class Fail

$$\lambda_c = \frac{n^\circ \, Busts \ for \ ec}{Observation \ Period}$$

PIPE ID	LENGTH (M)	DIAM. & MATERIAL	λ	MTTF (years)
…	….	…..	….	…
5038	48.72	110 PE	0.02013	49.7
5039	47.29	80 GH	0.03583	27.9
5040	22.10	80 GH	0.01674	59.7
5041	34.59	80 GH	0.02621	38.2
5042	112.48	63 PE	0.05553	18.0
5064	2.99	80 GH	0.00227	441.5
5065	92.20	80 FIB	0.07791	12.8
….	…	…	…	…

50	1	-	CI	$80 \le D \le 100$	1015	10	0.75760
40	-	-	CI	$D \le 65$	871	18	1.58897
32	1	-	ST	$80 \le D \le 125$	341	3	0.67730
25	-	-	-	-	-		

Break	λ_c
7	0.45352
44	0.41321
18	0.49364
5	0.44971
13	0.69328
23	0.84497
1	0.34407
20	0.39857
1	0.53256

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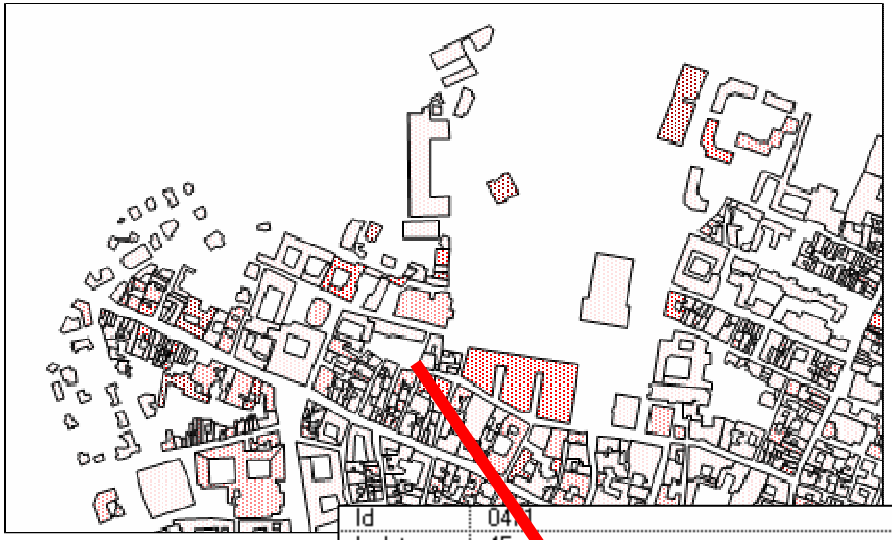
Definition of sensitive areas and sensitive customers



Id	04
Isolato	45
Edificio	4
N°_piani	3
Tipologia	Complesso di carattere religioso
Interrato	
Abitazioni	0
Attività_1	Pescheria - 3 Bar - Ristorante
Attività_2	Coop Alimentare+Altri 21negozi
Note	Palazzo dei Canonici (valore monumentale)
Cortile	
Giardino_p	

Customer type	Impact coefficient
Hospital	10
School	5
Commercial, farm and industry	1

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Definition of sensitive areas and sensitive customers

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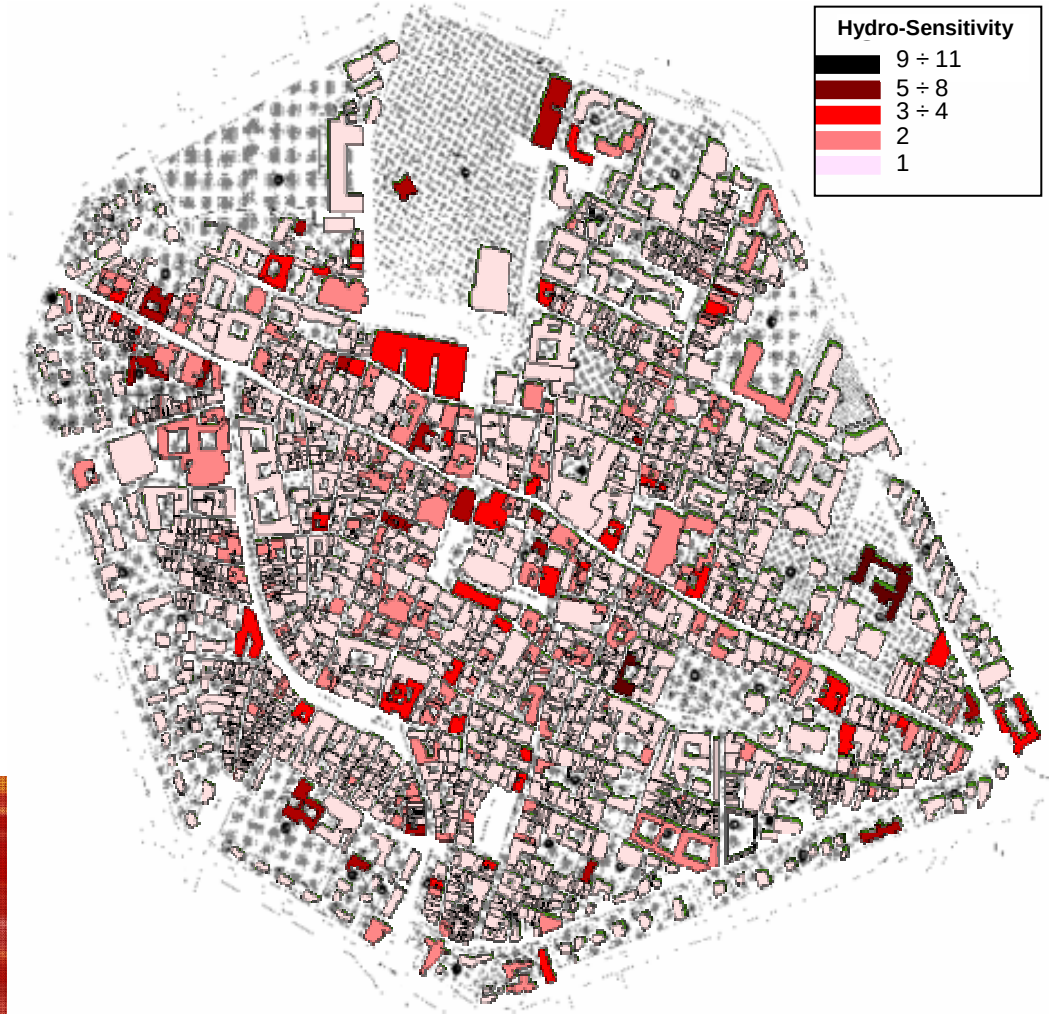
Case study: Reggio Emilia's drinking water system

Definition of sensitive areas and sensitive customers

Hydro-sensitivity Map



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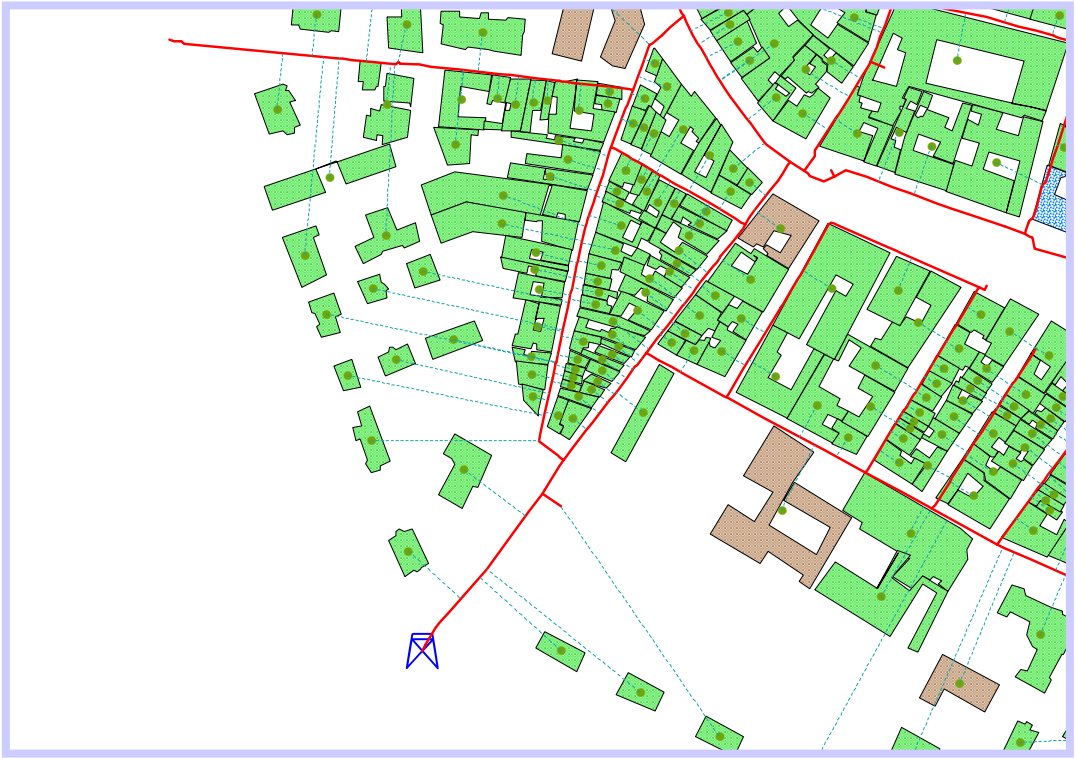
Definition of the weight for each network node

Every pipe has a score given by summing the sensitivity coefficient of each customer served



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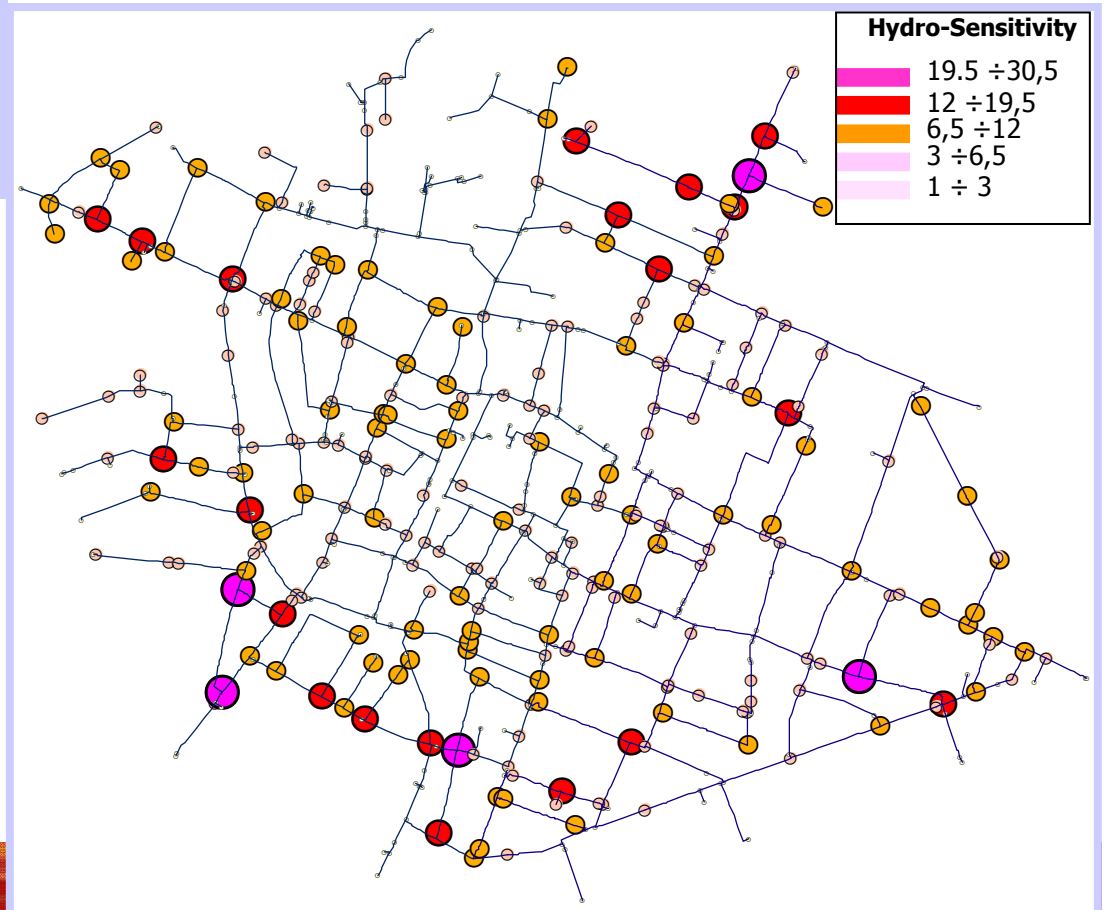
Definition of the weight for each network node

The node importance has been evaluated as the average score of the pipe connected to it



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Reliability tools selected

Selected Tools	Hydraulic Solver	Mechanical Reliability	HCI Hydraulic criticality index
Failnet-Reliab (*Cemagref*)	Internal solver	Yes	3 index: - Pipe Level - Node Level - Network Level
Relnet (*Brno University*)	EPANET	No	1 index: - Pipe Level

The Reggio Emilia drinking water network vulnerability

Definition of the Vulnerability coefficient

$$V_c = P_F \cdot k \cdot f(w_i)$$

Where:

P_F = weight defined by the utility's managers

k = hydraulic reliability index

$f(w_i)$ = expression of the function of the impact coefficients

The Reggio Emilia drinking water network vulnerability

First level approach

Network simulation with all pipes available

$Qtot$

Network simulation with one active failure (pipe break)

$Qnew$

Evaluation of HCI
Hydraulic Criticality Index

$$HCI = \frac{Qtot - Qnew}{Qtot}$$

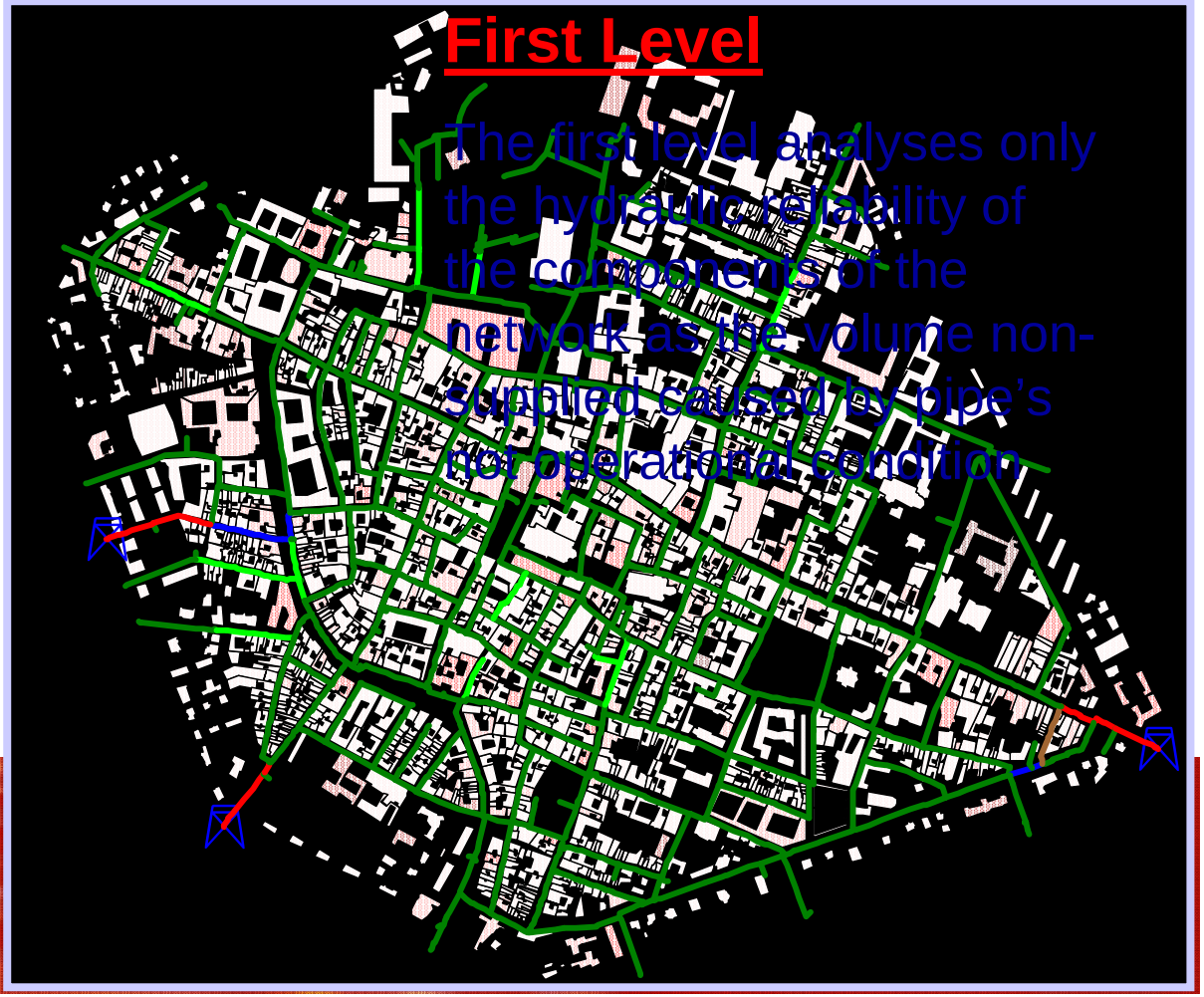
The Reggio Emilia drinking water network vulnerability

First level approach

$$V_c = P_F \cdot k \cdot f(w_i)$$

$$V_c = HCI$$

CRITICALITY
- very high
- high
- medium
- low
- very low



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The Reggio Emilia drinking water network vulnerability

Second level approach

Simulation of the not operational state of the pipe based on the probabilistic analysis

Failnet-Reliab

Hydraulic simulation of the network with the not operational condition of pipes

HCI
Hydraulic Criticality Index

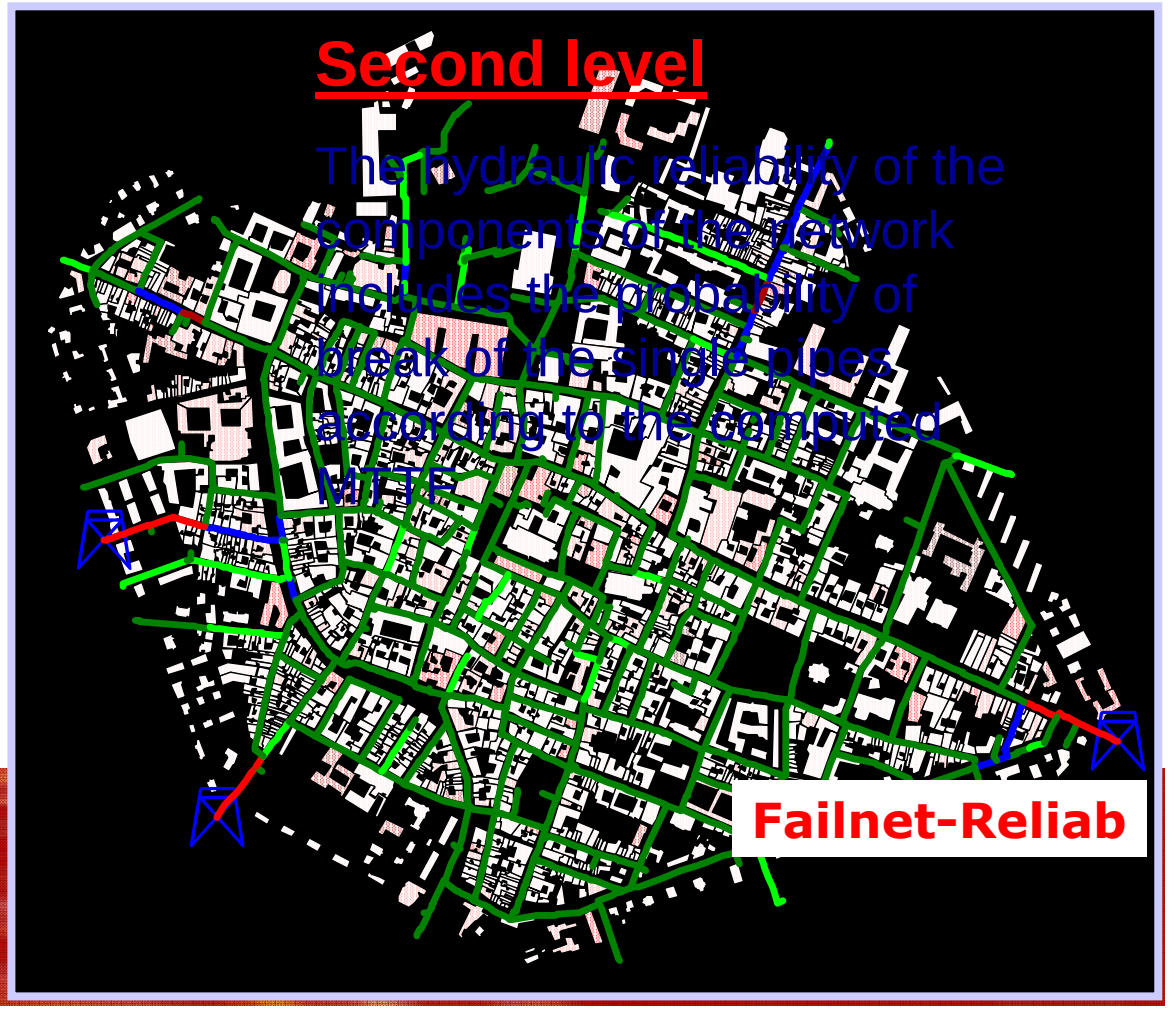
The Reggio Emilia drinking water network vulnerability

Second level approach

$$V_c = P_F \cdot k \cdot f(w_i)$$

$$V_c = HCI\_\lambda$$

CRITICALITY
- very high
- high
- medium
- low
- very low



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The Reggio Emilia drinking water network vulnerability

Third level approach

Simulation of the not operational state of the pipe based on the probabilistic analysis

Hydraulic sensitivity of nodes

Failnet-Reliab

Hydraulic simulation of the network with the not operational condition of pipes

HCI
Hydraulic Criticality Index

The Reggio Emilia drinking water network vulnerability

Third level approach

$$V_c = P_F \cdot k \cdot f(w_i)$$

$$V_c = HCI\_\lambda \cdot f(w_i)$$

Third level

Includes:

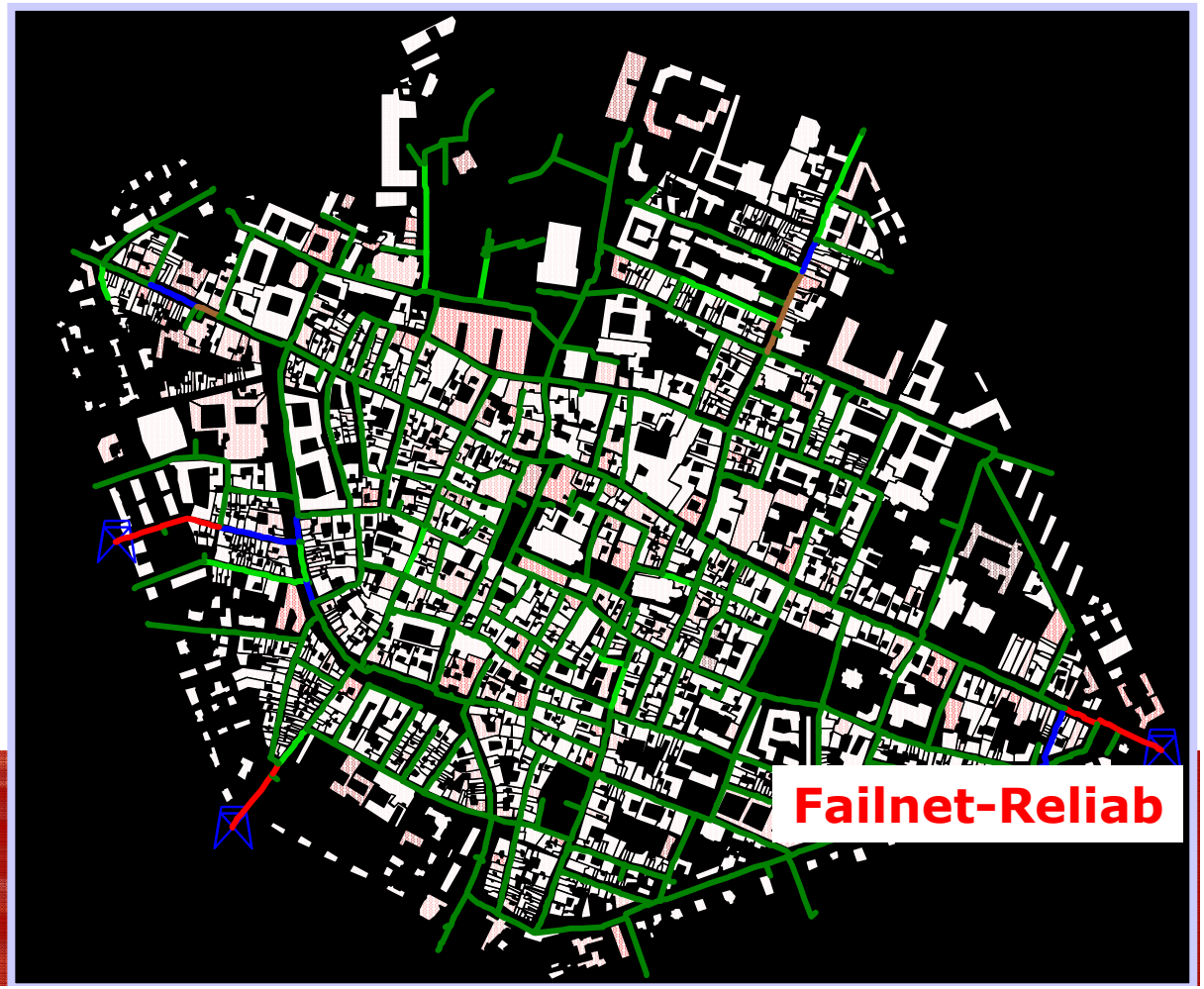
- the probability of break of the single pipes according to the computed MTTF
- the sensitivity of customers

The Reggio Emilia drinking water network vulnerability

Third level approach

$$V_c = P_F \cdot k \cdot f(w_i)$$

$$V_c = HCI\_\lambda \cdot f(w_i)$$



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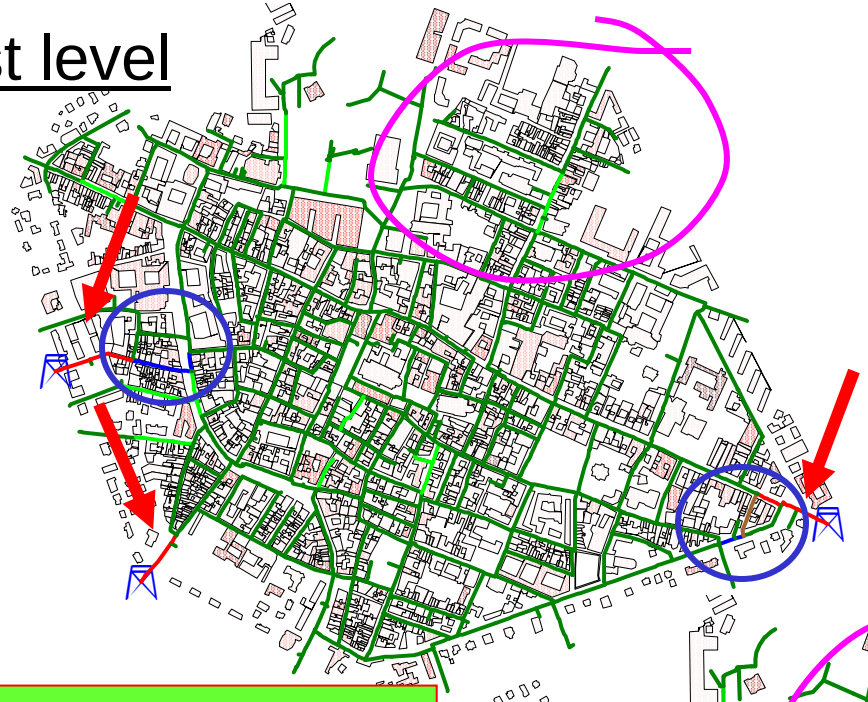
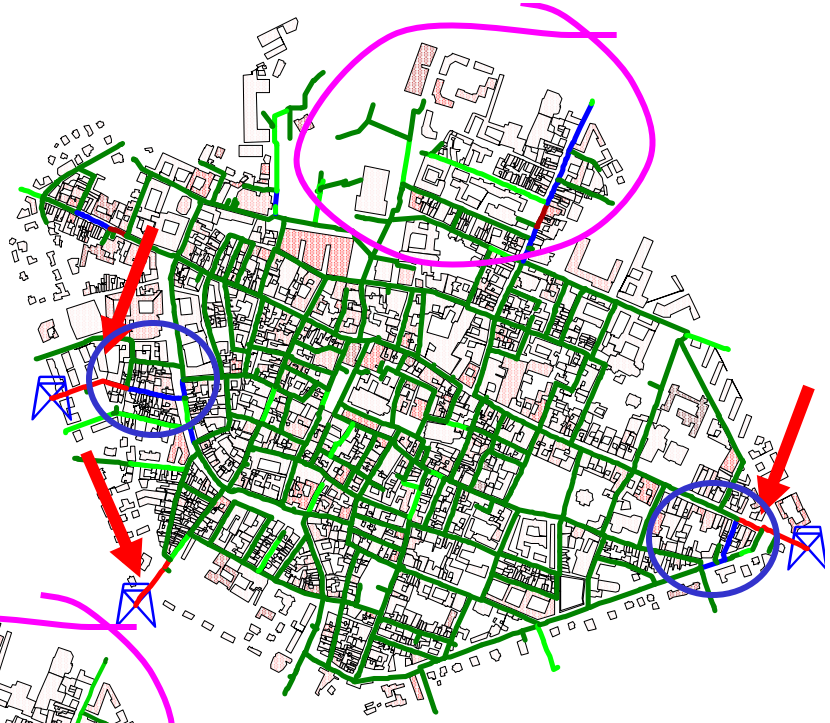
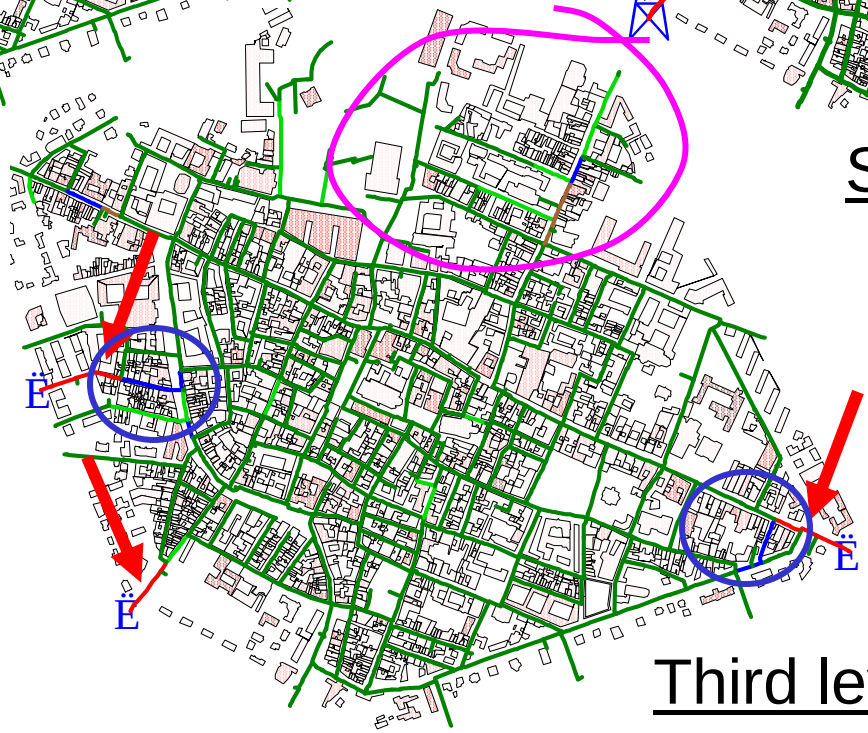
First level



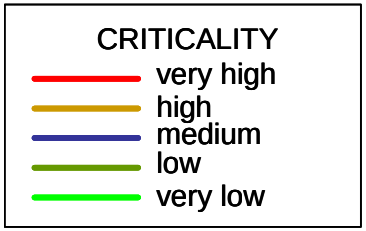


Second level

The criticality of some components decreases when we add the vulnerability concept to the simple hydraulic analysis, showing that for rehabilitation planning those pipes could be considered with lower indirect costs.



Third level



Conclusions

- The aim of this study was to develop a simple but feasible approach to assess the vulnerability of an Italian water distribution systems suitable with the level of data available: starting from a typical Italian case study;
- we defined what can be evaluated, analysed or calculated according to what can be obtained from the utility in terms of data quality and quantity;
- The approach, integrating hydraulic and structural reliability, customer sensitivity to water use and GIS features, provides the utility's managers with a list of vulnerable pipes in table and thematic maps format;
- In terms of asset management, the results show that rehabilitation projects, with same or similar direct costs, can eventually have different total costs when including indirect costs analysis, changing the selection of pipes to be prioritized for rehabilitation.
- We would like to make more sensitivity analysis to better define the "level of sensitivity of the customers" and add at least on more failure to compare the results.

Thanks for your attention…….