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Cost comparison method between a conventional and selective first inspection of sewers and connections

BMBF-research project Selerin *for the city of Braunschweig (1,200 km), city of Ingolstadt (18,000 connections), community of Marpingen (75 km) and waste disposal association Saar (750 km external main sewer) in cooperation with the Institute for Environmental Engineering of the* ***RWTH Aachen*** *and the* ***Sachverständigenbüro für Kanalsanierung Kleinblittersdorf / Krefeld****, Germany.*

First presentation of the research results on Wednesday morning, 3 September 2003 by Dipl.-Ing. C. Müller of the RWTH-Aachen on the occasion of the ATV-DVWK Bundestagung und Landestagung - Nord in Wolfsburg, Germany. Procedure and benefit are described in the following short description and in various articles (see article download http://www.kanalgutachter.de/service/artikeldownload.en.php).

With the **conventional inspection strategy** the condition of sewers and connections of a local drainage is evaluated using a chosen spatial or organizational procedure. The benefit of this inspection strategy is the definite condition evaluation of the inspected network parts. However, as this procedure can also be an inspection depending on the expected condition based on the operational experience the ranking of reach groups or partial networks is restricted.

The quality of this ranking cannot be evaluated, as this depends to a large extend on the knowledge of the operator. However, as this knowledge is normally missing, a ranking of the connecting pipes of a local drainage is generally not possible. Moreover, it is also not possible to evaluate the condition of uninspected network parts independent of the network structure.

The benefit of the **selective procedure** is the definite condition evaluation of the overall network condition on the basis of a random sample and a definite ranking of reach groups or partial networks. Thus, the required rehabilitation budgets and priorities can be planned. Reaches in need of rehabilitation can be inspected systematically and rehabilitated promptly as the required budget can be allocated in advance.

Thus, the **benefit comparison between both inspection strategies** does only evaluate the overall condition of the sewers and connections of a local drainage.

Based on these considerations a cost factor for the evaluation of the overall network condition of sewers and connections can be calculated. If some of the reaches have already been inspected the results can be used for the forecast on a pro-rata basis.

Normally approximately 30% of the existing TV-data can be used for a random sampling. If this is not possible, e.g. due to poor quality, it should be considered not to use these reports at all, as they might also be unsuitable for a conventional procedure.

According to experience the cost factors range about $1.10 \leq f_{ing,konv} \leq 1.20$ and $1.20 \leq f_{ing,sel} \leq 1.25$. The fixed costs (FC) can be estimated at 25,000 € for smaller networks between 75 and 100 km, at € 50,000 for networks of 500 km and at € 75,000 for networks of 1,000 km. However, the fixed costs do not increase proportionally to the network size. The same applies for the specific inspection costs kspez. as these vary depending on the local basic conditions.

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Also during the **selective first inspection, like the conventional procedure**, sewer network and connections are inspected one after the other. This inspection is performed depending on the expected condition of individual reach groups.

In individual cases it must be determined whether the extra costs associated with the selective first inspection resulting from the increased monitoring effort for the inspection of the sample and the fixed costs for the statistical evaluation (layering, projection and planning of further inspection) can be compensated by the benefit.

The benefits compared to conventional procedures are the early evaluation of reaches in need of rehabilitation, the possibility to systematically hold ready individual rehabilitation budgets for short, mid and long-term strategies in consideration of the ageing processes (deterioration of the network condition) with the sewer forecast model **AQUA-WertMin*** and thus the ability to rehabilitate these reaches directly after the inspection. Any further inspections can be performed in dependence of the condition or can focus on presumed damages that need to be rehabilitated and thus significantly enhance the informative value of the forecast model.

The necessity to re-inspect reaches in need of rehabilitation directly before the procedure cannot be excluded with the conventional procedure, as inspection findings become obsolete in the course of time.

The non-monetary benefits of the selective first inspection can only be realized in case of a time lead of the evaluation of the overall network condition. As the inspection with conventional strategies is generally carried out over a period of at least 2 to 3 years even for smaller networks, the evaluation of the overall condition with the selective strategy should be performed within one year and should not cause any extra costs in this year compared to the conventional procedure.

This leads to the consideration whether a selective inspection strategy is suitable if the **cost factors** for the evaluation of the overall network condition **Kkonv/Ksel are at least 2 to 3.**

For the planning of the selective inspection strategy we programmed the procedure tested in the BMBF-research project Selerin into **AQUA-Selekt Version 4.0** and added the condition class distribution for the year and group of construction for the subsequent processing in AQUA-WertMin 6.x. In this connection every uninspected reach is randomly assigned to a forecasted condition class and a mean inspection year.

Sachverständigenbüro für Kanalsanierung
12. Juli 2006

Kleinblittersdorf / Krefeld, Germany

***** Since 20 February 2001 **AQUA-WertMin** is approved for the self control regulation (EKVO) of Baden-Württemberg for the optimization of inspection intervals by means of a forecast inspection and rehabilitation planning.

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Latest references:

During the last twelve months selective condition data forecasts and forecast-based sewer rehabilitation strategies were developed by various users and us with AQUA-Selekt 3.0b and AQUA-WertMin 6.x:

1. Sewer network Regensburg with 450 km by AQUA engineers Ingolstadt.
2. Partial privatization of the sewer network Dresden with 1,650 km and 500 km inspecktion by ARGE IG Rudolph & Partner Dresden and SV-Büro Jansen.
3. Partial privatization of the sewer network Espelkamp with 220 km by ARGE Bockermann & Fritze Ing.-Consulting Enger and SV-Büro Jansen.
4. Sewer network Nohfelden with 120 km by Ing.-Büro Zimmer & Partner Merzig.
5. Only A-WM for sewer network Aidlingen with 57 km by Ing.-Büro Mayer Böblingen.
6. Sewer network Leipzig with 1,500 km and 850 km inspection by ARGE DW Ingenieure Unna and SV-Büro Jansen (Beginning of the treatment starting from January 2006).

Cost comparison method between conventional and selective sewer first inspection

Sachverständigenbüro für Kanalsanierung Kleinblittersdorf / Krefeld, Germany

Example: Version 1. No inspection at 1,500 km

Acceptance: Input fields | Result field

	Length	Med. H-Length	Qty Reaches	Sample size		Inspected reaches		Fixed costs	Spec. costs	Inspection costs			Profitability
								FC	Clean.+ TV	1)	2)	selective	
	(km)	(m)	(pc)	(%)	(pc)	(km)	(pc)	($)	($)	($)	($)	($)	Factor at least 2-3
	100	40	2.500	20	500	0	0	25.000	200	500.000		63.000	2,44
	150	40	3.750	20	750	0	0	25.000	200	750.000		81.000	2,86
	250	40	6.250	20	1.250	0	0	40.000	200	1.250.000		110.000	3,56
	500	40	12.500	20	2.500	0	0	70.000	200	2.500.000		190.000	4,16
	1.000	40	25.000	20	5.000	0	0	125.000	200	5.000.000		357.000	4,50
Ex. City	1.500	40	37.500	20	7.500	0	0	150.000	200	7.500.000	4.853.289	1.275.000	3,81

1) conventional without monitoring
2) conventional with monitoring

n_{sel} [-] =	7.500	reaches	sample size for selective first-TV inspection at least 10 to 20% depending on sewer network size
n_{vor} [-] =	0	reaches	number of inspected reaches (an average of only 30% is used!)
N [-] =	37.500	reaches	total network
FK =	150.000	$/reach	fixed costs for statistical evaluation at least $25,000 from 100 km, $70,000 at least 500 km and $125,000 from 1,000 km.
k_{spez} =	120	$/reach	specific costs for cleaning and inspection
$f_{ing,sel}$ [-] =	1,25		cost factor for monitoring of inspection and condition classification for selective first inspection (1.20 - 1.25)
$f_{ing,konv}$ [-] =	1,1		cost factor for monitoring of inspection and condition classification for conventional first inspection (1.1 - 1.2)
p [-] =	0,5		respective population rate
z [-] =	1,65		standard norm variable
a [-] =	0,05		probability value

K_{konv} = $4.853.289 costs for the evaluation of the overall network condition with conventional first inspection

K_{sel} = $1.275.000 costs for the evaluation of the overall network condition with selective first inspection

Profitability

$\frac{K_{konv}}{K_{sel}}$ = 3,81 greater than als req. cost factor 2-3!

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Cost comparison method between conventional and selective sewer first inspection

Sachverständigenbüro für Kanalsanierung Kleinblittersdorf / Krefeld, Germany

Example: Version 2. Inspection of 500 km at 1,500 km

Acceptance: Input fields | Result field

	Length	Med. H-Length	Qty Reaches	Required sampling		Inspected reaches		Fixed costs FC	Spec. costs	Inspection costs			Profitability
									Clean.+ TV	1)	2)	selective	Factor at
	(km)	(m)	(pc)	(%)	(pc)	(km)	(pc)	($)	($)	($)	($)	($)	least 2-3
	100	40	2.500	20	500	0	0	25.000	200	500.000		63.000	2,44
	150	40	3.750	20	750	0	0	25.000	200	750.000		81.000	2,86
	250	40	6.250	20	1.250	0	0	40.000	200	1.250.000		110.000	3,56
	500	40	12.500	20	2.500	0	0	70.000	200	2.500.000		190.000	4,16
	1.000	40	25.000	20	5.000	0	0	125.000	200	5.000.000		357.000	4,50
Ex. City	1.500	40	37.500	20	7.500	500	12.500	150.000	200	7.500.000	3.203.289	900.000	3,56

1) conventional without monitoring
2) conventional with monitoring

n_{sel} [-] =	7.500	reaches	sample size for selective first-TV inspection at least 10 to 20% depending on sewer network size
n_{vor} [-] =	12.500	reaches	number of inspected reaches (an average of only 30% is used!)
N [-] =	37.500	reaches	total network
FK =	150.000	$/reach	fixed costs for statistical evaluation at least $25,000 from 100 km, $70,000 at least 500 km and $125,000 from 1,000 km.
k_{spez} =	120	$/reach	specific costs for cleaning and inspection
$f_{ing,sel}$ [-] =	1,25		cost factor for monitoring of inspection and condition classification for selective first inspection (1.20 - 1.25)
$f_{ing,konv}$ [-] =	1,1		cost factor for monitoring of inspection and condition classification for conventional first inspection (1.1 - 1.2)
p [-] =	0,5		respective population rate
z [-] =	1,65		standard norm variable
a [-] =	0,05		probability value

K_{konv} = $3.203.289 costs for the evaluation of the overall network condition with conventional first inspection

K_{sel} = $900.000 costs for the evaluation of the overall network condition with selective first inspection

Profitability $\frac{K_{konv}}{K_{sel}}$ = 3,56 greater than als req. cost factor 2-3!

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Cost comparison method for the first inspection of sewers and connections:

Between conventional inspection strategy and selective approach for the evaluation of the condition of sewers and connections of community drainage

Equation 1:

$$K_{sel} = FK + n_{sel}\left(1 - \frac{n_{vor}}{N}\right) \cdot k_{spez} \cdot f_{ing,sel}$$

$$K_{konv} = \left(n_{konv} - n_{vor}\right) \cdot k_{spez} \cdot f_{ing,konv}$$

$$n_{konv} = N \cdot \left(1 - z \cdot \frac{\sqrt{4 \cdot n_s \cdot p \cdot (1-p)} + z^2}{\left(1 - \frac{\alpha}{2}\right) \cdot \left(n_s + z^2\right)}\right)$$

continued

$$\frac{K_{konv}}{K_{sel}} = \frac{\left[N \cdot \left(1 - z \cdot \frac{\sqrt{4} \cdot n_s \cdot p \cdot (1-p) + z^2}{\left(1 - \frac{\alpha}{2}\right) \cdot \left(n_s + z^2\right)}\right) - n_{vor}\right] \cdot k_{spez} \cdot f_{ing,konv}}{FK + n_{sel}\left(1 - \frac{n_{vor}}{N}\right) \cdot k_{spez} \cdot f_{ing,sel}}$$

with:

K_{sel}	[€]	costs for the evaluation of the overall network condition with selective first inspection
K_{konv}	[€]	costs for the evaluation of the overall network condition with conventional first inspection
n_{sel}	[-]	sample size for selective first inspection
n_{konv}	[-]	required sample size at a conventional first inspection
n_{vor}	[-]	number of inspected reaches
N	[-]	total network
FK	[€]	fix costs for statistical evaluation
k_{spez}	[€/reach]	specific costs for cleaning and inspection
$f_{ing,sel}$	[-]	cost factor for monitoring (BL) of inspection and condition classification for selective first inspection (1.20 - 1.25)
$f_{ing,konv}$	[-]	cost factor for monitoring (BL) of inspection and condition classification for conventional first inspection (1.10 - 1.20)
p	[-]	respective population rate
z	[-]	standard norm variable
a	[-]	probability value

List of references for value maintenance strategies for sewers with forecast rehab. planning partially selective first inspection

14.07.2006 10:57

Sachverständigenbüro für Kanalsanierung Kleinblittersdorf/Krefeld, Germany

NO	FIRST NAME	NAME	COMPANY	STREET	ZIP	CITY	TELEPHONE	REMARKS
1	Torsten	Harz	Prof. Dr. Dr.-Ing. Rudolph + Partner mbH	Sudhausweg 9	01099	Dresden	0351-816030	ARGE mit SV-Büro für 1.630km Aqua-Selekt + Aqua-WertMin (A-WM) 10/2003
1	Frank	Männig	Landeshauptstadt Dresden	Scharfenbergerstraße 152	01139	Dresden	0351-8221175	Hauptauftraggeber (Beginn April 2003 / Abgabe 23. Juni 2004)
2	Gerhard	Cramer	Volkswagen AG	Niedersachsenstraße	26723	Emden	04921-863073	31km selektive u. progn. Strategien Aqua-Selekt + Aqua-WertMin (A-WM)
3	Georg	Grunwald	HanseWasser Bremen GmbH	Schiffbauerweg 2	28237	Bremen	0421-9881150	Anwender Aqua-WertMin bis 2002
4	Klaus	Kremring	Volkswagen AG	Gifhorner Straße 180	38112	Braunschweig	0531-2984238	30km selektive u. progn. Strategien Aqua-Selekt + Aqua-WertMin (A-WM)
5	Edgar	Hartwig	Volkswagen AG	Brieffach 1471	38440	Wolfsburg	05361-921418	120km selektive u. progn. Strategien mit Aqua-Selekt + Aqua-WertMin (Juni 1997)
5	Edgar	Hartwig	Volkswagen AG	Brieffach 1471	38440	Wolfsburg	05361-921418	Überprüfung des Sanierungserfolges ab 1998 (Beginn Juni/Juli 2004)
6	Karsten	Müller	ISA RWTH-Aachen	Hainbuchenstr. 24	52074	Aachen	0241-8026159	450km progn. Strategien n. SüwVKan für Rheine mit Aqua-WertMin
7	Dietmar	Schlösser	Stadt Lohmar	Hauptstrasse 25	53797	Lohmar	02246-15417	Hauptauftraggeber
7	Jürgen	Kreuzer	Kreuzer	Schulstraße 5d	53797	Lohmar	02246-918812	28km selektive u. progn. Strategien
7	Christian	Eckers	Kreuzer	Schulstraße 5d	53797	Lohmar	02246-918817	Sachbearbeiter v. IB Kreutzer
8	Axel	Schmidt	WIBERA AG	Am Halberg 4	66121	Saarbrücken	0681-9814304	Betreute als Wirtschaftsprüfer das Proj. Nr. 8
8	Wolfgang	Kempf	Gemeindeverwaltung	Rathausstr. 15	66271	Kleinblittersdorf	06805-2008902	65km Erstbew. mit ND-Ber. u. jährl. Fortschreibung seit 1995 mit Aqua-WM
9	Dieter	Detemple	PWC Price Waterhouse Coopers	Am Halberg 4	66121	Saarbrücken	0681-9814133	Betreute als Wirtschaftsprüfer die Proj. Nr. 9
9	H. J.	Schmitt	Abwasserwerk	Rathausstr. 27	66571	Eppelborn	06881-969230	173km Erstbew. mit ND-Ber. u. jährl. Fortschreibung seit 1996 mit Aqua-WM
9	Manfred	Leibfried	Leibfried & Saar GmbH	Koßmannstraße 1	66571	Eppelborn	06881-9616530	ARGE Leibfried/Aqua-Ing. jetzt SV-Büro
9		Keller	Gemeindeverwaltung	Schulstraße 60	66629	Freisen	06855-970	83km Erstbewertung mit Nutzungsdauerber. mit Aqua-WertMin
9	Anne	Frank-Fuchs	Gemeindeverwaltung	Urexweilerstr. 11	66646	Marpingen	06853-911656	103km (BMBF-Selerin) Erstbewertung mit Nutzungsdauerber. Aqua-WertMin.
10	Bernd	Zimmer	IBZ GmbH Beratende Ingenieure	Im Seitert 3	66663	Merzig	06861-931735	Anwender Aqua-WertMin
10	Andreas	Jacobs	IBZ GmbH Beratende Ingenieure	Im Seitert 3	66663	Merzig	06861-931744	Maßgebender Sachbearbeiter
11	Fred	Schönborn	AQUA Ingenieure GmbH	St.-Michael-Str. 3	85055	Ingolstadt	0841-9930074	450km selektive + progn. Strategien für die Stadt Regensburg (bis 2004)
12	Gerhard	Meier	Stadtentwässerungsamt	Steinweg 26	38100	Braunschweig	0531-4702697	FuE-Vorhaben BMBF Selerin 1.200km selektive Erstinps. bis Okt. 2002
12	Wunibald	Koppenhofer	Stadtentwässerungsamt	Spitalstraße 3	85049	Ingolstadt	0841-3052380	FuE-Vorhaben BMBF Selerin 18.000 St. Hs.-Anschl. selektive Erstinps. 10/02
12	Anne	Frank-Fuchs	Gemeindeverwaltung	Urexweilerstr. 11	66646	Marpingen	06853-911656	FuE-Vorhaben BMBF Selerin 75km selektive Erstinps. bis Okt. 2002
12	Wolfgang	Wagner	Entsorgungsverband Saar	Mainzerstraße 261	66121	Saarbrücken	0681-6000111	FuE-Vorhaben BMBF Selerin 750km außerörtl.-HS selektive Erstinps. Dez. 03
12	Karsten	Müller	ISA RWTH-Aachen	Hainbuchenstr. 24	52074	Aachen	0241-8026159	Kooperationspartner BMBF-Selerin / Anwender Aqua-Selekt + Aqua-WertMin
12	Fred	Schönborn	AQUA Ingenieure GmbH	St.-Michael-Str. 3	85055	Ingolstadt	0841-9930074	Kooperationspartner BMBF-Selerin / Anwender Aqua-Selekt + Aqua-WertMin
13	Hendrik	Walther	Kommunale Wasserwerke GmbH	Johannesgasse 7-9	04103	Leipzig	0341-9692484	Machbarkeitsstudie selektive TV mit progn. San.-u. Finanzstrategie f. 1.800km (1998)
14	Mathias	Wiemann	Kommunale Wasserwerke GmbH	Johannesgasse 7-9	04103	Leipzig	0341-9692258	Hauptauftraggeber (April 2004)
14	Erich	Kerkemeier	DW-Ingenieure GmbH	Hertingerstr. 95	59423	Unna	02303-332465	Bewertung der Nutzungsdauern der Citykanäle und der Schadensersatzquote
15	Achim	Kindermann	BF-Ingenieurconsult	Dieselstr. 11	32130	Enger	05224-973737	Pilotprojekt Espelkamp zur überschlägigen Kanalvermögensbewertung (Verkehrswert)
16	Achim	Kindermann	BF-Ingenieurconsult	Dieselstr. 11	32130	Enger	05224-973737	Teilprivatisierung Espelkamp 220 km selektive + progn. Restnutzungsdauer / Kanalverkehrswert
17	Andreas	Jacobs	IBZ GmbH Beratende Ingenieure	Im Seitert 3	66663	Merzig	06861-931744	120 km selektive + progn. Kanalsanierungsstrategie Gemeinde Nohfelden für die WVW St. Wendel
18	Michael	Mayer	Ing.-Büro Mayer	Galgenbergstrasse 1/1	71032	Böblingen	07031-21621412	57 km progn. Inspektions- u. Kanalsanierungsstrategie Stadt Aidlingen