Status evaluation of water supply systems

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Summary: The condition of the water supply network is a measure of the substance of the system quality as well as the availability towards consumers. Therefore, it is necessary for the system components and system condition to be clearly and unambiguously documented. The foundation for the assessment of the systems is systematic inspection and service as well as its documentation and an assessment of the results. The legislators and the trade associations have developed guidelines regarding the type and frequency of inspections that are to be conducted so that recommendations and threshold values can be consulted for an assessment of the condition of the systems.

Due to the complex structure of the supply systems, the inventory data of the pipelines is managed in a Geographical Information System (GIS). This technique permits consistent data management from the consumers right up to the internal parts and systems in a graphical and alphanumerical form. This data inventory is the basis for the systematic inspection, service, and maintenance of the supply system. The results of the inspections are assessed. Necessary appraisals of repairs are entered in the damages file and analysed selectively. With this approach, limited resources are used optimally and a sustainable drinking water supply is guaranteed.

Keywords: Inspection and service of supply systems, water losses, damage statistics, specifications for assessing the condition, inspection strategy, pipe replacement, balance between maintanace costs- investment costs and budget, Geographic Informations System GIS.

1. Introduction

Companies for public water supply must manage two basic tasks:

- fulfilment of the public mandate (customer satisfaction, availability, corporate image, and reducing and keeping the pipeline network losses low and having low risks from external influences)
- efficient business management (cost of supply, corporate success and a long-term cost and rate structure)

The extent to which the company succeeds in striking a balance between these two tasks and successfully manages them is determined by the quality of the management and the long-term value of the supply systems.

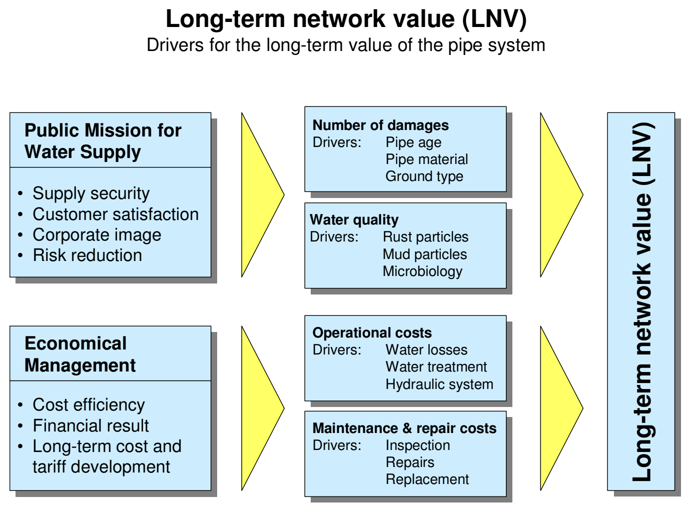


Figure 1: Factors influencing the management of the pipeline network

The condition of the pipeline system is determined by the level of annual pipeline network losses and the amount of damage or alternatively repairs. For the definition of the amount of damage, it is important for leak testing to be performed continuously so that these figures refer to existing and not to (coincidentally) discovered damage.

This group of rules refers to the systems and internal parts of the supply systems that have to be checked, the recommended measures, and the time intervals.

Besides inspection of the systems and internal parts, documentation of their condition and certification of the work carried out is also necessary.

2. Recording the Condition of the Pipeline Systems

Pipeline systems consist of pipelines (feed lines, main lines, supply lines, and connecting lines), internal parts (valves, hydrants etc.), and fittings. Within the scope of modern company management, the pipeline system is managed in a Geographic Information System GIS. For the individual objects, there are defined procedures for inspecting or alternatively defining the condition and the functional performance.

According to DIN 31501, the following terms apply as elements of maintenance:

- Inspection: in terms of scheduled monitoring of the operating condition and regular checking of the actual condition of system components and operating equipment.
- Maintenance: in terms of constant maintenance measures to maintain the desired condition, which can take place both on a regular basis as well as event-driven.
- Repair: as unforeseeable measures as a consequence of malfunctions (repairs) as well as foreseeable measures (improvement, renewal) to restore the desired condition

2.1. Goal-Orientated Maintenance

Within the scope of goal-orientated maintenance, the operating condition of drinking water pipeline networks must be monitored regularly and their internal parts must be monitored in addition due to special circumstances to make sure they can be found, that they have no leaks, and that they work.

Inspections of the system components must be documented in suitable lists and statistics containing the day, systems used, and the respective results. The results of the inspections must be managed in damage statistics. Furthermore, a variety of information regarding events, maintenance work, costs, and assessments of the inspected items must be documented.

2.2. Reason for Inspection Work

high water losses as a result of the annual water balance

high annual damage rates

fluctuating changes to the feed quantity or damage rate

changes of pressure or pressure surges

hazardous construction measures close to the pipelines

changes to the surface of the routes

customer complaints

2.3. Inspection of the Accessibility of the Items

Pipelines and system components must be accessible for operational and maintenance work. The pipeline route must be free of buildings and other solid local obstacles. Planting of trees and bushes must be prevented to allow work on the items.

Road caps and manhole covers for internal parts and the signs must be visible and accessible. The road caps should mark each of the built-in fittings with regard to the medium and function.

2.4. Inspection for Leaks in the Lines

The type, extent, and time intervals of line inspections is mainly determined by the level of water loss according to the creation of the annual balance, according to deviation between the registered feed quantity and comparative values, according to the frequency of damage, and according to the local conditions (subsoil, pipeline material, supply pressure, and so on).

The foundation for preparing the annual loss balance requires the maintenance and analysis of all feed and delivery quantities by means of suitable measuring equipment. So-called "internal consumption" and other water deliveries that are not billed must be recorded exactly and documented.

DVGW has developed key figures that provide an approximate value for the level of pipeline losses. However, is has been established that key values for the level of water losses can only be related to local conditions, which are affected by many factors. Each company must form its own key values and derive conclusions from them for technical and economical measures.

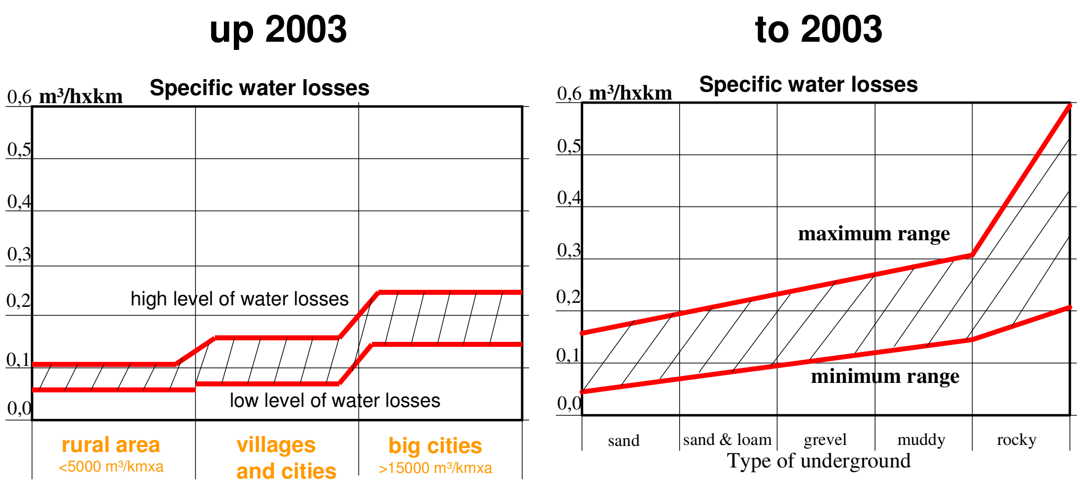


Figure 2: Key values from DVGW (W 392) with different approaches

Both key values have their justifications, but it appears that the key value up to 2003 makes the affect of the subsoil more comprehensible for the practitioner

2.5.Inspection of the Functional Operation of the Internal Parts

When the functional operation is inspected, the slide gates, hydrants, and special fittings are targeted, which must be checked regularly.

Inspection of the functional operation of internal parts, specifically shut-off devices and hydrants, essentially includes the accessibility, leaks, condition, cleanliness, cover, and functional operation.

3. Water Losses in Drinking Water Pipeline Networks

The water losses are reduced for hygienic, supply-related, ecological, and economical reasons. Low water losses are an important indicator of good pipeline network condition and lead to availability and reduced costs for maintenance.

The most accurate and comprehensive measurement possible for the water volumes fed into the pipeline network and discharged from it is an important element of determining water loss. Here, the model, installation, and size of the water meters must be selected according to the state of the art.

3.1. Calculation of Water Losses

The inflow quantity and the consumption quantity yield the difference that is sometimes referred to at the gross loss.

This difference includes

- real pipeline network losses and
- apparent losses such as:
  - meter deviations
  - creep losses
  - water theft
  - quantities provided but not billed
  - quantities for the fire department
  - internal or company consumption
  - other unrecorded quantities

It is expedient to document all unmeasured consumption quantities, even estimated quantities, for future optimisation of the “shortages”.

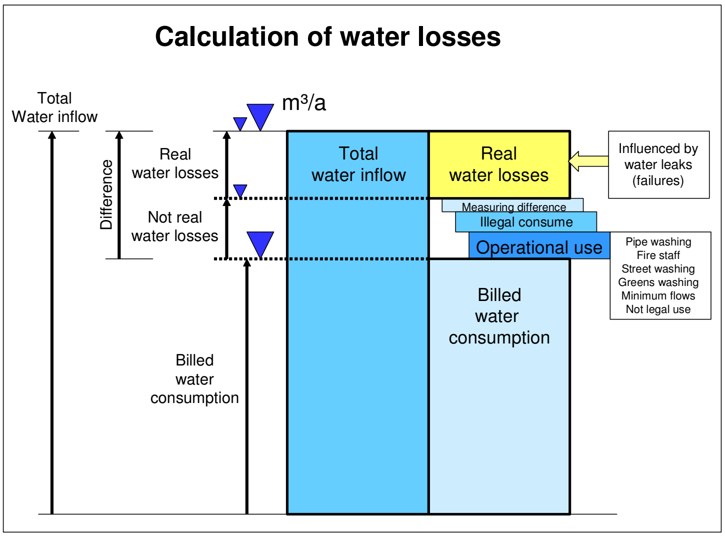


Figure 3: Quantitative calculation of water losses in a supply system

3.2. Influences of the level of Network Losses

The level of water losses are mainly influenced by the number of damages, the outflow quantity of the water trough the leak and especially by the flow time of the leak. The factor time of the outflow of the water is the main parameter.

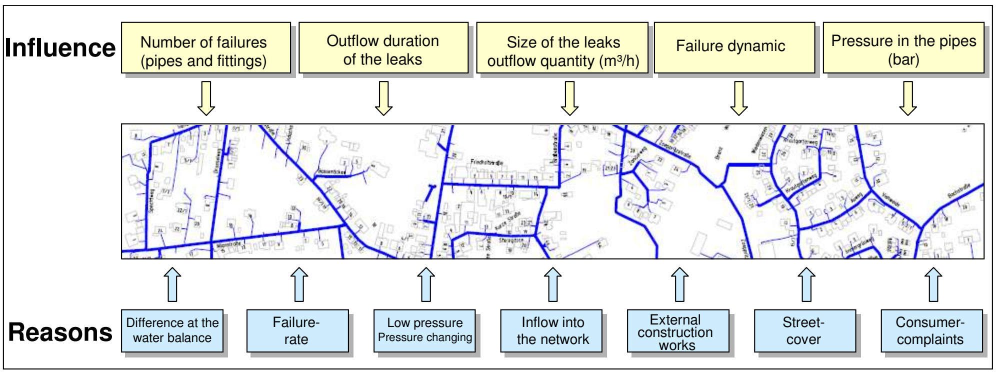


Figure 4: Influences affecting the level of water losses

Reason for the inspection and sources of the data

4. Damage Statistics

Damage statistics are entered in the PC program for all repairs made to the water supply system. The repairs are entered on a pre-made damage form with clearly defined names and terms so that all criteria are available to be analysed.

In its recommendation W 395, DVGW gives information about the required use of damage data.

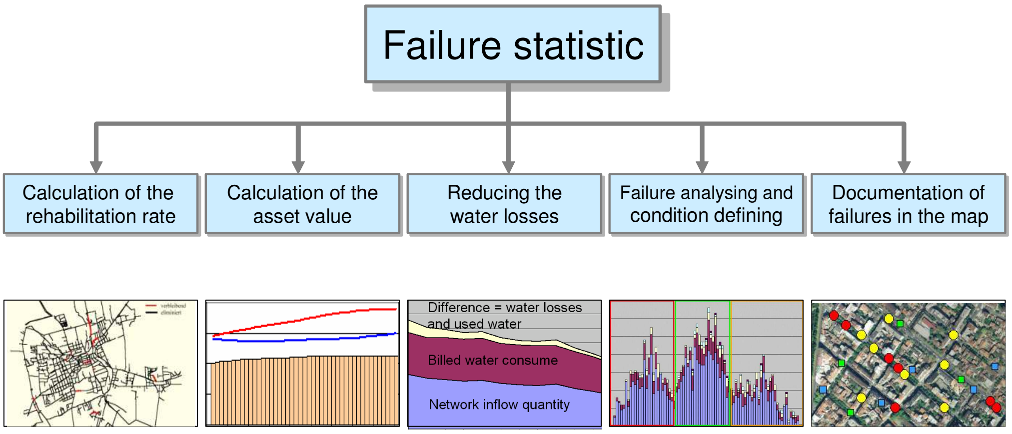


Figure 5: Influences affecting the results of damage data

It appears that to assess the condition of the supply system and to make other statements for future measures, damage data is necessary over an extended period of time so that damage trends can be recognised and evaluated.

The establishment of damage statistics is an indispensable requirement of operators of pipeline systems for the documentation and assessment of the condition of the system.

Failure data Water		**Failure number: ....**	
Place of the failure	Supply area Street name Pipe number House number	**Measure:**	Repair Separate Replacement Partly replacement Repair clamp ....
Registration	Day of information Day of repair Issue of water	**Information:**	Leak detection Issue of water Information ....
Defect on:	Transport pipe Distribution pipe Service pipe Pipe drilling Fitting	**Location:**	Measuring Correlation Acoustic
Type of the defect	Corrosion Diagonal burst Connection	**Selected information:**	

Condition of the pipe				
	Material	good	medium	bad
	Embetting	good	medium	bad
	Isolation	good	medium	bad
	Corrosion	good	medium	strong
	Controlled lenght			.... m
	Depht of the pipe			.... m

Figure 6: Example of a report on the damage data

The content of the damages file covers all the built-in components of the supply system.
The analyses and evaluations require experience and knowledge of the assessment of weak points because besides generating the statistics, these results are used to assess future investments and strategies to reduce water losses. Data from more than 10 years is necessary for a careful assessment of the pipeline condition.
Identical to the damage data, the pipeline inventory data should be managed synchronously to determine annual key values for changes to the damage dynamics. A modern GIS maintains an archive for the system inventory and the damage data. That way, the damage dynamics can be assigned to the respective current pipeline inventory of the past.

4.1. Analysis of the Damage Data:

It is important to know where the weak points in the network are located:

- in what system components
- in what streets or zones
- type of damage and cause of damage
- reason for repair (leak localisation or self evident)
- when did the damage occur or alternatively when was it repaired
- additional information about the pipeline, bedding, and measures

With this information it is possible to conduct the necessary analysis to assess the condition of the system.
The results can be statistically analysed for the entire network or individual supply zones, but also selectively for individual streets or line sections.
The analysis of the damages file is varied and is performed in accordance with the problems so that technical/economical decisions can be made.
In the following, some analyses of the damage statistics are shown which are best shown in a graphic form.

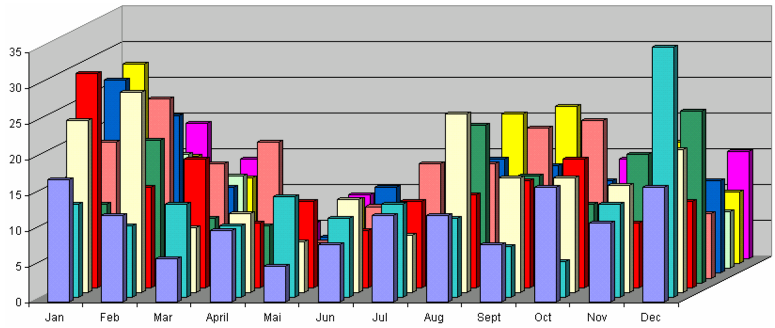


Figure 7: Monthly damage behaviour in a pipeline network over 10 years

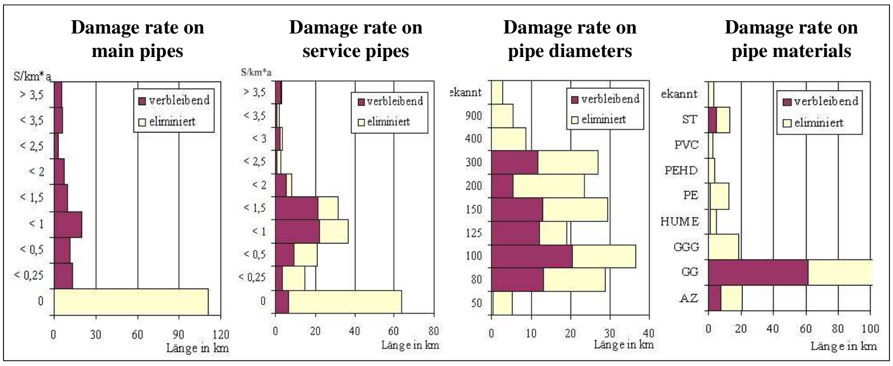


Figure 8: Damage assignment according type of line, dimensions, and material

Selected failure evaluation – Specific failure rate

Evaluation from: 01-1987 to: 12-1998

STREET		Pipe lenght (m)	No. service (Stk.)	Number of failures				Specific failure rate	
				VL	AL	Arm	Sonst	Failure pro km -VL	Failure on servicein %
0001	Abtgasse	44.00	3	2	-	-	-	45.45	-
0005	Aidlinger Straße	128.00	9	2	-	2	1	15.63	-
0010	Albrecht-Dürer-Straße	554.00	36	1	-	3	2	1.81	-
0015	Alemannenstraße	435.00	34	3	2	-	-	6.89	5.88
0017	Alexanderstraße	120.00	11	1	2	-	1	8.33	18.18
0019	Allgäuer Straße	185.00	14	2	2	1	-	10.81	14.28
0021	Allmendweg	432.00	29	3	3	2	3	6.94	10.34
0023	Alpenrosenstraße	1147.00	109	1	1	6	2	1.74	0.91
0025	Altinger Straße	152.00	11	-	2	-	-	-	18.18
0027	Am Feger	392.00	35	3	5	2	-	7.65	14.28
0029	Am Hirnach	338.00	32	1	2	3	-	2.95	6.25
0031	Amselweg	712.00	69	2	3	6	2	2.80	4.34
0033	Arthur-Gruber-Straße	126.00	14	1	1	-	-	7.93	7.16
0035	Bachstraße	298.00	31	-	3	2	1	-	9.67
0037	Bahnhofstraße	248.00	28	3	3	1	-	12.09	10.71
0039	Berliner Platz	3720.00	117	14	9	9	8	3.76	7.69
0041	Berner Straße	149.00	9	2	2	-	-	13.42	22.22
0043	Brahmsstraße	304.00	12	1	2	3	1	3.28	16.66
0045	Calwer Straße	722.00	26	3	5	4	-	4.15	19.23
0047	Chopinstraße	752.00	34	6	5	6	1	7.97	14.70
0051	Dachsweg	651.00	73	11	6	5	2	16.89	8.21
0053	Dagersheimer Straße	174.00	18	4	4	1	1	45.97	22.22

Figure 9: Key values of the damage analysis for one year sorted by streets, based on the inventory data of the pipeline system

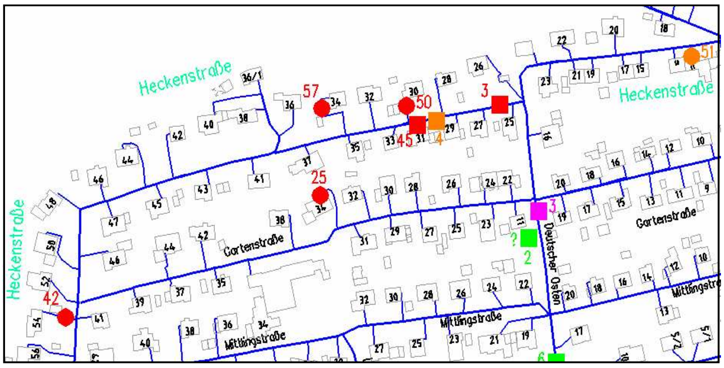


Figure 10: Local assignment of the different damage in a GIS

4.2 Key Values for Damage Rates in Supply Networks

For orientation purposes, DVGW reports guide values for damage rates. They are reported in worksheets and in the annual statistics as operating key values. The data in the following table are average values within one year.

Each supply company should maintain equivalent statistics and use them to establish a trend of a time period of at least 5 years to assess the condition of the pipeline system.

Every company must establish its own key values taking into consideration the local conditions and develop a strategy for operations management based on them.

Ranges for failure rates in the supply network	**Failure rates in the pipe network**	**Failure rates in the pipe network**	**Failure rates on fittings**	
	Mains- and supply-pipes	Service-pipes	Valves butterfly valves	Hydrants
	Failures/km*a	Failures/1000HS*a	Failures/1000pc*a	Failures/1000pc*a
Low failure rate	< 0,1	< 5	< 2	< 5
Medium failure rate	> 0,1 bis < 0,5	> 5 bis < 10	> 2 bis < 5	> 5 bis < 10
High failure rate	> 0,5	> 10	> 5	> 10

Figure 11: Key values for the assessment of the pipeline network damage rate (DVGW)

4.3 Maintaining the Substance of Pipeline Systems

The pipeline systems and facilities are constantly ageing and therefore are also more susceptible to damage and water losses. The availability become less certain and the costs for inspections and maintenance increase. As with all system components in our lives, which are in permanent use and subject to a great variety of loads, there is always wear and tear. Here, we are talking about the service life of the lines and facilities. This is the service life after which the pipelines and system components have to be renewed in order to ensure the reliability and efficiency of the supply.

To calculate the service life of the pipeline systems, the following data and information must be available:

- material
- dimensions
- year of installation or period of installation
- type of pipeline
- pipeline sections
- damages according to the results of the damage analysis with assignment to the individual pipeline sections

(The damage data from 5 or even better 10 years must be available and the pipeline components or pipeline sections must be assigned).

With this data, a service life calculation is performed for the individual pipeline sections and renewal through individual projects is established according to priority. After the economic, local, and hydraulic assessment of individual projects, they can be shown graphically in the GIS.

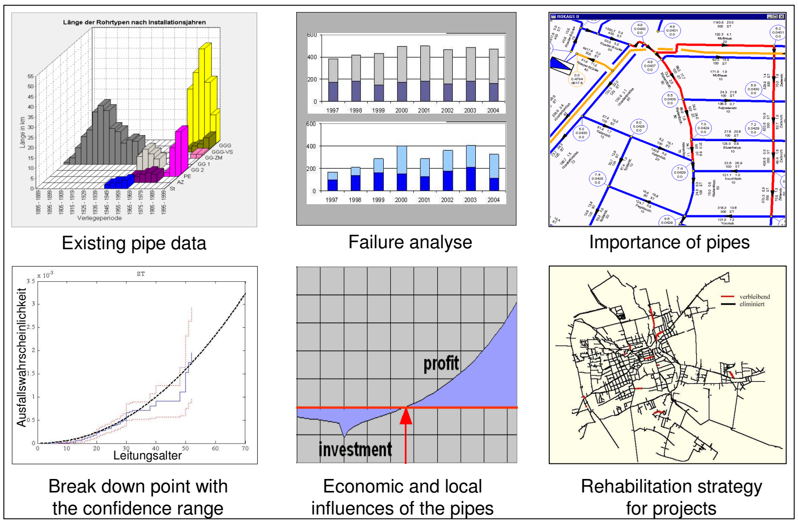


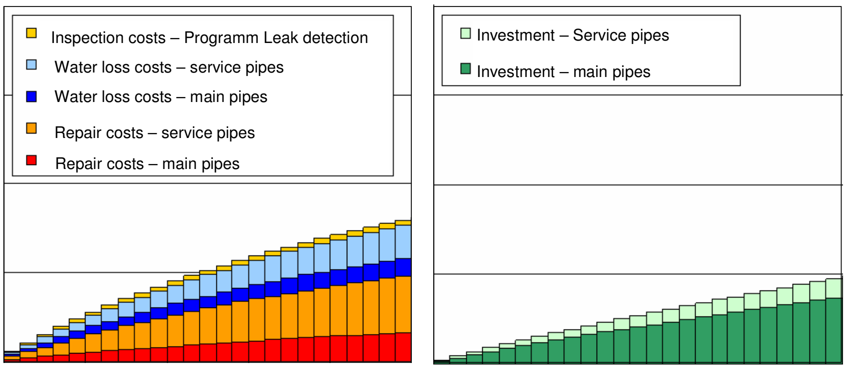
Figure 12: Steps for a renewal procedure for pipeline systems:

existing pipeline data – damage analysis – service life of the existing pipelines – necessary rate of renewal corresponding to forecast analysis – economic efficiency of renewal – renewal projects shown graphically in GIS

If one proceeds on the assumption of a mean practical service life of 50 years for supply lines (including co-renewal and moves), then this results in an annual renewal rate of 2% of the asset investment.

If there is no or too little pipeline renewal, then the pipeline system will overage, the availability will decrease and the maintenance costs will increase.

The next generation must pay increased costs for rehabilitation.



Maintenance costs Investment costs

Figure 13: Comparison of the economic efficiency of maintenance and investments

The economic efficiency of reducing losses must be determined individually due to the many different influencing factors, which are mainly due to local conditions. That way, the right measures can be taken.

The substance of pipeline systems represents the value and functional efficiency. Related to this are the age and condition of the pipeline system as shown in the following charts.

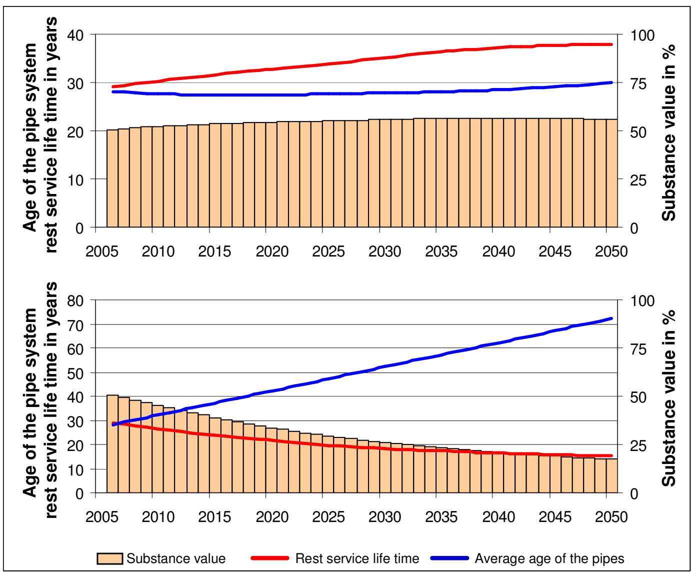


Figure 14: Examples of the development of the substance of a pipeline system

Top chart: Renewals in the pipeline system are carried our regularly.
The average age remains the same to a great extent.
The residual service life also remains the same or increases slightly.
The substance value of the system facilities is approx. 50%.
This pipeline network can be passed on to the next generation.

Bottom chart: Renewal is not performed adequately.
The average age increases in a disturbing way.
The residual life expectancy drops equivalently to the increasing average age.
The substance value of the system facilities drops from 50% to 20%.
This pipeline network has poor substance; the availability is very endangered,
The maintenance costs increase.
The next generation has an excessive need for investment.

5. Implementation of a customer complaint file

All problems, faults and repairs in the water supply system are documented in a customer complaint file. The information on the faults comes from consumers, public experts or from the operational staff of the company. The results of the analysis of these data are the basis for:

- Repairs
- Elimination of faults
- Inspection activities
- Consumer assistance
- Cultivation of the image of the company
- afm.

The analysis of the fault and damage statistic data over a long period results in information about the condition and reliability of the water supply and the satisfaction of the consumers with their water utility as supplyer of drinking water.

Further, the results of the fault and damage statistic are the main drivers for a number of activities:

- Rehabilitation or replacement of pipelines
- Flush out of pipelines and supply areas
- Selective inspection of pipelines, fittings and facilities
- Planning of activities to eliminate the faults and damages

6. Condition assessment of water supply networks

In addition for the base data of the water supply system (data of objects, construction costs and depreciation period afm.) the condition (faults, repairs, operational function afm.), the costs for rehabilitation of the supply systems, the priorities for the operational continuity of the water supply, and the yearly budget are parameters for the decision on the rehabilitation of the network.

Water supply networks	condition						costs				priorities		
	number of damages (losses)	number of repairs (mechanical)	number of faults (functional)	number of faults (hygenical)	number of faults (hydraulical)	monitoring	inspection	repairs	water losses/energy costs	others	risiks for the water supply	importance of the pipes	importance of the fitting function
transport pipelines	●	●		●	●	●	●	●	●	●	●	●	
distribution pipes	●	●		●	●	●	●	●	●	●		●	
service pipes	●	●		●		●	●	●	●	●			
fittings	●	●	●	●			●	●	●	●			●
	site evaluation performance indicators												

Figure 15: Condition assessmentof the water supply networks

With the above data (base data, condition, costs, priorities and costs for rehabilitation or replacement) the value assessment of the supply network can conducted and the economically optimal pricing for consumers can be calculated.

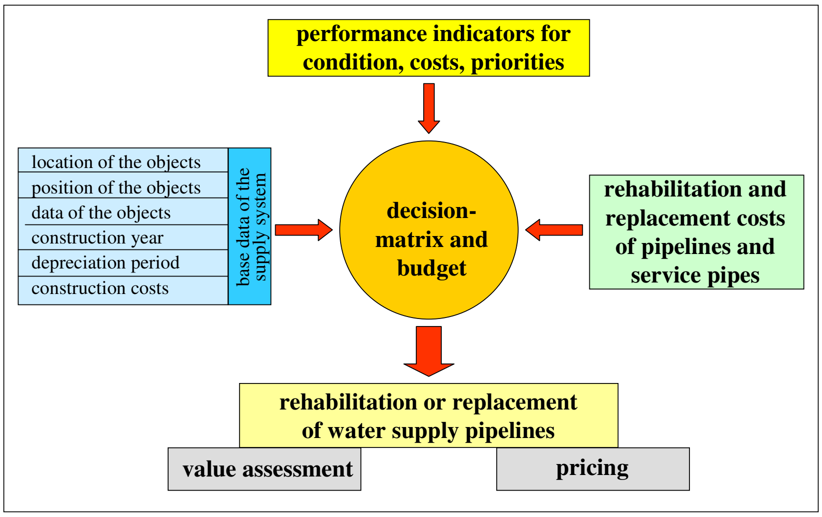


Figure 16: Influence factors for the decision of rehabilitation activities

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