S & P CONSULT GERMANY

New-Generation, Life-Cycle Asset Management Tools

Dr.-Ing. Robert Stein
Executive Partner: Prof. Dr.-Ing. Stein & Partner GmbH and S & P Consult GmbH

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Company Background

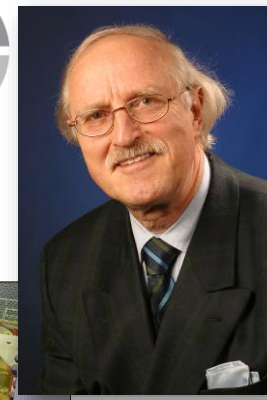
Underground Construction Technology / Jan. 29.-31., 2019 / Fort Worth, TX

Prof. Dr.-Ing. Stein & Partner GmbH

S & P Consult GmbH	S & P Consult International GmbH	visaplan GmbH	CargoCap GmbH

Prof. Dr.-Ing. Stein

- Initiator for the development of the DWA leaflet M 143
- Publication of the first books on the subject of rehabilitation of drain and sewer systems (1987)
- Initiator, founder and scientific director of IKT (2003)

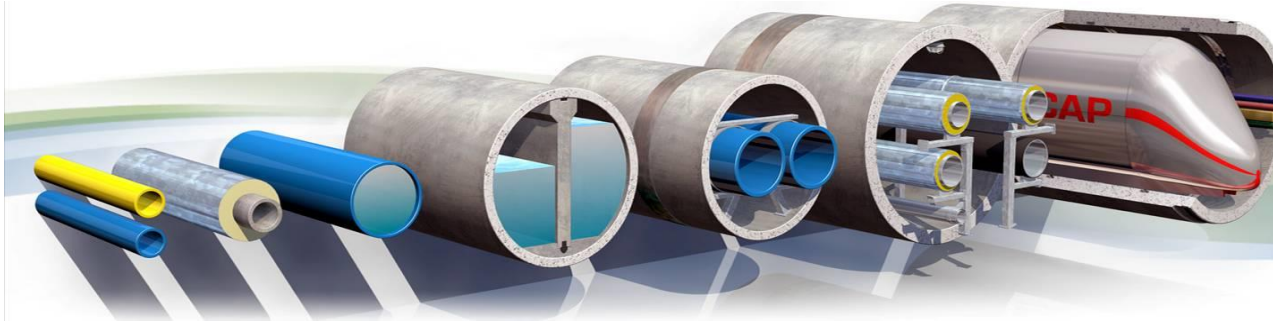


Prof. Dr.-Ing. D. Stein

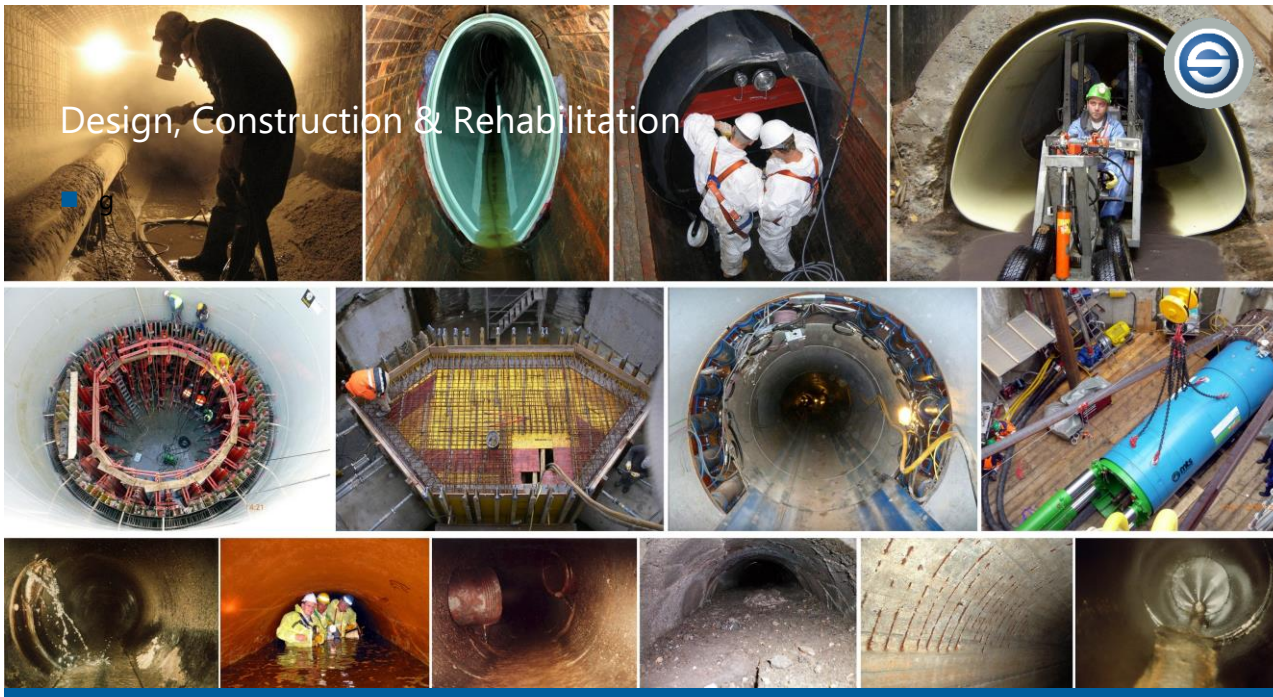
Prof. Dr.-Ing. Stein & Partner GmbH
Service Areas

Publishing house

Design, Construction & Rehabilitation



- Gas
- Water
- Wastewater
- Utility duct
- Utility tunnel
- Waste and freight tunnels



Calculation & Dimensioning

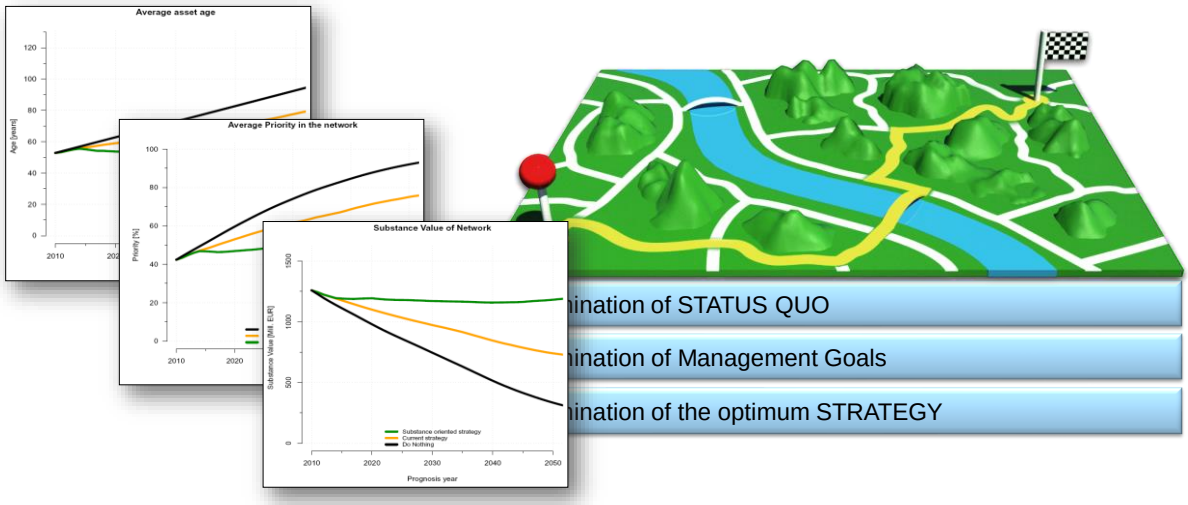
Member of working group:

- DWA-A 127: Static calculation of sewers and pipes
- DWA-A 127-10: Material specifications
- DWA-A 161: Pipe Jacking
- DWA-A 143-2: Static calculation for the rehabilitation of sewers
- RSV-M 3.3 Renovation - Grouting of annular space

Development of computation core for

- Liner software → EASY Pipe
- Monitoring and Computation of jacking projects → CoJack
- Ageing Modell for sewer infrastructure → BaSYS – infrastructure management system

Assessment & Management



Expertise & Consulting

CargoCap GmbH

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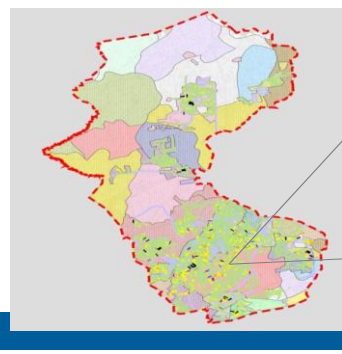
Clients
analyzed networks: 25,000.00 km

Generated profit for clients due to improved strategy and investment (period 30 years) 2,500,000,000.00 € (estimated)

Asset-Management Clients

Düsseldorf (capital city NRW)

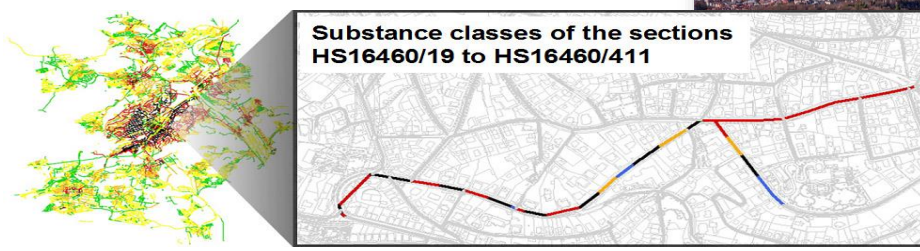
- Area 217 km²
- Population 600.000
- Length of Sewer Network 2.400 km



Asset-Management Clients

Stuttgart (capital city Baden-Würtenberg)

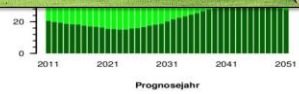
- Area 207 km²
- Population 600.000
- Length of Sewer Network 1.900 km

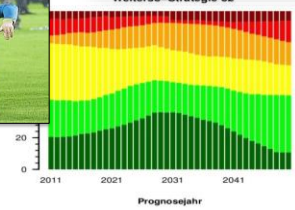


Asset-Management Clients

Dortmund

- Area 280 km²
- Population 600.000
- Length of Sewer Network 1.900 km

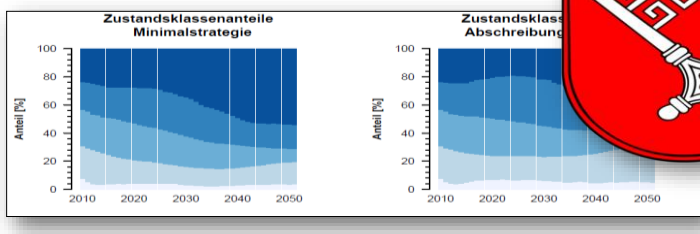




Asset-Management Clients

Bremen

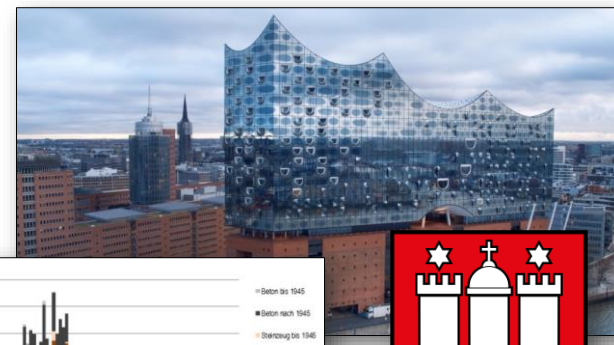
- Area: 325 km²
- Population: 547.000
- Length of Sewer Network: 2.200 km

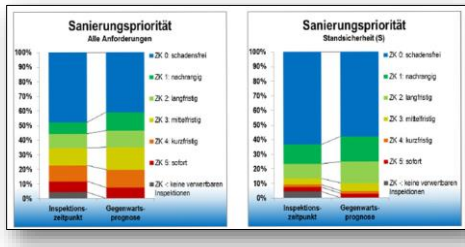


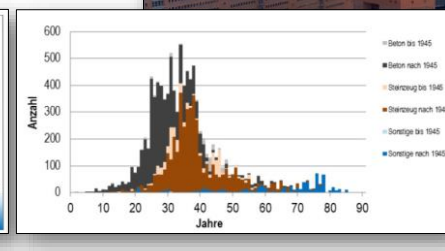
Asset-Management Clients

Hamburg (state of Germany)

- Area: 555 km²
- Population: 1.800.000
- Length of Sewer Network: 5.600 km







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Life-Cycle Asset Management Tools

STATUS

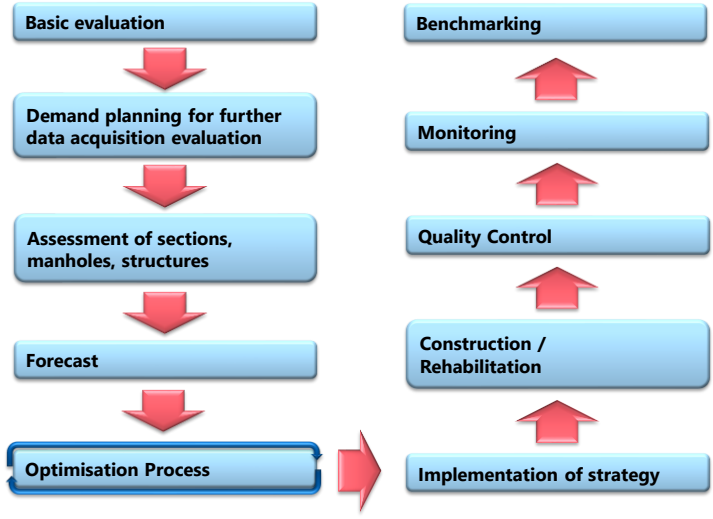
Asset-Management
ISO 55002, 2014

- The organization should be able to create and demonstrate a link between the actions that address the risks and the organization's approach to risk management and business continuity planning.
  - …
  - Evaluate the level of risk
  - Evaluate the level of risk over time
  - Evaluate the tolerability of the risks
  - Determine treatment of the risks
  - …

See also ISO/TC 224: Guidelines for management of assets of water supply and wastewater systems – Part 3 Wastewater collection networks (2016)

Asset Management
It is all about money

Asset Management Process



Benefits of our asset management process

- Total cost of ownership
- Net asset (present) value
- Return on capital employed
- Performance against plan
- Level of service
- Return on investment
- Asset system availability
- Asset system performance
- Life cycle cost
- Life expectancy
- …

- Optimization/ stabilization/ consolidation of:
  - financial needs
  - wastewater fees/ revenues
  - rehabilitation length/ volume
- determination of future
  - rehabilitation and investment needs
  - human resources according to rehabilitation needs

- improving the information base for external consultants and auditors
- improving the communication between technical and financial management
- improving transparency of the utility to their respective customers
- …

Prevention of asset losses
State of the art in the creation of rehabilitation / investment plans

Thesis

Your Rehabilitation- and investment plans for parts of networks and entire networks are wrong!

Reason

- The database used is insufficient
- (Only a certain percentage of the network is inspected and these data are often not correct and plausible)

- Defect assessment is carried out over two and more decades. Only a minor amount of defect data represent the current situation
- Condition Class as a criterion for the present function fulfilment / urgency of rehabilitation is insufficient to derive rehabilitation decisions
- All plans are based on the assumption that the structural condition of objects is maintained between CCTV inspection and rehabilitation

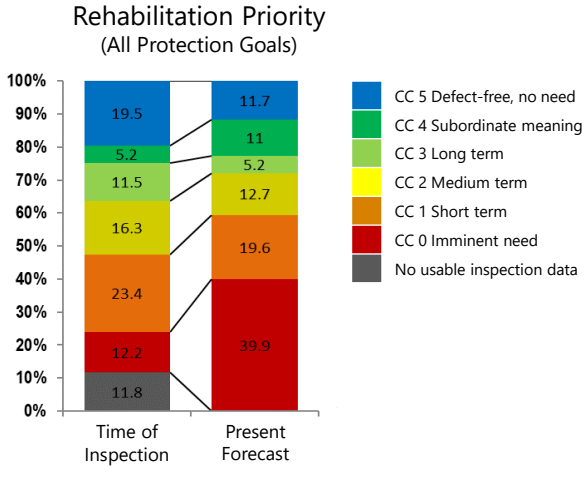
Condition class

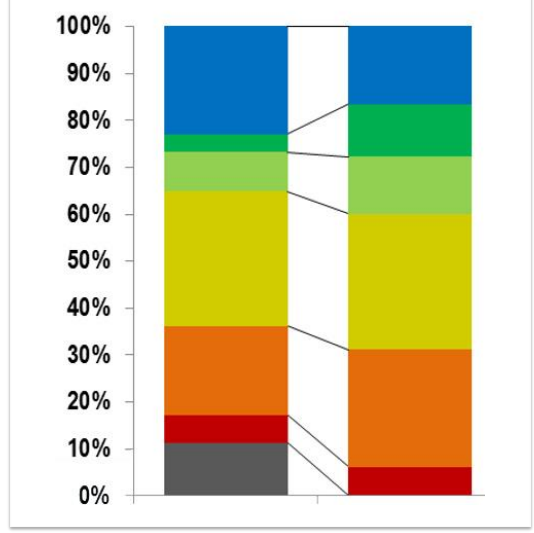
Condition Class (Priority)
Criterion for the present function fulfilment ⇒ **Rehabilitation priority**

Consideration of the most severe single defect

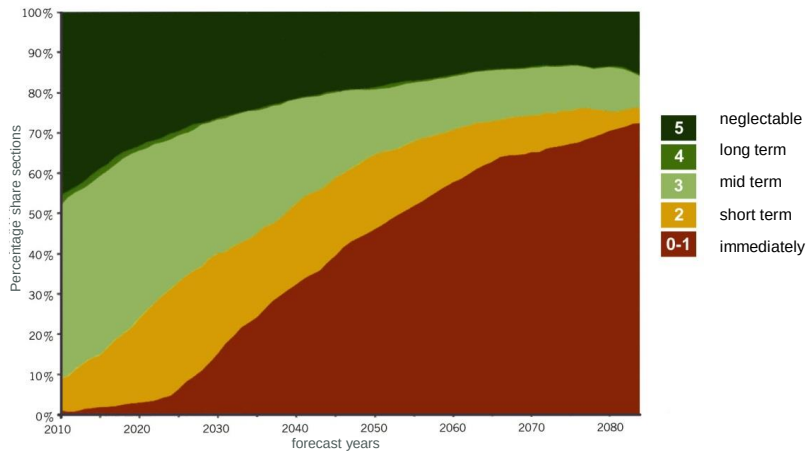
CC 0	Defect-free, no need
CC 1	Subordinate meaning
CC 2	Long term
CC 3	Medium term
CC 4	Short term
CC 5	Imminent need

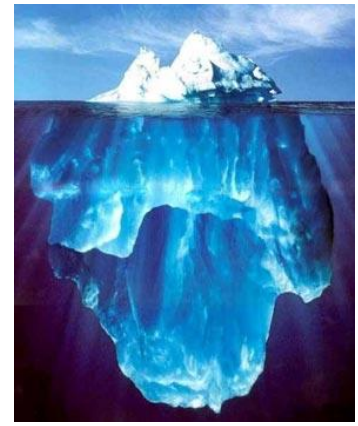
Condition class
Comparison inspection time vs. present forecast





Condition class
Evaluation of the development over time (Düsseldorf, Germany)





Fabric deterioration class (Section Assessment)

Imminent need for action

Car 1
two very server defects

Function not usable
Condition Class – –

Car 2
many moderately severe defects

Function usable
Condition Class +

Need for action in the medium term

Function	→ **Condition Class** (Development of risks, urgency of rehabilitation)
Value	→ **Fabric Deterioration Class** (deterioration, life cycle or service life)

Fabric deterioration class (Section Assessment)

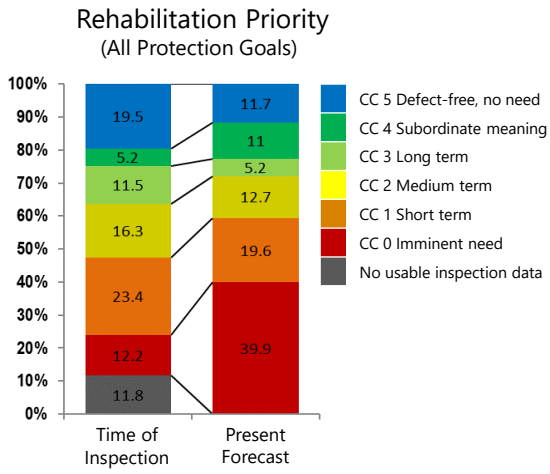
Fabric Deterioration Class

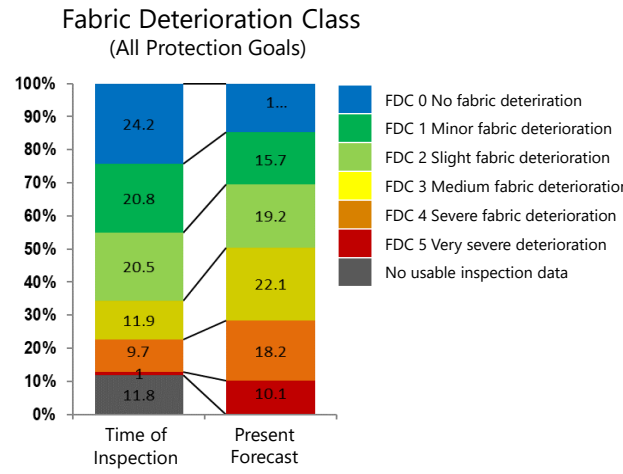
Criterion for the remaining service level (performance reserve, asset deterioration / erosion) ⇒ **Rehabilitation type**

Consideration of distribution, extent and degree of the defects

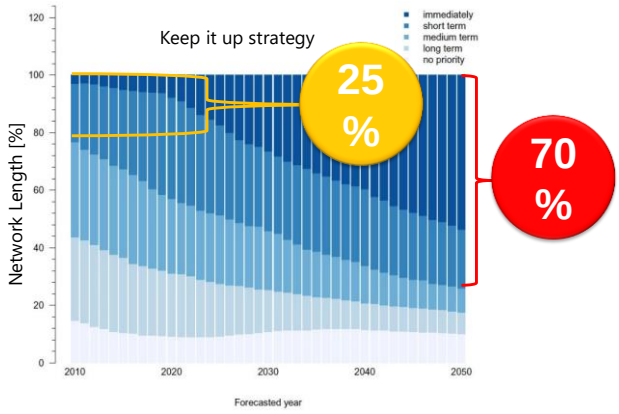
FDC 0	No fabric deterioration
FDC 1	Minor fabric deterioration
FDC 2	Slight fabric deterioration
FDC 3	Medium fabric deterioration
FDC 4	Severe fabric deterioration
FDC 5	Very severe fabric deterioration

Fabric deterioration class
Comparison inspection time vs. present forecast

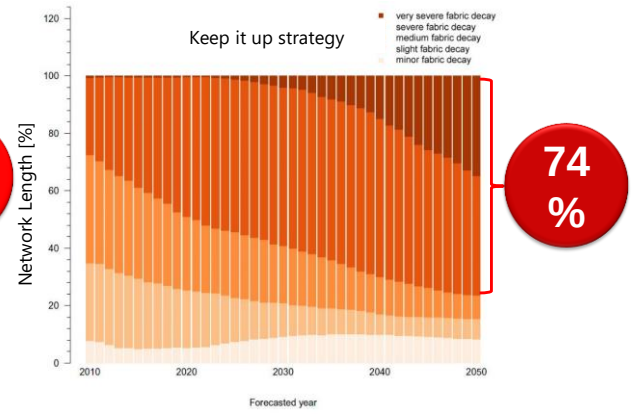




Condition class and Fabric deterioration class Development over time

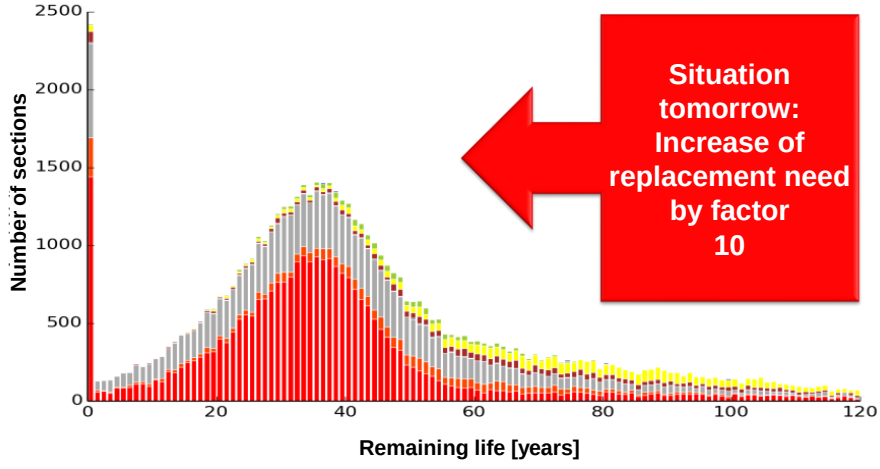


Development of the condition classes for the next 40 years to come starting in 2010 (time of assessment) [S&P]



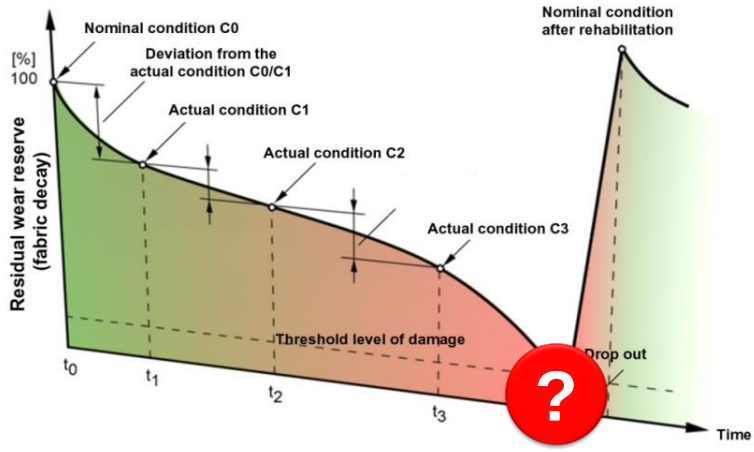
Development of the fabric deterioration classes for the next 40 years to come starting in 2010 (time of assessment) [S&P]

Development of the need for replacement (probability of default)



Distribution of the remaining life based on a Monte-Carlo Simulation

Sustainability risk



Sustainability risk

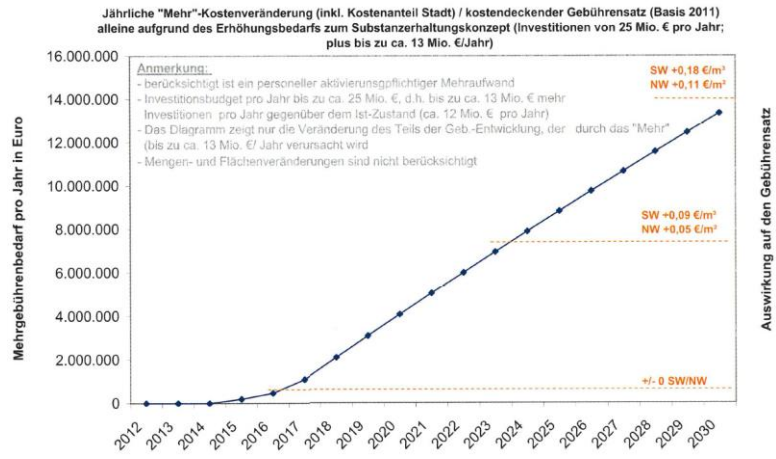
New insights into the useful life of sewers have to be taken into account for fee calculation, since changes in the useful life lead to changes in the calculation of the imputed depreciation and interest and thus in fees.

Missing of the right time for a renovation causes:

- 4-5 times higher costs
- Interest losses
- Depreciation losses (losses from write-downs on financial investments)

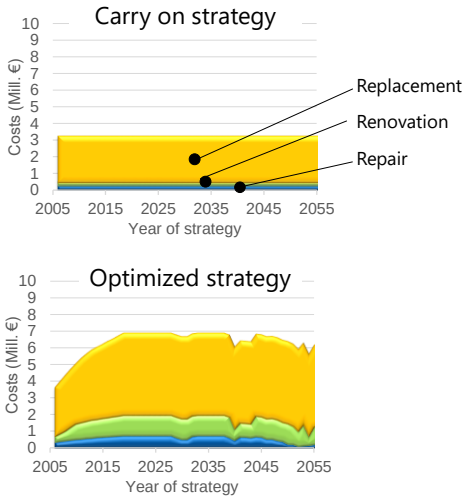
Results of asset management process
Example state capital Düsseldorf, Germany

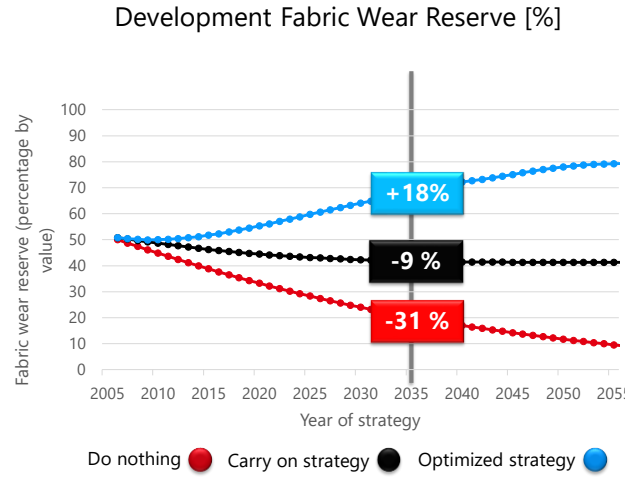
"*This means an increase in the fees for the implementation of the asset conservation concept up to the year 2023 of a total of 0.09 Euro per m³ of wastewater, or 0.05 Euro per m² of connected rainwater*"



Source: City Düsseldorf

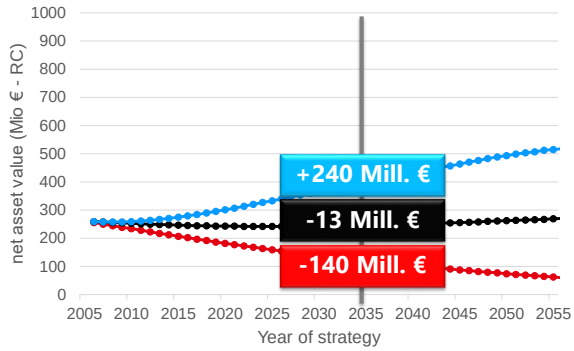
Results of asset management process
Example for 500 km



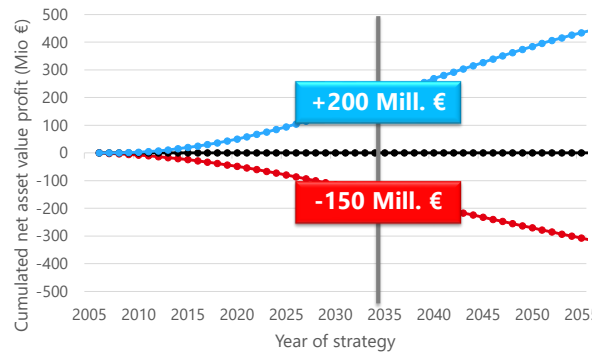


Results of asset management process
Example for 500 km

Net asset value (replacement costs)



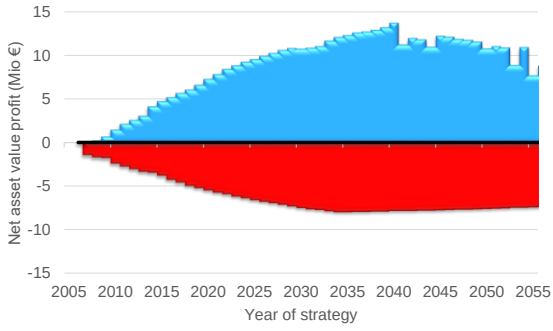
Cumulative net asset value profit (Mio €)



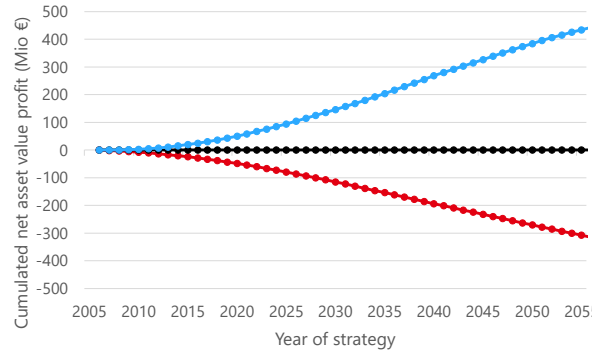
Do nothing Carry on strategy Optimized strategy

Results of asset management process
Example for 500 km

Net asset value profit / Resilience (Mio €)

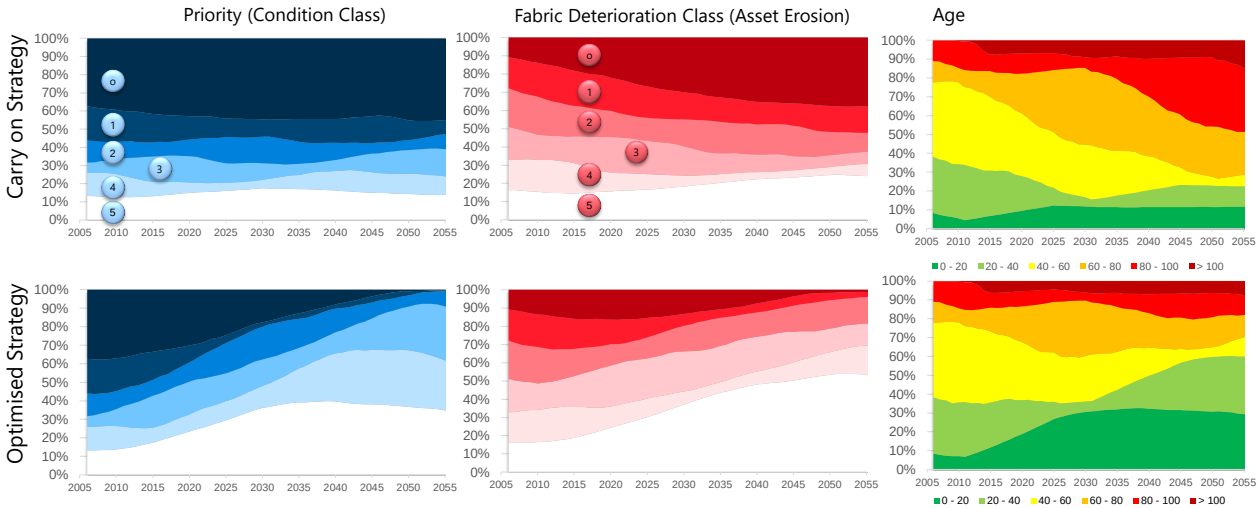


Cumulative net asset value profit (Mio €)

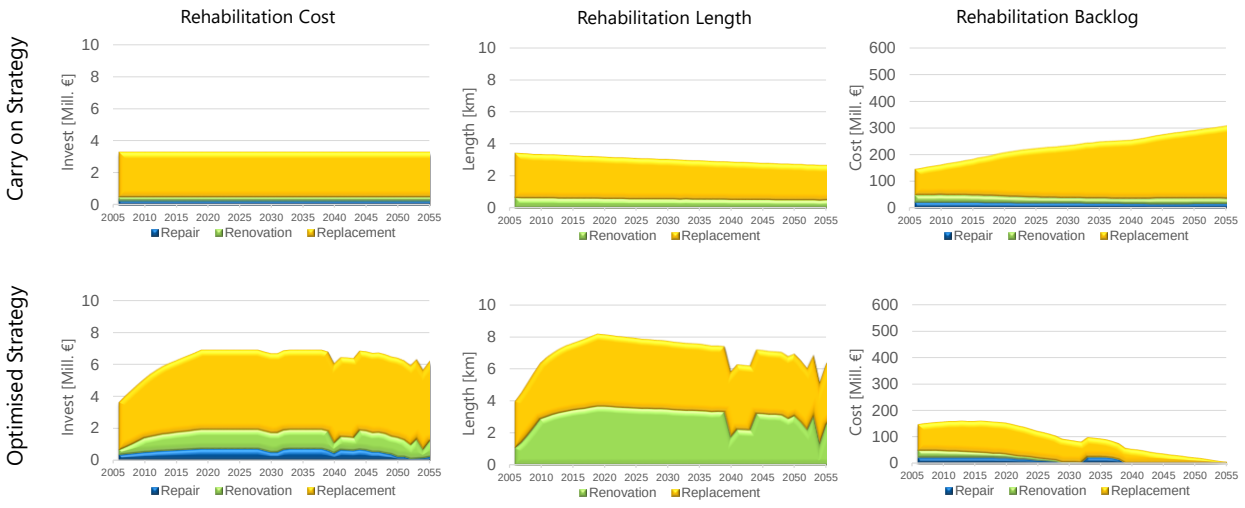


Do nothing Carry on strategy Optimized strategy

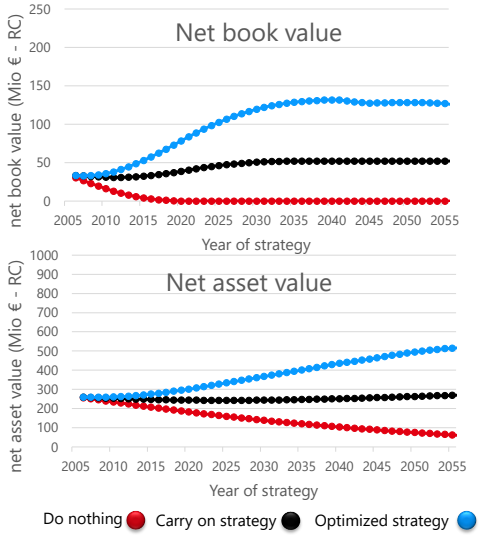
Results of asset management process
Example for 500 km

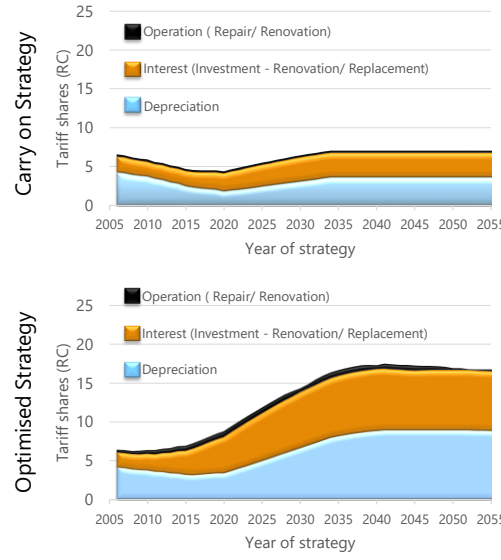


Results of asset management process
Example for 500 km

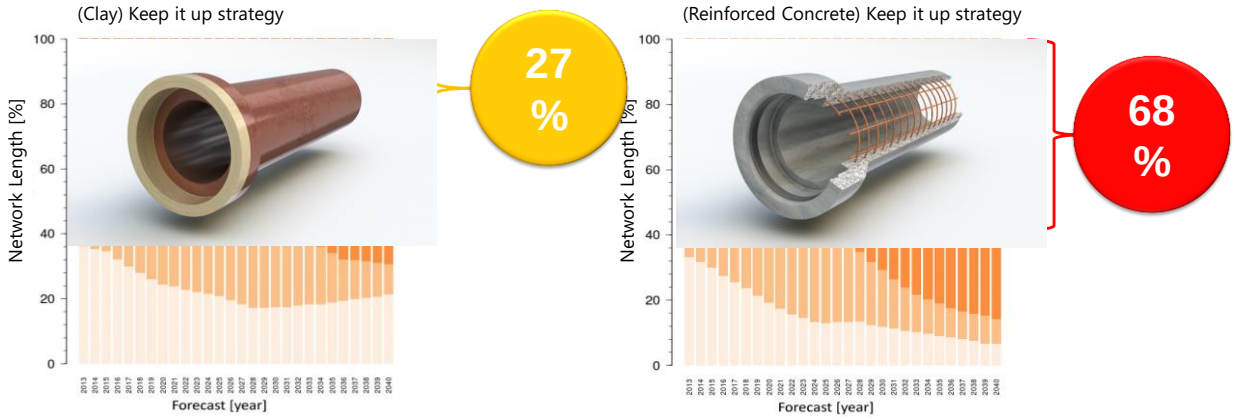


Results of asset management process
Example for 500 km



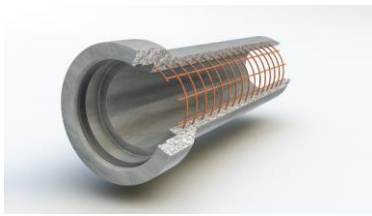


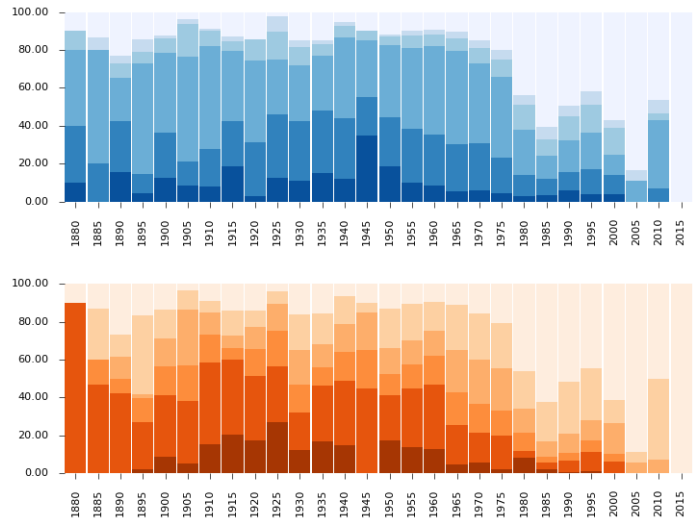
Results of asset management process
Further example



Development of the fabric deterioration classes for the next 37 years to come starting in 2013 (Clay and Concrete pipes)[S&P]

Results of asset management process
Class shares after year of construction for concrete (CC / FDC)

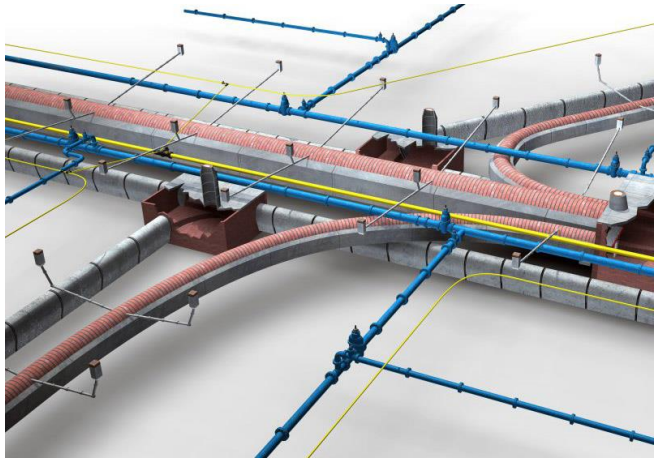




Results of asset management process

Strategies		Null-strategy (zero maintenance)	Carry-on strategy	Budget-plus strategy	Sustainable strategy	Optimized strategy
Repair	Cost	0,00 Mio €	18,50 Mio €	18,50 Mio €	35,39 Mio €	40,49 Mio €
	Cost Ø p.a.	0,00 Mio €	0,25 Mio €	0,25 Mio €	0,48 Mio €	0,55 Mio €
Renovation	Cost	0,00 Mio €	14,80 Mio €	14,80 Mio €	74,00 Mio €	83,57 Mio €
	Cost Ø p.a.	0,00 Mio €	0,20 Mio €	0,20 Mio €	1,00 Mio €	1,13 Mio €
Replacement	Cost	0,00 Mio €	207,20 Mio €	318,20 Mio €	236,80 Mio €	314,02 Mio €
	Cost Ø p.a.	0,00 Mio €	2,80 Mio €	4,30 Mio €	3,20 Mio €	4,24 Mio €
Priority	Strategy start (number)	64,98 %	64,07 %	63,85 %	63,30 %	64,03 %
	Difference Ø p.a. (number)	0,45 %	0,05 %	-0,09 %	-0,32 %	-0,46 %
	Strategy end (number)	98,22 %	67,80 %	56,84 %	39,69 %	30,05 %
Wear reserve (Fabric deterioration)	Strategy start (number)	51,67 %	52,36 %	52,58 %	52,87 %	52,37 %
	Difference Ø p.a. (number)	-0,66 %	-0,17 %	0,06 %	0,18 %	0,38 %
	Strategy end (number)	3,02 %	40,12 %	56,83 %	66,48 %	80,56 %
	Strategy end (RC)	2,76 %	40,91 %	57,06 %	66,99 %	80,75 %
Network value (RC)	Net asset value (start of strategy)	255,49 Mio €	259,23 Mio €	260,72 Mio €	262,04 Mio €	259,30 Mio €
	Net asset value (Difference Ø p.a.)	-3,18 Mio €	0,56 Mio €	2,14 Mio €	3,09 Mio €	4,49 Mio €
	Net asset value (end of strategy)	20,33 Mio €	300,57 Mio €	419,18 Mio €	490,97 Mio €	591,40 Mio €
	Depreciated book value (start of startegy)	30,56 Mio €	33,45 Mio €	34,91 Mio €	34,62 Mio €	33,45 Mio €
	Depreciated book value (Difference Ø p.a.)	-0,41 Mio €	0,25 Mio €	0,54 Mio €	0,83 Mio €	0,97 Mio €
	Depreciated book value (end of strategy)	0,01 Mio €	51,92 Mio €	74,71 Mio €	95,67 Mio €	105,36 Mio €
Balance sheet (RC)	Rehabilitation cost (total)	0,00 Mio €	**240,50 Mio €**	351,50 Mio €	346,19 Mio €	**438,08 Mio €**
	Rehabilitation cost (Ø p.a.)	0,00 Mio €	3,25 Mio €	4,75 Mio €	4,68 Mio €	5,92 Mio €
	Net asset value profit/losses (total)	-235,16 Mio €	41,34 Mio €	158,46 Mio €	228,93 Mio €	332,10 Mio €
	Book value profit/ losses (total)	-18,77 Mio €	21,82 Mio €	42,11 Mio €	38,04 Mio €	41,61 Mio €
	Revenue & Losses (total)	40,98 Mio €	471,95 Mio €	652,44 Mio €	836,81 Mio €	1.033,13 Mio €
	Added value (total)	-194,18 Mio €	**272,79 Mio €**	459,40 Mio €	719,55 Mio €	**927,15 Mio €**

STATUS - Deterioration model, Strategy development, analysis and -optimization



"Germany – Land of Ideas" is the competition "365 Landmarks in the Land of Ideas", which awards ground-breaking and innovative ideas

On behalf of the President of Germany
Dr. Horst Köhler

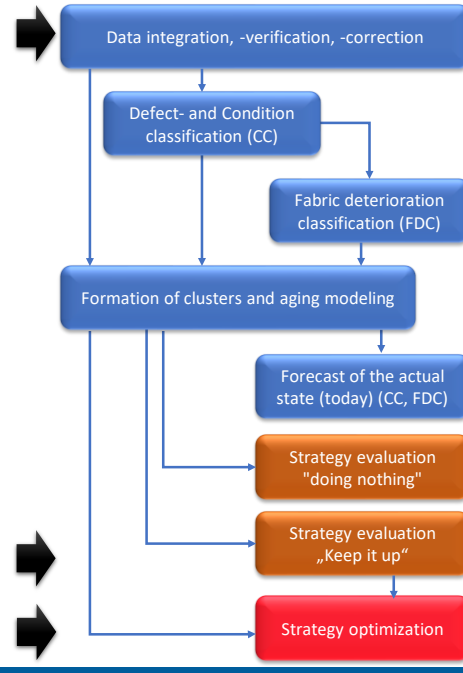
Process

Input

1. Database (master, condition, hydraulic, cost data, etc.)
2. Current budget requirements and restructuring parameters
3. Planned budget requirements and restructuring parameters

Output

1. Complete, compatible, up-to-date, consistent, plausible and accurate database
2. Object specific assessment of individual defects and determination of condition classes for the protection goals (tightness, operation, structural stability)
3. Object specific assessment of the fabric deterioration class for the protection goals (tightness, operation, structural stability)
4. Object specific assessment of all objects in relation to condition class and fabric deterioration class taking into account the protection goals (tightness, operation, structural stability)
5. Natural aging development of the network without investment: Object specific residual service life analysis, net asset value development, condition class, fabric deterioration class development
6. Reference strategy (impact analysis) with the help of which the previous procedure can be analysed and examined for its future stability and sustainability



Differentiated defect classification

Common systems:

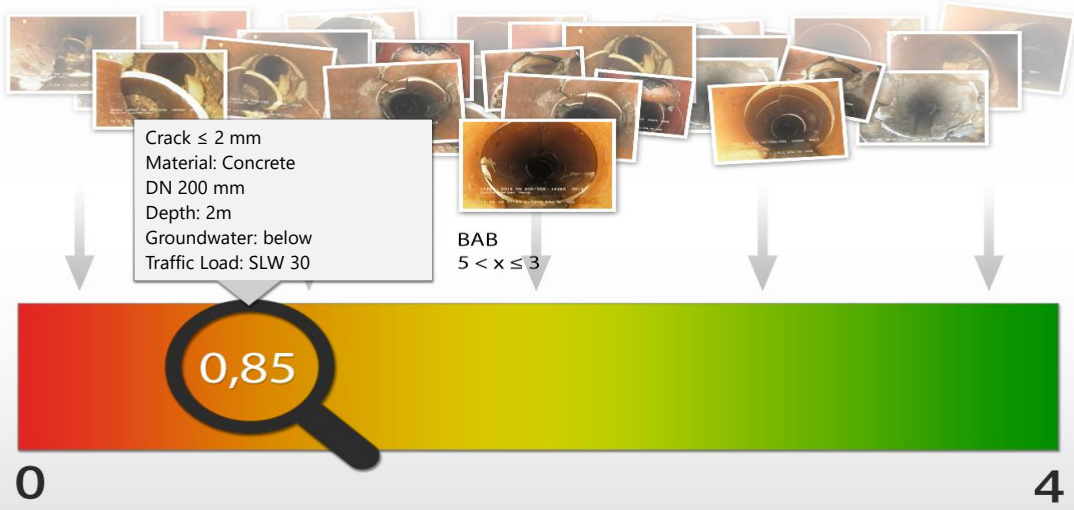
- Defect type and extend
- Tightness, defect location
- Binary assessment logic

STATUS Sewer:
+ Material
+ Diameter
+ Wall thickness
+ Ground water level
+ Surrounding soil
+ Load impact

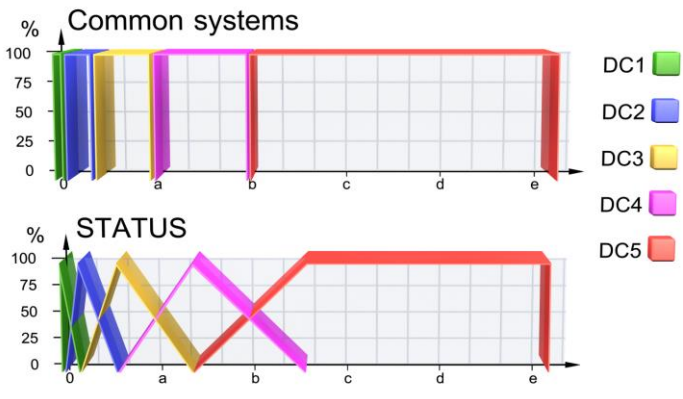
Differentiated defect classification
Loss of information with conventional procedure

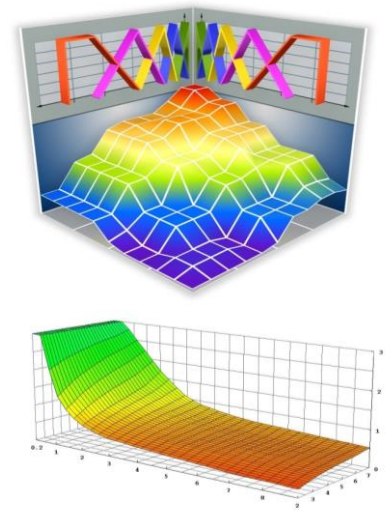
Information losses are to be avoided in the calculation process.

Differentiated defect classification
No loss of information



Differentiated defect classification
Fuzzy process

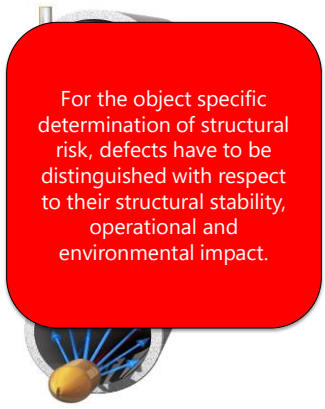




Abolishment of the strict condition class limitations

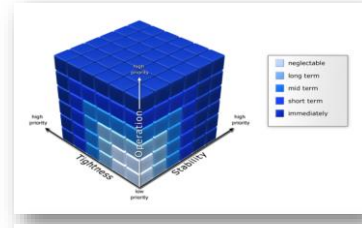
Differentiated defect classification
Consideration of protection goals

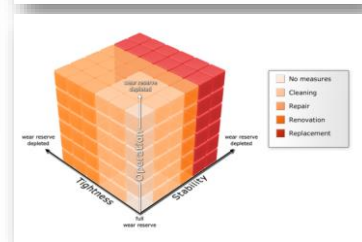
Differentiation with respect to functional requirements leads to a quadrupling of the required calculations



For the object specific determination of structural risk, defects have to be distinguished with respect to their structural stability, operational and environmental impact.

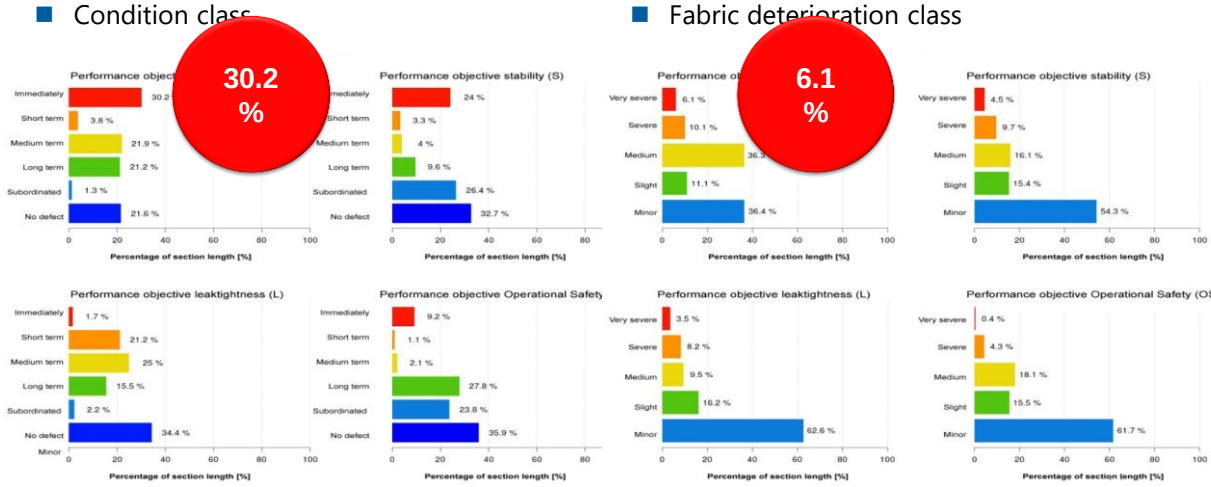
Tightness	Structural Stability	Operation



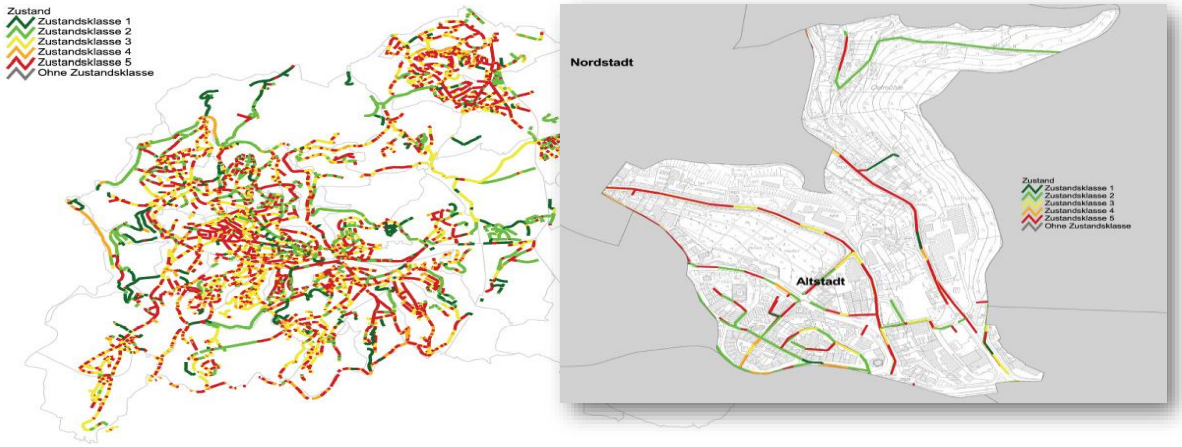


Section assessment
Condition class and fabric deterioration class distribution

- Condition class
- Fabric deterioration class

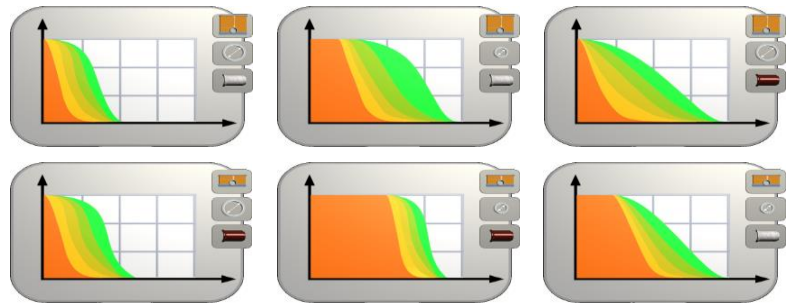


Forecast condition class (priority) - Today



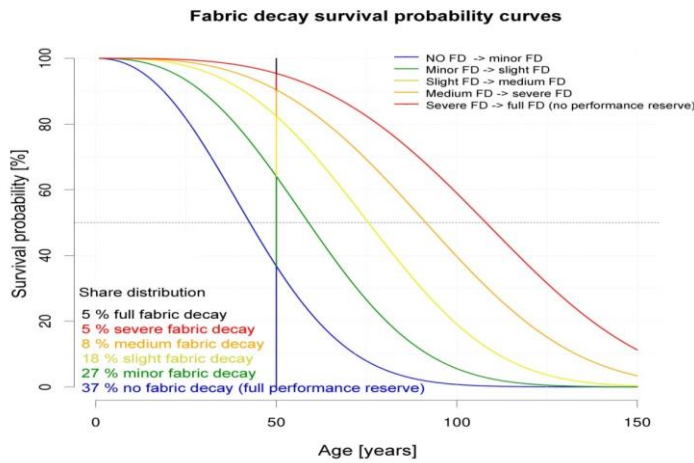
Forecast fabric deterioration class – Today

Clustering of the network
Determination of the survival functions



- Clustering of the network to determine of the survival functions

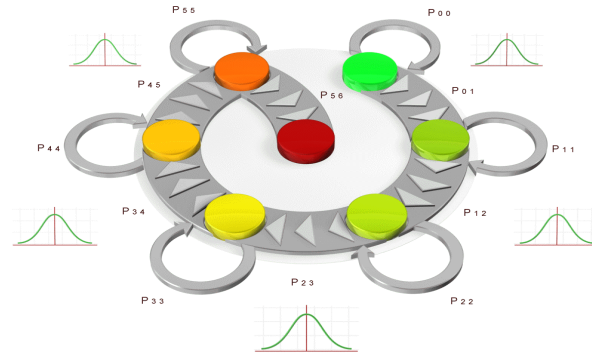
Clustering of the network
Determination of the survival functions



Mathematical forecasting model Semi-markov-chains

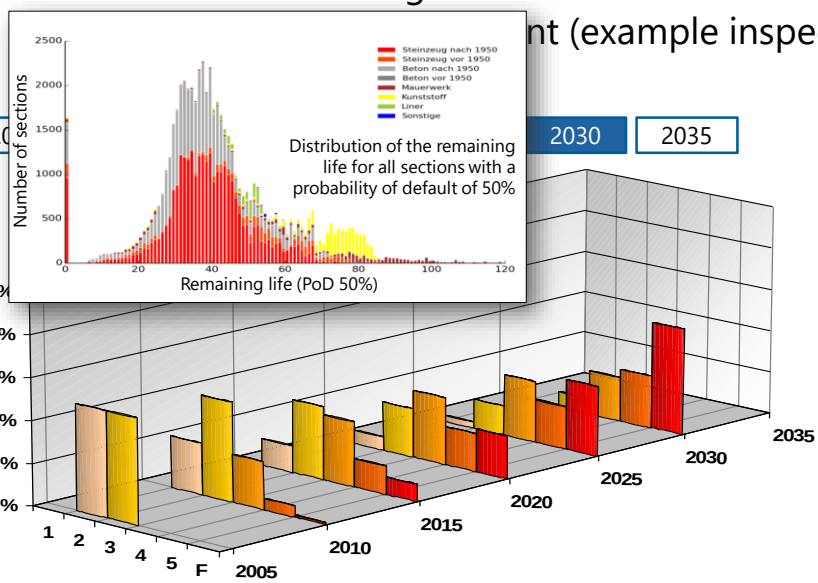
Basement are unidirectional semi-markov-chains

- Determination of the transition probabilities of a section between the different classes into the next condition/ substance class
- Determination of the state probabilities of a section within the different condition/ substance classes
- Determination of condition and substance from the state probabilities



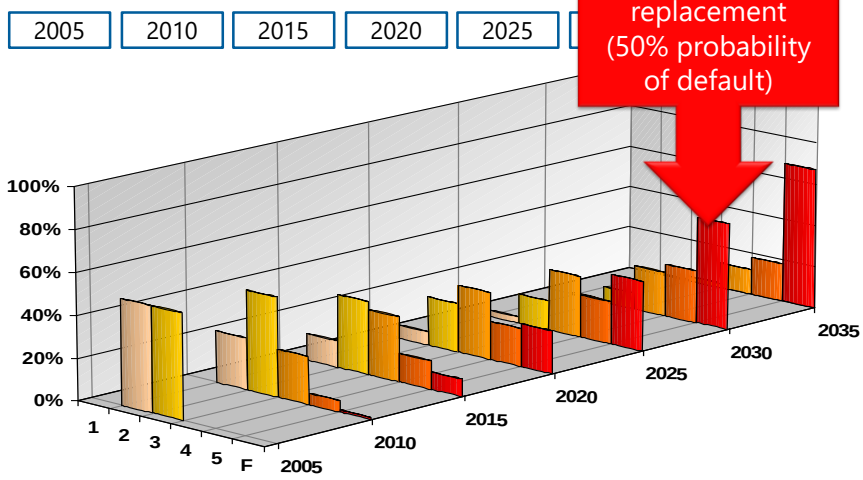
Mathematical forecasting model

nt (example inspected section)



Probability	
Fabric deterioration class 1	
Fabric deterioration class 2	1.2%
Fabric deterioration class 3	7.7%
Fabric deterioration class 4	21.0%
Fabric deterioration class 5	25.0%
Probability of default (Failure probability)	51.0%

Mathematical forecasting model
Fabric deterioration developmer ected section)



Probability	
Fabric deterioration class 1	
Fabric deterioration class 2	0.4%
Fabric deterioration class 3	2.0%
Fabric deterioration class 4	12.0%
Fabric deterioration class 5	18.0%
Probability of default (Failure probability)	67.0%

Strategy development and analysis

The implementation of strategies often fails because the strategies:

- are interpreted differently
- and not completely understood

by

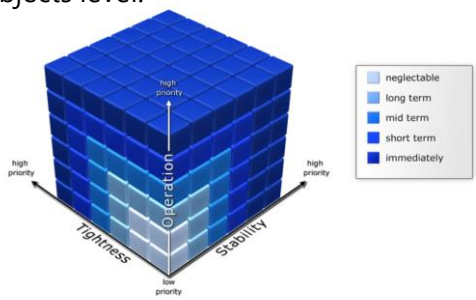
- management (economical decision maker) and
- staff (technical decision maker).

In the process of strategy optimization all relevant boundary conditions, as well as specific requirements of the network operator must be taken into account.

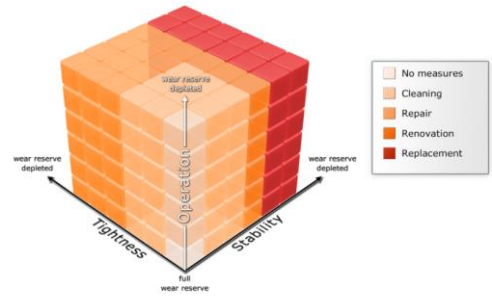
Therefore strategies should have a clear structure and should be easily understandable.

Strategy development and analysis

The structural criteria in the form of object specific condition and fabric deterioration classes results in the significant opportunity to connect rehabilitation decisions regarding **rehabilitation priority** (Priority of intervention) and **rehabilitation type** (type of intervention) on objects level.

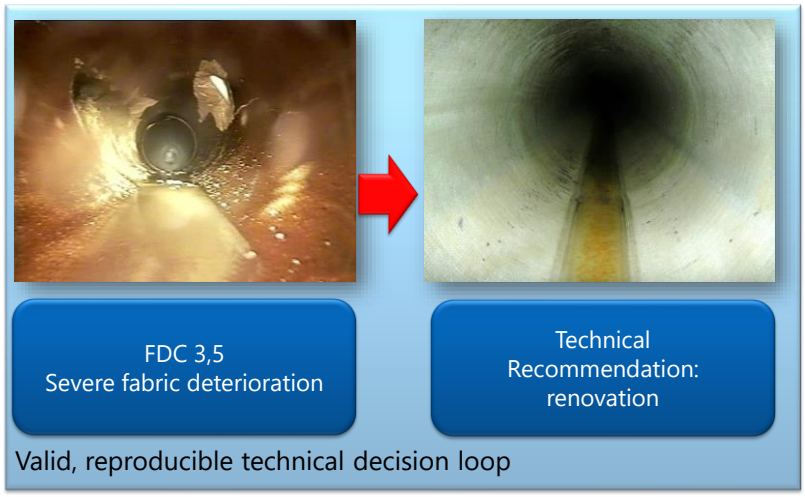


Rehabilitation Priority



Rehabilitation Type

Strategy development and analysis
Decision tree



Strategic decision
depends on the remaining depreciation period, remaining useful life, rehabilitation priority
→ e.g.
no renovation, since no service life extension due to CIPP by 10 years

Strategy development and analysis
Further aspects influencing the rehabilitation strategy

The aging model must be able to process any complex decision trees, which reflect the decision-making process of the Client. So further parameters need to be part of the analysis process.

Parameters of various decision trees, in addition to the **condition** and **fabric deterioration** class and yearly **budget** are:

- Depreciation (Year),
- Type of drainage system,
- Spatial position in the drainage area,
- Distance to the groundwater,
- Hydraulic load,
- Pipe material,
- Depth of cover,
- Diameter,
- Combination with large measures or other sectors,
- Effluent quality, etc.

Results per strategy

Object-specific development of condition classes	Object-specific development of fabric deterioration classes	Object-specific development of age groups and age distribution	Mean condition development (comparison of all strategies)
Mean fabric deterioration development (comparison of all strategies)	Development of average construction year distribution	Mean remaining useful life for all objects and individual clusters	Object specific expectation values for the remaining useful life
User fees necessary	Development of fixed assets / net book values	Development of maintenance costs	Development of maintenance/ rehabilitation lengths [km, mi]

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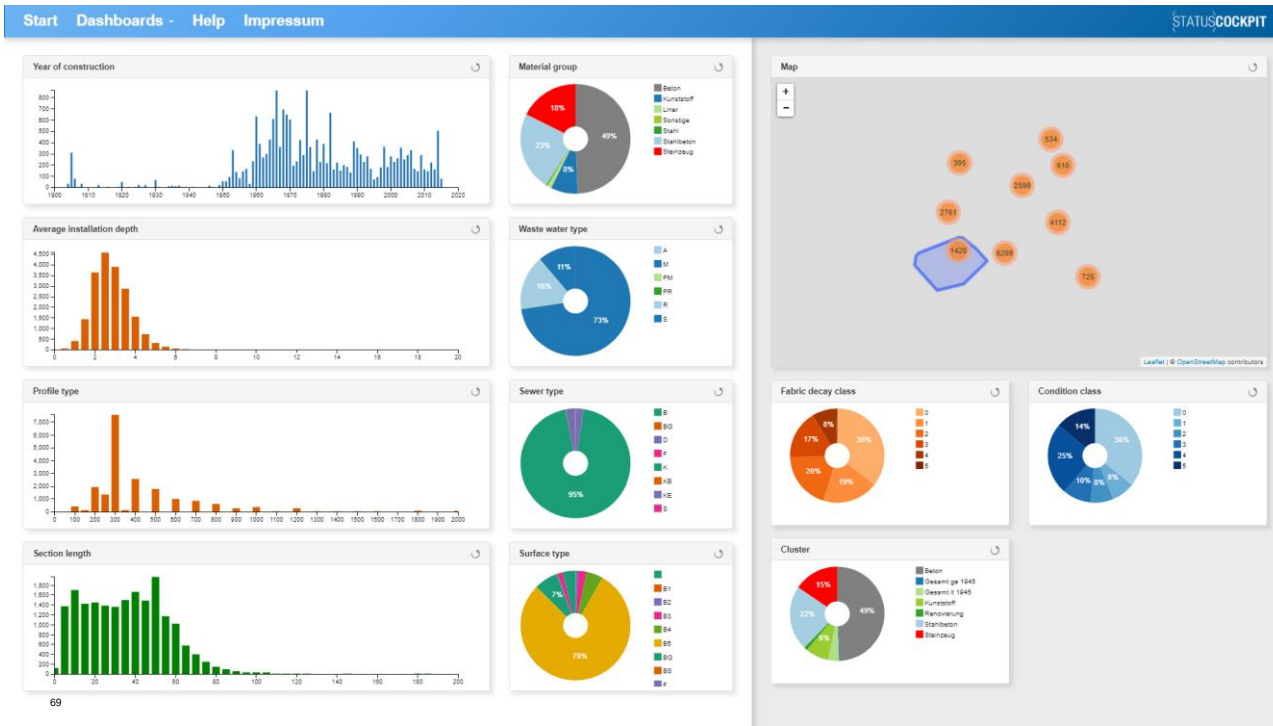
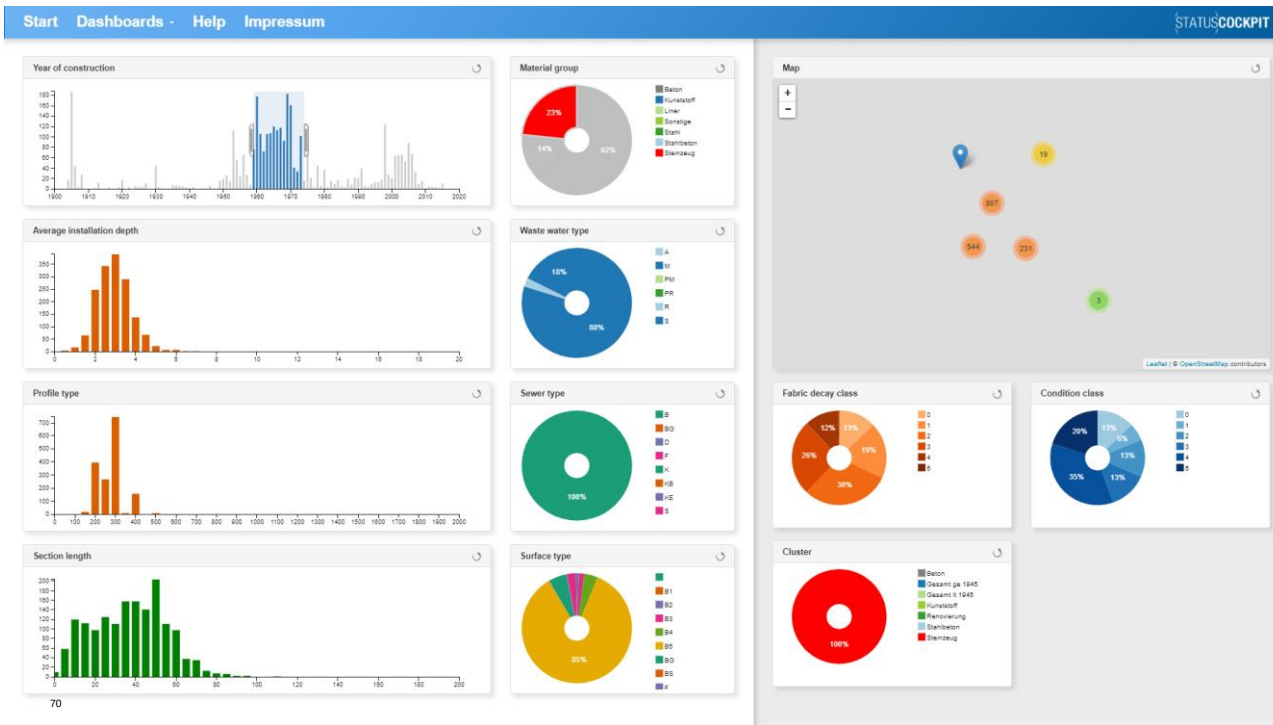
Monitoring

Monitoring STATUS Cockpit


Start
Dashboards
Help
Impressum
STATUSCOCKPIT
Year of construction
Material group
Map
Average installation depth
Waste water type
Profile type
Sewer type
Fabric decay class
Condition class
Section length
Surface type
Cluster

69


Start
Dashboards
Help
Impressum
STATUSCOCKPIT
Year of construction
Material group
Map
Average installation depth
Waste water type
Profile type
Sewer type
Fabric decay class
Condition class
Section length
Surface type
Cluster

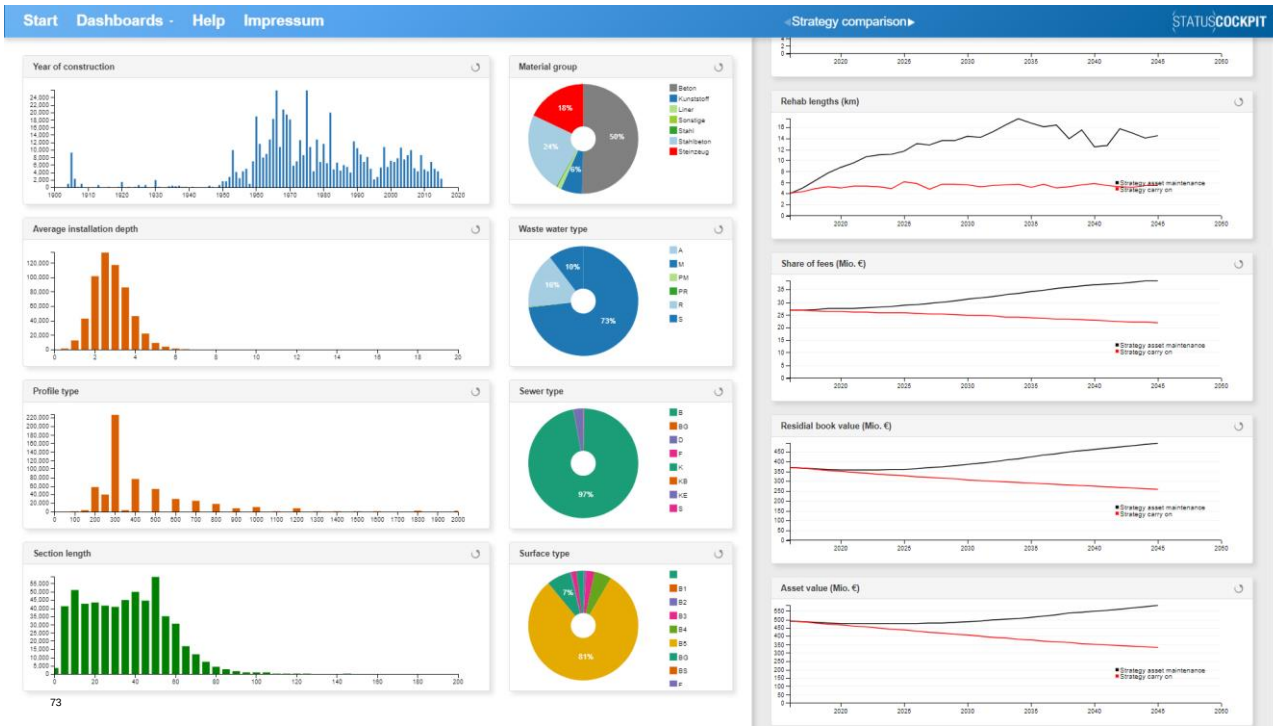
70


Start
Dashboards
Help
Impressum
STATUSCOCKPIT
Year of construction
Material group
Remaining life - 30 % probability of failure WBK (Mio. €)
Average installation depth
Waste water type
Remaining life - 50 % probability of failure WBK (Mio. €)
Profile type
Sewer type
Remaining life - 70 % probability of failure WBK (Mio. €)
Section length
Surface type
Remaining life - Monte Carlo WBK (Mio. €)

71


Start
Dashboards
Help
Impressum
STATUSCOCKPIT
Year of construction
Material group
Remaining life - 30 % probability of failure WBK (Mio. €)
Average installation depth
Waste water type
Remaining life - 50 % probability of failure WBK (Mio. €)
Profile type
Sewer type
Remaining life - 70 % probability of failure WBK (Mio. €)
Section length
Surface type
Remaining life - Monte Carlo WBK (Mio. €)

72


Start
Dashboards
Help
Impressum
Strategy comparison
STATUSCOCKPIT
Year of construction
Material group
Beton
Kunststoff
Liner
Sonstige
Stahl
Stahlbeton
Steinzeug
18%
50%
24%
6%
Rehab lengths (km)
Average installation depth
Waste water type
A
M
PM
PR
R
S
10%
16%
73%
Share of fees (Mio. €)
Profile type
Sewer type
B
BG
D
F
K
KB
KE
S
97%
Residial book value (Mio. €)
Section length
Surface type
B1
B2
B3
B4
B5
BG
BS
F
7%
81%
Asset value (Mio. €)
Strategy asset maintenance
Strategy carry on

73


Start
Dashboards
Help
Impressum
Strategy carry on
STATUSCOCKPIT
Year of construction
Material group
Beton
Kunststoff
Liner
Sonstige
Stahl
Stahlbeton
Steinzeug
18%
50%
24%
6%
Share of fees (Mio. €)
Average installation depth
Waste water type
A
M
PM
PR
R
S
10%
16%
73%
Rehab lengths (km)
Profile type
Sewer type
B
BG
D
F
K
KB
KE
S
97%
Rehab costs (Mio. €)
Section length
Surface type
B1
B2
B3
B4
B5
BG
BS
F
7%
81%
Distribution of fabric decay classes

74

75

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