Impact of Inspection Data Quality on Structural Substance Assessment of Sewers

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Abstract

Both the well-established condition assessment and the newly developed assessment of a sewers structural substance are based on visual (CCTV)-inspection and defect coding, and thus a prone to errors and incomplete inspection data. In this study, we aim at understanding the sensitivity of structural substance assessment of sewers to several sources of uncertainties in the inspection procedure. We identified main uncertainty sources in the assessment procedure and propagated this uncertainty in the structural substance assessment of 80,000 sewer pipes. By comparing original inspection data with manipulated one, the effect of specific error types became quantifiable. It was observed that the use numerical assumptions for defect severity instead of performing a single case defect evaluation had a smaller impact on the substance assessment than on the condition assessment. However, the structural substance is more sensitive towards errors related to the extension of defects. While some errors can change the substance value / substance class of single reaches significantly, the mean impact is much lower. The substance assessment of a whole sewer network is thus quite robust against the here considered errors of inspection data.

Keywords

CCTV Inspection, Condition assessment, Pipeline, Sensitivity analysis, Substance assessment, Wear

Introduction:

For the rehabilitation planning of sewer systems, a condition assessment is carried out using a standard methodology in Germany (DWA-M 149-3). It provides information on the rehabilitation urgency of sewers and thus supports short-term rehabilitation planning. However, it has been shown that the data is not suitable for setting up long-term rehabilitation strategies and for identifying the best rehabilitation technique (Kerres et al., 2020). To fill this gap, as a supplement to the traditional condition assessment, a standardized structural substance assessment was developed in the SubKanS project. In contrast to the condition assessment, the structural substance is not based on the assessment of the most severe individual defect of a reach. It considers mainly the defect density and distribution and is defined as the structural wear of a reach. The note lies between 0 % (sewer in new condition) and 100 % (completely worn). Both ratings assign a class between 0 (very low condition/substance) and 5 (very high condition/substance) to a reach and are based on the visual inspection and the defect coding according to NS 13508-2 (EN 13508-2:2003+A1:2011).

The CCTV visual data is evaluated manually. To each of the detected defects a severity class is assigned afterwards that is linked to the defect code. Errors can occur during coding that affect the subsequent assessment. Caradot et al. (2017) found, that the condition of 20 % of pipes in bad condition was overestimated. Furthermore, for some of the defects the severity class needs to be assigned on an individual basis by qualified engineers. The substance algorithm however was aimed to be automated. Therefore, these case-by-case decisions were replaced by numerical values suggested in the BFR Waste Water Guidelines (2019).

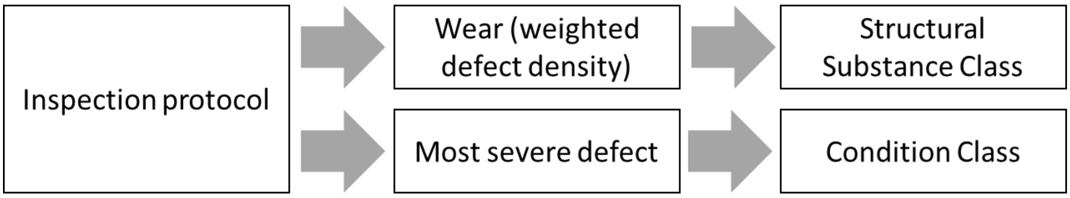

Figure 1: Simplified Structural Substance and Condition assessment based on inspection protocols

In the presented sensitivity analysis, the extent to which errors in defect coding and falsely assumed numerical values influence the calculation of the wear and the subsequent substance classification. The analysis was also performed comparatively for the condition classification.

Methods:
In the project, a set of inspection data from approx. 80,000 damaged sewers from various large German cities was collected. First, the consortium identified typical coding errors based on expert knowledge. The frequency of occurrence of errors was roughly divided into four classes: "frequent", "occasional", "rare" and "unpredictable". Subsequently, sewers were selected on which these errors could potentially occur and the inspection data of these sewers were manipulated to simulate the presence of the errors. Lastly, the assessment results with and without the manipulation have been compared to understand the sensitivity of both assessments (condition and substance) to input data errors. The type of errors and the manipulation procedure are listed in table 1.

Table 1 Inspection error types and manipulation of a data set.

Error type	Manipulation
False numerical assumptions for defect severity	All Pipelines with a defect requiring a case-by-case decision were selected. Instead of the numerical standard assumption a different severity class was chosen. Four different cases were evaluated separately: the numerical assumption was decreases by two classes, decreased by one class, increased by one class, increased by two classes
Missed defect	This was analysed for each defect severity class separately. All Pipelines with at least one defect of the corresponding severity were selected. One defect was randomly removed from the inspection data.
False defect code	For some defects there is a tendency for them to be incorrectly coded more often. Pipelines with such defects were selected and the defects were changed to a code they are frequently confused with. (i.e. spalling (BAF B) is coded as collapse (BAC))
False defect type	Pipelines with a coded longitudinal defect, that can by definition only be a punctual defect, were selected. The longitudinal defect was changed into several punctual defects. The number of punctual defects depended on the kind of defect.
False pipeline length	The manhole might be falsely added to the sewer length in the inspection protocol, leading to an increased pipeline length and thus lower defect density. All pipelines were selected. The pipeline length was decrease by 1 m.

The probability of the manipulation leading to a different classification of the sewer was calculated. For the wear, a mean deviation due to the manipulation was calculated, as well as the 20 %, 50 %, 80 %, and 95 % quantiles around the mean.

Results and Discussion:

In this section two examined error types are described in more detail. The full analysis is available in the project report (Kerres et al., 2021).

According to the estimation in the project consortium, an underestimation of the severity by using numerical assumptions is “frequent”. If the severity assumption was indeed too low by 2 classes, this would as a consequence underestimate the wear of a reach on average (median) by 4.2 % (Figure 2). However, there are also reaches where the wear is underestimated by more than 40 %. This depends on the reach length and the type of defect. For 42 % of all considered reaches, this assumption would result in a different substance class. Within the condition classification, however, the effect is much higher. A closer look at the class distribution reveals that most of the 72 % wrongly classified reaches are distributed especially to the two most critical classes.

An automation with numerical values has an impact on both classifications, but is clearly less critical with the substance classification.

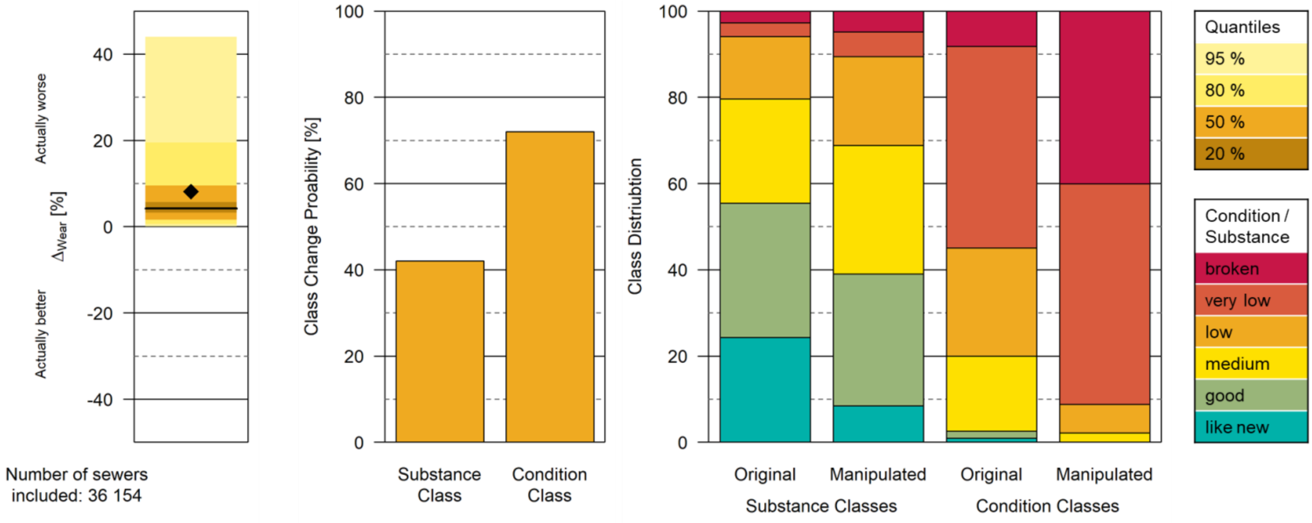

Figure 2 The effect of the use of a false blanket value when defect is actually more severe by two classes. Diagrams show the impact on the wear, the probability of a resulting change of substance class and condition class and the class distribution (original: blanket value used; manipulated: Severity two classes higher).

The overlooking of severe defects has a particularly strong effect on the condition classification. Here, the substance classification is more robust, as it considers the entirety of all damage. However, extreme defects are rarely overlooked. This happens more frequently with medium severe defects (classified as “occasional”), which has only a minor impact on the condition classification. By removing medium damage, only 11 % of all sewers changed their condition class, which is distributed among pipelines with medium to good condition (Figure 3). Defects over the entire reach, however, have a large effect on the density of defects. In the dataset, almost 40 % of the medium longitudinal defects spread over the whole pipeline length. The wear and substance classification react here particularly sensitive. Overlooking these damages leads on average (median) to an underestimation of the wear by 12.7 %. This error is by far the one with the greatest effect on the substance assessment. All remaining error types resulted in an average wear deviation of less than 5 % (data not shown),

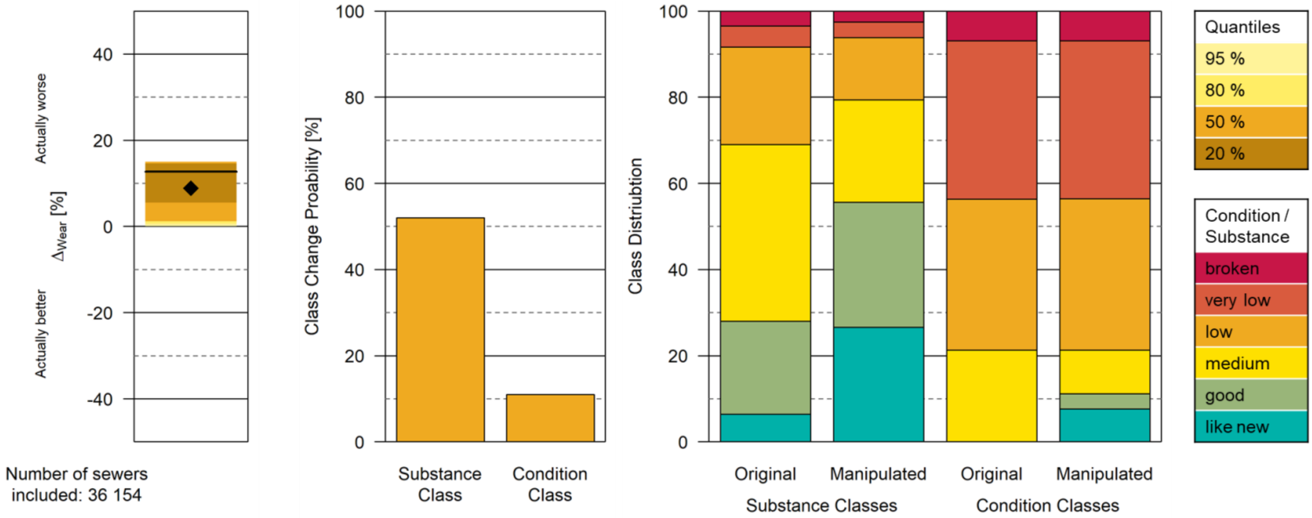

Figure 3 The effect of an overlooked medium severe longitudinal defect. Diagrams show the impact on the wear, the probability of a resulting change of substance class and condition class and the class distributions (original: defect observed; manipulated:defect missed).

Conclusions:
The sensitivity analysis shows that uncertainties in the inspection data, which were previously negligible in terms of the condition assessment, can be of greater significance for the substance classification and vice versa. The use of numerical values for defect severity without considering the individual case can have a significant impact on the condition assessment, especially for the most critical condition classes and thus might lead to a false prioritisation of rehabilitation measures. The substance classification however, is more robust, which justifies the use of numerical assumptions and allows for an automated assessment. Errors or false estimations can have a large effect on the wear of a single pipeline, however, in average the deviation of wear is less than 5 % except for the presented overlooked medium severe longitudinal defects.

REFERENCES

BFR Waste Water Guidelines, 2019 „Baufachliche Richtlinien Abwasser – Arbeitshilfen zu Planung, Bau und Betrieb von abwassertechnischen Anlagen in Liegenschaften des Bundes“, Bundesministerium des Innern, für Bau und Heimat (BMI)

Caradot, N., Rouault, P., Clemens, F., Cherqui, F., 2018. Evaluation of uncertainties in sewer condition assessment. Structure and Infrastructure Engineering 14, 264–273. https://doi.org/10.1080/15732479.2017.1356858

EN 13508-2:2003+A1:2011, Investigation and Assessment of Drain and Sewer Systems Outside Buildings - Part 2: Visual Inspection Coding System

DWA-M 149-3 German Guideline: „Zustandserfassung und -beurteilung von Entwässerungssystemen außerhalb von Gebäuden – Teil 3: Beurteilung nach optischer Inspektion“, Hennef, 2015

Kerres, K., Gredigk-Hoffmann, S., Jathe, R., Orlik, S., Sariyildiz, M., Schmidt, T., Sympher, K.-J., Uhlenbroch, A., 2020. Future approaches for sewer system condition assessment. Water Practice and Technology 15, 386–393. https://doi.org/10.2166/wpt.2020.027

Kerres, K. et al. ,2021: Entwicklung eines Standards zur Bewertung und Klassifizierung der baulichen Substanz von Abwasserkanälen und Schächten (SubKanS). Final report of the BMWi-Project SubKanS. (Download: www.Subkans.d