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Improved transparency with digital twins of urban drainage systems

A. N. Pedersen*,**, M. Borup**, A. Brink-Kjær*, L. E. Christiansen*** & P. S. Mikkelsen****

*VCS Denmark, Odense C, Denmark, anp@vandcenter.dk, abk@vandcenter.dk
**DTU Environment, Technical University of Denmark, Kgs. Lyngby, Denmark, morb@env.dtu.dk, psmi@env.dtu.dk
***DTU Compute, Technical University of Denmark, Kgs. Lyngby, Denmark, laec@dtu.dk

Corresponding author: Agnethe Nedergaard Pedersen, Industrial PhD student, anp@vandcenter.dk, VCS Denmark, Vandværksvej 7, 5000 Odense C, Denmark, +45 61149310

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SUMMARY
VCS Denmark is currently reconstructing its digital twin (DT) to include new and more optimized features. A DT can provide increased transparency throughout the entire utility thereby improving the support of employees for taking better actions. The utility's primary needs are within better models for planning and design as well as improving operational tasks, all with help from the DT environment. Features that need upgrading are identified and replaced with better and more flexible solutions. In the future error diagnostics will be a part of the DT toolbox, in order to reduce model uncertainty and the risk of operational errors. The DT is expected to reduce the environmental impacts from the urban drainage system and to support smarter investments.

KEYWORDS
Digital Twin, Error diagnosis, Transparency, Urban Drainage systems

INTRODUCTION
Urban drainage networks are complex, large and very dynamic in terms of flows and physical changes, which make it hard for utilities to acquire and maintain a complete overview of the systems. Models are thus made of the systems, which fit for some purposes and for some purposes not, and this makes it essential to identify the uncertainty of the models. The same models are often used for designing new systems and redesign of the current system, and large model uncertainty can have big economic consequences. Spills of wastewater in operation is inevitable and can have large environmental or societal consequence especially if they are detected too late. A Digital Twin (DT) can help reducing the risk of errors happening – or if they do happen, they may be detected faster than today and the uncertainty of the models may be reduced if a DT is established to regularly compare model results with observations. Thereby the uncertainty of future investments may be reduced.

A DT of an urban water system such as an urban drainage network is defined as a "systematic virtual representation of the elements and dynamics of how a physical system operates and works" (Pedersen et al., submitted; Autiosalo et al., 2020; Karmous-Edwards et al., 2019). This is not the same as a model (Wright & Davidson, 2020), but a simulation model usually plays a substantial role in a DT. A DT can help the staff in a utility to achieve and maintain a better understanding of the system beneath the ground.

VCS Denmark is the utility in the municipalities of Odense and Nordfyn and is responsible for the urban drainage system, the water resource recovery facilities and most of the water supply in the area. It handles wastewater from app. 240,000 inhabitants from an area of 757 km^2 both containing city area as well as rural areas. VCS Denmark (VCS) currently has a simple DT of the urban drainage system, in which a model is run, and model results are compared with observed water levels in a few locations every day. This DT will be updated significantly in the coming years, where different features will be improved. The aim is to ensure transparency of the system through establishing a comprehensive a digital twin, aiming to supervise and support the employees of the entire organization to take the best action possible on an operational, tactical and strategic level.

METHODS

A DT can have many features and the first step in developing a DT is to identify what needs the utility has. When the needs are identified the utility can start building the DT including as many features as needed. The elements could for instance be (**Figure 1**) data link, coupling, identifier, security, data storage, user interface, simulation model, analysis, artificial intelligence or computation (Autiosalo et al., 2020; SWAN, 2020). Urban drainage systems are dynamic by nature, as there will be new infrastructure, system redesign as well as new sensors and actuators in the future. The DT solution should therefore be robust and prepared for these changes, so that utilities can incorporate new features in their DT as additional needs are identified.

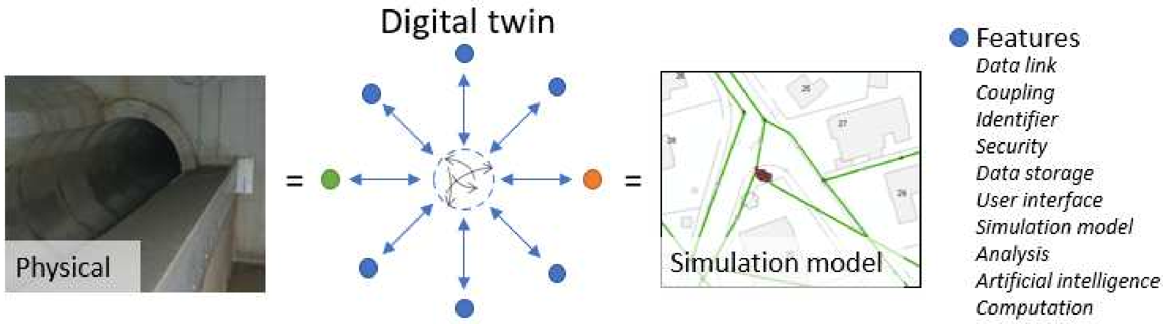

Figure 1 Illustration of the concept of digital twin (DT) for urban drainage systems. The DT consists of a virtual part linked to a list of features and to the physical counterpart. ◯ refers to the feature Data link, which is the center of a star structure surrounded by other features. ● refers to the feature coupling and ● refers to the feature simulation model. Inspired by Autiosalo et al. (2020). Figure from Pedersen et al. (submitted).

RESULTS AND DISCUSSION

Until now, the primary reason for having a DT was to document and make a simple validation of the hydraulic model. VCS has implemented a schedule for regular updating of the model, which can happen with few manual inputs. With the improvement currently being developed, VCS has spotted a need to also include e.g. operational staff into the world of digital twins (Pedersen et al., submitted). The operational team will benefit from the DT by identification of planned maintenance as well as an increasing knowledge of the current system and the easy access to historical observations. For locations in the system not observed by sensors, results from the simulation model can help giving an estimate of the system state and dynamics. Besides operational improvements, one of the primary purposes of having a DT is still to improve the hydraulic models generally, so that they better represent different operational conditions (i.e. dry weather, rainy periods) in different parts of the areas covered by the models. Thereby it is possible to gain trust in the models, and to put more confidence in the investments and operational decisions made based on the model results.

Figure 2 illustrates some of the features in the current DT workflow in VCS. The data storage, visualization platform and analysis tools are currently being redesigned. The idea is to continuously learn from the analysis results, shown in the visualization platform, to regularly update/adjust the models behind the solution or the sensors. However, any adjustment needs to be justified by a proper analysis of the reasons behind a potential update.

The DT consist of many features, and to make the solution as robust and flexible as possible, the environment is based on plug'n'play solutions, like LEGO bricks than can be replaced. Solutions will differ during the years to come, and the environment must be robust for future innovation potential. The solutions will where possible support open data standards.

The "analysis tool" feature is undergoing a major revision, with focus on error diagnostics that can help identifying model errors and errors in sensors. From today analyzing the model performance in a subjective and manual way, the future DT will include objective and automatic validation methods, which will allow a more detailed analysis of the performance of the models.

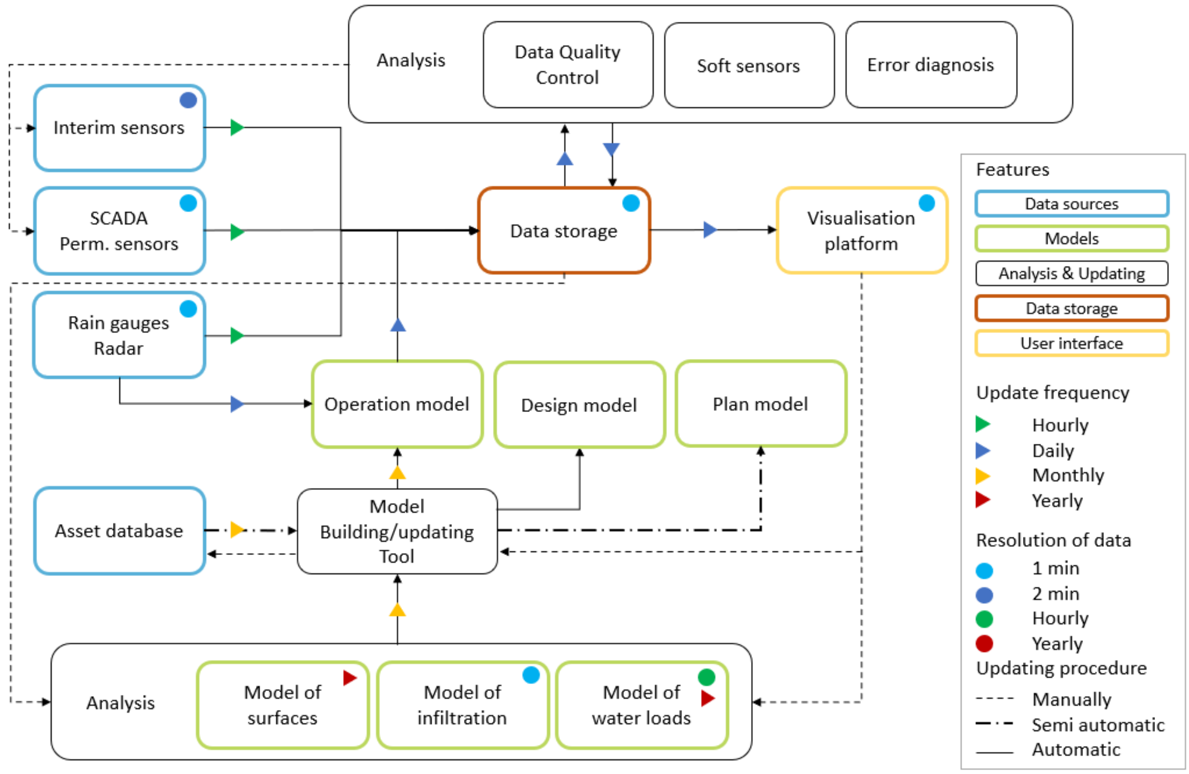

Figure 2 Workflow of the current digital twin (DT) environment in VCS with different features. Figure from Pedersen et al. (submitted).

CONCLUSION

A DT is an efficient way to explore the digital transformation of a utility and the potential users of DTs are found to be within many fields of work. The objectives of a DT should not be limited to only a few staff groups. In VCS the objectives of the DT are primarily within operation and planning, but e.g. documentation can be included as well. The current workflow of the VCS DT is illustrated, and this helps VCS analyzing the needs for improvement in the further development of the DT. In the future, error diagnosis tools will be implemented among other things.

By having a DT, it is possible to support a larger transparency of data and workflows, in order to achieve the common goal of a better environment and a more robust utility.

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