FinEst Centre
for Smart Cities

SMART CITY CHALLENGE 2025
Solution idea for the city challenges

Max 3 pages
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Solution Idea Title Smart Management of Urban Water Networks

Planned pilot project duration – 24 months

Main contact/-s – Ivar Annus, ivar.annus@taltech.ee, 5298810, Tallinn University of Technology, Department of Civil Engineering and Architecture
Maarja Kruusmaa, Maarja.kruusmaa@taltech.ee, 5183074, Tallinn University of Technology, Department of Computer Systems

1. Which urban challenge or problem are you planning to provide a solution to?

- **Intelligent Management of Sewer and Stormwater Networks proposed by Tallinn, Estonia.**

2. The solution you are proposing

Heavier rainfalls, aging pipes, and stricter environmental rules are forcing cities to rethink how they operate and manage their water systems. Today, most maintenance is done only after problems like pipe breakages, stormwater floods or drainage clogging appear, and it requires a lot of manual work. To keep water systems running reliably in the future, cities need smarter tools that can spot issues early and help to plan maintenance before failures happen.

Proactive asset management needs far more—and much better—data, including information from sewer sections that we currently can't reach or inspect.

We propose a solution that:

1. **Uses robots to collect data** inside sewers, including areas that are currently hard or impossible to reach for humans.
2. **Uses robots to place sensors** throughout the sewer network, even in sections that are now almost inaccessible.
3. **Couples the collected data with GIS to turn it into a decision-support system** that helps engineers and operators decide where, when, and how to inspect, maintain, and repair the network.

More specifically, we are developing robots and sensor-deployment methods that allow robots to enter and exit the sewer system through manholes and attach sensors along the pipes. A wireless communication setup will send data via a LoRa network to 4G gateways located in manholes, and from there to a cloud platform.

The data will feed into an integrated asset management (IAM) tool built on a GIS platform comprising high-fidelity digital twin of the existing sewage and/or stormwater system. We will use the USEPA SWMM model to simulate flow dynamics and GIS to analyze spatial data – for example, other infrastructure in the vicinity. The digital twin will be linked to three modules, developed in GIS by implementing MATLAB and Python:

1. **Calibration and validation module** – a semi-automated system to check how reliable the digital twin is under different conditions. It will incorporate new data gathered by the robots, such as infiltration rates, pipe conditions, unknown connections and inflows, blockages, sedimentation that are currently not monitored or hard to monitor.
2. **Data-driven asset management module** – this will identify which parts of the network are most suitable and most important for new monitoring solutions. It will use graph-based methods together with advanced asset-management approaches (e.g. Annus et al., 2024[1]) to detect and propose monitoring routes for the robots and to support the asset owners with data-driven reconstruction and renovation planning.
3. **Scenario builder** – this module will propose operating strategies that reduce flooding or combined sewer overflows under current and future conditions. It will use the digital twin, expanded data sets, and input from stakeholders to generate these scenarios.

3. Innovation and piloting of your pilot solution.

The existing asset management practices are based on the traditional monitoring data that rely on the CCTV camera images about the pipeline conditions, historical data about the failures and periodic or real-time monitoring of the system status in limited number of measuring points. Although there exist a number of machine learning tools that can be used to analyze the CCTV camera footages, the condition of monitoring remains reactive and quite labor intensive. The calibration of the digital twins of the sewage and stormwater systems is challenging due to the lack of data and constantly changing operational and environmental conditions. The project will develop and test both new monitoring solutions to acquire more data from more locations to catch the changes in the conditions and flow dynamics that traditional monitoring approaches are not able to detect. The consideration of changing conditions will pose a challenge how we define the boundary conditions for the digital twins and how we detect suitable parameters for the models in case of changing boundaries.

In order to test the solution, cities need to provide detailed GIS data sets about their underground water system assets to generate the digital twins of the systems. The digital twins will be used to analyze the feasibility of applying robots to monitor the performance and conditions of the systems. The cities have to agree to share the data and provide access to their sewage and/or stormwater system.

The consortium is composed of two TalTech teams, on having profound competencies in robotics and urban water systems.

The team lead by Prof. Maarja Kruusmaa has long experience in the field of robotics and environmental monitoring in underwater and underground environments. She currently leads a European Horizon funded research project PIPEON for developing autonomous robots for underground monitoring. Her team has also excessive experience in building sensors and sensor networks for rugged environments for long-term deployment, including methods of data processing and data analysis of environmental data.

The team lead by Prof. Ivar Annus has solid background on modelling urban water systems, GIS and developing different data driven toolsets for the municipalities and water companies to support the transition from solely expert-based decision making to data-based one. In the past three years the team has developed inhouse modules to support Tallinn Water Company to update their combined sewage system and drinking water models making these to high-fidelity tools that are linked with

[1] Annus, I.; Kändler, N.; Vaksmann, M.; Kaur, K.; Truu, M.; Koor, M.; Vassiljev, A.; Kütt, U. (2024). Pipeline rehabilitation combined strategy for urban water systems. Urban Water Journal, 21 (2), 155−167. DOI: 10.1080/1573062X.2023.2273535.

existing databases and validated by monitoring data. In addition, the team has developed and piloted a data-driven combined pipeline reconstruction strategy for Tallinn Water Company that has been implemented to support their everyday practice and are currently steering nation-wide data-based water system initiatives for pluvial flood risk assessments in urban areas and a digital toolset for combined stormwater strategy (Sademeveegiid).

Both teams have established a good cooperation with Tallinn water utility (AS Tallinna Vesi) and its subsidiary Watercom OÜ. They initiated together a formal cooperation agreement between AS Tallinna Vesi and TalTech for testing novel solutions in the sewer system of the city of Tallinn and non-disclosure terms for data analysis from the sewer network. Therefore, the cooperation between the end-users is expected to be smooth and fast.

Tallinn, as a medium-sized city is perfectly appropriate for piloting the technological solutions and testing the technologies in a fast feed-back loop. It is logistically easy and cheap to pilot the technologies near the TalTech campus, in Mustamäe region of Tallinn.

4. Expected impact of your pilot solution.

The implementation of the proactive management and monitoring framework will:

- Improve the reliability and functioning of the sewer network
- Provide more accurate data about the system conditions and performance
- Optimize the system reconstruction need and operational and monitoring costs

We estimate that data collection from the sewer system can be speeded up by an order of magnitude. If currently an average sewer network is inspected with an average rate of 2% per year, the robotic data collection would allow inspecting 15-20% of the infrastructure per year, thus the whole city infrastructure could be inspected every 5-7 years. That would be enough to have the GIS database and digital twin of the infrastructure to be sufficiently up to date so that most of the repairs can be planned. Data-based planning of the reconstruction and repairs in turn cause less disruptions for the city traffic, mitigate potential flooding risks and activation of the combined sewer overflows, are less expensive and do not damage properties. Also, it reduces the risk of polluting natural water bodies and groundwater. By eliminating leakages from broken sewer pipes, the potential environmental damages will be significantly reduced.

Recent studies on multi-system intervention planning frameworks for interdependent infrastructures have shown that effective implementation of such models can led to up to 25 % cost savings when considering service unavailability costs for infrastructure on a regional scale. Similar efficiency is expected to be achieved on local scale.