Advancing Sewer Asset Management with Data-Driven Solutions

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Abstract: Sewer rehabilitation is a costly challenge for cities like Berlin, with annual investments exceeding €100 million, compounded by aging infrastructure and low replacement rates. Traditional CCTV inspections, used since the 1980s, face limitations in data completeness, accuracy and automation. To address this, Kompetenzzentrum Wasser Berlin and Berliner Wasserbetriebe developed SEMAplus, a suite of data-driven tools modernizing sewer asset management. The system uses machine learning to prioritize inspections and forecast long-term network conditions. This abstract highlights advancements in deterioration modeling and innovation pathways for the digitalization of sewer management. As workforce shortages, budget constraints, and sustainability goals intensify, these innovations are crucial for optimizing investments and strengthening sewer system resilience.

Keywords: sewer, infrastructure, machine learning, robotic, decision support, urban planning

1 Introduction

Sewer rehabilitation is a critical yet costly challenge for cities like Berlin, with annual investments exceeding €100 million. Aging infrastructure and limited replacement rates under 1% in Europe [Eu21] underscore the urgency for efficient asset management. Approximately 20% of Germany's sewers require immediate attention [Be20]. Closed-Circuit Television (CCTV) inspections, standard since the 1980s, remain the primary method for sewer assessment, providing defect data for condition modeling and rehabilitation planning. However, traditional methods often struggle with incomplete data, limited automation, and inefficient prioritization. In response, Kompetenzzentrum Wasser Berlin and Berliner Wasserbetriebe developed SEMAplus, a suite of data-driven tools to modernize sewer asset management. Currently, SEMAplus includes two main modules: the pipe simulator, which uses machine learning to prioritize inspection and rehabilitation needs, and the strategy simulator, which forecasts long-term network conditions based on investment scenarios. However, recent research advances highlight opportunities for improving models and adopting a more automated, holistic approach to asset management. The aim of this abstract is to present the state of the art of deterioration modelling for sewer asset management and to highlight promising innovation pathways for the digitalization of asset management practices.

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2 Deterioration Modelling

2.1 Core Features and Functionality

At the pipe level, Random Forest (RF) model assesses the condition of sewer pipes that have not been inspected (or recently inspected) based on pipe characteristics (e.g., age, material) and environmental factors (e.g., soil type, groundwater coverage). The model is calibrated with utility data through pre-processes like targeted data preparation, plausibility checks and predefined condition classes. Hyperparameter optimization ensures accuracy, while tailored evaluation metrics minimize risks of undetected critical defects and unnecessary interventions [Ca18]. At the network level, a statistical survival model based on Gompitz curves [Le08] predicts long-term sewer network conditions. It groups pipes into cohorts by characteristics like material and construction year to simulate aging and deterioration, enabling utilities to plan investments and rehabilitation strategies effectively. A recent innovation is a risk assessment module based on the ELECTRE-TRI method, developed with INSA Lyon and first applied in Lausanne, Switzerland. This module aids in prioritizing rehabilitation by considering technical, financial, social and environmental risks of degraded sewer pipes.

2.2 Data-Driven Modelling: Ongoing and Planned Innovations

In recent years, utilities have begun to embark on a comprehensive digitalization journey. The increasing availability of CCTV data and geographic information systems, as well as the adoption of automated fault detection with AI and recent innovations in AI algorithms, have enabled the development of new approaches to strategic and operational management of sewer assets. In this context, three innovation paths can be highlighted:

1. The **performance of deterioration model** can still be improved. By integrating defect-level data from multiple inspections, models can now better capture the evolution of defects over time. Machine learning techniques such as Random Survival Forests will incorporate aging processes into condition modeling, bridging spatial and temporal characteristics while potentially unifying the currently separate pipe and strategy simulators. Graph Neural Networks will address missing data on pipe properties and inspections, improving model performance and transferability, even for systems with limited data availability.

2. In addition to the technical and financial implications of asset management strategies, **environmental impact assessment** is becoming increasingly important. With strategic goals to combat climate change and related targets of 'net zero' operations in terms of carbon footprint, most utilities require quantitative information on the impact of asset management strategies on their organization’s greenhouse gas emissions. Incorporating environmental impact metrics through Life-Cycle Assessment will enable utilities to evaluate CO_2e footprints of rehabilitation measures and integrate sustainability into their

strategic planning. This will support the adoption of low-impact asset management strategies.

3. Over recent decades, **renovation and repair techniques** have emerged alongside traditional sewer replacement via excavation. Trenchless technologies like Cured in Place Pipe (CIPP) lining has gained popularity in Europe, enabling cost-effective sewer rehabilitation with minimal traffic disruption and reduced greenhouse gas emissions. Nevertheless, the consequences of lining large parts of sewerage infrastructure need to be carefully assessed to ensure the future resilience of networks and avoid high costs of retrofitting. New methods are needed to allow the inspection and structural monitoring of liners and assess their added value over the long term.

3 Conclusion

Addressing aging infrastructure and budget constraints requires a holistic asset management approach to support both strategic and tactical decision-making. As workforce shortages and limited budgets become increasingly prevalent, automating key asset management steps – such as inspection, defect detection, condition assessment, and decision-making – becomes essential. Modelling solutions empower utilities to make informed, data-driven decisions, optimizing investments for sewer network rehabilitation, while continuously improving efficiency, sustainability, and decision-making to play a crucial role in enhancing sewer infrastructure asset management.

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