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# Future approaches for sewer system condition assessment

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## Abstract

Different analytical approaches exist to describe the structural substance or wear reserve of sewer systems. The aim is to convert engineering assessments of often complex defect patterns into computational algorithms and determine a substance class for a sewer section or manhole. This analytically determined information is essential for strategic rehabilitation planning processes up to network level, as it corresponds to the most appropriate rehabilitation type and can thus provide decision-making support. Current calculation methods differ clearly from each other in parts, so that substance classes determined by the different approaches are only partially comparable with each other. The objective of the German R&D cooperation project 'SubKanS' is to develop a methodology for classifying the specific defect patterns resulting from the interaction of all the individual defects, and their severities and locations. The methodology takes into account the structural substance of sewer sections and manholes, based on real data and theoretical considerations analogous to the condition classification of individual defects. The result is a catalogue of defect patterns and characteristics, as well as associated structural substance classifications of sewer systems (substance classes). The methodology for sewer system substance classification is developed so that the classification of individual defects can be transferred into a substance class of the sewer section or manhole, eventually taking into account further information (e.g. pipe material, nominal diameter, etc.). The result is a validated methodology for automated sewer system substance classification.

**Key words:** condition classes, strategic asset management, substance classification, substance preservation

## IMPORTANCE OF CONDITION CLASSIFICATION FOR STRATEGIC ASSET MANAGEMENT

Due to their great length and investment level, city and community drainage systems represent the major part of municipal fixed capital. The increasing age of drainage networks and long service life expectancy for renewed assets prompts many network operators to plan budgets with foresight and develop sustainable rehabilitation strategies to preserve the substance.

While there are generally common analytical standards to classify rehabilitation priority, various approaches exist for describing the structural substance or wear reserve of sewer sections (Figure 1), and few if any have been standardised.

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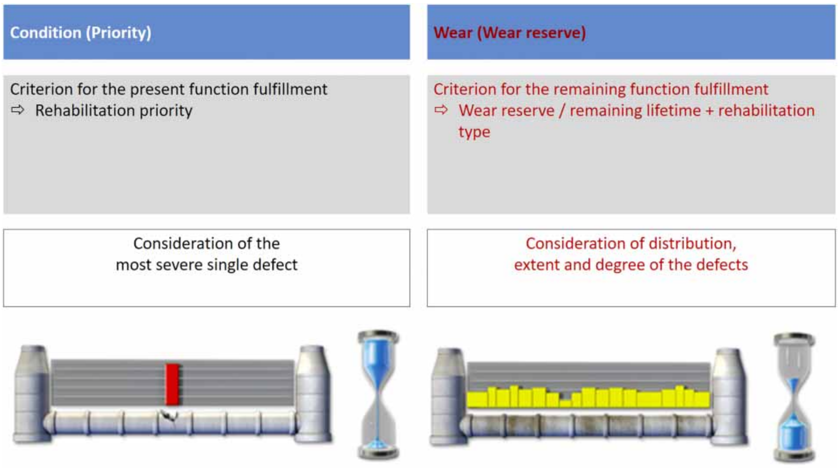


**Figure 1** | Classification of rehabilitation priority vs. classification of wear reserve. Stein & Stein (2014).

The aim of all approaches is to convert engineering assessments of often-complex defect patterns and boundary conditions into computational algorithms, and thus determine the substance/wear reserve. This parameter serves for weighting and ranking procedures as a substance class for a sewer section or manhole. The calculation methods differ clearly in parts, so that the substance classes of different approaches are only partially comparable, if at all.

Comparability of asset assessment results is needed, however, to ensure consistent and sustainable asset management processes (e.g. rehabilitation and maintenance). The long life cycle of pipe-based network infrastructure and the numerous similar, single-investment elements built in (e.g. pipes, manholes), require analytical instruments that deliver key figures to support transparent and consistent decision-making reproducibly and at a level to match the quality of single decisions made from manual assessment by experienced engineers. The worldwide urbanisation trend and resulting growth in public service networks will increase the need for such decision-making support.

## DEFINITIONS OF 'CONDITION' AND 'WEAR RESERVE'

In Germany, classification of the structural condition of sewers and manholes generally takes place according to DWA-M 149-3 (DWA 2007). The aim of the condition assessment and evaluation is to determine the structural and operational rehabilitation needs, ranked by individual rehabilitation priority.

The inspection results for sewers and pipes, manholes and inspection openings, and local drainage infrastructure buildings – recorded in line with BS EN 13508-2 (BS EN 2011) and the corresponding German advisory leaflet DWA-M 149-2 (DWA 2006) – provide the data base for the subsequent condition classification. For asset condition classification, each separate defect must be classified first.

For application in operational practice, tables or decision support systems with fixed values and strict class thresholds are used, as well as systems with continuous class transition (e.g. fuzzy logic) and simultaneous inclusion of influencing factors.

Sewer sections and manholes are the subject of the condition classification, so the results of classifying their individual defects must be merged into a single classification result (Figure 2), which takes a number of criteria into account, including:

- the most severe individual defect;
- the frequency and extent of further defects;
- the extension and length of individual defects.

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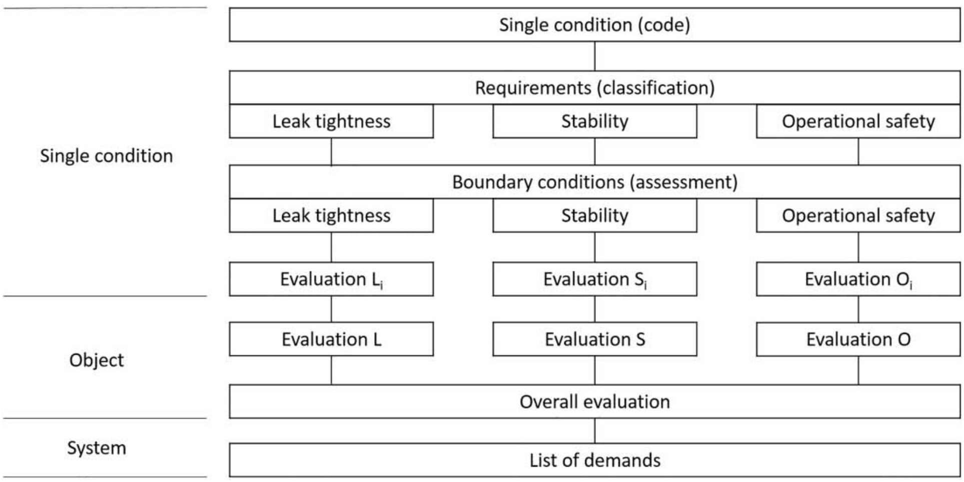


**Figure 2** | Condition evaluation procedure for sewers – German standard. DWA (2007).

The condition classification result represents the current performance level at the time of inspection (rehabilitation priority). Substance, on the other hand, is the technical measure of the remaining 'wear reserve' and thus service level then (Figure 3).

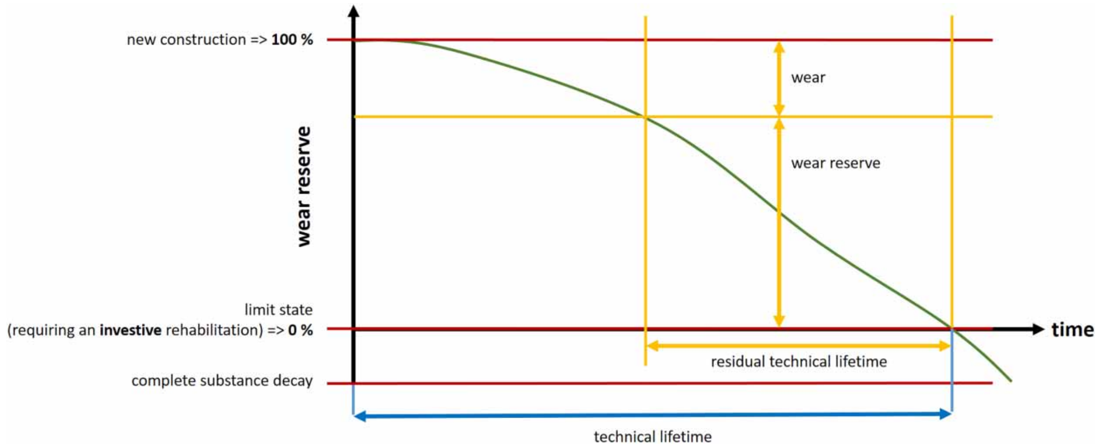


**Figure 3** | Development of the wear reserve over an asset's technical lifetime.

DIN 31051 (fundamentals of maintenance) says that deterioration leads to a reduction in the wear reserve, caused by chemical and/or physical processes. The wear reserve is an element's inherent performance level under defined conditions, due to its construction, rehabilitation and/or improvement. The wear reserve is dimensionless, so the wear of sewer sections and manholes refers to the technical (non-monetary) effort required to restore the element's full function (operation, stability and tightness of the section or manhole), not the priority with which this must be done. (DIN 2019).

The wear reserve of a sewer section or manhole is depleted if, from an engineering point of view, one or more thresholds is reached for technical reasons because of its structural condition (ascertained by visual inspection), which requires rehabilitation investment and renders maintenance measures unnecessary. This is substance class 0 and is not, physically or mathematically, an absolute and mandatory classification or assignment, but rather the result of engineering consideration and thus of determinations.

Automated substance classification is intended to map such decision-making with sufficient accuracy as an important step in higher-level infrastructure management.

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## CONDITION AND SUBSTANCE CLASSIFICATION FROM THE OPERATOR'S POINT OF VIEW

ISO guideline series 24516 'Guidelines for the management of assets of water supply and wastewater systems', articulates that the operator's task is to define both functional and performance requirements for the wastewater infrastructure system controlled. Their degree of fulfilment must be reviewed regularly and, if there are deviations, strategies and programmes must be developed for a needs-based system of adjustments (ISO 2017). With the help of the asset service's operating units, measures and projects for individual plant components must be planned and implemented.

Abstract goals, such as legally compliant disposal security, sustainable function, and value preservation or financial stability must be specified by the infrastructure management unit as a decision-making basis in the company's divisions. Strategic Asset Management must determine the framework conditions relevant to the company to achieve these objectives. In turn, Operative Asset Management translates them into specific targets, and assigns them to the technical and organisational areas of the overall system. In order to track the development of corresponding target values, measurement variables or key performance indicators (KPI) are also required. The guideline series (op cit) recommends the definition of corridors by defining so-called trigger and target levels, for monitoring and controlling KPIs.

Accordingly, a management concept must be scalable and incorporate basic principles, in particular the generally applicable set 'Plan-Do-Check-Act' (PDCA), to be developed with other available methods and standards into an applicable form.

Integral sewer management, according to BS EN 752 'Drainage systems outside buildings – sewer management' (2019) and the associated technological rules (DWA sub-standards, worksheets and advisory leaflets, etc.) have been the de facto standard of drainage system planning, construction, operation and rehabilitation for many years. The basic investigation and assessment activities, to develop possible solutions, as well as plan and implement measures, are understood and handled according to DWA-M 149-1 (DWA 2018) respectively according to DWA-M 143-1 (DWA 2015) and DWA-A 143-14E (DWA 2005), as individual steps in a repetitive management process (explicitly according to the PDCA cycle). In particular, the methods for determining and assessing sewer condition and for the prognostic derivation of the short-, medium- and long-term need for action for the asset group – sewer sections and manholes – are to be regarded as valuable models.

The condition classification method is used to derive a priority list for action, determined for individual elements based on standardised defect descriptions. The condition class primarily supports the operator, therefore, in ranking the necessary rehabilitation measures and is thus predominantly a decision factor (for now). A corresponding substance class, as a measure of the remaining capacity in the element under investigation (in the sense of ISO 24516: the remaining performance), can supplement the decision basis. In addition, the standardised substance class offers an important application option to infrastructure managers. As it can be used to indicate confidence in the potential, future technical usability of individual components in the system, the operator has a means of developing transparent forecasts for element groups, sub-networks or the total network. Thus, recurring technical and monetary resource requirements can be forecast and it becomes possible to establish the monitoring and control – for example, of intended effects and/or aims – needed for management. It will also enable objective comparison between operators; for example, during benchmark projects.

For these reasons, the operators involved in 'SubKanS' have a major interest in the development a standardised classification method using condition data already available in network operation.

## EXISTING SUBSTANCE CLASSIFICATION METHODS

Deterioration arises from all detected individual defects; local dependencies and interactions between individual defects must be taken into account. State-of-the-art models for sewer rehabilitation

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strategies consider both the priority and substance of each element in the network. Approaches may differ in the number of parameters included and/or their set focus, but all are funded on the same basic principles:

- all observed deficiencies and their respective descriptions (main code, characterisations, quantification, location) are relevant;
- all deficiencies are assigned individual lengths, even if not recorded in inspection protocols (i.e. point deficiencies are given start and end longitudinal locations);
- the deficiencies within a sewer, with their varying impacts on sewer deterioration, create a distribution pattern of defective and non-defective areas that impacts the residual wear reserve of that element significantly.

The aim with all models is to support the engineers evaluating the inspection protocols and the corresponding records, to determine the rehabilitation action priority required (based, mainly, on the most severe defect). They also provide an assessment of the rehabilitation action's nature – whether maintenance is sufficient to restore the required functionality/service level, or whether investment (rehabilitation or renewal) is needed.

The models differ in the way that the decision parameters are included. Some separate the core assessment of the wear reserve – based on structural and functional issues – from the decision process, which incorporates additional financial aspects and ancillary conditions such as the surrounding area or groundwater level. Other models describe the extents of deficiencies by rehabilitation needs, and thus consider structural and functional requirements, local conditions, rehabilitation costs and residual lifetime in step with actual practice from the very beginning.

## OBJECTIVES AND METHODOLOGY OF 'SUBKANS'

Within 'SubKanS', various research facilities, sewer network operators and model providers are currently developing a practically oriented procedure describing the residual technical lifetime period (wear reserve) in a referenced and transparent form, and preparing a rehabilitation decision. Standardisation facilitates strategic rehabilitation planning for sewer network operators by providing a uniform basis for forecasting calculations incorporating the following properties:

- Methodology and results adapting operator requirements to practical suitability (the basis of the substance classification calculation takes the generality of operator data available into account by being robust with respect to data quality fluctuations).
- Results enabling conclusions to be drawn about the rehabilitation (main) procedure (renewal, renovation or repair) of a defective element, as well as expected rehabilitation costs.

Existing substance classification methods usually refer to the condition description and condition classification related to individual defects in accordance with DIN EN 13508-2 and DWA-M 149-3E (BS EN 2011, DWA 2007). These simplifications can lead to improper classification of the structural substance of sewer sections.

'SubKanS' yields a classification methodology for individual defects with regard to the structural substance of sewers, based on real data and theoretical considerations analogous to the condition classification related to individual defects (Figures 4 and 5). The result is a catalogue of defect patterns and characteristics, as well as associated classifications related to the structural substance of sewer systems (substance classes).

The sewer system substance classification methodology is developed so that the classification of individual defects can be transferred into a substance class for the sewer section or manhole, eventually taking into account further information (e.g. pipe material, nominal diameter, soil,

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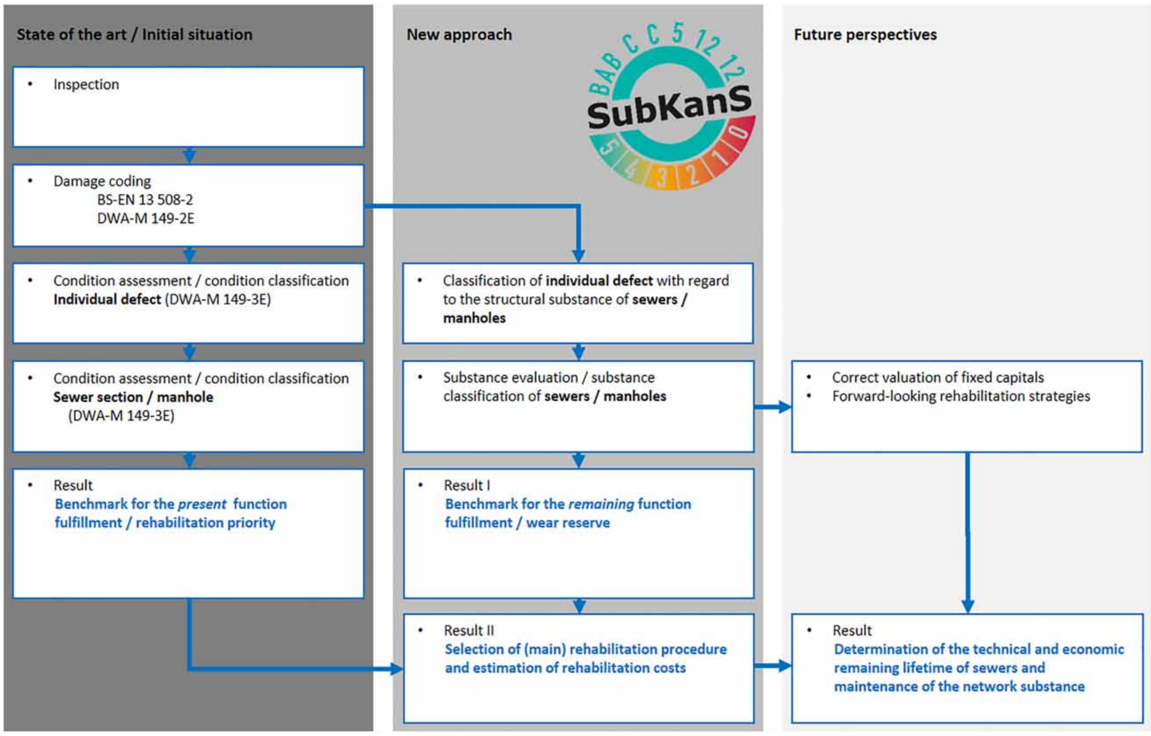


**Figure 4** | 'SubKanS' in the context of state-of-the-art and future perspectives.

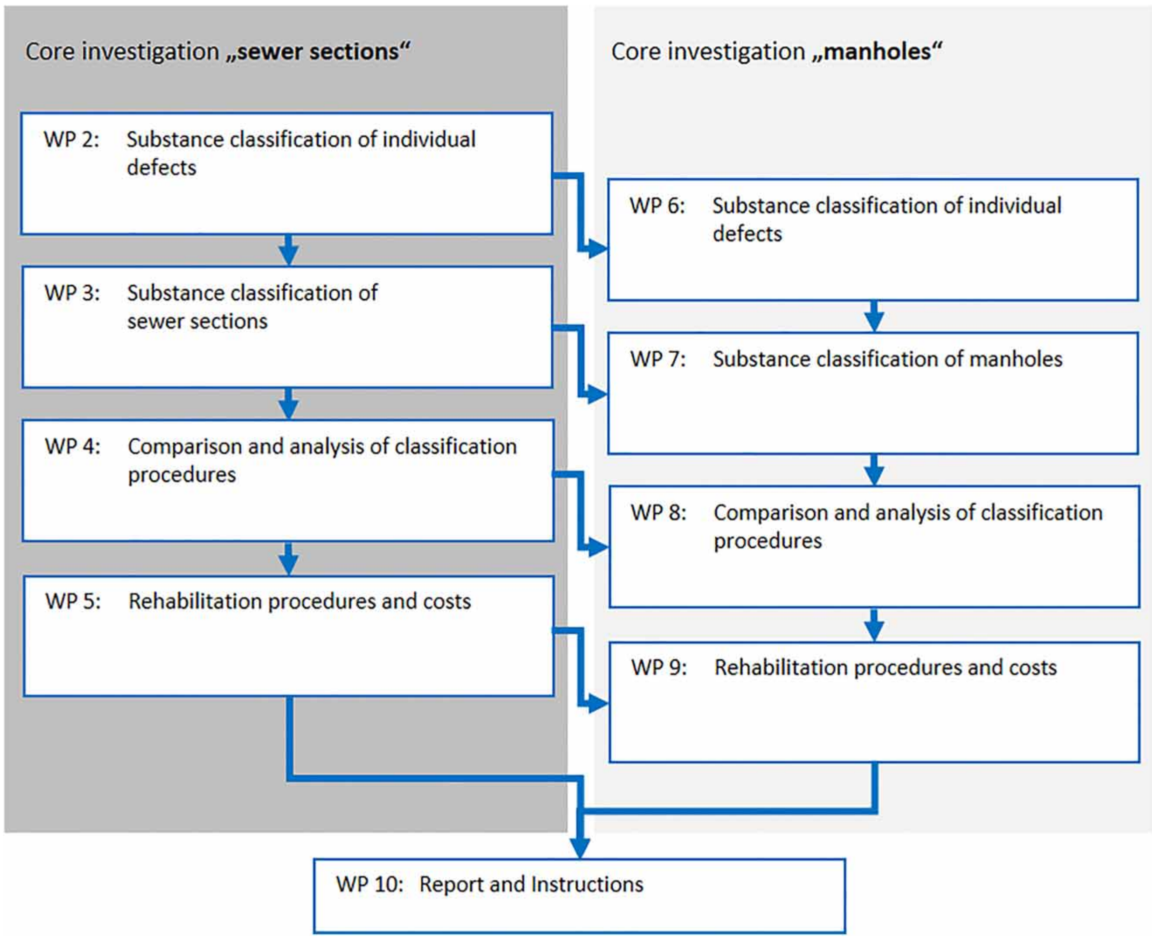


**Figure 5** | 'SubKanS' working programme.

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groundwater etc.). The result is a validated methodology for the automated classification of sewer system substances.

## RELEVANCE OF INDIVIDUAL DEFICIENCIES

Sewer inspections generate coded observations, each related either to individual element deficiencies or their inventories. All observations contribute to the total picture of the element, from which subsequent conclusions regarding rehabilitation priority and action are made.

Thorough discussion of each deficiency code in the European standard BS EN 13508-2 to describe sewer element indications, their relevance for and contribution to the wear reserve covered all three fundamental requirements of condition assessment – structural stability, leak tightness and operational reliability (Figure 2).

At individual deficiency level, none of the codes relating to the element's fabric or operation can be considered irrelevant or negligible for determining the remaining wear reserve. This is mainly true because every deficiency has a potential impact on the wear reserve when interactions with other indications are taken into account.

The question was also raised as to whether inventory codes that are not graded as deficiencies might have an impact on the wear reserve. Inventory codes for point repair, for instance, certainly relate to element aging.

## CONCLUDING REMARKS

The aim of the 'SubKanS' R&D project is to establish a new classification approach for the actual structural condition of sewer network elements. This new approach will help to define the state of an sewer element (e.g. a sewer or manhole) in relation to the integrity of its substance. The approach will also inform the main rehabilitation procedure (repair, renovation or replacement) depending on the actual defect pattern.

The classification approach was developed using a small sub-set of about 100 selected defect patterns from available sewer inspections. The patterns were selected to define necessary data points; for example, for sewer wear being either 100% or 0. Sewer rehabilitation specialists also assigned their preferred main rehabilitation procedures to the selected defect patterns. Different calculating possibilities for numerical wear values were tested, on the basis of the specialists' assignments. This enabled the consequences, operating limits and robustness of different classification approaches to be investigated and optimised.

The classification approach needs further calibration for general use in practice. For this, a dataset of about 30,000 sewers will be established covering a large variety of possible defect patterns. Differences in defect patterns and the resulting differences in calculated wear are tracked by a number of statistical procedures in this dataset. If unrealistic outcomes are detected, the classification approach will be optimised further.

All approaches are discussed with and evaluated by experts in sewer network operation and/or rehabilitation. The intention is to publish the proven method as a German standard by the German Association for Water, Wastewater and Waste (DWA).

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