

Krakow, 19 October 2005
Sveinung Sægrov, SINTEF



Computer Aided REhabilitation of W ater networks



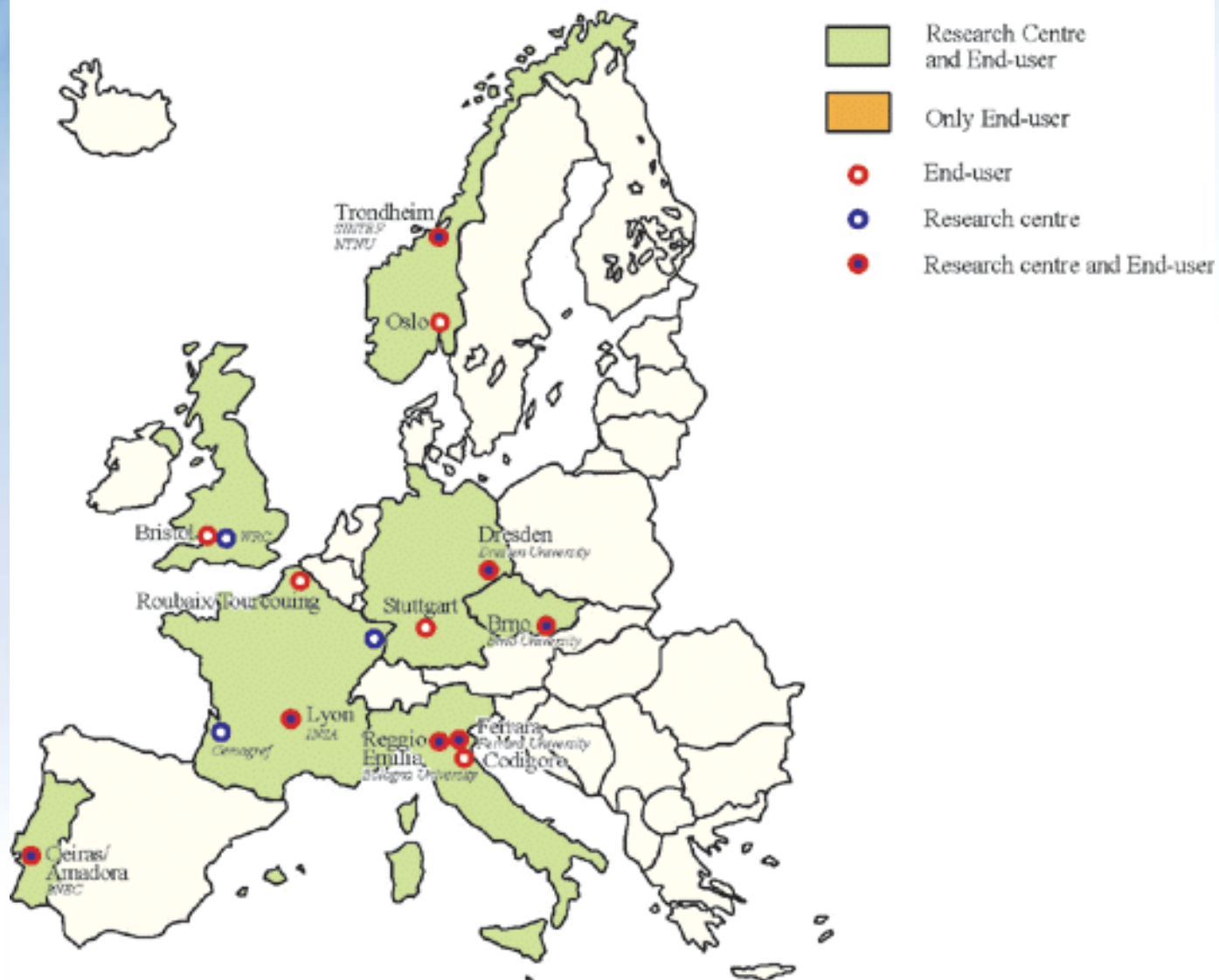
What is CARE-W?



- ◆ ...stands for Computer Aided REhabilitation of Water Networks
- ◆ ...is a computer based system to support water companies to maintain and upgrade their water networks
- ◆ ...was developed by 10 European research groups and 13 cities ("end-users").
- ◆ ...supported by the European Commission under the 5th Framework Programme for Research and Development.
- ◆ ...had a budget of 3 mio € (2,1 mio £)

Consortium

CARE-W



The need for CARE-W



- ◆ 1,5 mio miles of water pipes are owned by public or private utilities in Europe. Their age is increasing and the repair budgets limited.
- ◆ Annual rehabilitation need is $> 0,5\%$, i.e. 10.000 km/yr at a cost of 5 billion €.
- ◆ Efficiency of rehabilitation can be improved by
 - ◆ selecting the right projects
 - ◆ avoiding consequences of failures, i.e. water supply abrupton, flooding, traffic disturbances etc.
- ◆ In Europe the economic potential by using CARE-W is in the order 1 billion € annually

CARE-W answers these questions:



- ◆ What is the structural condition of a specific pipe - and of the entire network?
- ◆ Which are the most vulnerable pipes?
- ◆ Will the future failure rate increase or not?
- ◆ How should I rank my rehab projects?
- ◆ What are the future investment needs?
- ◆ What is the optimal management of my water distribution network?

RE-ACTIVE APPROACH



PRO-ACTIVE APPROACH

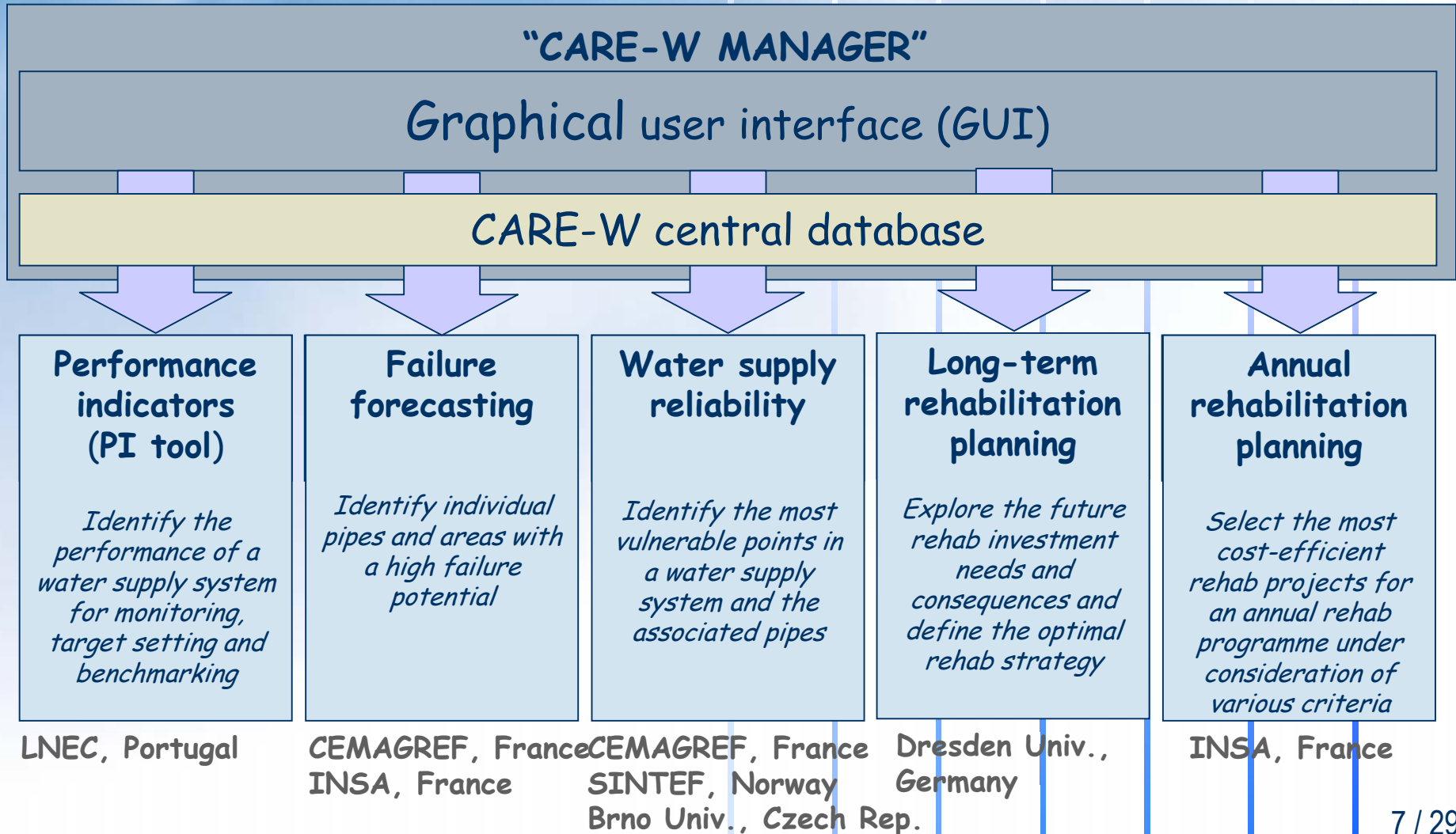


Our mission: Develop methods and integrated software supporting efficient rehabilitation decisions

CARE-W prototype



WRc, UK



CARE-W prototype



"CARE-W MANAGER"

Graphical user interface (GUI)

CARE-W central database

Performance indicators (PI tool)

Identify the performance of a water supply system for monitoring, target setting and benchmarking

Failure forecasting

Identify individual pipes and areas with a high failure potential

Water supply reliability

Identify the most vulnerable points in a water supply system and the associated pipes

Long-term rehabilitation planning

Explore the future rehab investment needs and consequences and define the optimal rehab strategy

Annual rehabilitation planning

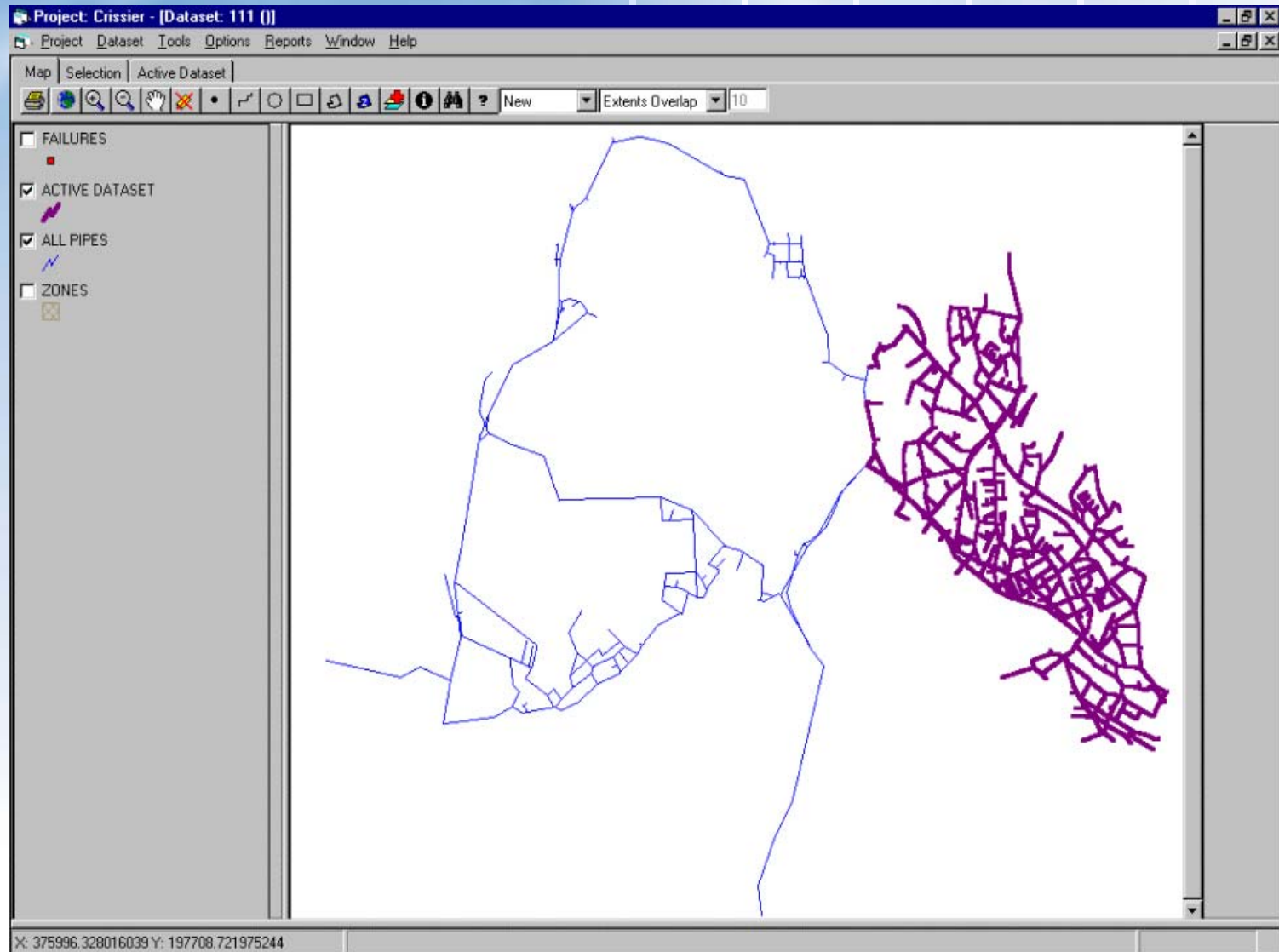
Select the most cost-efficient rehab projects for an annual rehab programme under consideration of various criteria

"CARE-W manager"

- ◆ Manages a central database
- ◆ Contains an imbedded GIS
- ◆ Allows for data import/export
- ◆ Is an integrating platform for all the individual modules
- ◆ Allows to generate the input files and run any of the associated applications
- ◆ Allows for graphical data input and results representation.

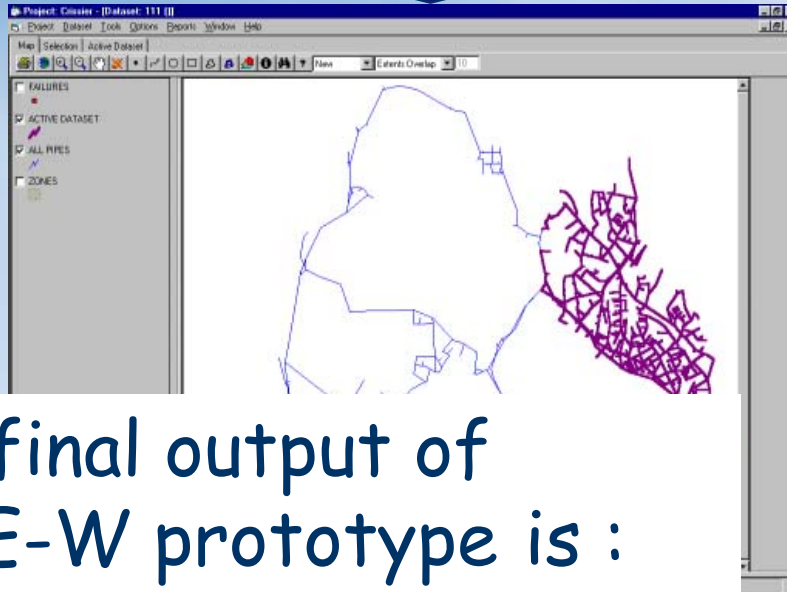
"CARE-W manager"

- example of data selection



INPUT DATA

CARE-W TOOLKIT



The final output of
CARE-W prototype is :

List of pipes with
higher rehabilitation
priority

Contributions for
the short and long
term strategic
planning, including
some economic
analysis

Input

Results

Performance
indicators (PI)

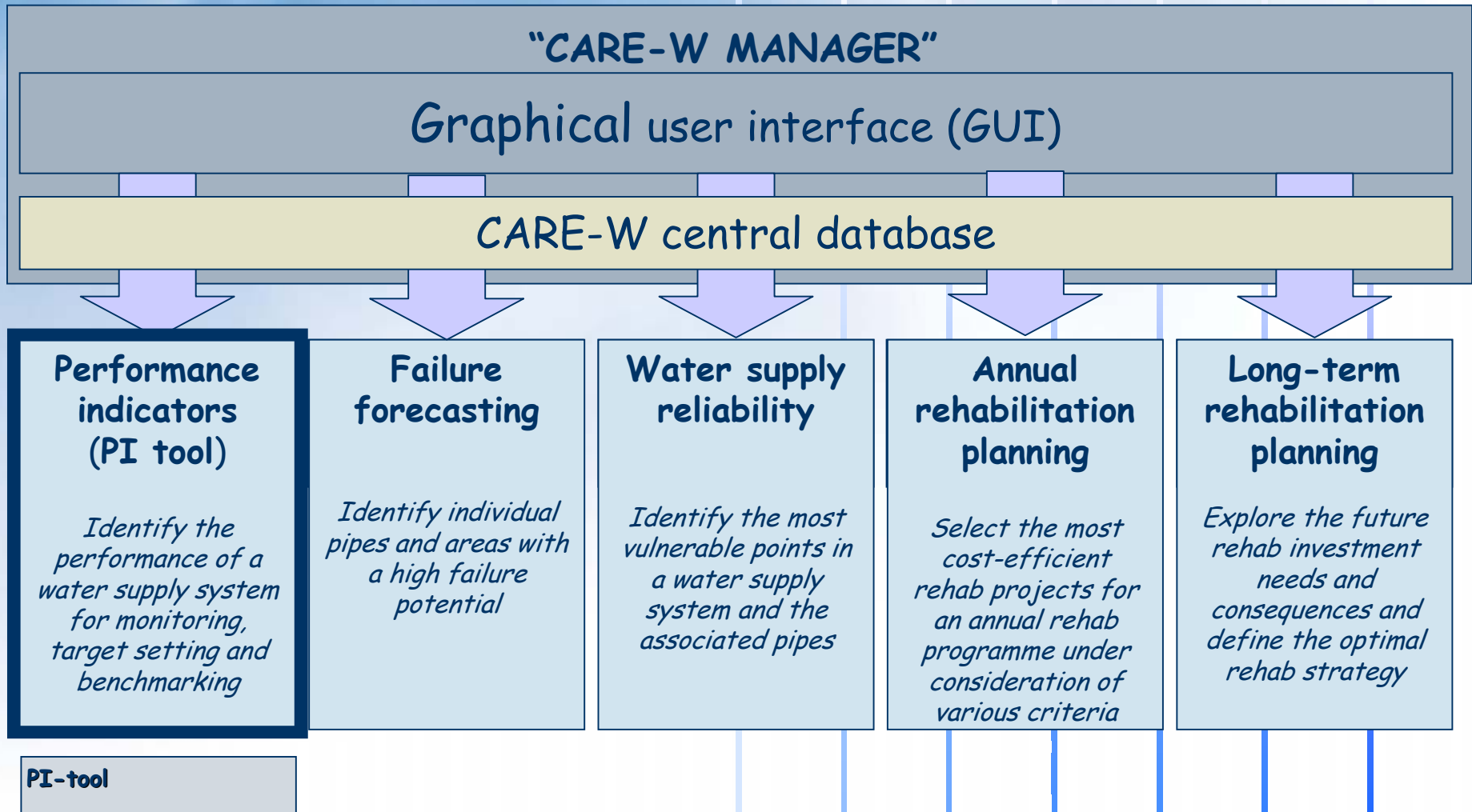
Failure
forecasting

Water supply
reliability

Long-term
rehabilitation
planning

Annual
rehabilitation
planning

CARE-W prototype



Performance indicators (PI)

- ◆ The CARE-W PI module incorporates a rehabilitation PI system to support network diagnosis
- ◆ Is based on the IWA PI system
- ◆ PI-Tool allows for:
 - ◆ PI and variable selection
 - ◆ Import / export
 - ◆ Data input and PI assessment
 - ◆ Production of tables and graphs with the results

Indicators

- ◆ General description of condition
- ◆ Compare areas (internal "benchmarking")
- ◆ Compare with other cities
- ◆ Estimate the benefit of rehab programs

Appropriate for documentation towards policy agencies, investment planners

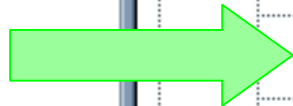
Example of a PI tool window: PI/UI manager

PI/UI Manager: Gubbio, from beginning of 07/2002 to end of 10/2002

Select PI/UI:

- ☐ Gubbio-PI
 - ☐ Water Resources
 - ☐ WR1 / Inefficiencies
 - ☐ WR2 / Resources
 - ☐ Physical
 - ☒ Ph3 / Transmission
 - ☐ Ph7 / Valve der
 - ☐ Operational
 - ☐ Quality of Service
 - ☐ Financial

- ☐ Gubbio-UI
 - ☐ Physical Assets
 - ☐ Water Volume
 - ☐ A1 / Annual abs
 - ☐ A2 / Imported w
 - ☐ A4 / Water abst
 - ☐ A5 / Imported ra
 - ☐ A6 / Exported ra
 - ☐ A7 / Water proc
 - ☐ A8 / Imported tr
 - ☐ A9 / Exported tr
 - ☒ A19 / Authorise
 - ☒ A20 / Water los
 - ☐ A24 / Real losse
 - ☐ Operational
 - ☐ Quality of Service
 - ☐ Financial



UI properties

Code

A19

Name

Authorised consumption

Definition

Total annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorised to do so by the water supplier, for

Comment

Note that authorised consumption may include items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building

Unit

m3/year

Data Type

Real

IWA UI

A19

Reference day/month

Min Value

Max Value

Group

Water volume data

Subgroup

-

Used by the following PI

WR2; Ph3; Fi1; Fi2; Fi18a; Fi21

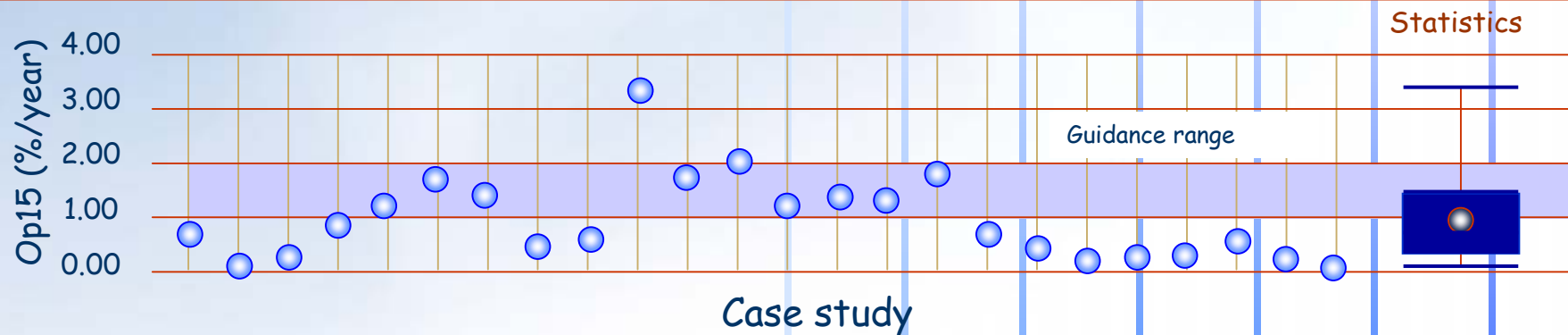
Detailed PI result analysis

Op15 - MAINS REHABILITATION (%/year)

Concept: Length of transmission and distribution mains rehabilitated during the year / total mains length $\times 100$

Processing rule: $Op15 = D18/C6 \times 100$

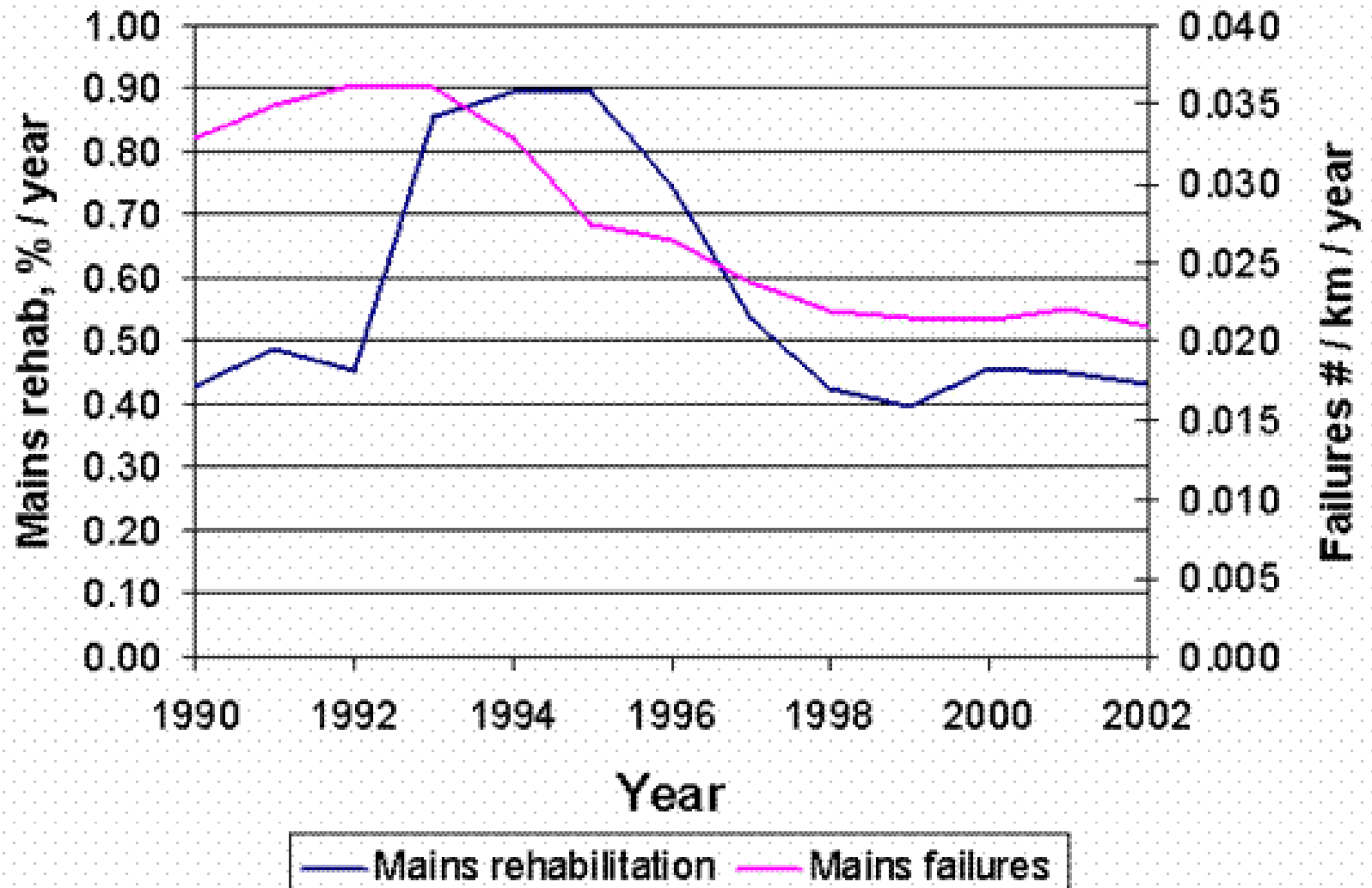
Variables: D18 - Mains rehabilitation (km/year)
C6 - Mains length (km)



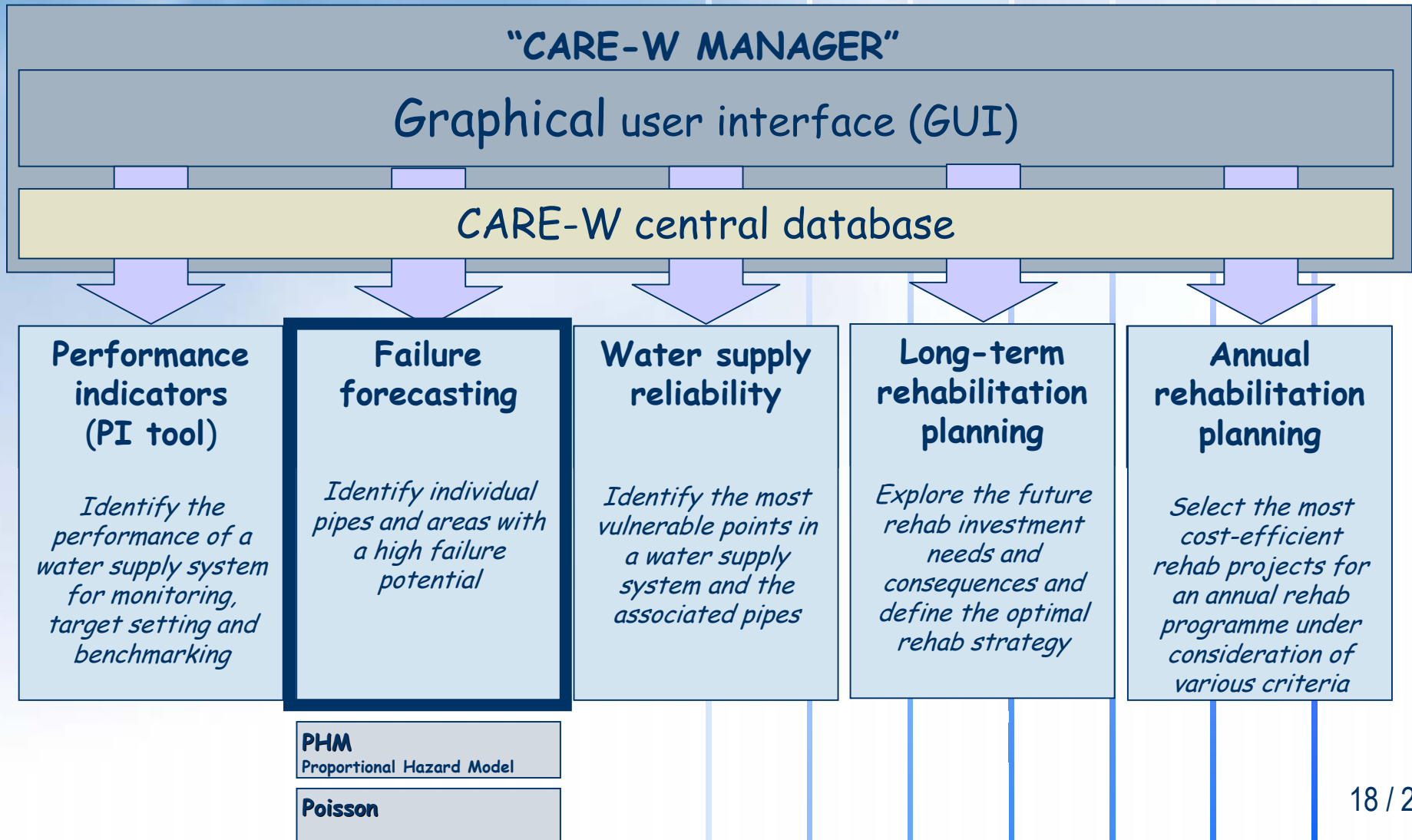
- Comments:** The mean value of the results collected is 0.91% of mains rehabilitated per year and 50% of the case studies are situated in the range from 0.25 to 1.3% of mains rehabilitated per year. As it might be expected, a significant number of case studies present relatively low rehabilitation rates, corresponding in average to a mains lifetime of 110 years.
- Difficulties:** A few end-users had difficulties with D18 (Mains rehabilitation). This difficulty seems to be due to the lack of record, not to the complexity of the variable itself, and nobody recommended abandoning this PI due to assessment difficulties.
- Relevance:** This PI is considered essential or important by all end-users.
- PI guidance range:** At this stage, a tentative recommended threshold seems to be 1.0-2.0% of mains rehabilitated per year, representing a global network renovation within a period of 50 to 100 years.

Indicators, example

PI tool, Mains failures and rehabilitation



CARE-W prototype



Failure forecasting module

- ◆ Predicts the probability of pipe failures
- ◆ Pipes are grouped in clusters of similar behaviour
- ◆ In general 5 years of data are sufficient to get useful results
- ◆ Tests showed that it is more important to have **good data** than many data

Example of a PHM window

Strata and FStat configuration

Strata configuration

Strata 1 | Strata 2 | Strata 3 | Strata 4

List of variables
available in the
survive file

C1:Length (m)
C10:type of joint
C2:Diameter (mm)
C3:material
C4:installation dat
Cn:Number of pre
MAT

Click here to add
or remove a
variable in analysis

List of variables to
include in analysis

List of variable used in the
original strata

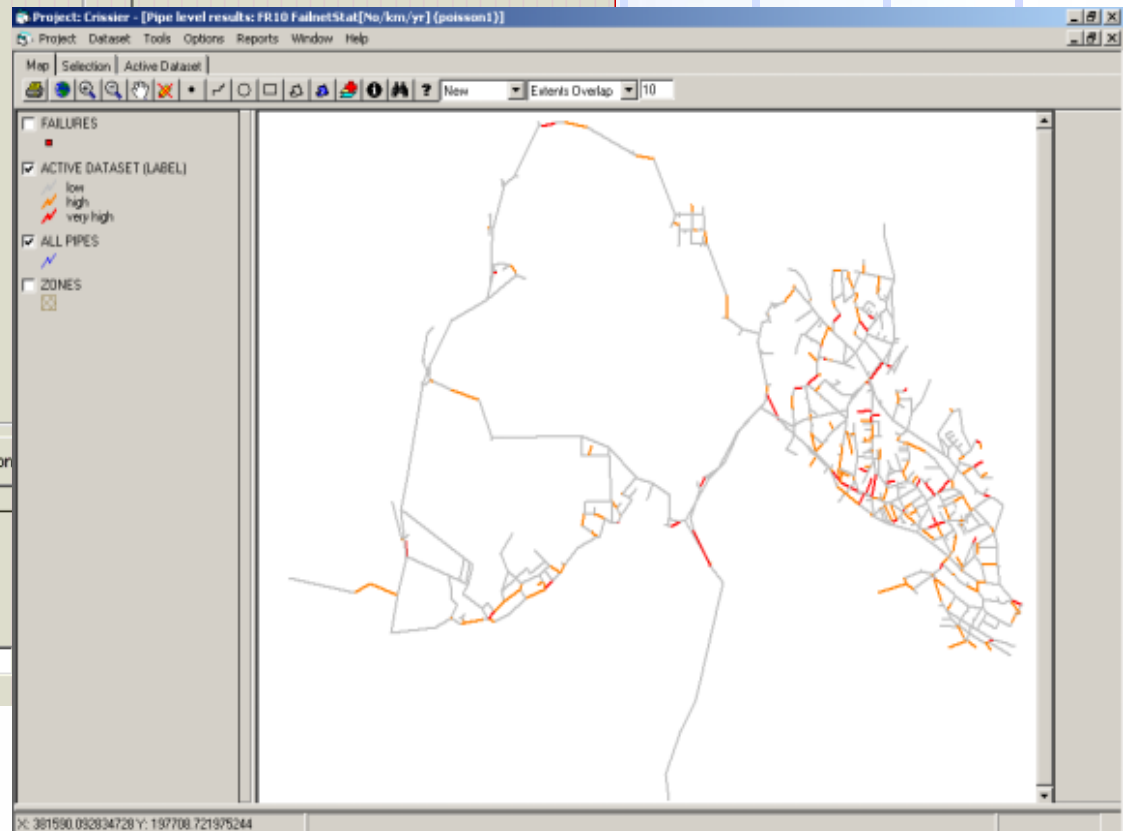
C1:Length (m)
C10:type of joint
C2:Diameter (mm)
C3:material
C4:installation date
Cn:Number of previous failure(s)
MAT

Validate this strata con

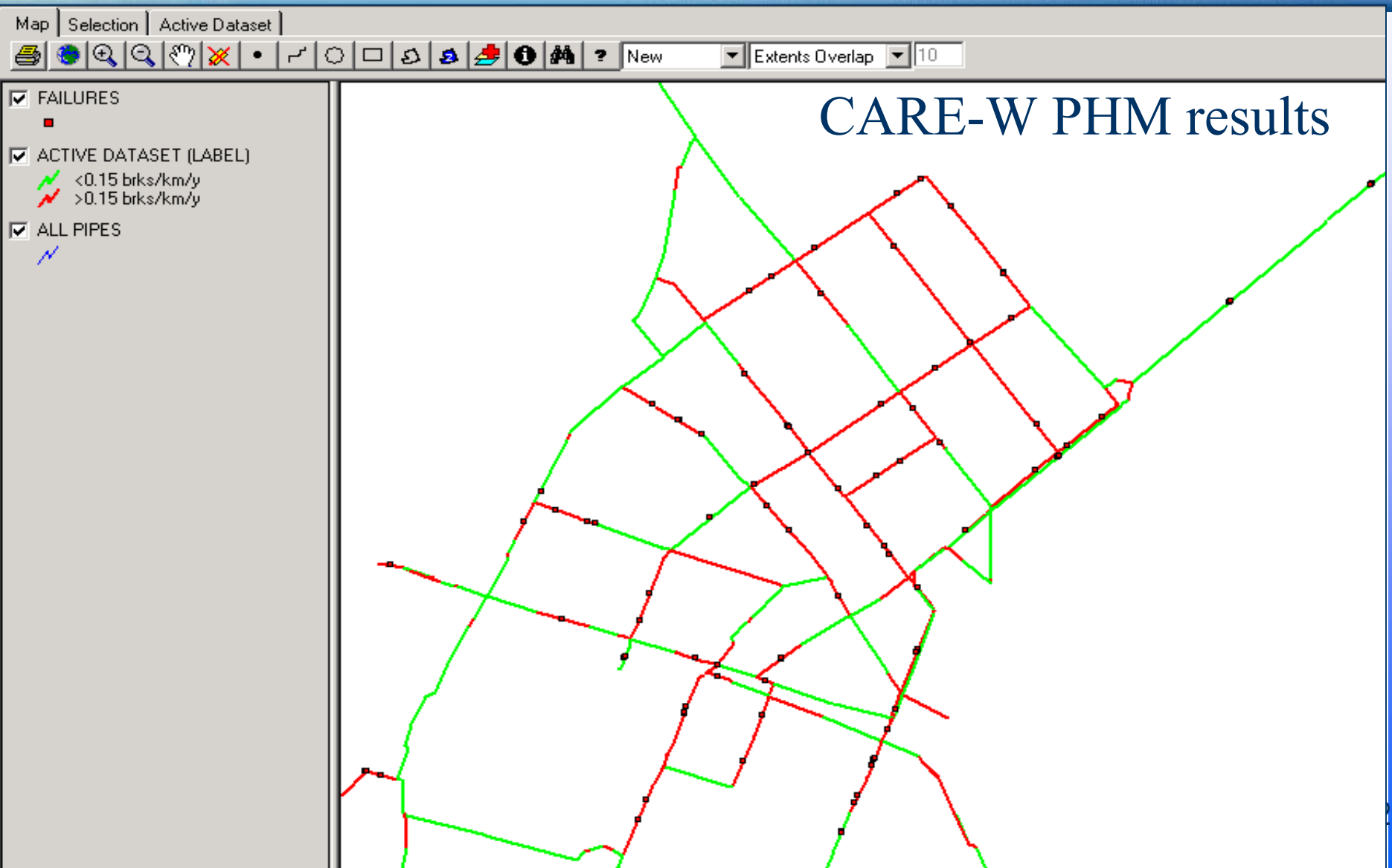
Forecast time horizon

Change number of strata

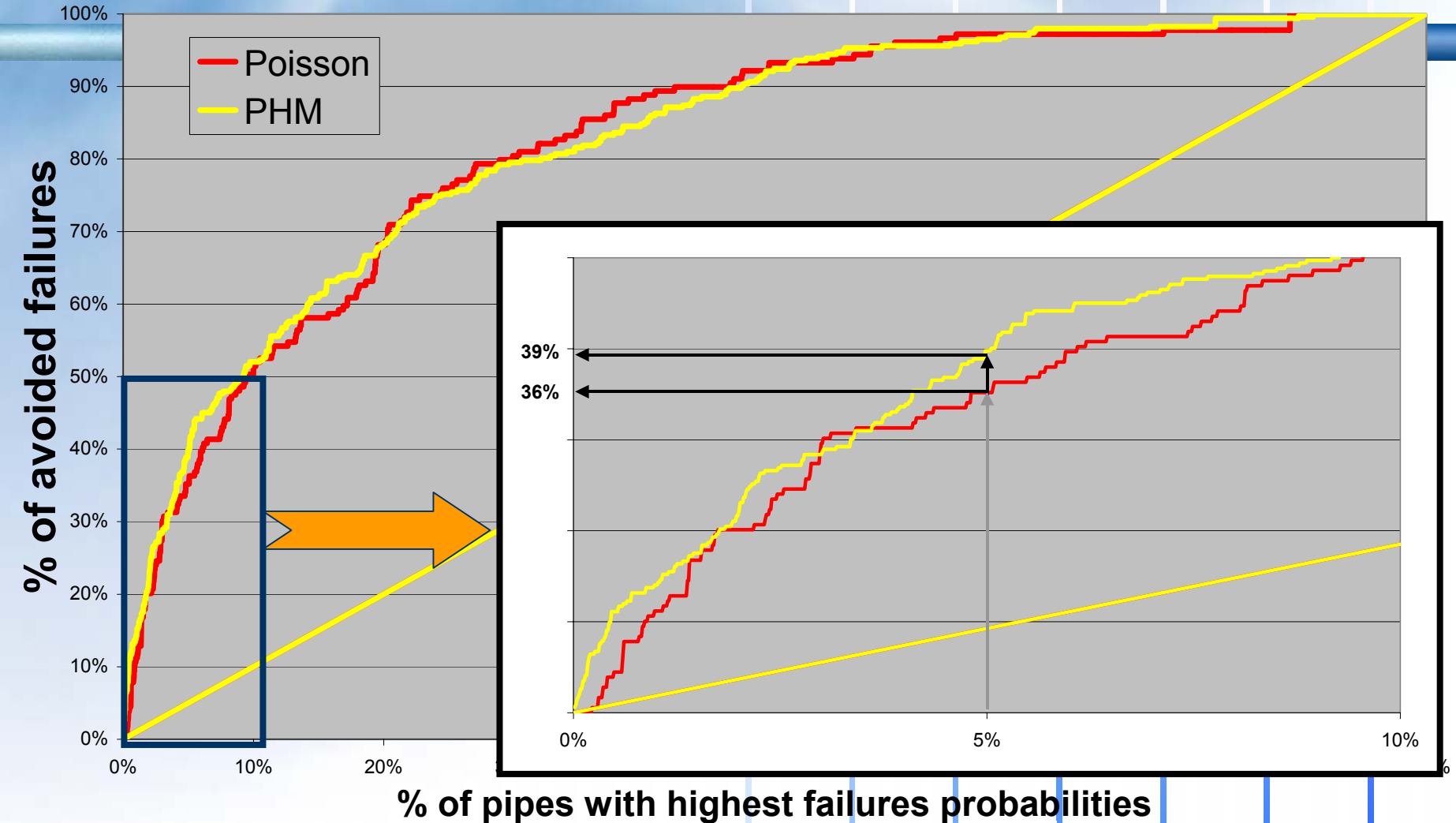
Number of strata of this survive file	2
Number of failure of each strata	0 1



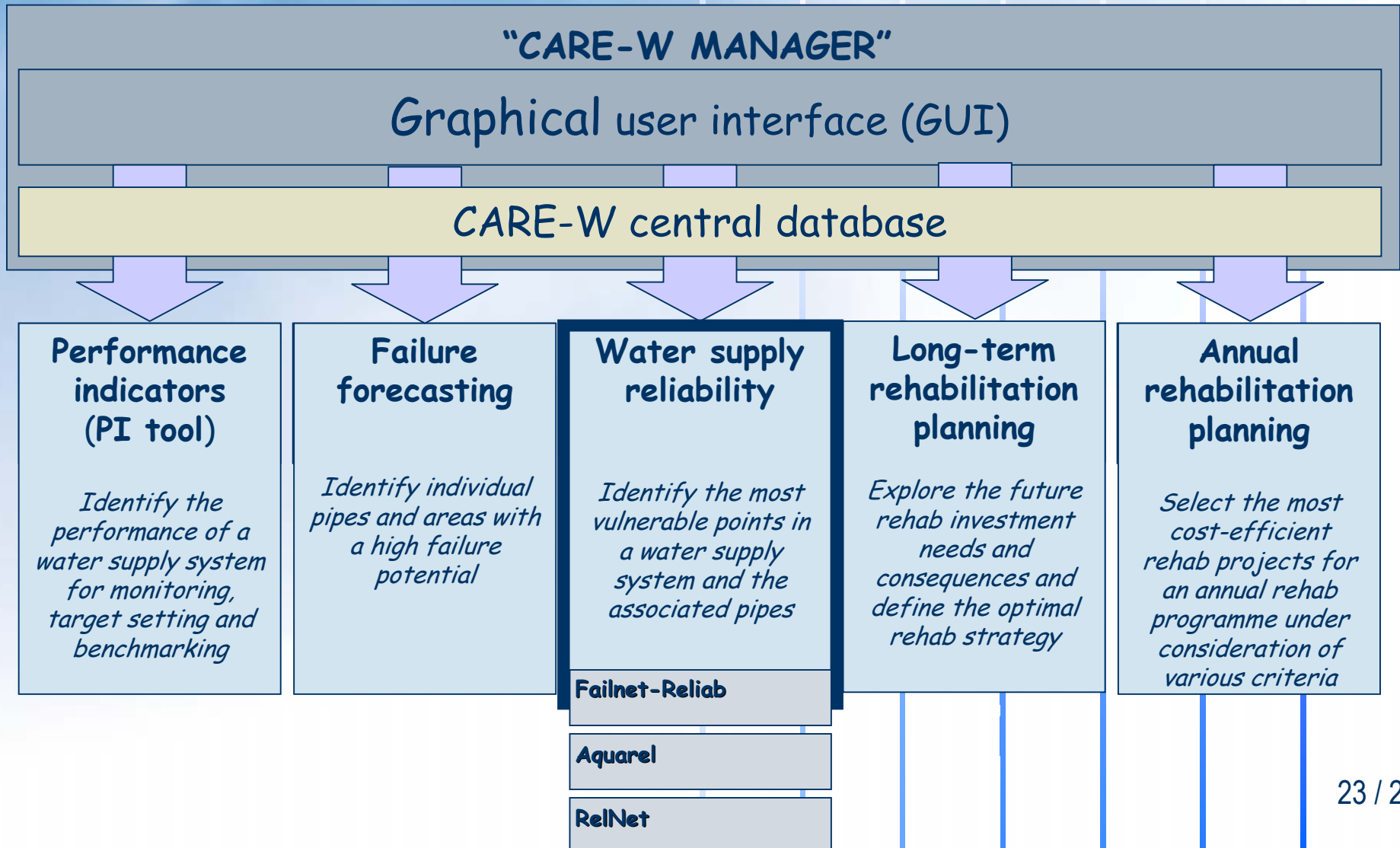
Example of a PHM window



Benefit of using these tools



CARE-W prototype



Reliability analysis

- ◆ Assesses the relative importance of each pipe in terms of hydraulic reliability
- ◆ Is based on the input data file of a hydraulic simulation model

- ◆ Assesses the relative importance of each pipe in terms of hydraulic reliability (MTTF, MTTR, consequence)
- ◆ Is based on the input data file of a hydraulic simulation model (e.g. epanet)

CARE-W REL tools

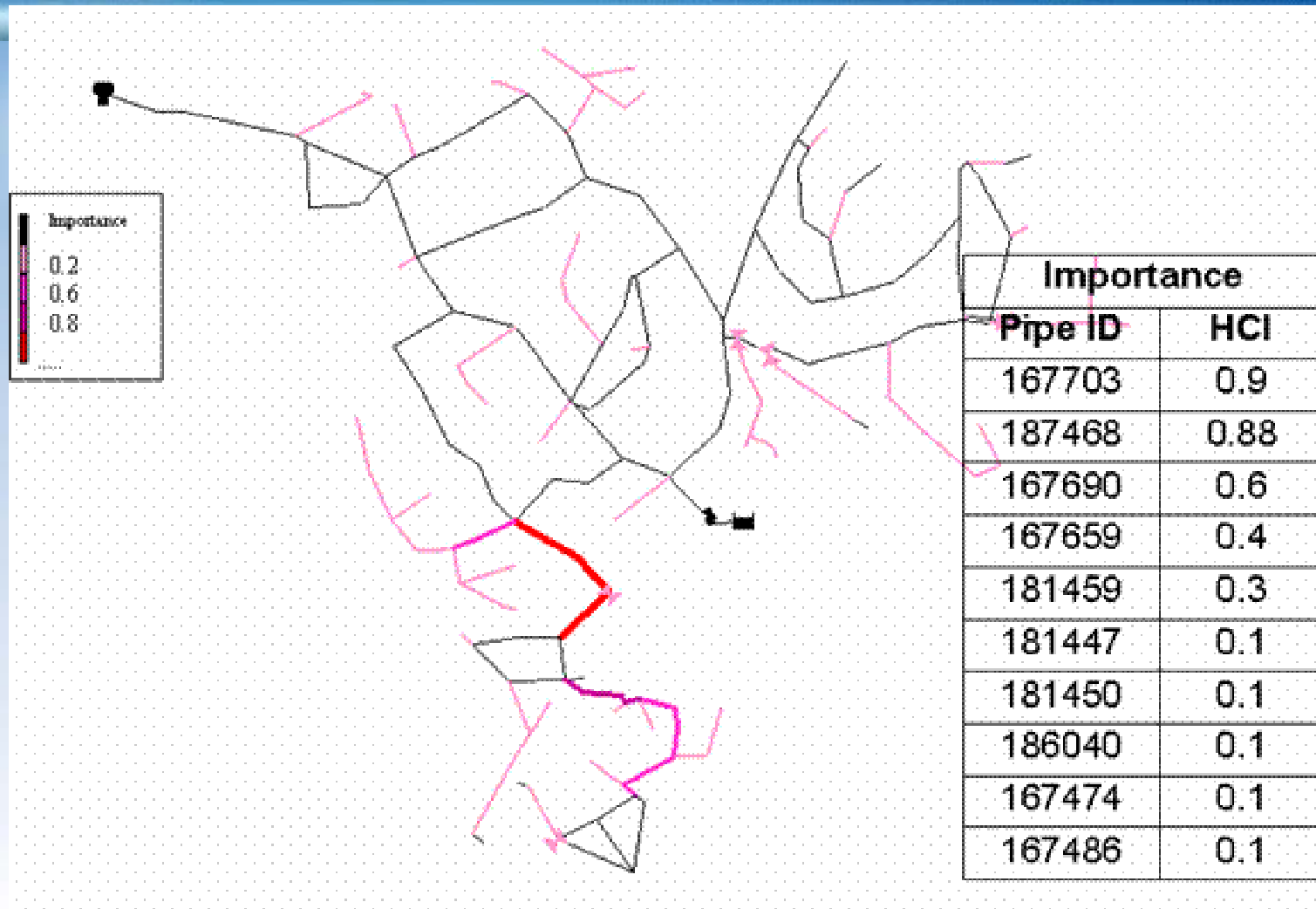
Feature	Hydraulic model	Equipment integration	Failure rate	Indices
Aquarel	Classical model (EPANET) on 24h, considering tank water levels	Yes	Yes	One index (0-1)
Failnet-Reliab	Head dependent demand model (based on "Porteau" Model)	In progress	Yes	2 indices (0-1 and non-supplied water volume)
Relnet	Classical model (EPANET)	Yes	No	One index (0-1)



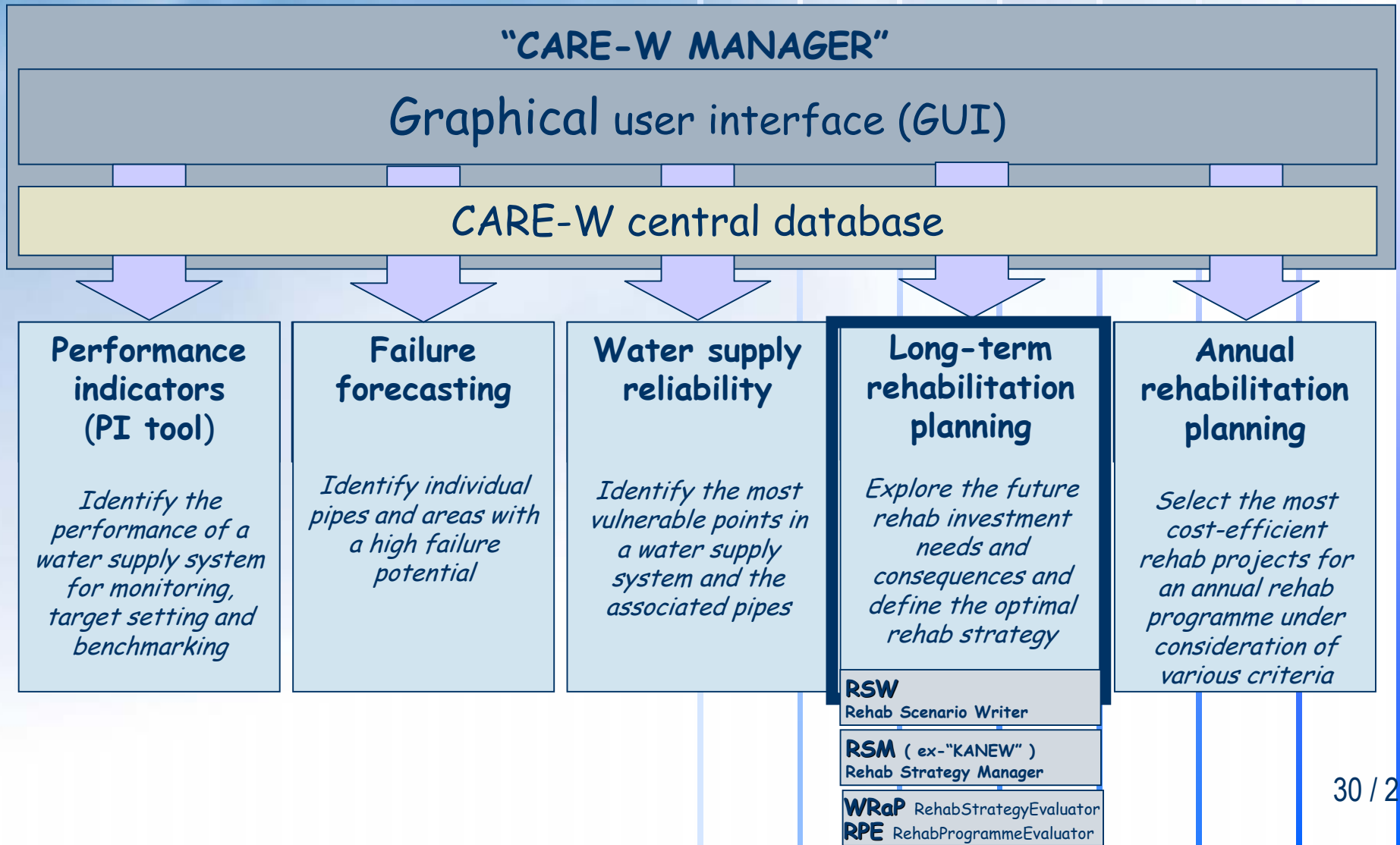
Example of a Relnet window



Example result from Aquarel



CARE-W prototype



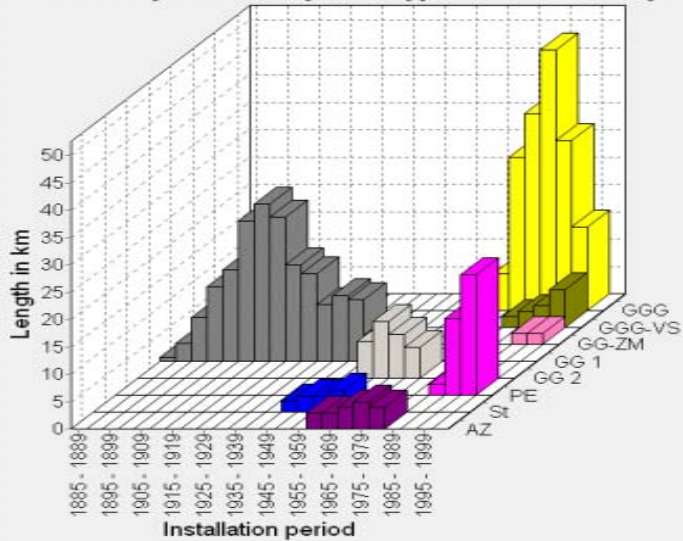
Long term rehabilitation planning (LRP)



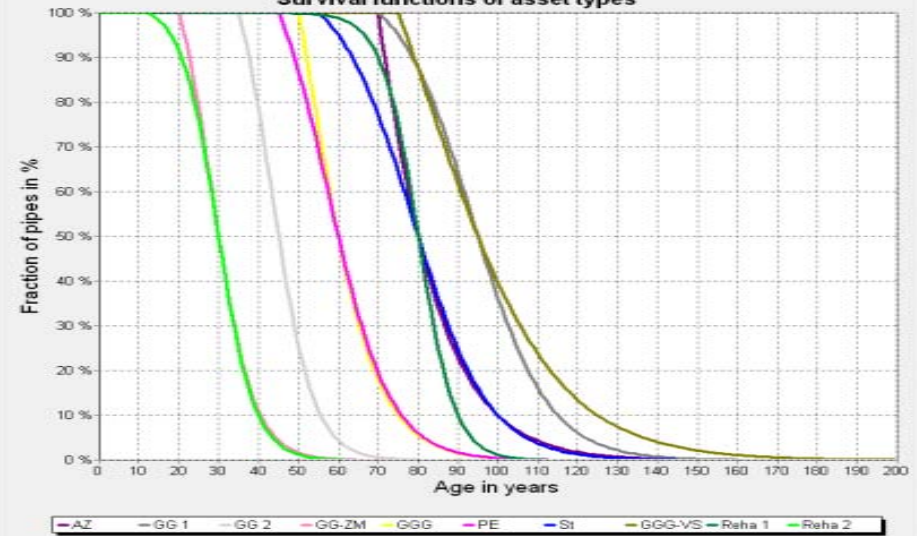
- ◆ Allows to predict the long term network behaviour for pre-defined rehabilitation scenarios
- ◆ Is based on the life expectation distribution for each group of materials
- ◆ Provides a global budget to support the strategic rehabilitation plan

Example of LRP results

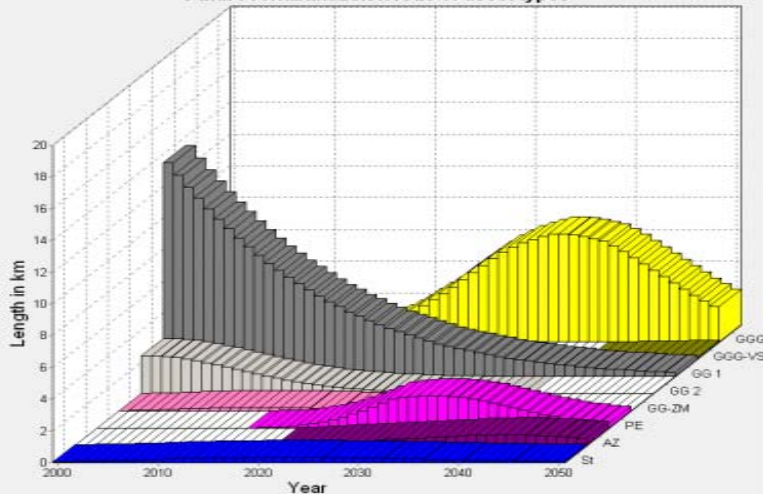
Inventory of assets by asset type and installation year



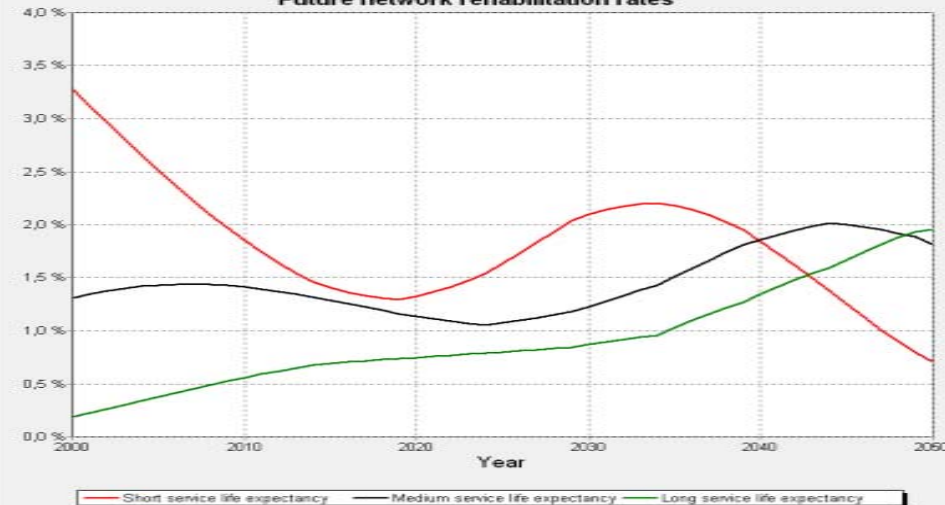
Survival functions of asset types



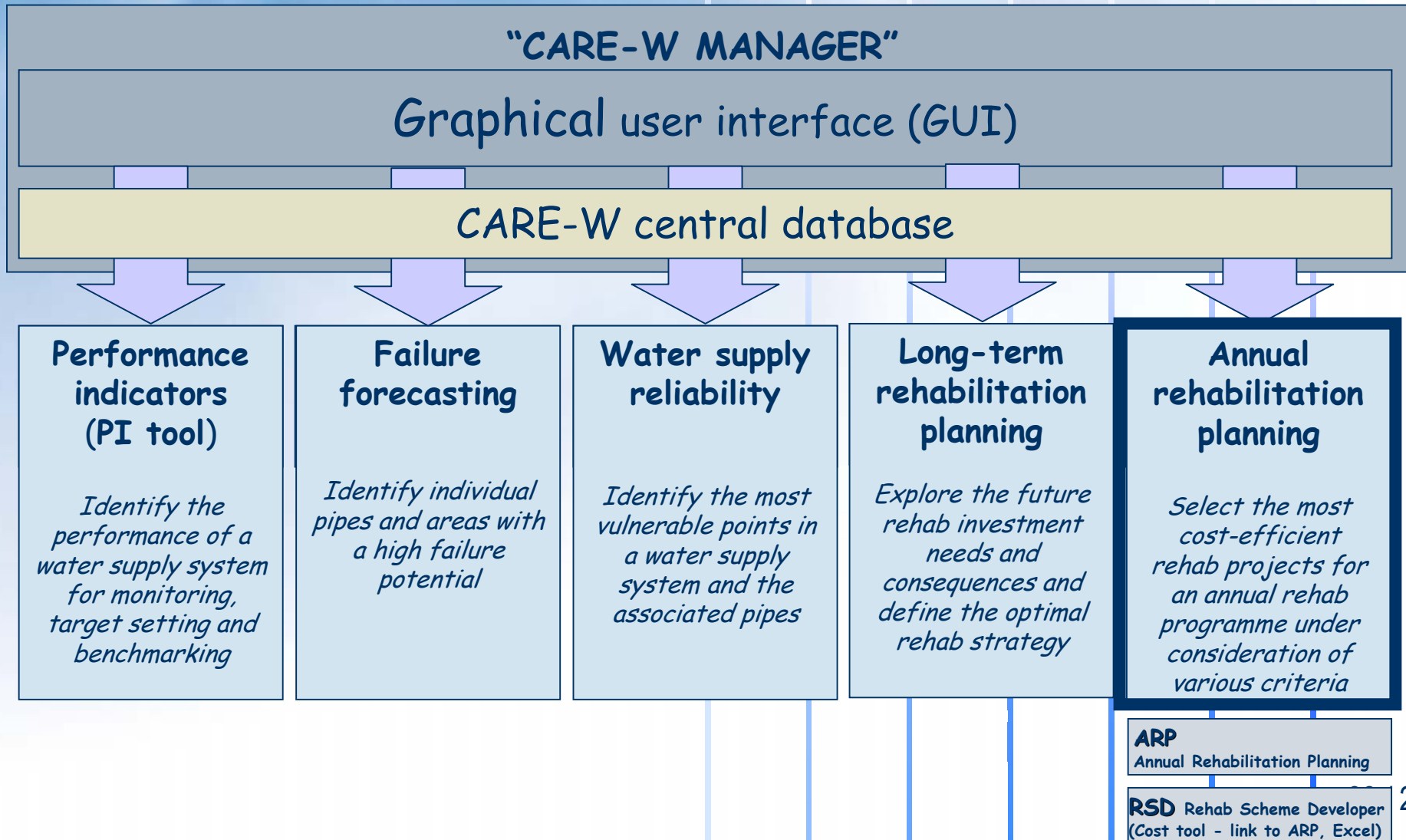
Future rehabilitation needs of asset types



Future network rehabilitation rates



CARE-W prototype



Annual rehabilitation planning (ARP)

- ◆ ARP is a multi-criterium decision-support tool
- ◆ Helps selecting the pipes with higher prioritization to be rehabilitated
- ◆ The user selects and customises the criteria to be adopted (results from other tools Fail, Rel etc)
- ◆ ARP allows for the comparison of results from different scenarios

Example of an ARP window

Available criteria

Close

Criteria that can be calculated with this data set

Criteria that can't be calculated with this data set

Points of view	Criteria
Co-ordination	Co-ordination-score - COS(i)
Repair costs	Annual Repair Costs - ARC(i)
Water losses	Water losses index - WLI(i)
Water interruptions	Predicted Water Interruption - PWI(i)
	Predicted Critical Water Interruption - PCWI(i)
	Predicted Frequency of Water Interruption - PFWI(i)
Damages and disruptions	Damage due to Flooding in Housing - DDFH(i)
	Damage due to Flooding in Industrial Areas - DDFIA(i)
	Damage due to soil movement - DSSM(i)
Water quality	Traffic disruptions - DT(i)
	Damage and/or disruption on other infrastructure - DDIO(i)
	Water quality deficiencies index - WQDI(i)
Hydraulic reliability	Hydraulic criticality index - HCI(i)
Rehabilitation costs	Unit cost of rehabilitation - UCR(i)
	info1
	info2
	info3
	info4
	info5

Project: Tøyen carew Bath - [Pipe level results: ARP_Status (Results)]

Project Dataset Tools Options Reports Window Help

Map Selection Active Dataset

FAILURES

ACTIVE DATASET (L)

ALL PIPES

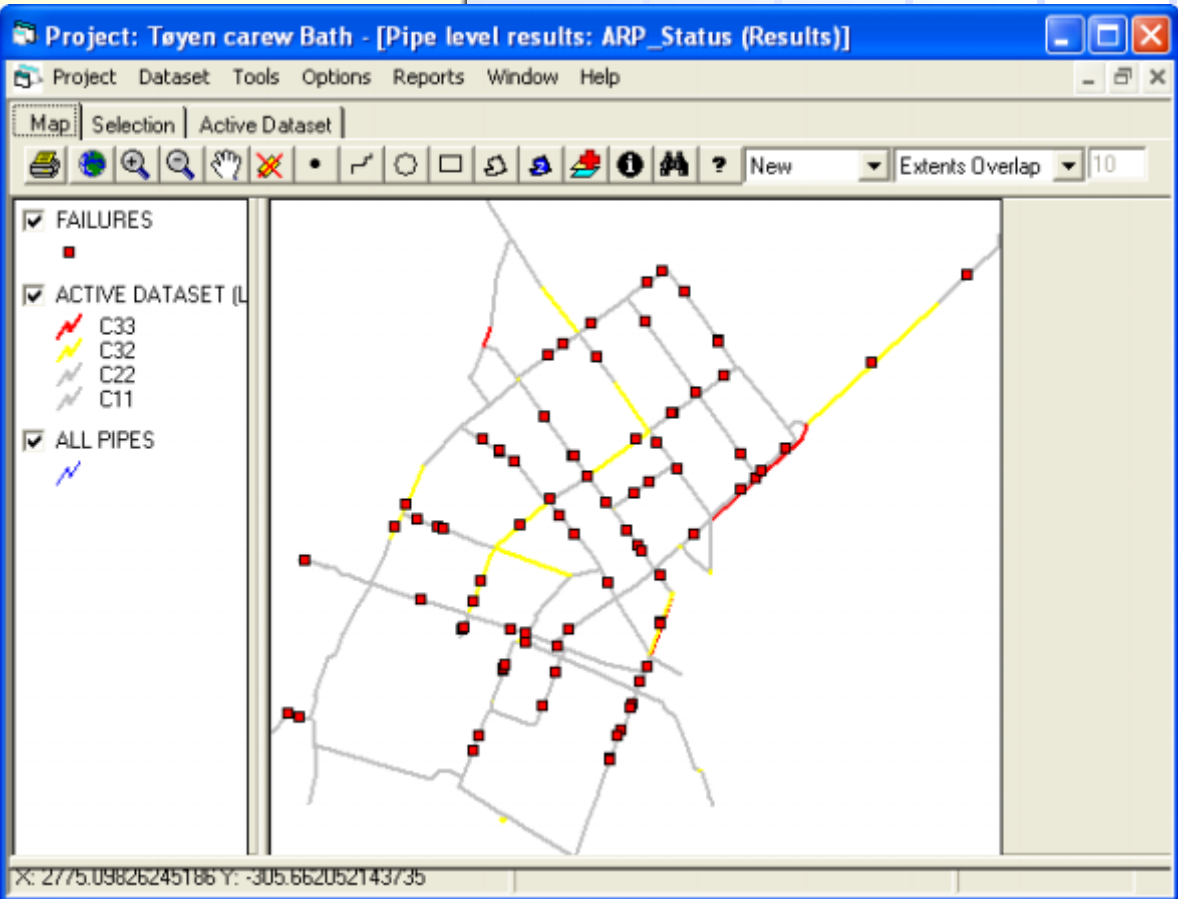
C33

C32

C22

C11

X: 2775.09826245186 Y: -305.662052143735

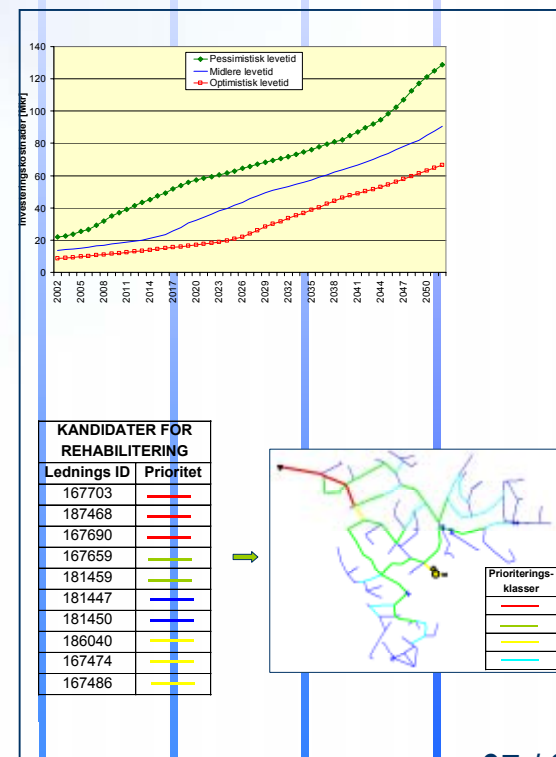


Using the CARE-W Rehab. Manager



- ◆ Importing data
 - ◆ Define specification for user GIS/CSV files
 - ◆ Use pre-existing tool formats (e.g. Poisson, Relnet)
- ◆ Viewing project data
 - ◆ Integral GIS viewer
 - ◆ Some limited tabular views
- ◆ Working with data(sets)
 - ◆ Search/selection facilities on project database
 - GIS selection tools
 - Expression Builder
- ◆ Reporting results
 - ◆ Tabular
 - ◆ Geospatial

Workload in CARE-W



Examples of data errors

- ◆ Missing pipe data (e.g. material, year, length or diameter are missing).
- ◆ Illogical combinations of pipe material, diameter and installation year (e.g. 150 mm PVC laid in 1930).
- ◆ Failure date pre-dates year of installation.
- ◆ Multiple breaks at the same pipe in the same day.
- ◆ Rehabilitation date pre-dates year of installation.
- ◆ Breaks not linked to pipes

Concluding remarks

- ◆ Some of the CARE-W tools are more data hungry than others.
- ◆ End-users appreciate CARE-W approach, although the prototype still needs further consolidation.
- ◆ The "hands-on" experience is necessary to make the CARE-W tools most useful.
- ◆ CARE-W is currently available as prototype.

Acknowledgments

Co-authors :

- ◆ Sveinung Sægrov
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