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Indicators of equipment management of network sanitation

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ABSTRACT: This communication talks about the methodological problem of ornamental the results of visual inspections for the assessment of the anomaly level of the object of study. This question is studied on the case of sanitation networks but the results can be transferred to other areas. The anomaly level can be defined by three arguments: specialist rules, comparison of a summary note with threshold values and analysis of a longitudinal profile. The calibration of the threshold values requires comparison of the results of assignment of anomaly levels with the statements of the specialists serving as reference. We propose a calibration index that takes into account the costs associated with the different allocation errors.

KEYWORDS: Sections; absolute; anomaly; ranking; indicator; Assignment error; visual inspection; imprecise; Sewerage network; Threshold setting.

1 INTRODUCTION

The aim of the management of the sewerage network is to maintain the equipment in a satisfactory state with respect to health, environmental, economic, etc. It includes the acquisition of knowledge, appreciation of equipment performance, and the rehabilitation of elements or subsystems considered to be weakened or at risk. The assessment of the sanitation network must be structured by defining indicators or performance indicators, such as those defined in the Strategic Protocol of the National Sanitation Program of Morocco (SPNA 2008). The aim of these performance indicators is to exploit information obtained through complementary channels: visual inspections of collectors, network measurements, data from network operation, data on the vulnerability of the exposed environments, etc. Visual inspections, in particular television inspections (ITVs), constitute a privileged method of investigation to assess the state of health of sewerage networks. Here, we discuss the development of the results of these inspections to determine anomaly indicators on a four-level scale (from 1 - satisfying 4 - major anomaly). The question is formulated as follows.

2 DEVELOPMENTS OF VISUAL INSPECTION REPORTS

The question is formulated in the following way: how to translate into an anomaly level all the investigations obtained on a section? This question refers to several steps and problems presented in Figure 1. The first step consists in translating the investigations into a sequence of codes, in accordance with a managerial or standardized coding system (a system of permutation allowing to link these Two encodings). A further step concerns the quantitative translation of these codes in order to obtain a sequence of notes which can be the subject of a more or less elaborate aggregation procedure (calculation of a single note and / or calculation of a longitudinal profile Of health status). Finally, an anomaly level is defined by combining three possibilities: a) the use of rules directly exploiting the code sequence, b) the comparison of the summary note with 3 threshold values delimiting the 4 possible conclusions, c) Analysis of the longitudinal profile. These three arguments are complementary: they make it possible to take into account situations of localized or evenly distributed degradation on the section

2.1 CODING SYSTEMS FOR OBSERVED DEFECTS

Concerning the survey of the anomalies observed during the inspections, professional practice has undergone a significant evolution thanks to the recent application of standard NM 10-95; 11-03 and NF EN 13508-2 (AFNOR, 2003) which standardizes the coding of anomalies. This guarantees the comparability of the results obtained and also allows for the sharing of data. Each observation is described by means of a main code consisting of three letters and additional information. For example: BAB-C-A indicates a longitudinal open crack, BAJ-A indicates insufficient nesting, BBA- ... the presence of roots. Thus, an inspection report will contain a set of codes, each code being associated with a distance from the inspection look-up.

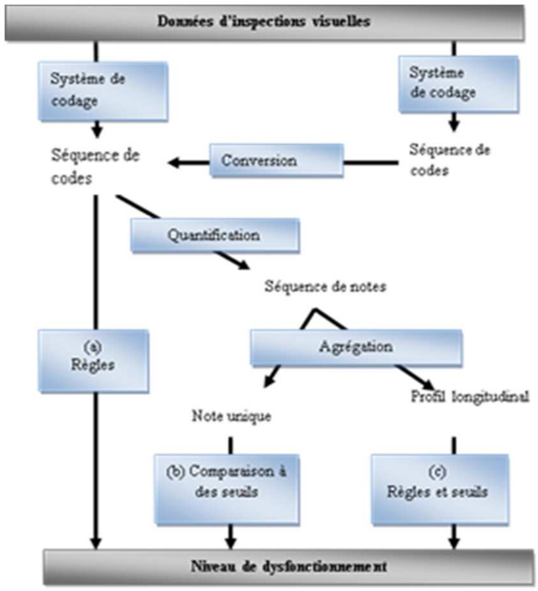

Figure1. Steps and sub-problems for the assessment of an anomaly indicator from the visual inspection data of a section

2.2 CONVERSION OF INSPECTION DATA INTO ANOMALY LEVEL

From the visual inspection report, each anomaly is qualified using the proposed approach Figure 1. The SPNA 2008 defines 12 types of anomalies: infiltration, exfiltration, overflows, abnormal spills, decreased hydraulic capacity, silting, Blocking, destabilization of the soil-conducting complex, chemical attack, degradation by intrusion of roots, degradation by abrasion and risk of collapse. The rules of the specialists (procedure a of Figure 1) depend on the anomaly studied; They have a veto forcing classification in level 4 (major anomaly) in particular situations, such as the combination of specific disorders that can lead to a major anomaly. The sampling, which aims to translate each code into an elementary note Ni, is carried out taking into account the gravity of each assessment (by attributing a weight) with respect to the anomaly under consideration, Extent of appreciation (length Li of anomaly). A fixed extent P is attributed to point anomalies. The weight of each anomaly is given from a scale defined by a single parameter α and four gravity levels: 1, α, α^2, $\alpha 3$. Thus, for each section, a set of notes Ni corresponding to each anomaly and its location is obtained from the general formula:

Ni = αn x P (or Li), with n = 0, 1, 2, or 3 and α = 2, 3, or 4 [1]

Figure 2 shows an extract from the table for the assessment of INF4 - leakage anomaly, evaluated from an inspection, used to study infiltration anomalies. The whole of the notes is then aggregated according to a single note (procedure b in FIG. 1). Given the heterogeneity of the length of the sections (between 10 and 70 m), the most appropriate synthesis note seems to be the density D:

N = Σ Ni / LT with LT: length of section (m) [2]

This density is to be compared to a numerical value scale with 3 thresholds (S1, S2 and S3):

- Level 1 if D ≤ S1: "little or no observed anomaly"
- Level 2 if S1 <D ≤ S2: "Small situation, section to be monitored"
- Level 3 if S2 <D ≤ S3: "Severe situation requiring action but to be prioritized"
- Level 4 if D> S3: "Situation intolerable in any context, requiring action"

The calculation of the density makes it possible to judge the state of the whole of the section but does not make it possible to detect a possible critical concentration of disorders. To compensate for this lack, the Ni scores can be aggregated per unit length to obtain a longitudinal profile (procedure c in Figure 1). Rules must then be used to classify the section according to a level of anomaly (note of the weakest section, etc.). Finally, the determination of the level of anomaly for the section will be a synthesis of the three procedures (a, b and c Figure 1): the worst ranking will be retained.

Severity:	1	α	α²	α³	
Significant Fissure Disorders:	BAB B	–	BAB C		Extended L- obs.
Rupture / collapse:	–	–	BAC A	BAC B/C	P
Connection defective:	–	–	BAH B/C/D	–	P
Sol visible by default	–	–	–	BAO	P
…					….

Fig 2. Excerpt from the table containing the assessment rules for indicator INF4: leakage anomaly, estimated from an inspection

3 Experimentations On A Real Sample

3.1 Presentation of the case study

We present in this paper the application of the proposed calibration method on a real case. These are 30 ITV reports for 15 sections located in Goba Negro-Maroc and 15 sections in the commune of Akanda north of Libreville-Gabon. Each section is estimated by one or more specialists, anomaly by anomaly. In a first step of the experiment, all the observations were re-coded according to standard NM 10-95; 11-03 and NF EN 13508-2. The next step was to calculate the values of the 7 indicators estimated from inspections concerning anomalies: INF / EXF - infiltration / exfiltration, HYD - hydraulic capacity reduction, ENS - silting, BOU - plugging, DSC - destabilization RAC - intrusion degradation of roots, EFF - alteration of structural integrity, risk of collapse. These 7 indicators were evaluated for 100 inspections carried out at least 3 years after the date of laying of the waste water pipes.

3.2 Determination of thresholds with expert opinion

The thresholds S1, S2 and S3 define the action level as a function of the value of the calculated density. Their resolution was based on the hypothesis that the presence of a major anomaly should lead to the classification of the section in level 4. The thresholds are thus a function of α and the average length of the sections. The results obtained are in agreement with the hypothesis stated. In addition, comparison with a specialist's assessment (from a sample of ITVs) is presented in Table 1.

Table1. Comparison of the calculation of the seven anomalies with the expert opinion for α = 3 and α = 4

α=3					
Avis des spécialistes	Anomalies Calculé				
	1	2	3	4	**Total**
1	**26**	3	1	0	30
2	3	**3**	3	2	11
3	3	1	**4**	11	19
4	4	0	1	**13**	18
Total	**36**	**7**	**9**	**26**	**78**

α=4					
Avis des spécialistes	Anomalies Calculé				
	1	2	3	4	**Total**
1	**26**	4	0	0	30
2	3	**5**	2	1	11
3	3	5	**9**	2	19
4	4	0	3	**11**	18
Total	**36**	**14**	**14**	**14**	**78**

The table above makes it possible to compare the opinion of specialists (each row corresponds to a level of anomaly with the result of the calculation (in column).) The reconciliation was carried out for two values of α The definition of the severity of the anomalies, see eq.1) The values of the diagonal of the table correspond to the concordance between expertise and calculation The results show a good concordance between the calculated levels and the expert opinion. Value of α = 3 leads to increase the number of level 4 anomalies actually detected, with respect to the value α = 4: 13 evaluated cases of level 4 among

18 are thus identified (11 for α = 4). Results show the importance of choosing the thresholds Whatever the thresholds chosen, there will necessarily be errors of assignment, and we propose in the following paragraph a thresholding method to control these assignment errors.

4 Identification Of The Stalling Error At A Stretch

The imprecise set theory provides the tool suitable for explicitly representing inaccurate information, in the form of membership functions. It avoids shifting suddenly from one level of evaluation to another, considering that a section may belong in part to two successive classes. FIG. 3 illustrates the problem of setting thresholds intended to define a level of anomaly on the basis of the synthesis note used.

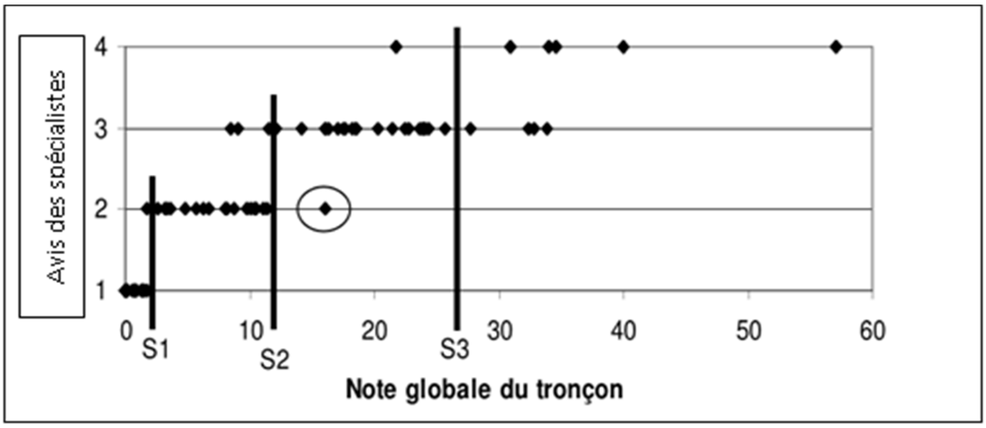

Figure 3. Confrontation between the assignment resulting from the calculation (evaluation of an overall score and then comparison with three thresholds) and the specialist opinions taken for reference.

The surrounded point corresponds to a section assigned in state 2 by the specialist (this opinion serves as a reference) but assigned in state 3 by the calculation procedure (note of the section between the thresholds S2 and S3): in this case there is Overestimation of the level of anomaly. Using the terminology of the detection tests, we can speak here of "false positive": segment classified erroneously among the situations of anomaly. Conversely, sections assigned in state 3 by the specialty can be assigned in state 2 (or even 1) by the calculation: we will then speak of "false negatives". In Table 1, the false positives correspond to the gray boxes located in the upper triangle and the false negatives correspond to the gray boxes located in the lower triangle. The setting of the thresholds S1, S2 and S3 aims to minimize the consequences of deviations of assignment between calculation and specialists. We propose a calibration index C that allows to take into account the costs associated with the different situations of false positives and false negatives:

$$C = \sum_{i=1}^{3}\left(\sum_{j=i+1}^{4} C_{FP}(i,j)P(C_j / E_i)P(E_i)\right) + \sum_{i=2}^{4}\left(\sum_{j=1}^{i-1} C_{FN}(i,j)P(C_j / E_i)P(E_i)\right) \quad [2]$$

With:

Ei ∈ {E1, E2, E3, E4}: level of anomaly of the section (stated by the specialist for the sections of the calibration sample); Cj ∈ {C1, C2, C3, C4}: calculated anomaly level (function of the thresholds); Evaluation and calibration of anomaly indicators based on expert judgment P (Cj / Ei): probability of a calculated value Cj for a section in state Ei (is estimated with a calibration sample, and depends on the three thresholds sought); P (Ei): probability that a section is in state Ei; This probability depends on the population on whom the procedure is to be applied; CFP (i, j) weight associated with an assignment error CFP = 0 if j = i CFP (i, j): weight associated with a false negative FN (i, j) (Ei and the calculated value Cj, j <i) CFP (i, j): weight associated with a false positive FP (i, j), (Ei and the calculated value Cj, j> i) This index "total cost of assignment errors" is based on the expression of different CFP (i, j) and CFP (i, j) weights, which allow us to represent the issues privileged by a manager and his practices Of an assignment Cj). Let us note finally that this index may lead to retain different thresholds for two populations of different sections such as P (Ei) ≠ P '(Ei).

5 DISCUSSIONS

Absolute thresholds make it possible to transform a numerical evaluation into an anomaly level. The procedure presented to calibrate these absolute thresholds makes it possible to minimize an overall cost criterion. However, the minimization of an overall error does not make it possible to control the error associated with a section. In addition, inspection reports are not always reliable. Finally, the opinions of specialists are not always unanimous. This is why we propose an alternative approach, based on the use of the theory of imprecise subsets. The imprecise approach makes it possible to define the imprecision of the transitions between two classes of state. The calibration of the three independent imprecise thresholds was made on the assumption that a section belongs at most to two states. Experiments have shown that:

- The ratio (Cj, j <i / Cj, j> i) is an important factor for effective control of assignment errors. By increasing the values of the ratio (Cj, j <i / Cj, j>), the values of the thresholds decrease. In the case of inaccurate calibration, increasing the ratio (Cj, j <i / Cj, j>) reduces the inaccuracy (ie the size of the imprecise thresholds);
- The use of imprecise thresholds makes it possible to induce nuances by taking into account possible aspects of inaccuracy. These findings show the importance of the ratio (Cj, j <i / Cj, j>) and the need for a sensitivity study relative to these parameters.

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