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USE OF MULTI-CRITERIA DECISION METHODS FOR PRIORITIZING THE REHABILITATION OF SEWER SECTIONS

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Abstract: *In the contents of the paper, the author presents the necessity of prioritizing the actions related to sewer sections rehabilitation in an urban environment. Dealing with aging sewer systems is not an easy task for the water and sanitation companies and they must plan their actions in such a way to have minimal disruption of their services. A first step in that direction is to plan and execute survey actions in the sewer system especially by means of CCTV inspection and to assess the real technical status of sewer section. The second step would be to plan and execute repair and rehabilitation actions for those sewer sections. But which one should be repaired or rehabilitated first? This paper offers one possible solution.*

Key words: *multi-criteria decision methods, sewer faults, prioritization, CCTV inspection, pipe rehabilitation.*

1. Introduction

In the sections of a sewer system an entire series of faults can be found which were discussed in [1] an [2]. Some of these faults are major and necessitate immediate action for repair in order to re-establish the functioning of the sewer. In this category we include total collapse of the sewer pipe (Figure 1), missing portions of the pipe wall, and protrusion of tree roots in the sewer pipe, big deposits of sediments and major cracks with infiltrations of ground water or used water exfiltration in the surrounding soil. In other cases the faults are in incipient phase or they are not affecting significantly the functioning of that sewer sections. This category comprises: small cracks, faulty joints, minor cross section deformation (ovalization), small deposits of sediments due to incorrect pipe slope and so on (Figure 2). For this second category of faults, ideally we must act before the fault aggravates and degenerates into a major one, comprised in the first category. It is more difficult to establish the priority for repair or rehabilitation in this case because damaging because these sewer sections are still functional. Managers are using for decades now multi-criteria decision methods in their activity and some of this methods can be adapted for our purpose. By doing this we will have a tool that will

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Fig. 1. *Total collapse of a concrete sewer pipe. The sewer section is impossible to use. The picture illustrates the faults included in the first category.*

Fig. 2. *Small deposit of sediments (below 10%). The sewer section capability of transporting used water is not yet affected significantly. The picture illustrates the second category of faults.*

permit us to substantiate our decisions in regard of repairing or rehabilitating one sewer section before another.

2. The Overall Performance Index Method

This is the multi-criteria decision making method proposed by the author to be used in the prioritisation of sewer section rehabilitation. It consists in several steps that must be undertaken. First, the discussed sewer sections must be chosen. Secondly the criteria of evaluation are chosen and to each criterion gets a numerical coefficient of importance. In the third step each sever section is evaluated in respect with each criterion and gets a rating which is later transformed in a score. These ratings are arranged in scales. The scales can be with 3, 4, 5, 7 and 10 levels. In the 4th step for each criterion is calculated the overall performance index with the fallowing formula [3], [4], [5]:

$$I_G = \sum_{j=1}^{n} N_j \cdot K_j \qquad (1)$$

In the formula *Nj* – represents the given score for each criterion, *Kj* – represents the numerical coefficient of importance and *n* is number of evaluation criteria. These calculations are made usually in tables and the rehabilitation hierarchy is established. The sewer sections with the greater value of the overall performance index are more urgent to rehabilitate.

3. Example of Application of the Method

Let's consider 6 sewer sections, S1 to S5, in need of rehabilitation. S1 is made of concrete, has an age of 30 years and a nominal diameter of 500mm. During its CCTV inspection were detected several minor erosion points, and fine cracks but not at the crest of the pipe. All the lateral connections are from residential houses. S2 is made of PVC, has an age of 12 years, a nominal diameter of 400mm. The section presents a slight ovalization, two faulty joints with the rubber seal expulsed from its place and minor sediments deposits. Lateral joints are from residential houses and a school. S3 is made of PVC, has an age of 17 years, a nominal diameter of 500mm. during inspection was revealed a crack on the pipe crest in length of 2.5m with minor cross section deformation. The lateral connections to this sewer section are from social-administrative buildings. S4 is made of GRP, has an age 8 years and a nominal diameter of 600mm. CCTV inspection shows 12% sedimentation at the bottom of the cross section, 2 faulty joints and one protruding lateral connection. Lateral connections are from two production facilities and several other industrial buildings. S5 is made of concrete has an age of 22 years and a nominal diameter of 400mm. During survey were found several points of erosion, three bad joints and several cracks on the lower portion of the pipe. Lateral connections are from residential buildings. S6 is made of GRP, has an age of 11 years and a nominal diameter of 400mm. Inspection revealed several faulty joints, in two of them the seal was expulsed from its place and 'used water leaks into surrounding soil. Also a small ovalization was noticed. Lateral connections are from residential and social-administrative buildings. By establishing that these are the 6 sewer section in discussion the first step is concluded.

In step two are established the criteria of evaluation and each criterion gets a coefficient of importance. In this example

5 criteria will be used but other numbers are possible.

C1 – imminent collapse conditions (for example, cracks on the pipe crest);

C2 – pipe diameter;

C3 – age of the sewer section;

C4 – destination of buildings connected to the sewer section;

C5 – pollution hazard (contaminated water leaking into surrounding soil).

The importance coefficients are given in Table 1.

In the third step we choose a tree level scale for rating the sewer sections in relation to each criterion and we generate the ratings matrix. Of course, if a finer differentiation is necessary we can opt for a scale with more levels. Table 2 shows the ratings and the scores given and table shows the ratings matrix

Criteria of evaluation and their coefficient of importance Table 1

Criterion of evaluation Cj	Explanation of evaluation criterion	Numerical coefficient of importance Kj
C1	Imminent collapse conditions	1
C2	Pipe diameter	2
C3	Age of the sewer section;	3
C4	Destination of buildings connected to the sewer section	2
C5	Pollution hazard	3

Three level rating scale Table 2

Rating	Rating symbol	Score
Less urgent rehabilitation needed	LU	1
Urgent rehabilitation needed	U	2
Very urgent rehabilitation needed	VU	3

Ratings matrix Table 3

Sewer section	Cj				
	C1	C2	C3	C4	C5
S1	U	U	VU	LU	U
S2	LU	LU	LU	U	U
S3	VU	U	U	U	LU
S4	LU	VU	LU	VU	U
S5	U	LU	VU	LU	U
S6	LU	LU	LU	U	VU

In Table 4 is presented the scores matrix which practically transforms the ratings into numerical values. The last step is the calculation of the overall performance index with the formula presented earlier in the paper. These calculations are made in Table 5.

The column to the right shows the ranking of the six sewer sections, rank 1 being the most urgent to be rehabilitated and the rank 6 being the less urgent to be rehabilitated.

Scores matrix Table 4

Sewer section	Cj				
	C1	C2	C3	C4	C5
S1	2	2	3	1	2
S2	1	1	1	2	2
S3	3	2	2	2	1
S4	1	3	1	3	2
S5	2	1	3	1	2
S6	1	1	1	2	3

Overall performance index calculation Table 5

Sewer section	Cj					Overall performance index	Rehabilitation ranking
	C1	C2	C3	C4	C5		
	Kj						
	1	2	3	2	3		
	Nota (Nj)						
S1	2	2	3	1	2	23	1
S2	1	1	1	2	2	16	6
S3	3	2	2	2	1	20	4
S4	1	3	1	3	2	22	2
S5	2	1	3	1	2	21	3
S6	1	1	1	2	3	19	5

As it can be seen in table 5 the most urgent sewer section to be rehabilitated according to this multi-criteria decision making method is S1 fallowed by S4, on the third place is S5, on the fourth pace is S3, on the fifth is S6 and the last one is S2.

4. Conclusions

The overall performance index method is a multi-criteria decision making method that can substantiate the decisions related to prioritisation to rehabilitation of sewer section. This method does not eliminate the human factor in decision making because the sewer specialist is the one who chooses the evaluation criteria and the importance coefficient of each criterion. Also he is the one who judges what rating is given to each sewer section according to each criterion. The knowledge of selecting the most important criteria and to give the appropriate rating comes after years and years of work, when the engineer has the experience of many situations and has seen faults evolving in the system from minor ones to more challenging ones. Ideally this experience must be shared with the entire team so that the entire sewer system to be kept in best condition with minimum of costs.

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