SEWER ASSET MANAGEMENT:

ASSESSING CRITERIA FOR A MULTICRITERIA DECISION SUPPORT ON A COUNTY LEVEL DATABASE

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ABSTRACT

The Council of Bas-Rhin county in the east of France is developing an active policy of computing data on water management and water related utilities (including networks). Following a first inventory of all the water pipes (6 300km) in 2000 within a pilot national initiative for 8 *Départements*, the Council decided, in 2003, on its own initiative, to do a same inventory on all sewer networks (5 300 km). Data on the pipe characteristics and the pipe environment were collected but also information on failures and dysfunctions coming from CCTV inspection concerning sewers coded in a homemade codification. In the same time issued results of a French national project RERAU (rehabilitation of urban sewer networks) proposing criteria regarding dysfunctions and impacts to be introduced in a multi-criteria procedure for organizing both investigation and rehabilitation programs. Dysfunction criteria issued from CCTV information (coded on Standard EN 1308-2) were valuated on the Bas-Rhin database, the results are presented in this paper.

KEY WORDS

sewer networks, database , Multi-criteria Decision Making, dysfunction, defect, CCTV

INTRODUCTION

France, inland, is divided in 36 565 municipalities, located in 96 administrative counties called *Départements* managed by a county council compounded by elective people. The county council provides solidarity between territories among the population living in. So it has a social role and can act also for building infrastructure and equipment or for helping to do it, and so in particular for water infrastructure. So it can provide technical assistance and subsidies, for rural utilities essentially, within some times its own technical services. The *Département* of Bas-Rhin is leading a global reflexion on his regional development policy

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called “Des Hommes et des Territoires” (Men and Territories). Within this reflexion a great part concerns environment and especially water aspects (Conseil Général du Bas-Rhin, 2004a, 2004b).

The *Département* of Bas-Rhin gathers 1M inhabitants on 4 755 km^2. It is compounded by 526 municipalities organised in 152 sewerage utilities including the Urban Community of Strasbourg (CUS) whose sewerage utility concerns, on it only, 28 municipalities (450 000 inhabitants, 1500 km of sewers). The whole sewers represent 6 800 km; 5 300 km of them (outside CUS) are concerned by the database put in place in 2003. We will first of all present the database made within the inventory work and the housemade codification for CCTV used and registered in the database. Then we will move to the RERAU methodology after having presented the new standard EN 13508-2, required in this methodology, and finally present the valuation work done on 7 dysfunction criteria.

THE COUNTY LEVEL DATABASE

DATA COLLECTION

In 2000, the *Département* of Bas-Rhin was involved as pilot site for a national operation concerning 8 *Départements*, for making an inventory of water networks equipment. 6300 km of pipes were registrated into a database with data on the pipe characteristics and its environnement and failure history if available. A specific work of data analysis has been made on 1000 km with a five years failure data set to establish the link between failures and the different data available in the database and to propose renewal planning (Werey et al., 2002). Following this, the county launched in 2003, on its own initiative, a similar inventory operation for sewer networks. 5300 km have been registered in the data base representing 135 000 links[4] . 700 km concern only rain water, they are not concerned by this work. The rest of the networks are essentially combined sewers.

The variables presented on table 1 are in the database and are mostly good informed.

Table 1: database variables

Pipe caracteristics	Environment information	CCTV inspectionss
Network type Material Diameter Length Nb of connections Laying year...	Population natural region surface use traffic nature of sol...	Inspection date Nb of previous inspections 64 defects coded gravity note

[4] a link is defined as the pipe between two manholes.

Concerning the CCTV inspections, on the 4 600 km of sewers 1 00km have been inspected almost once since 1980 for networks were the oldest were laid in the 1900 years. So 32 000 CCTV have been exploited within the database

CCTV CODIFICATION

A defect codification has been put in place within the 1980 year were CCTV inspections have really begun. In fact most of the inspection gathered in the database have been made by a same team: an internal department of the technical services from the *Département* of Bas-Rhin. This codification arises in part from the german way of coding CCTV inspections (ATV-DVWK, 1999). It is compounded by a defect code, an information presence of humidity, an information when soil is visible and a note from 1 to 5. 1 signifies that it is urgent to do something on this pipe, 4 and 3 that there is need to program a rehabilitation operation a mean time, 2 and 1 that nothing has to be foreseen.

RETRANSCRITION ACCORDING TO STANDARD EN 13508-2

In 2003 issued the French version of the a new standard for CCTV codification of defects EN 13508-2 (CEN, 2001) which will be compulsory by September 2006 in France. So as far as RERAU methodology is based on the new codification, and considering that it will be the best way for taking into account data existing before the new codification besides the new ones, a recodification work has been done in 2005 on the whole database.

The new codification proposes 4 level of information:

- the main code (BA concerning the fabric of the pipe, BB the operation, BC, inventory…)
- 1 or 2 caracterisations using a code to give further description of the observation
- 1 or 2 quantifications,
- circumferential localisation

Table 2 gives an exemple of Break/collapse defect:

Table 2: example in EN 13508-2 codification (CEN, 2001)

Defect:	**Break/collapse**	
Main code	**Aditional information**	**description**
BAC	characterisation	The nature of the observation is: - Break (A) – pieces of pipe visibly displaced - Missing (B) – missing pieces of wall - Collapse (C) – complete loss of structural integrity
	quantification	The length of the observation in millimetres
	Circumferential location	The position of the observation

Table 3 presents an example of transcription of a defect in the Bas-Rhin codification in the EN 13508-2 standard: from l line coding, we get 3 lines in the new coding.

Table 2: Recodification example in EN 13508-2 standard (CEN, 2001)

Local coding	Heap of fallen fragments,	visible soil, water infiltartion
EN 13508-2	**Main code**	**characterisation**
BAC-B	BAC (break/collapse)	B (missing pieces)
BAO	BAO (soil visible through defect)	
BBF-C	BBF (infiltration)	C (flowing – a continuous flow)

Concerning the data base the circumferential localisation exists as a variable but is poorly informed. Some difficulty appeard also to take into account the 1 to 5 notes who representy the gravity of the defect in a certain way where as the new codification proposes a quantification of the defect. So the department making CCTV inspections considers, up to now, that he may continue to use the 1 to 5 notes even when the new codification will be used.

The number of defects codes in EN 13508-2, after transcription, are presented on figure 1:

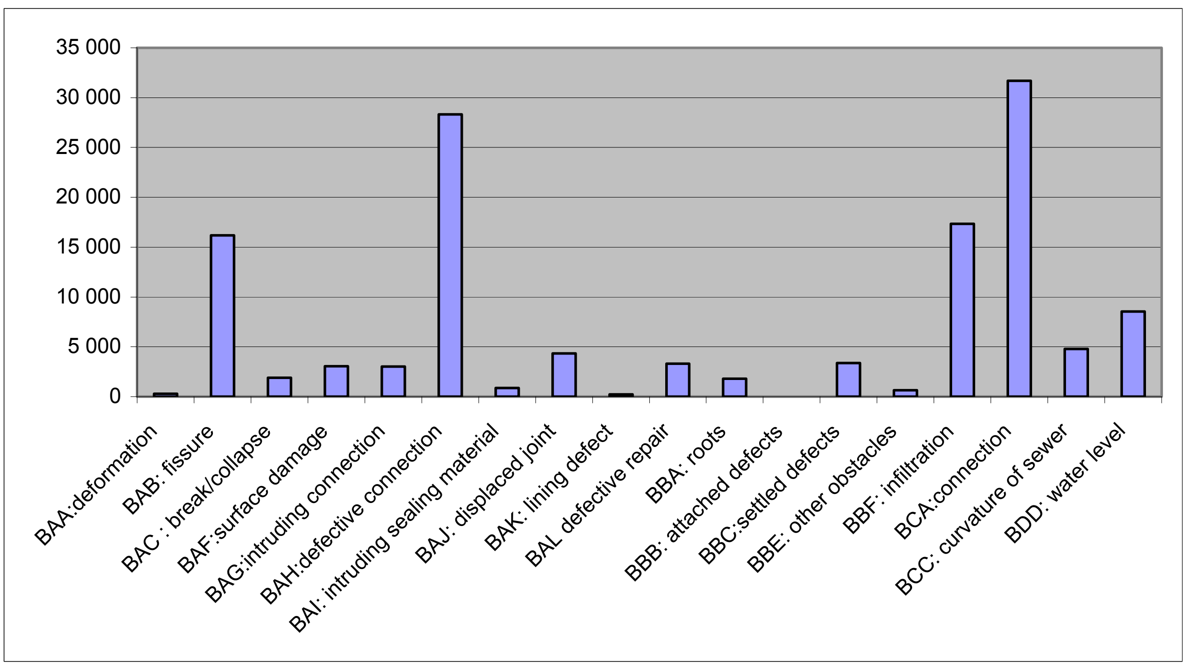

Figure 1: Number of defects within the database distributed according to the EN 13508-2 main codes (Dorchies, 2005).

The most frequent defects are BAH: defective connection, BBF: infiltration, BAB: fissure. BCA is an inventory code for coding the presence of a connection, the Bas-Rhin codification of Bas-Rhin gives information on the connection defects, all of these are recorded now under BAC code.

RERAU METHODOLOGY

PRESENTATION

The work carried out within the French R&D RERAU program (Rehabilitation or urban sewer networks) proposes performance indicators in two different sets for investigation and rehabilitation programs (Le Gauffre et al., 2004a, 2004b).

Decision criteria are proposed from complementary performance indicator regarding:

- defects: charaterizing the actual physiaal state of the pipe, defects are generally observable by CCTV inspections
- dysfunctions: consequences of defects on facility operations
- impacts: degree to which dysfunctions induce effects depending on the context taken into account within vulnerability factors.

This different indicators are assessed through:

- Direct observation: it is the case of CCTV inspections
- Observation-based estimations: some time results of defects obsercved by CCTV
- Estimations based on risk factors: step before CCTV inspection.

The different criterion are proposed either at the sewer segment level (e.g. probability of collapse) or at the catchment level (e.g. infiltration rate).

Finally each criterion is assessing a contribution of a particular dysfunction of a sewer segment to a particular impact.

So were defined 159 criteria, were 64 concern dysfunctions. They are displayed in 12 families. presented in table 4:

Table 4: typology of dysfunctions

name	Disfunction
INF	Infiltration
EXF	Exfiltration
HYD	Decrease of hydraulic capacity
DEB	Flooding
DEV	Overflow
ENS	Sand silting
BOU	Blockage
DSC	Destabilisation of ground-pipe system
ATC	Ongoing corrosion
RAC	Ongoing degradation from roots intrusion
ABR	Ongoing degradation from abrasion
EFF	Risk of collapse

DYSFUNCTION CRITERIA ASSESSED FROM CCTV INSPECTION DATA

The assement on Bas-Rhin database has essentially been made on the dysfunctions at pipe level assed within CCTV inspection informations, that is to say INF4-E/O-T, EXF4-E/O-T, HYD3-E/O-T, ENS4-E/O-T, BOU4-E/O-T, RAC4-E/O-T, EFF3-E/O-T (E=estimated by using O=observation, information at T=segment level).

RERAU methodology proposes for each of the criteria valuation rules using the EN 13508-2 codification and a 4 level gravity analysis of the dysfunction (4 is the worst).

Tables 5 and 6 presents the evaluation rule for INF4 E/O-T:

Table 5: example of a criteria estimated by CCTV inspection (Le Gauffre et al., 2004a)

Dysfunction	INFILTRATION
DYSFONCT indicator	INF4-E/O-T Infiltration risk, estimated by CCTV inspection
Valuation scale	Network and sub-system ➢ segment
Valuation type	Observed Dysfunction ➢ Observed-based estimation of Dysfunction Estimations of Dysfunction based on risk factors
Unit or gravity levels	level : 1/2/3/4
Valuation	1 – coding Ci of observations Oi according standard EN 13508-2 ; 2 – translating in Ni of coded observations Ci according following table ; 3 – calculation of density D = N / Lt ,

with N = Σ Ni, et LT :length of the segment (m) ; 4 – comparison of D with thresholds S1, S2, S3 : level 1 if D ≤ S1 ; 2 if S1 < D ≤ S2 ; 3 ifi S2 < D ≤ S3 ; 4 ifi S3 < D.

Table 6 presents an extract of the rules used for translating the observations Oi, oded in Ci in Ni notes which will be summed on the all segment to give the global note and the density of dysfunction.

Table 6: extract of INF4 valuation rules (Le Gauffre et al., 2004a)

Observation Oi	Code Ci	I	α	α^2	α^3	Extent of the gravity
Deformation	BAA		BAA			P
Fissure	BAB	BAB B		BAB C		L_obs
Break/collapse	BAC			BAC A	BAC B/C	P
Missing mortar	BAE		BAE			P
Defective connection	BAH			BAH B/C/D		P
…	…					
…	…					

Defects are classified according to their estimated implication in considered the dysfunction and the 4 levels of gravity are quantified by 1, α, α^2, $\alpha^{3.}$ The value 1 means no dysfunction, α^3, means a total dysfunction. The presence of α defects in one levelleads to step in the higher level. P represents the extend of the defect.

To implement this methodology, the next step is to define the value of the different thresholds in order to identify segments being in poor state that is to say belonging to class 4.

An implementation of this method has been done on the Bas-Rhin database in 2005 (Dorchies, 2005). The results will be presented in the following paragraph.

VALUATING OF THE 7 DYSFUNCTIONS CRITERIA ON THE BAS-RHIN COUNTY LEVEL DATABASE

METHODOLOGY

As presented in the first part of this paper , the CCTV data available in the database have been recoded according the standard EN 13508-2.

Then we calculated for each segment, all over the data base, the density for each of the 7 dysfunctions considered in our valuation. The parameter P is not available in the database so it was not applied. The gravity note (5 to 1) is in part taken into account for the first characterisation (4th letter); it helped to classify a default over the valuation tables similar to table 6 besides the EN 13508-8 codification . For instance for roots defects BBA, BBA-A means tap roots, BBA-B means independent fine roots, BBA-C means complex mass of roots. Table 7 shows how both informations have been combined for HYD3 (reduction of hydraulic capacity.

Table 7: adaptation of RERAU methodology to Bas-Rhin data

Observation Oi : ROOTS	Code Ci	I	α	α^2	α^3
EN 13508-2	BAA	B		A/C	A/C >50% of section
Bas-Rin information	note	4/5	3	2	1

For instance for 2 defects roots with note 3, Ni=2.α. First application was made with α=3 as introduced by Boinel (1995) in order to calculate the different densities per segment using the formula 1:

$$D = 100 \frac{\sum_{i=0}^{nb\,déf} N_i}{LT} \quad (1)$$

The interest of calculating a density is that long segment with many defects will not be too much penalised but it leads to absurd values for little segments. So, a correction index has been put in place for each dysfunction using the guiding coefficient of a linear regression line called *a*, exemple for INF4 is given on figure 2.

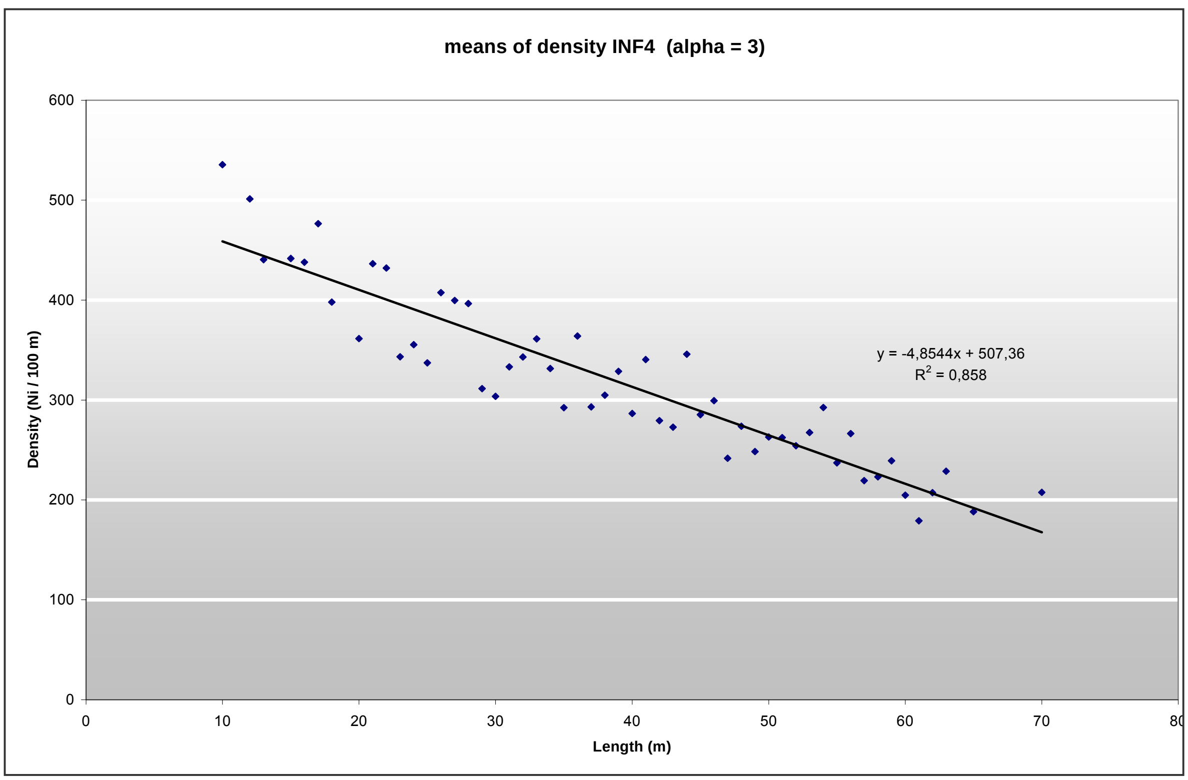

Figure 2: linear regression on mean value of INF4 densities (Dorchies, 2005).

The next step was the valuation of the thresholds using formula 2:

$$S_{2\,or\,3} = \frac{\alpha^{2\,or\,3}}{LT_{mean}} - a \cdot LT_{mean} \qquad (2)$$

RESULTS

Following results were obtained for the different threshod valuations, as presented in, table 8:

Table 8: S1,S2,S3,S4 thresholds calculation (Dorchies, 2005)

		According to Ni			According to density			Coefficient of correction *a*	According to a corrected density		
Dysf.	Mean length of the segment	S1	S2	S3	S1	S2	S3		S1	S2	S3
BOU4	44,5	0	9	27	0,0	20,2	60,7	-0,88	0,0	59,4	99,9
EFF3	41,9	0	9	27	0,0	21,5	64,4	-1,10	0,0	67,4	110,4
ENS4	42,8	0	9	27	0,0	21,0	63,1	-1,01	0,0	64,1	106,2
EXF4	41,2	0	9	27	0,0	21,9	65,6	-2,26	0,0	115,0	158,7
HYD3	42,8	0	9	27	0,0	21,0	63,1	-1,07	0,0	66,7	108,8
INF4	41,2	0	9	27	0,0	21,9	65,6	-2,26	0,0	115,0	158,7
RAC4	46,1	0	9	27	0,0	19,5	58,5	-0,84	0,0	58,2	97,2

We compared this results with those obtained by an attribution according direct observation in the different levels by considering the observed defects. So by using table 6 for instance, when we have BAC-B defect on the segment we will be sure ta the segment appear in level 4 for INF dysfunction.We obtained following results, presented in table 9:

Table 9: comparison of levels obtained by direct observation and by corrected density calculation, on all the dysfunctions (Dorchies, 2005)

Per density calculation	Dysfonction per directobservation e				
	1	2	3	4	Total
1	170 495	0	0	0	170 495
2	0	14 865	2 779	0	17 644
3	0	5 693	6 505	725	12 923
4	0	1 210	4 814	18 538	24 562
Total	170 495	21 768	14 098	19 263	225 624

We obtained better results with corrected density, 98% of the dysfunctions estimated by density and presenting a major defect are in level 4. But 32% of dysfunctions presenting defects from level 2 are estimated in level 3 or 4.

To try to explain this overestimation and also in a validation step we submitted our results to an Expert working on 13 CCTV inspections made on a same municipality. So we could indentify some mystranslation between the Bas-Rhin and the RERAU approach, we proposed to put α=4 and got a better answer of the threshold calibration.

CONCLUSION AND PERSPECTIVES

This valuation work shows the interest of the RERAU method. Of course we only investigated a little part of the dysfunctions proposed. Following this valuation a data analysis is under way in order to identify environment variables explaining the different defects in order to make a typology of pipes. The idea is to propose a short term planning for rehabilitation measures but also for investigation programmes. Further steps could be the evaluation of the other criteria and especially the impacts of failures making the link with the results of the European project CARE-S[5] (Torterotot et al.,2006) in order to process a multi-criteria analysis.

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