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SWAN
SMART WATER NETWORKS FORUM

Digital Twin Readiness Guide

Applying SWAN's Digital Twin Architecture to the water industry

Brown AND Caldwell

DHI

Contents

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Introduction

Introduction

Utilities of all sizes face unprecedented challenges from increased cost, greater customer expectations, talent management, and knowledge retention.

These challenges create overwhelming complexities to operate water throughout its lifecycle. Digital Twins offer a promise to revolutionize the way utilities are managed, yet there hasn't been any guide for utilities to best leverage this technology into a common environment where utility personnel are fully supported.

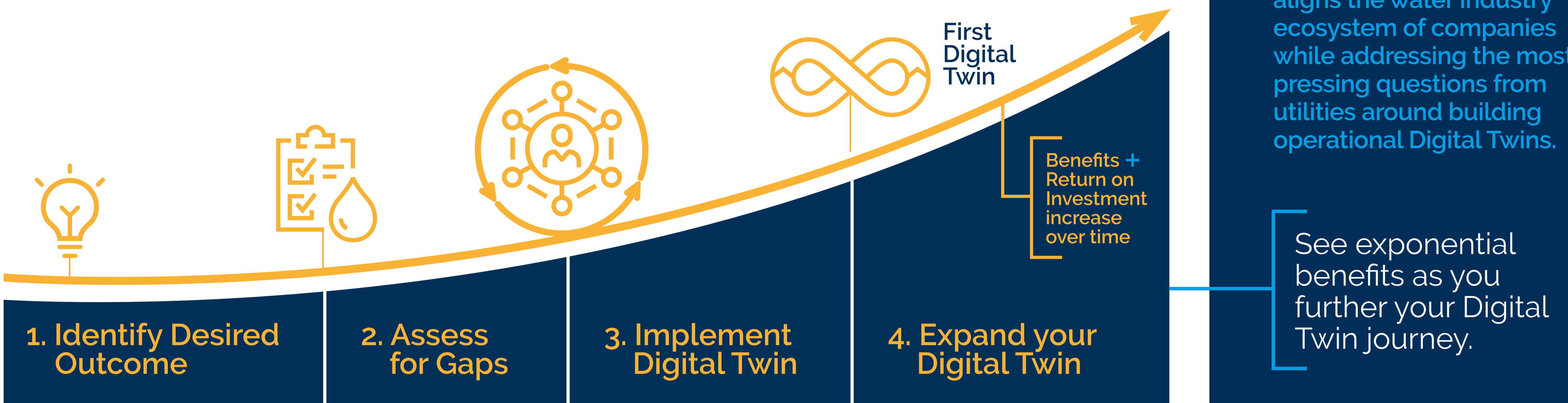
A Digital Twin is a dynamic digital representation of real-world entities and their behaviors using models with static and dynamic data that enable insights and interactions to drive actionable and improved outcomes. Although the Digital Twin can be used throughout the lifecycle of the water infrastructure, this Digital Twin Readiness Guide focuses on the operational Digital Twin. This Guide provides foundation, the necessary steps, and the path for each utility to achieve those essential insights that lead to an efficient and optimized utility.

In early 2019, the Smart Water Networks Forum (SWAN) created a global working group, the Digital Twin Holistic Architecture Sub-Group, to focus on Digital Twins. Comprised of more than 80 participants and more than 45 companies, the group has successfully established the Digital Twin architecture and, through this Readiness Guide, has launched a roadmap for implementation.

The Journey toward a Digital Twin

While the path to implementing a Digital Twin is unique to each utility, the steps toward successful implementation are foundationally the same.

The implementation process is a journey. A true implementation is scalable and iterative and will likely be phased over many years, depending on the unique needs, budget, and starting point of each utility. Each utility will be approaching Digital Twin implementation from a unique set of desired outcomes, and infrastructure, budget, and software requirements. The good news is that implementing a Digital Twin is a flexible, scalable process that can accommodate these individualized needs effectively.



This Digital Twin Readiness Guide provides the foundation, the necessary steps, and the path for each utility to achieve necessary insights leading to more intuitive water systems operations making the utility more efficient. This Readiness Guide also seeks to establish a common terminology that aligns the water industry ecosystem of companies while addressing the most pressing questions from utilities around building operational Digital Twins.

The Digital Twin Readiness Guide is truly a whole of many parts.

18

months of document development with contributions resulting from

49

companies

70

meetings

14

workshops

Digital Twin has Arrived

"As leading global utilities, we believe the SWAN Digital Twin Readiness Guide can transform the water sector by enabling utilities of all sizes and the industry as a whole to understand the foundation of a Digital Twin as they embark or continue their Digital Twin journey."

—SWAN Digital Twin Utility Advisory Group

SWAN Digital Twin Utility Advisory Group

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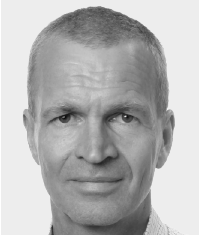

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About the Digital Twin Work Group

Developing a common strategy for a Digital Twin to drive operational efficiency by bringing together global utilities, solution providers, and leading industry thought leaders.

Launched in 2019 in partnership with Gigi Karmous-Edwards and guided by the SWAN Digital Twin Utility Advisory Group, the global SWAN Digital Twin Work Group is home to diverse utility and industry thought leaders shaping Digital Twin strategy and implementation. Open to SWAN Members, this specialist Work Group provides ample opportunities to attend calls, workshops and webinars, as well as learn, network and collaborate to challenge assumptions and produce tangible results.

"We believe this timely Digital Twin Readiness Guide brings much-needed clarity around Digital Twins. This first of its kind Guide is an industry-leading resource and is the culmination of intensive efforts from over 80 dedicated water professionals. Together we continue to push the boundaries of technology forward. We believe this practical guide will enable and accelerate the use of Digital Twins in the water industry."

—Digital Twin Readiness Guide Leadership

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SWAN

SMART WATER NETWORKS FORUM

SWAN is the leading, global voice for the smart water sector. A membership based non-profit, we bring together water utilities, solution providers, and proactive industry experts to advance the adoption of "smart," data-driven solutions for drinking water, wastewater, and stormwater networks worldwide.

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The content provided in this Digital Twin Readiness Guide is intended solely for general information purposes and should not be construed as professional advice applicable to your particular situation.

Acknowledgments

"Special thanks to the leadership and following people for their dedication to advancing Digital Twins and sharing their knowledge, time and experiences to advance the industry."

— Amir Cahn SWAN Executive Director

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> "Every single water drop is under control."
>
> —Andreu Fargas-Marquès, Co-chair SWAN Digital Twin Workgroup

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Section 1

Digital Twins for Water

A starting point:
Addressing questions regarding Digital Twin technology

Common questions regarding Digital Twin implementation

Every utility has unique needs and a unique community they serve, but most have a similar set of questions when considering Digital Twin implementation.

This Readiness Guide serves to demystify these questions and provide a roadmap to move forward.

Each utility will be approaching Digital Twin implementation from a unique set of software, infrastructure, and budget requirements. The good news is that implementing a Digital Twin is a flexible, scalable process that can accommodate these individualized needs effectively.

What is a Digital Twin, and what benefits does it provide?

Understanding what Digital Twin technology is as well as what it has to offer is critical.

This Readiness Guide Provides:

A clear definition of Digital Twin and, through example case studies, the benefits a Digital Twin can provide.

Where do I start?

Every utility will begin from a different starting point. Your unique system will help dictate the best approach to success.

This Readiness Guide Provides:

Guidelines to help assess your current software, needs, and infrastructure so that you can make an informed decision on where to begin.

Should I start my Digital Twin now or wait?

The journey toward a Digital Twin may be slow or fast, but beginning the process sooner rather than later will provide immediate benefits while aligning each technology investment with a long-term objective.

This Readiness Guide Provides:

Case studies that document Digital Twin success achieved for a diverse array of utilities and identifies where other utilities have started their journey and are seeing immediate benefits.

Can I customize and scale a Digital Twin to best fit my needs?

Yes. Knowing how Digital Twin implementation offers flexibility and customizations will result in a Digital Twin that specifically meets your needs.

This Readiness Guide Provides:

Documentation of how each Digital Twin is scalable and through the individual case studies, show the approaches that utilities have taken to tailor the technology to best fit their needs.

Digital Twin Defined

To realize the promise of Digital Twins, a common understanding of Digital Twins is needed across the water industry.

Digital Twins are a digital representation of the physical world built from a composite of many separate applications and data sets involving technology providers, engineering companies, and utility staff, to name a few, enabling all stakeholders to have a similar understanding and reference of a Digital Twin.

Within utilities, cross-departmental collaborations will need to have a consistent view of a Digital Twin. The Digital Twin is truly a whole of many parts that are constantly in flux, and it is imperative that the water sector agrees on the fundamental concepts of what a Digital Twin is. Without this agreement, Digital Twins can lead to more confusion and make it difficult to attain the desired outcomes they deliver.

A common understanding also helps technology providers tailor their products to help utilities and engineering companies assemble the various components seen in the architecture drawing. For example, technology providers may provide and tailor specific Digital Twin application programmable interfaces (API), for the exchange of data and insights across applications to streamline connection between platforms.

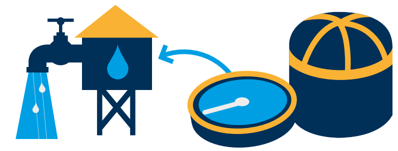
Definition: A Digital Twin is a dynamic digital representation of real-world entities and their behaviors using models with static and dynamic data that enable insights and interactions to drive actionable and improved outcomes.

Industry aligned definition led by SWAN Digital Twin Working Group and "American Water Works Association Digital Twins Committee

There are some key distinctions between a conventional model and a Digital Twin.

"The water industry has a long history of using models to leverage collected data to help design and manage water systems—and with great success; however, Digital Twins look to overcome conventional model limitations while helping realize the longstanding aspirations of these models—to help operate water systems more efficiently."

—Pusker Regmi,
Wastewater Process Expert




Conventional Models	Digital Twin
Based on static datasets	Diverse systemwide information that includes real-time and meta data
Data screening and cleansing	Includes advanced data analytics
Models updated periodically with static data	Models closely represent physical system and update continuously and dynamically
Slower decision support; model outputs are interpreted manually	Faster decision support; models outputs are interpreted automatically
Outputs and potential actions are interpreted manually	Outputs are interpreted automatically and provide real-time alerts, insights, and actions

The Promise of Digital Twin

Digital Twins have the power to modernize the way the water sector designs, builds, renews, and operates water systems.

Although Digital Twin concepts have been around for decades, in recent years, the water sector has embraced digital technologies and applied them to gain efficiencies in the water cycle.

Over the past three years, the SWAN Digital Twin Work Group has advanced and clarified the conversation around Digital Twins in water sector. The promise of Digital Twins has been made possible by the recent progress in the areas of sensing and the internet of things (IoT), secure data integration and management, advanced data analytics, and continuously updated physics-based models, data-driven models, or a combination of both, called hybrid models.

Technology ecosystems are becoming interoperable and provide a common environment in which utility personnel can communicate, train, and understand what is sensed and not directly sensed about how a utility operates. The result is a clear understanding throughout the entire water lifecycle and across utilities.

As the Digital Twin strategy grows from a piece of equipment or a process to utilitywide operations, it can provide more useful and actionable results.

Component and process Digital Twins will lead to more accurate and detailed insights for utility staff, while also paving the way for more nested Digital Twins that allow the larger system to leverage more precise information for greater simulation accuracy.

Digital Twins will achieve compliance at lower operational cost.

Digital Twins of the future will continue to gain simulation accuracy, which will provide more detailed and accurate insights and lead to improved compliance and lower operational cost. Replacing approximations of the input variables of model simulations with actual near-real-time data feeds from remote sensors, devices, etc., will lead to better calibration of the models, accurately provide anomaly detection, more informative insights, and better forecasts for operations.

Establishing the foundation of your Digital Twin is cost effective, and the earlier you begin the better the savings.

As the utility establishes a technical and organizational foundation for a Digital Twin, the opportunities for savings will accelerate. As data silos are integrated and easily accessible through the use of APIs and data storage techniques it will be easier to build more advanced Digital Twins removing previously isolated data and knowledge silos between departments. This will enable a new paradigm of common understanding and holistic view of the complexities within utility. Early adopters, as shown in the case study summaries at the end of this Digital Twin Readiness Guide have leveraged this approach leading to new levels of efficiency. This efficiency has accelerated support and eased the way for future expansion.

As Digital Twins evolve, we will likely see more plug and play capability across multiple digital technologies/systems, a rise of component Digital Twins will serve to improve the accuracy and timeliness of data and information exchange with and across the more extensive Digital Twin network. The integration or interconnection of multiple Digital Twins will give rise to a more holistic digital ecosystem allowing for a more comprehensive operational view of our entire water cycle."

—Thomas Kuczynski, DC Water

Across the globe, many utilities have already realized the promise of Digital Twin technologies.

Each of these utilities has conducted a customized implementation. Ten summaries of case studies are included at the end of this Digital Twin Readiness Guide that represent an array of Digital Twin success stories.

Case Study 1
Tarragona Water Consortium (CAT), Spain

Case Study 2
Valencia Metropolitan Area, Spain

Case Study 3
Romagna Acque Società delle Fonti, Italy

Case Study 4
BlueKolding, Denmark

Case Study 5
Gruppo CAP, Italy

Case Study 6
Waterschapsbedrijf Limburg, The Netherlands

Case Study 7
PUB, Singapore's National Water Agency, Singapore

Case Study 8
BIOFOS, Copenhagen, Denmark

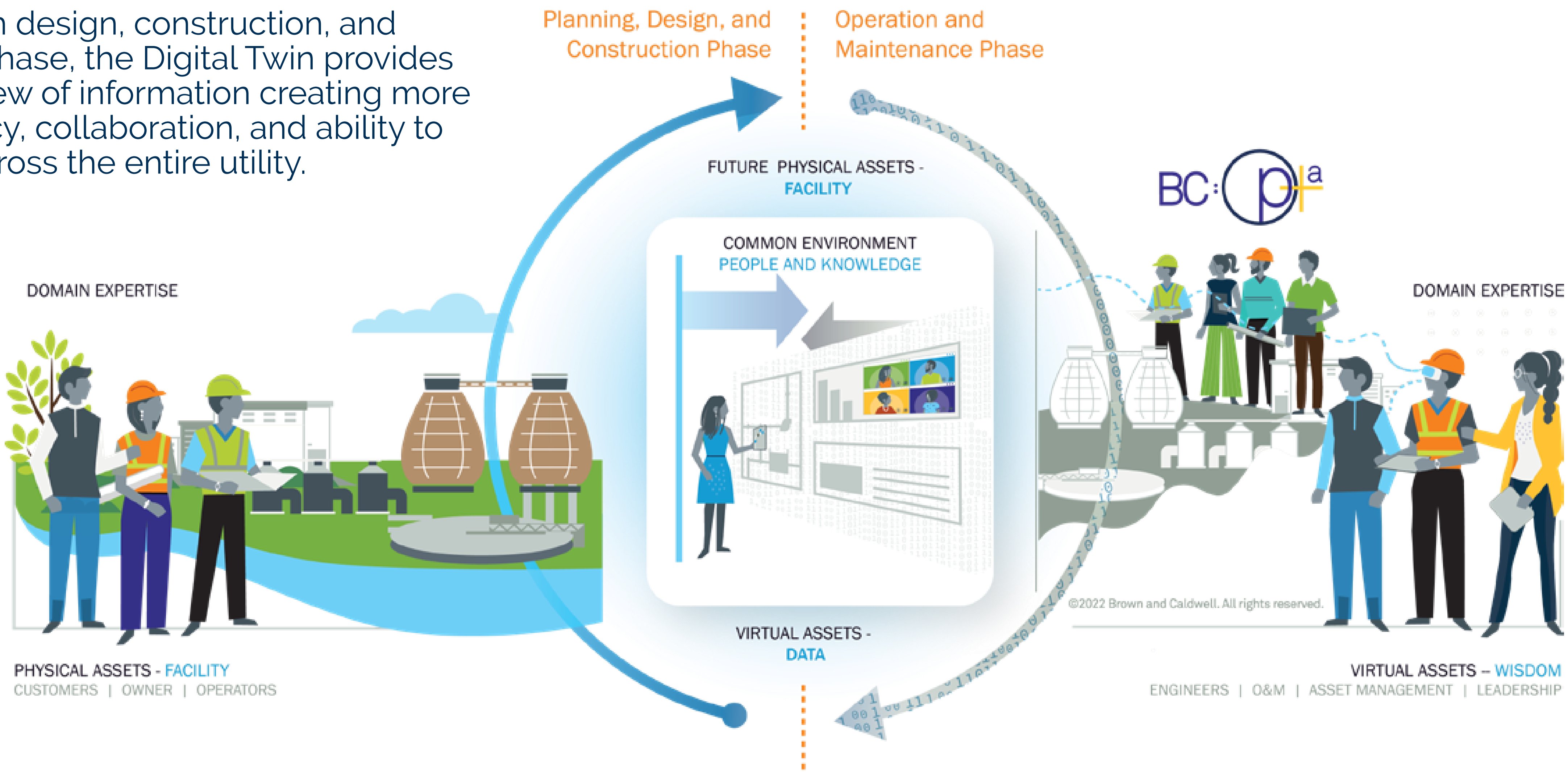
Case Study 9
VCS, Denmark

Case Study 10
Kempner Water Supply Corporation, United States

Digital Twin Benefits

The water industry has much to gain from leveraging Digital Twins bringing expertise and technology together into a common environment.

Across each design, construction, and operation phase, the Digital Twin provides a holistic view of information creating more transparency, collaboration, and ability to innovate across the entire utility.



Digital Twin Benefits

Digital Twins will enable understanding of what can't be seen across individual components and the entire system, e.g., pipes to pump stations to the entire distribution or collection systems and treatment facilities. This understanding of operations leading to insights and opportunities for optimization.

Optimization

- Multi-objective simulations for optimal cross-sector design
- Experimentation in digital form prior to implementation
- Improved decision making
- Increased stakeholder collaboration
- Reduced construction and maintenance conflicts
- Continuous operational optimization

Collaboration and Transparency

- Transparency across sectors and departments
- Increased interdepartmental collaboration
- Knowledge retention for new workforce
- Proactive workforce
- Understand historical engineering and operational decisions

Holistic Operational Oversight

- One comprehensive view
- Reduced maintenance costs and unplanned outages by early alerts
- Improved asset management
- Anomaly detection
- Reduced cost of operations
- What-if analysis of multiple scenarios
- Reduced compliance issues

Predictive Analysis

- Proactive operation instead of reactive, which helps avoid future missed moments or failures
- A near real-time holistic connection between the physical and the digital world
- Ability to run what-if analysis at any time
- Ability to adapt and respond to rapidly changing scenarios and disturbances

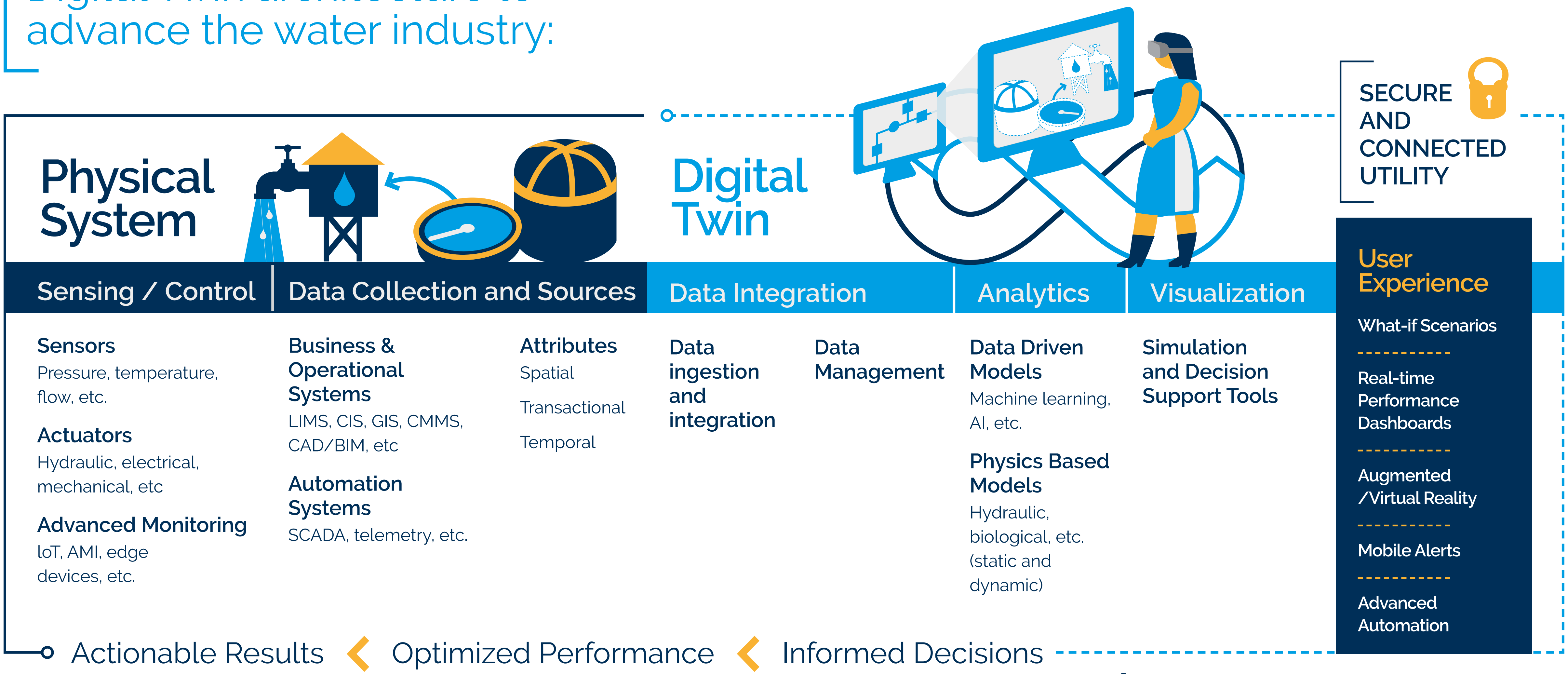
Digital Twin Architecture

The SWAN Digital Twin Holistic Architecture Group began development of a holistic architecture in 2019 to provide a consolidated framework to support Digital Twin objectives.

The goal of this Digital Twin architecture is to include the entire ecosystem of technologies to leverage secure and connected platforms that enable incremental development of Digital Twin to achieve immediate and long-term outcomes. This standardized Digital Twin architecture with a universal framework encompassing the individual technology components is needed for successful industry adoption. This architecture sets the water industry standard for planning and implementing Digital Twin.

The most helpful facet of the architecture is that it lays out essential components and interdependencies for utilities to consider as they embrace and leverage Digital Twins. Sensing control and data collection and sources are the underlying elements that utilities have been implementing. These improve over time and serve as a backbone for implementing Digital Twin. The Digital Twin architecture framework provides a good overview of the different components of a Digital Twin, but there is no one-size-fits-all Digital Twin for a utility. Each utility has its own challenges, infrastructure, and technology stack.

SWAN's state-of-the-art Digital Twin architecture to advance the water industry:



Digital Twins architecture serves any Digital Twin

Using this Digital Twin architecture enables each utility to represent their technology according to each category to assess their digital infrastructure helping identify opportunities and needs.

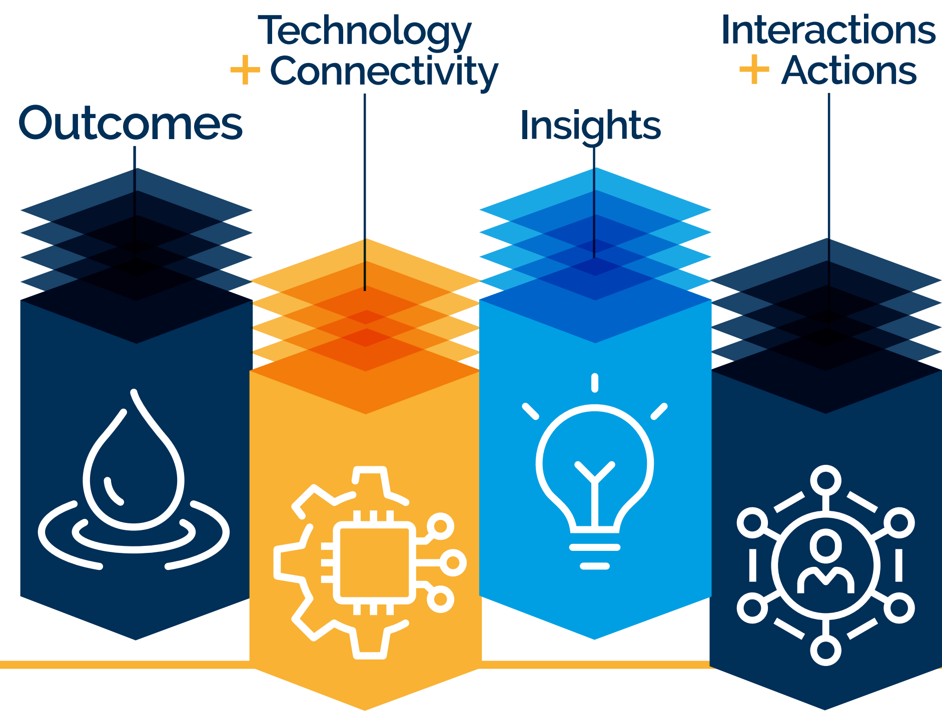
Digital Twin varies in completeness from representations of the physical twin in a map or model with some operational data to advanced real-time physics-based models. These advanced systems can represent distribution systems, collection or treatment system models which include weather, hydraulics, and biological treatment models.

Analytics leverage data and/or physics-based models to crunch data and run scenarios. Visualization provides the ability to ideate the physical scenarios and monitor the current system. Modern User Interfaces/User experience interfaces makes Digital Twin intuitive, reliable, and trustworthy to utilities. The foundation of successful Digital Twin implementation is provided by the secure and connected utility. And, the outcome of a Digital Twin is to make informed decisions that optimize performance and help create actionable results.

Four Pillars of Digital Twin

The pillars of the Digital Twin journey is a framework that helps utilities assess the key parts of their Digital Twin journey.

These pillars form a foundation that grows as each utility progresses with the Digital Twin journey. Each pillar has its own maturity level and can either positively or negatively impact the other pillars in achieving the desired outcomes. The pillar with the least maturity can be a future focal point in advancing a utility's Digital Twin journey.



THE PILLARS grow and evolve throughout Digital Twin implementation.

Outcomes

Desired goals that drive the direction of a Digital Twin.

Digital Twin implementation should be outcome-driven and these outcomes (e.g., improved regulatory compliance, lower cost operations, and a more reliable and resilient system) should be as quantifiable as possible. These outcomes can be used to plan where the Digital Twin should go to meet the desired outcomes. They can also guide utilities to understand what components are missing in the existing Digital Twin and which components should be further developed or upgraded. These outcomes can be further used to track the performance of Digital Twins and to plan further development.

Technology + Connectivity

The technological level and connectivity of assets.

This measures and tracks how much infrastructural assets are securely integrated, digitally sensed, and controlled. This is an important measure because the technological level and the connectivity of assets limit how much influence and impact a Digital Twin will have. A utility with high connectivity and high technology will be able to provide a Digital Twin with more real-time data, making the Digital Twin more reflective of the actual operational conditions. It will also enable a Digital Twin to have the possibility of providing more intelligent decision support and advanced automation.

Insights

Insights generated from the Digital Twin.

Insights are generated by analysis of simulations from data-driven, physics-based models (or a combination of both). Insights give you an idea of what is happening, what has happened, and what will happen in your system. Some examples of analysis are anomaly detection, what-if scenarios, and predictive operational parameters. Typically, physics-based models (e.g., hydraulics model) excel in simulating expected design operating conditions in a utility, while a data-driven model simulates patterns in actual operating conditions. By combining real-time data in both physics- and data-based models, synergies are created that help generate more accurate and deducible insights for faster and better decision making.

Interactions + Actions

Interactions and actions to achieve desired outcomes.

In the most basic scenario, the Digital Twin will provide decision support for staff that includes both operators and engineers. This support can be suggested setpoints or suggested work orders to create. In the more advanced scenario, Digital Twins can supplement programmable logic controllers (PLC) and provide intelligent control automation. This functions similarly to an airplane's co-pilot, but for certain operational areas of the utility. This operational co-pilot gives operators the ability to control devices like pumps and valves more dynamically and in more discrete time steps, all under their direct supervision.

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Section 2

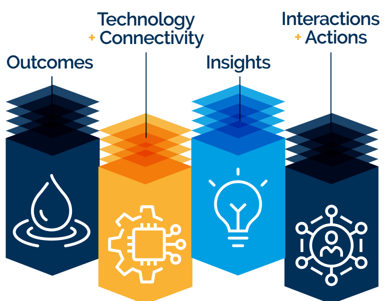
Digital Twin Implementation

Digital Twin Journey
A Scalable and Flexible Approach

"A true implementation is scalable and iterative, and will likely be phased over many years depending on the unique needs, budget, and starting point of each utility.

—Michael Karl, Digital Twin Holistic Architecture Co-Chair

THIS INFOGRAPHIC presents the roadmap to a successful Digital Twin, but this process is not necessarily linear or finite.



First Digital Twin

Benefits + Return on Investment increase over time

1. Identify

DECIDE what you want to achieve

- A desired digital twin outcome, with a clear, concise list of priorities and goals

2. Assess

REVIEW key questions and analyze

- A review of key implementation questions

EVALUATE existing infrastructure

- A review of your existing technology in reference to the Digital Twin architecture that can be be leveraged to create your Digital Twin

MEASURE the value of the investment

- Cost-benefit analysis and value proposition over time

3. Implement

TAKE an agile implementation approach

- An iterative approach that allows for flexibility

REVIEW outcomes using a feedback loop

- A process to review the Digital Twin to fine tune the implementation

4. Expand

CONTINUE ongoing maintenance

- Continued efforts to refine and adapt the Digital Twin to best fit needs moving forward

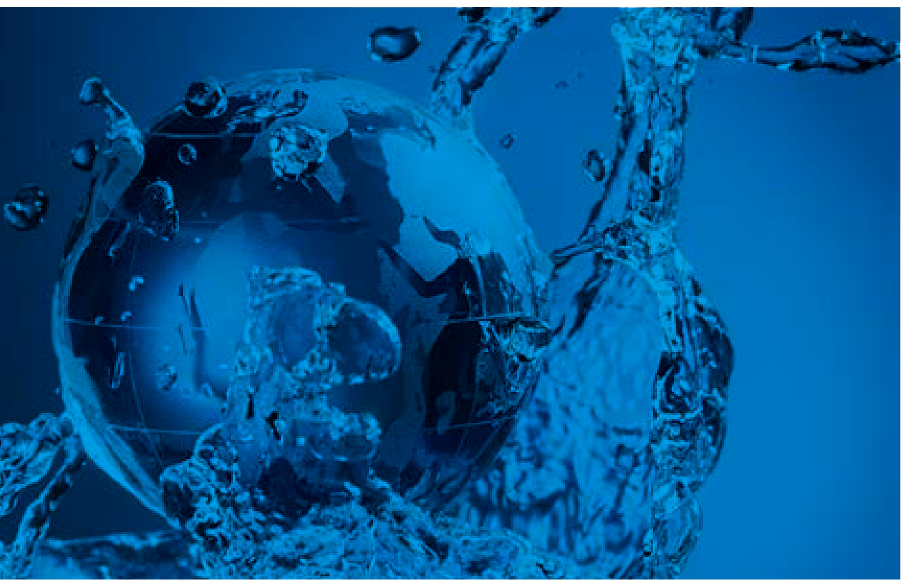
EXPAND capabilities and functionality of your Digital Twin

- A link between each individual Digital Twin to generate additional outcomes

Supported by Digital Twin Pillars

While the path to implement a Digital Twin is unique to each utility, each Digital Twin involves the same major steps."

—Chengzi Chew, Digital Twin Holistic Architecture Co-Chair



The following pages discuss each step in detail.

Identify

KEY OUTCOME: A desired Digital Twin outcome, with a clear, concise list of priorities and goals based on short-term needs focused on quick wins and then expanding towards long-term objectives.

Decide what you want to achieve

A successful implementation begins with sorting out the most pressing issues that will provide the most benefits. Understanding the motivation for developing Digital Twins is key to knowing what success will look like.

A good starting point is asking what initial drivers will impact your organization the most. Some example initial drivers could be regulatory shifts, the desire to raise service standards, or the need to increase revenue. Pairing these initial drivers and a knowledge of your organization's appetite for technological and organizational change is also important. Understanding if you need to focus on major strategic outcomes or start with smaller tactical gains and build on those is critical to success can help your organization understand where to start. Often, quick and simple wins from your Digital Twin can set your utility up for success in the long term.

Given that it will take time to achieve results towards each driver through the development of a Digital Twin, the right pathway that works within your organization makes a difference. For example, deciding if the best approach would be to develop an initial Digital Twin for single process area or geography of your utility could provide guidance and foundations for future developments. Then as you've learned from this initial focus, you can then expand to other process areas or geographies; or alternatively, identifying a single operational improvement that can be applied to many other areas of your utility.

Assess

KEY OUTCOME: An understanding of existing infrastructure, overall implementation needs, and a cost-benefit analysis for developing an implementation plan that is scaled to meet your needs and value proposition.

How to begin your journey

Recognize that the short and long-term potential opportunities Digital Twin can be vast and it can be easy to become overwhelmed trying to achieve all of them at once.

The journey starts with developing an understanding of the existing technology infrastructure, as well as the basis for how your organization evaluates investment return on value, then aligning these with your short- and long-term objective priorities.

Having chosen outcomes that would work for your organization, you know what success would look like for you in both the short term and long term. Start by assessing the suitability of your existing infrastructure against the SWAN Digital Twin architecture. Then, assess what investment plans suit your organization by using the pillars of the Digital Twin journey.

There are many assessment frameworks available, but a simple SWOT (strengths, weaknesses, opportunities, and threats) analysis using the Digital Twin architecture and pillars of the Digital Twin journey works well.

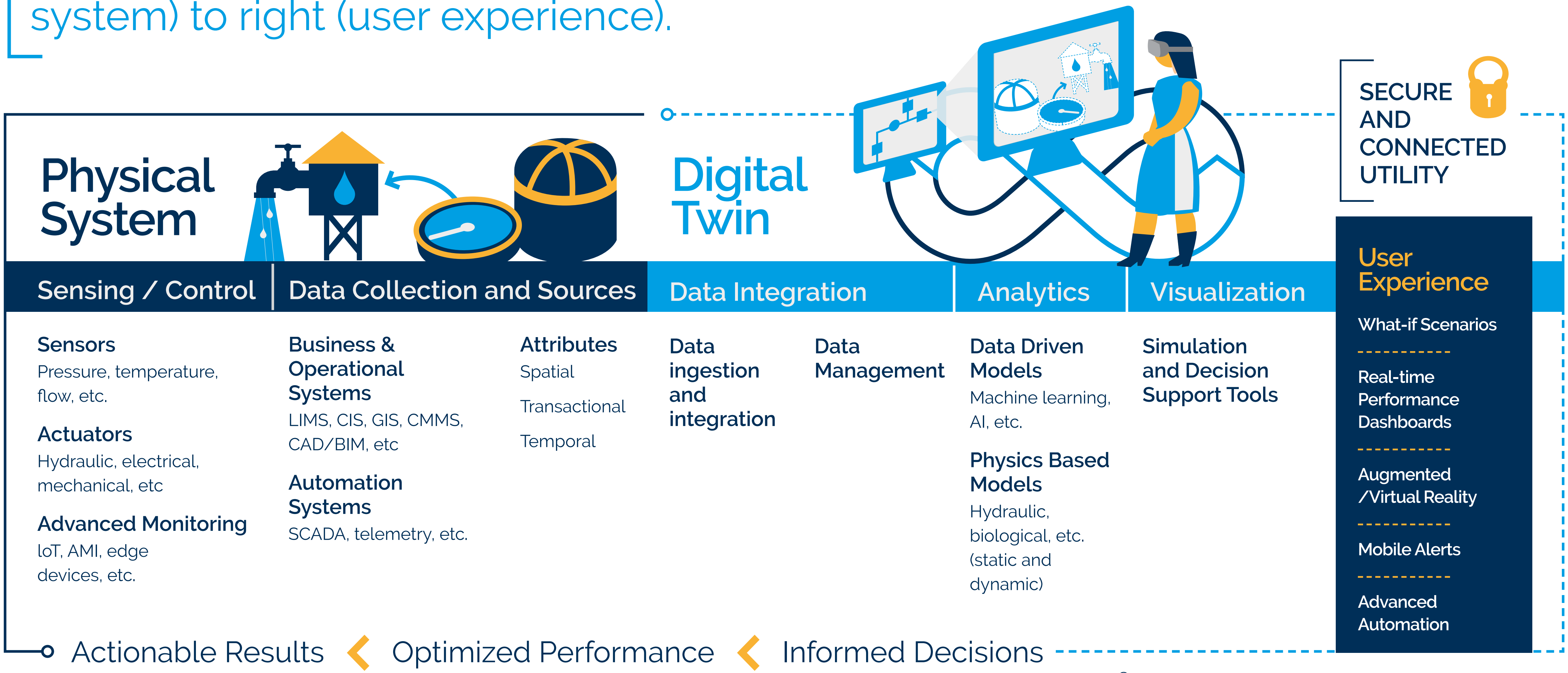
Assess existing infrastructure

An important starting point for Digital Twin implementation is to assess the infrastructure you already have that can be leveraged for your desired outcome.

In general, you are looking to find essential components that you may already have that can be leveraged or that can be adapted. This results in a much clearer picture of what is yet to be developed.

It is important to evaluate your physical system condition that can benefit immediately from the incorporation of a Digital Twin, or if a Digital Twin will help plan the upgrades to your physical system. This assessment is partly about the completeness, i.e., what pumps, valves, pipes, etc., you have and the state of their existing condition. But assessing how well the physical system performs and how robust it is also important. This foundation of understanding the physical system is important to understand the potential limitations of building your Digital Twin.

This following pages review the SWAN Digital Twin architecture from left (physical system) to right (user experience).



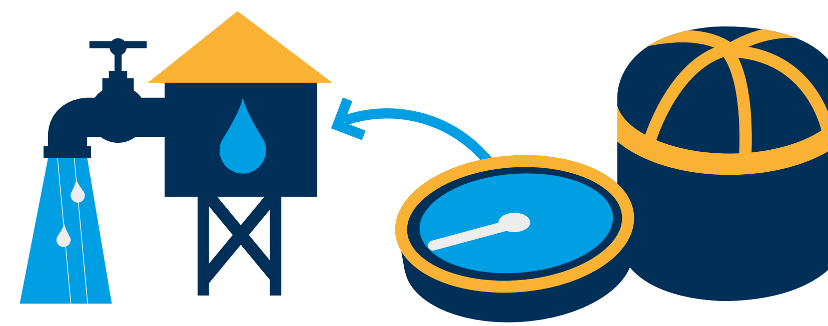
Physical System

Sensing and control

How do you know which sensors and controls are available and are working correctly?

Digital Twins benefit from accurate information of what has happened or is happening in the physical world. You may want the Digital Twin to manage or control changes to how the physical system works. Therefore, it is important to understand both the sensors and controls for the Digital Twin.

Documenting what sensors and controls are in place, their working condition, and which are used regularly is important. Are they controlled or sensed physically onsite, remotely under user control, or by an automated remote system? It is also important to make note of how reliable the sensors and control are and note any deficiencies to achieve your desired Digital Twin outcome.



Data collection and sources

What data systems are in place and what data can be extracted?

Business and operational systems include LIMS, CIS, GIS, CMMS, CAD/BIM, weather forecasting systems, etc. Knowing what your organization has in place or access to and how to tap into that knowledge for the Digital Twin can bolster implementation.

Similarly, knowing what data from automation systems (SCADA, telemetry, etc.) can be extracted and if data can be securely fed back into them will also enhance the implementation process.

Gather an understanding of each of these systems (Business & Operational Systems and Automation Systems) and the different data they provide. Then correlate with the quality, availability, and history of this data to develop a holistic understanding of what is available and the current methods of collection.

SWAN Digital Twin architecture continues

Digital Twin

Data Integration

As Digital Twins grow and expand, they need the ability to handle and correlate a large amount of data.

A Digital Twin will need the ability to interface with the physical world, through the individual sensors and controls at the physical system as well correlate this data with the underlying business and operational systems utilities use to management them. All of this will need to occur in a frequency and fidelity that supports the objectives you are looking to accomplish.

When evaluating how the Digital Twin interfaces with the physical environment, often it may not connect directly to the sensors and controls (through systems like SCADA or IoT). Instead, data may be managed by establishing a foundational storage and management system(s) allocated for Digital Twin and similar technology efforts; that provide connection, storage, and a set of federated relationships between the systems and their underlying data models.

Organizations are sometimes over-optimistic about their level of data integration. Often the practice of keeping unmanaged files on local drives or standalone systems will result in a rocky start to Digital Twins. Well-managed and constantly updated professional data management systems providing automated data and meta data access provides a much better foundation. Having an data management specialist assigned to the team is highly recommended.

Document an understanding of how each of the data sources are managed currently, how their underlying data models relate or may relate to each other, what practices exist to validate and manage the quality and storage of these data models that you may be building a foundation upon in the future.

Integration of data with security best practices is required although out of the scope of this guide.

SWAN Digital Twin architecture continues

Digital Twin
CONTINUED

Analytics

What type of model is best for you?

Analytics generate insights from data-driven or physics-based models or a combination of both. Typically, physics-based models (e.g., hydraulics model) excel in simulating expected design operating conditions in a utility, while a data-driven model simulates historical patterns in actual operating conditions. By combining real-time data in both physics-based models and data-driven models, there are synergies to generate better insights for better operational excellence.

What analytics does your desired Digital Twin outcome need? Evaluate if it requires a data driven, physics-based model or a combination. Find out if your current models can be leveraged how current they are, how they are maintained, and how they would be connected with real-time data.

Visualization

How far down the path are you toward a comprehensive visualization strategy?

Assess if you have any existing visualization systems that can be tapped into or re-purposed. Because the Digital Twin will be operational, existing-use visualization would probably already be used in the control room. For example, SCADA, GIS, 2D, 3D or even augment or virtual reality may be available for re-use, but there may be other smaller purpose-built visualization systems that could be used. Re-using existing systems can save money and support a quick start-up but be aware that multiple visualization systems can create confusion.

Understanding what visualization approach of simulation and decision support tools and software that will best support your Digital Twin outcome is key. This will allow the users to interact and understand the results from the Digital Twin.

SWAN Digital Twin architecture continues

User Experience

What does the user need?

Assess the needs of different personnel who will be using the Digital Twin to improve the way they perform their tasks (e.g., what-if scenarios, real-time performance, and automated control) This can be operators, engineers, planners, management, and others. Different types of users have different needs on which data to view and how they should interact with the Digital Twin. A tailored and streamlined user experience is important for intuitive interactions which improves the productivity and enables new users to be onboarded more easily.

Assess the value of the investment

Each utility will follow its required procurement process for technological and organizational developments, and financial assessment will be an important aspect of procurement. This is the time to assess the intended value (monetized) of the expected improvements to service. The value could come in intangible benefits (e.g. collaboration between departments or improved customer satisfaction) or tangible improvements from operations, engineering, or asset management, resulting in CAPEX and OPEX savings.

This assessment is specific to the outcomes you want to achieve and is probably different from one part of the utility to another. For the investment in Digital Twin, know the anticipated outcomes that have appropriate value to operations, engineering, and asset management. This assessment will help make a strong financial case, and will also help identify your core team members.

Understanding from which budget(s) the costs will be drawn (CAPEX, OPEX, engineering project, research and innovation, etc.) is also critical. Consider whether you can build on or leverage existing projects and budgets. For example, you may already be implementing improved monitoring and data-communications networks that could also feed into Digital Twins, or there may be control-room improvements underway that would enhance visualization for Digital Twins. Leveraging these existing projects and budgets can propel your Digital Twin implementation forward.

Implement

KEY OUTCOME: An iterative approach to developing your Digital Twin in which teams build incrementally and are guided by desired outcomes.

Take an agile implementation approach

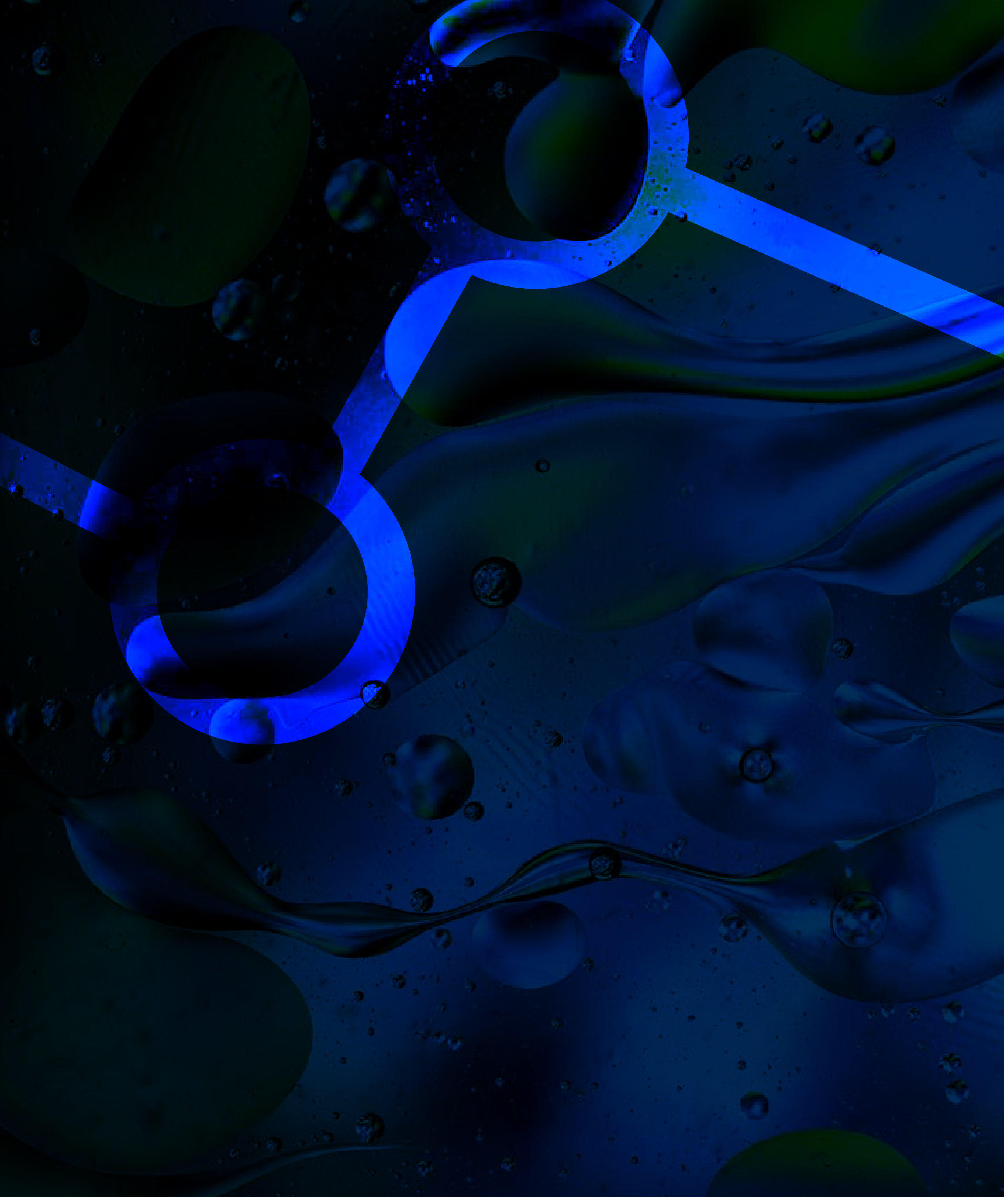
Teamwork is vital for the delivery of Digital Twins, and the multi-disciplinary team will need influence and a broad spread of skills and experience covering operations, engineering, and management. As the delivery project goes forward, it will go through phases such as proposal, system development, implementation, roll-out, operations, and expansion.

The team will deliver best if it develops as it goes through the phases and takes an agile approach from the start, as this will help drive successful outcomes and lower risks in a changing world. Digital Twin implementation should include a roadmap of stages that define the path from clear goals to established targets. Success should be measured at each stage, and each future stage should be re-assessed as the implementation moves forward. Asking questions such as "Has the overall goal changed? Have we veered off the roadmap? In light of the knowledge and experience we have gained, should we adjust the roadmap?" helps support controlled reassessment and modification throughout implementation.

Review Outcomes using a feedback loop

The agile management process depends on frequent, regular, and quick assessment of progress. This management process considers questions such as "Is the project on track to achieving the outcomes? If not, how can we adapt and change to get it back on track?". This review and feedback could be as frequent as every day or could be every 2 weeks for a wider team review. These reviews identify issues, as well as highlight successes that can be repeated.

The focus of monitoring and reviewing should always be on outcomes, not just the planned tasks. Relevant stakeholders should be included in the reviews to assess how the Digital Twin implementation is getting closer to the chosen outcomes. If the team is working hard but drifting away from outcomes, the agile management process will help determine why and allow for course correction.



Expand

KEY OUTCOME: Expand features and functionality to achieve desired outcomes.

Add or connect Digital Twins

Once the first implementation of a Digital Twin is achieved and the outcomes achieved reviewed, several paths are available.

What's Next: A few options:

If you are satisfied with the current implementation of the Digital Twin:

Look at other operations or processes where there's value to creating a new Digital Twin. Start again from the top of the implementation steps.

If you're not completely satisfied with the current implementation:

Expand and improve the current Digital Twin. Use the assessment framework of the Digital Twin architecture and the pillars of the Digital Twin journey to identify gaps and opportunities in the current implementation and work to improve on them. For example, there can be other information systems or data sources that can be further integrated into the Digital Twin to make operations more efficient, automated, and seamless.

If you have other Digital Twins implemented in your utility:

Use the same framework to identify any synergies to connect the Digital Twins. This can help bring down silos within the organization and further improve the operational efficiencies. For example, a water distribution operations Digital Twin can be connected to a wastewater collection system operations Digital Twin to correlate the amount of water entering the collection system vs how much is being used outside the home.

Continue usage and maintenance

The Digital Twin should be continuously used and maintained. Regular usage will enable you to understand better where there's room for improvement and where the Digital Twin works best. This will improve the confidence of operators and engineers using it.

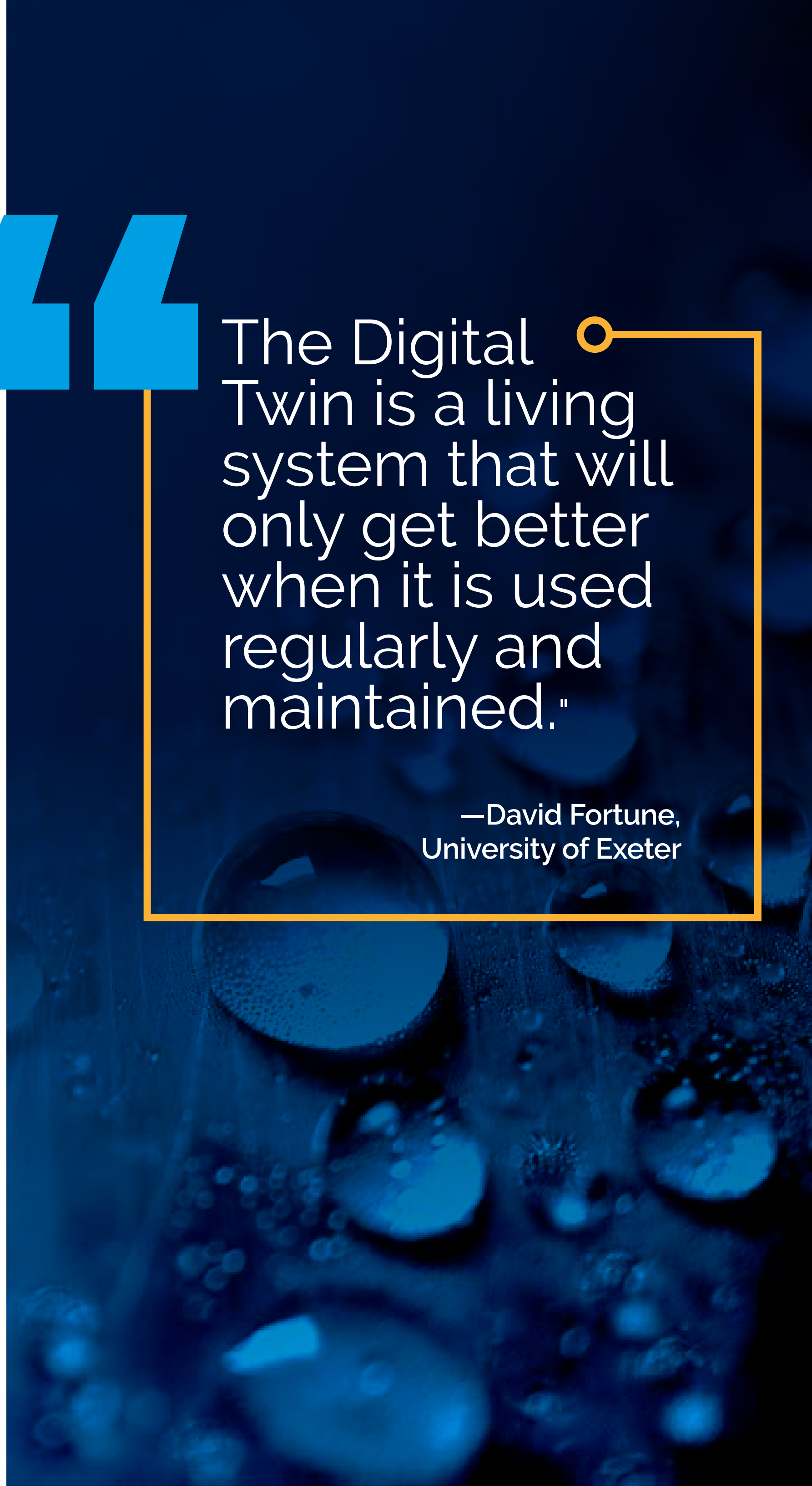
Regular maintenance is also needed. Like any software, a Digital Twin is built on top of one or many different software components. These components need to be updated regularly to keep up with technology advancements, discovery of unintended software bugs, and new security threats. New technology can also be an opportunity to upgrade either hardware or software to further improve operational efficiency.

Continually measure your benefits

When you implement a Digital Twin, you will have specific outcomes in mind that are unique. By tracking these intended outcomes throughout implementation (not just at the end), you can assess how well they have been met. Additionally, the comprehensive nature of Digital Twins often leads to inadvertent outcomes. These unexpected outcomes are just as important as the planned outcomes. Tracking both planned and unplanned outcomes and incorporating them into the next implementation project contributes to success and return on investment.

Successful implementation is always the goal, but tremendous learning opportunities come from things that don't go as planned. Evaluating where there is room for improvement in the implementation or planning of the Digital Twin is a key element in accessing the outcomes. Asking questions such as "What did we not achieve in the implementation? Why? And how can we improve?" is important to ongoing success.

While it is good to be focused on the end-point for delivery, by tracking benefits you will be building the case for expanding the Digital Twin or developing the next. For example, many of the case studies summarized in this Readiness Guide demonstrate success in a specific way, yet they also identify further benefits that can be achieved with the development of the Digital Twin.

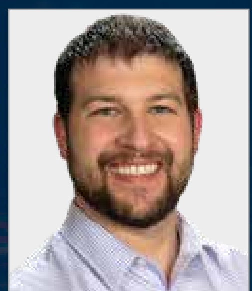


> The Digital Twin is a living system that will only get better when it is used regularly and maintained."
>
> —David Fortune, University of Exeter

Let's get Digital

Make your impact - Join the SWAN Digital Twin Holistic Architecture Group

Reach out to:



Michael Karl
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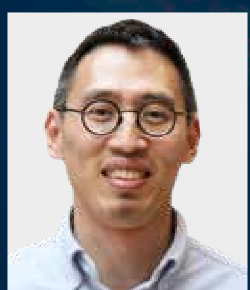


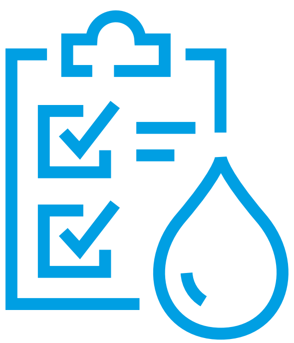
Chengzi Chew
czc@dhigroup.com

Section 3

Case Study Summaries

Case Study Summaries

Each of these utilities has conducted a customized implementation. Ten summaries of sample case studies are included on the following pages. These case studies represent a wide range of Digital Twin success stories.



Case Study 1

Tarragona Water Consortium (CAT), Spain

Water Network, Water Treatment

Andreu Fargas

Case Study 2

Valencia Metropolitan Area, Spain

Water Network

Pilar Conejos, Marta Hervás, Joan Carles Alonso

Case Study 3

Romagna Acque Società delle Fonti, Italy

Water Network

Giulia Buffi, Gilberto Forcellini Mazzoni

Case Study 4

BlueKolding, Denmark

Wastewater Network, Wastewater Treatment

Cynthia Haddad, Ran Segoli

Case Study 5

Gruppo CAP, Italy

Wastewater Treatment

Roberto Di Cosmo, Marco Muzzatti, Michele Platè

Case Study 6

Waterschapsbedrijf Limburg, The Netherlands

Wastewater Network

Léon Verhaegen, Melchior Schenk, Aris Witteborg

Case Study 7

PUB, Singapore's National Water Agency, Singapore

Wastewater Treatment

Kian Ming Phua, Liyun Tai, Otto Icke, Daan van Es

Case Study 8

BIOFOS, Copenhagen, Denmark

Urban Drainage

Laura Frølich, Barbara Greenhill, Sten Lindberg

Case Study 9

VCS, Denmark

Urban Drainage

Agnethe Pedersen, Annette Brink-Kjaer

Case Study 10

Kempner Water Supply Corporation, United States

Pump Station Optimization

Rodney Seaver, Perry Steger, Juan Gamarra

Understanding Case Studies

Digital Twin Architecture Components

Sensing / Control
- ☐ Sensors
- ☐ Actuators
- ☐ Advanced Monitoring

Data Collection and Sources
- ☐ Business & Operational Systems
- ☐ Automation Systems
- ☐ Attributes

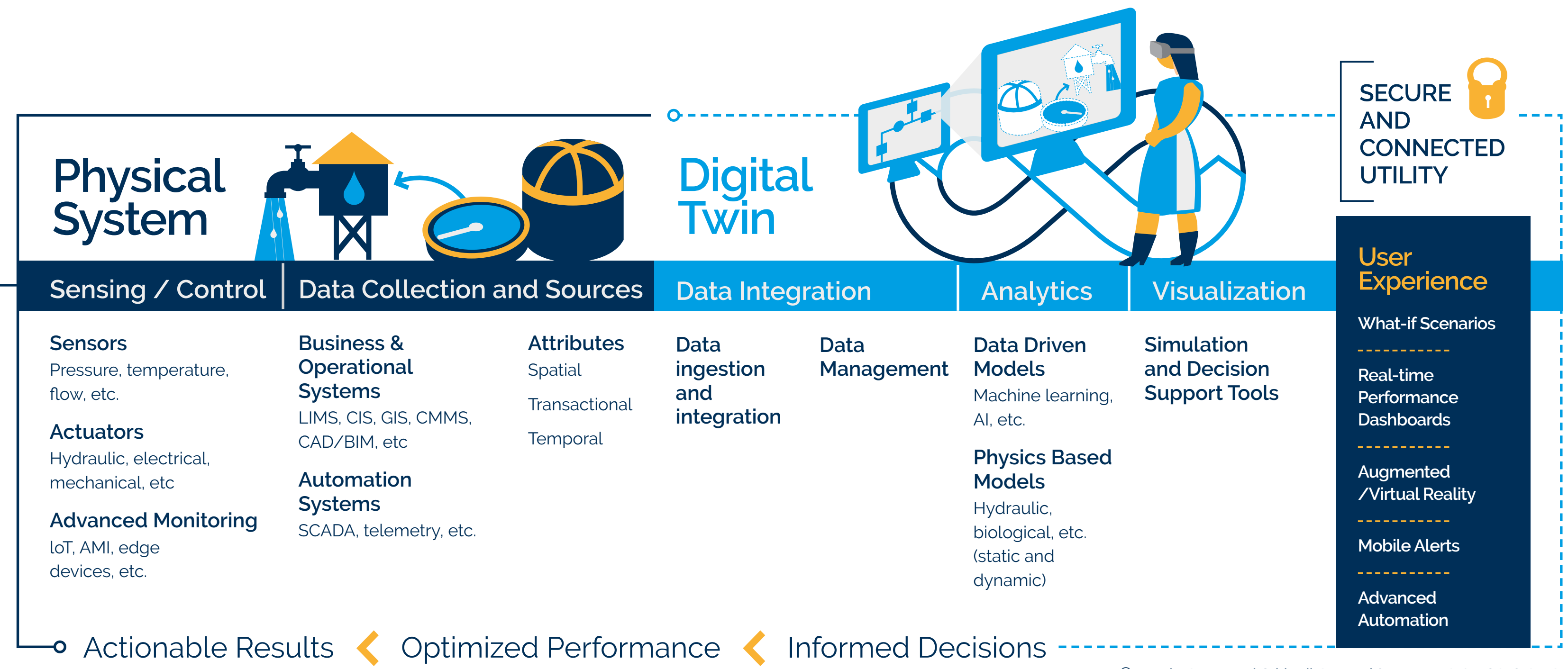
Data Integration
- ☐ Data ingestion and integration
- ☐ Data Management

Analytics
- ☐ Data Driven Models
- ☐ Physics Based Models

Visualization
- ☐ Simulation and Decision Support Tools

User Experience
- ☐ What-if Scenarios
- ☐ Real-time Performance Dashboards
- ☐ Augmented /Virtual Reality
- ☐ Mobile Alerts
- ☐ Advanced Automation

Checkmarks appear next to the applicable components of Digital Twin architecture for each case study.



CASE STUDY 1 Water Network, Water Treatment

Tarragona Water Consortium (CAT), Spain

The Digital Twin focused on operation optimization, cost reduction, and standardization.

Scope

Utilitywide system, including catchment, treatment plant, pumping stations, and final user delivery.

Specifics of the Application

- Energy cost minimization
- Automated water distribution based on client demand
- Operation standardization

Digital Twin Architecture Components

Sensing / Control

- [x] Sensors
- [x] Actuators
- [ ] Advanced Monitoring

Data Collection and Sources

- [ ] Business & Operational Systems
- [x] Automation Systems
- [ ] Attributes

Data Integration

- [x] Data ingestion and integration
- [x] Data Management

Analytics

- [ ] Data Driven Models
- [x] Physics Based Models

Visualization

- [x] Simulation and Decision Support Tools

User Experience

- [x] What-if Scenarios
- [x] Real-time Performance Dashboards
- [ ] Augmented /Virtual Reality
- [ ] Mobile Alerts
- [x] Advanced Automation

Identify

The main objective was to reduce the electrical energy cost to deliver the water to customers.

Additional Goals

- Being able to use advanced tariffs (real time, 24-hour) in a secure environment, to reach the cost reduction
- Capture operator knowledge in a tool that would standardize and optimize water distribution

Assess

Existing infrastructure was assessed to develop a custom implementation plan leveraging the tools already in place.

Existing Inputs to the Digital Twin

- Up-to-date system hydraulic model
- Data collection and SCADA visualization
- All site automation with security interlocks

Digital Twin Design Approach

- The DT uses the hydraulic model of the whole system to simulate and optimize the water distribution.
- Data analytics is used to define the demands of the different users.
- The system is developed over a commercial tool: Aquadapt of Derceto Ltd. (now Aquadvanced Energy of Suez Smart Solutions).
- A tested solution was a requirement to obtain a quick implementation, due to the urgency of cost reduction.
- All main stakeholders participated during design and implementation. Final users were targeted with specific training.

Implement

With electrical prices increasing since 2005, CAT decided to act to improve energy costs.

Challenges and Opportunities

- To deploy the DT, several initial steps were ready and that were crucial
  - Had a good hydraulic model
  - High automation of all sites, including local security interlocks
  - Data integration and visualization in SCADA
- Unexpected issues appeared during project implementation. Quick response was key to reach the expected outcome.
- DT implementation is a never-ending journey: A DT implementation is never finished, as continuous improvements are needed: Data quality, model calibration, interlocks, new assets.
- Operator training is fundamental to the success of the project. This is still a challenge not completely solved.
- Final user training and implication is key for the DT success

The agile implementation approach allowed for key features to be implemented and assessed, then adjusted to meet the specific needs.

Digital Twin Key Features

- Schedules water catchment, treated water, pumps, and valves for the next 48 hours to minimize energy costs
- Calculates solutions with client water delivery as maximum priority
- Recalculates a new solution every half-hour to adapt to distribution changes
- Runs in real-time, calculates in minutes, and communicates directly to SCADA to send the planification
- Standardizes operation, smoothing it between operators

> Every single water drop is under control."
>
> —Andreu Fargas-Marquès, SAOOEC Project Manager

Benefit

Clear benefits included cost savings and operational optimizations. The DT has changed the overall planning and management of water catchment, treatment, and distribution.

- Cost reduction-stabilization achieved
  - 15% cost reduction
  - 3-year project payback
- Flexibility on electrical tariffs - optimized operation with any chosen electrical tariffs
- Improvement in overall automation and operation safety
- Improvement in standardized operation – independent of operators
- Maximizes pump energy efficiency
- Improves water quality by implementing water level cycler on large water tanks
- A well-implemented DT can pay its value back

Expand

The implementation was a success that allows for future extensions and future phases.

Future Plans

- Asset changes to improve the behavior of the optimized system:
  - Pump changes
  - Inclusion of variable-speed drives
  - New tank regulators
- Extend the DT to allow model self-calibration, quality and asset monitoring, and leakage detection
- Implement a process DT for the water treatment plant
- Interconnect the different DTs

CASE STUDY 2 Water Network

Digital Twin in Valencia Metropolitan Area, Spain

SWAN
SMART WATER NETWORKS FORUM

The Digital Twin focused on the water distribution network to support design of new infrastructures and daily operations.

Scope and Specifics of the Application

- Valencia Digital Twin has been developed for the water distribution network
- It contains all pipes (900 km) and regulating elements of the network: 50 pumps, 250 valves and 30 tanks

Digital Twin Architecture Components

Sensing / Control

- [x] Sensors
- [x] Actuators
- [x] Advanced Monitoring

Data Collection and Sources

- [x] Business & Operational Systems
- [x] Automation Systems
- [x] Attributes

Data Integration

- [x] Data ingestion and integration
- [x] Data Management

Analytics

- [x] Data Driven Models
- [x] Physics Based Models

Visualization

- [x] Simulation and Decision Support Tools

User Experience

- [x] What-if Scenarios
- [x] Real-time Performance Dashboards
- [ ] Augmented /Virtual Reality
- [x] Mobile Alerts
- [x] Advanced Automation

Identify

The main objective and driver for the Digital Twin was to address big challenges including population growth, prolonged droughts, and infrastructures near their maximum capacity.

Increased

- Security of operation, including being more proactive than reactive, and more resilient
- Quality of the service, including better pressure level, fewer disruptions, and fewer customer complaints
- Effectiveness of investment in new infrastructures
- Training and engagement of people

Decreased

- Cost of maintenance
- Carbon footprint (reduction of energy consumption, reduction of vehicle displacement)
- Water needs: Reduce network leaks and detect customer leaks

Assess

Valencia Digital Twin is the result of the digital transformation journey of the utility.

Digital Twin Design Approach

- Valencia DT works upon a hydraulic model that runs live simulations
- It is connected with information provided in real time by 600 physical sensors deployed in the network providing 3,000 virtual sensors, thanks to the hydraulic simulation
- In addition, advance analytics, like AI, are used to improve data management and give more insights (AI is very valuable in both data analysis and data filtering processes, it allows us to better keep the whole system consistency data)
- It has several types of visualization according to the users: synoptic views, geographical maps, and dashboards

Implement

Focusing on objectives and defining first goals for the DT allowed for a beneficial DT with the potential for future growth.

Challenges and Opportunities

- Definition of a clear business case and objectives
- Data silos and quality
- Development and calibration of a hydraulic model that runs in real time
- People engagement
- Keeping it simple and focusing on the main challenges
- Preserving data quality from the source
- DT implementing requires a new innovative culture

A use case of GoAigua Digital Twin, Valencia Digital Twin provides a holistic view of system performance.

Digital Twin Key Features

- Valencia Digital Twin has been used to design the new infrastructures and to support the daily operation (containing all pipes (900 km) and regulating elements of the network: 50 pumps, 250 valves and 30 tanks)
- Valencia Digital Twin has been developed using GoAigua technology, so it is a use case of GoAigua Digital Twin
- GoAigua Platform integrates and normalizes information provided by sensors and different systems already deployed in the utility (SCADA, GIS, CMMS...)
- By leveraging the GoAigua Platform it is able to keep the model running live and provide a holistic view of the system performance

> “Old ways do not open new doors.”
>
> —author unknown

Benefit

High accuracy, reliability, and friendly interface have made people adopt, trust, and use the DT.

The development of the DT has allowed:

- Assessment and design of new required infrastructures
- Improved daily operation, i.e., more efficient and proactive (early detection of issues)
- Improved response under emergency conditions
- Improved the decision-making process, which minimizes risks, time, and costs

Expand

The implementation was a success that allows for future extensions and future phases.

Future Plans

- Add more capabilities for the DT
- Expand the DT for further water cycle phases

CASE STUDY 3 Water Network

Romagna Acque Società delle Fonti, Italy

SWAN
SMART WATER NETWORKS FORUM

The Digital Twin focused on locating and reducing leaks, and operational optimization and standardization.

Scope

Utilitywide system, including potabilization plants, transport network, tanks and pumping stations, and final user delivery

Specifics of the Application

- Identifying operating anomalies
- Identifying planning anomalies
- Quickly locate leaks
- Standardizing operation

Digital Twin Architecture Components

Sensing / Control

- [x] Sensors
- [ ] Actuators
- [ ] Advanced Monitoring

Data Collection and Sources

- [x] Business & Operational Systems
- [x] Automation Systems
- [ ] Attributes

Data Integration

- [x] Data ingestion and integration
- [x] Data Management

Analytics

- [x] Data Driven Models
- [x] Physics Based Models

Visualization

- [x] Simulation and Decision Support Tools

User Experience

- [x] What-if Scenarios
- [x] Real-time Performance Dashboards
- [ ] Augmented /Virtual Reality
- [x] Mobile Alerts
- [ ] Advanced Automation

Identify

The main objective was to reduce the time of water leakages and decrease water losses.

Additional Goals

- Increase and optimize the SCADA system
- Define standard operating procedures
- Increase efficiency of operators
- Capture operator knowledge in a tool that would standardize and optimize water distribution

Assess

The DT platform has been developed to provide a simple and effective decision support tool to be used for daily operations.

Digital Twin Design Approach

- The DT uses the hydraulic model of the whole system to simulate the water distribution system.
- Data from SCADA is used to define the demands of the different users and boundary conditions.
- The system is based on the commercial suite developed by DHI: WaterNet Advisor and WD-Online.
- The DT operates in different modes: hindcast, real-time, forecast.
- Water Utility Technicians have been involved during all project phases to ensure a proper and detailed training: the platform has been developed to be a simple tool available for daily operations.

Implement

National Authority requires reduction of water losses and service improvements

Challenges and Opportunities

- Good knowledge of geometrical data, pressure and flow, operational rules of the network are crucial to be able to create a DT that correspond to real word.
- It is fundamental to setup a model well calibrated and ready to simulate all configurations of the network
- Model setup and calibration is an important phase of the project because it uncovers data gaps or errors.
- A DT implementation is never finished, as continuous improvements are needed: Data quality, model calibration, interlocks, new assets.
- Operator training is fundamental to the success of the project and has to be done in each step of the platform development.

The agile implementation approach allowed for key features to be implemented and assessed, then adjusted to meet the specific needs.

Digital Twin Key Features

- Performs hindcast analysis: operators are able to set up a complex model in few steps.
- Performs realtime comparison: it is possible to get a view of the network and detect functional alarms with a delay less than 1 hour.
- Performs forecast analyses: every day the next 48 hours are analyzed to help detect planning anomalies.
- Runs in real-time, calculates in minutes, and communicates directly to SCADA to send alarms
- Standardizes operation, smoothing it between operators

Benefit

Clear benefits included cost savings and operational optimizations.

- Resolution of many errors, gaps and uncertainties in network data and system operations knowledge: the implementation of this type of decision support system helps to discover data gaps and increase knowledge of water distribution network.
- The implementation makes it possible to see data in a smart platform rather than in the SCADA interface; this was a big advantage to the technicians as it helped save time and increase efficiency.
- Improvement of SCADA system following project recommendations (unsatisfactorily long gaps or delays = time offsets in some of the SCADA data).
- Defined standard procedures for maintaining data consistency, e.g., how to define sensors IDs, how to rename, how to add, etc.
- Helped determine better sensor positions and optimize valve status and settings.

Expand

The implementation was a success that allows for future extensions and future phases.

Future Plans

- Integration of the DT with water balance along trunks
- Better integration with SCADA interface: training of SCADA operators, specific SCADA interface for alarms from DT
- Asset changes to improve the behavior of the optimized system (new control rules based on seasonal flows, new valve settings)
- Substitution of old and low-performing measurement stations.

CASE STUDY 4 Wastewater Network, Wastewater Treatment

BlueKolding, Denmark

More than 50 wastewater treatment plants optimized with the plant module of Hubgrade™ Performance.

Scope

Software solutions for capacity extension and operations optimization for the entire wastewater system, from the sewer network to the water resource recovery facilities (WRRF).

Objectives of Hubgrade Performance deployed on the WWTP + sewer network of BlueKolding utility in Denmark:

- Carbon footprint, energy, and chemical savings - OPEX saving
- Increase capacity - CAPEX avoidance - improved compliance

Digital Twin Architecture Components

Sensing / Control

- [x] Sensors
- [x] Actuators
- [x] Advanced Monitoring

Data Collection and Sources

- [x] Business & Operational Systems
- [x] Automation Systems
- [x] Attributes

Data Integration

- [x] Data ingestion and integration
- [x] Data Management

Analytics

- [x] Data Driven Models
- [x] Physics Based Models

Visualization

- [x] Simulation and Decision Support Tools

User Experience

- [x] What-if Scenarios
- [x] Real-time Performance Dashboards
- [ ] Augmented /Virtual Reality
- [x] Mobile Alerts
- [x] Advanced Automation

Identify

The mission was to reduce environmental impact and create added value for BlueKolding customers by supplying advanced data analysis and interpretation for real-time, continuous optimization, and stabilization of the entire wastewater system's operation.

Additional Goals

- Reduce operating costs
- Increase hydraulic capacity
- Reduce sewer overflows compliance and stable operation
- Achieve energy balance optimization in the energy grid
- Gain access to data from the entire waistewater system combined with weather forecasts and rain radar data

Assess

The custom implementation approach considered existing software and operator needs to create a holistic approach across sewer networks and treatment processes.

Digital Twin Design Approach

- Hubgrade Performance is an online DT, Software as a Service (SaaS) for the wastewater treatment plant and the sewer network. It uses predictive analytics in real-time to provide optimized setpoints to the PLC control and deliver insight to the operators, process engineers, and management.
- The SCADA operator enables the instructions from the cloud, instructing Hubgrade to optimize with the right balance of cost savings, capacity increase, or compliance.
- The solution is built as SaaS on cloud platform; most algorithms where already standard prior to the project. With Kolding, we have fully developed a holistic approach across all sewer networks and treatment processes.

Assess CONTINUED

Buy-in from stakeholders

- Our users take part in our digital journey. We onboarded the stakeholders and train them to use the system, we collect feedback on user experience, and analyse it to develop the product, new releases, etc.
- As part of the SaaS, we service and monitor the operations of our customers, and users enjoy monthly releases and seamlessly adapt new features and regular improvements.
- The solution has more than 60 advanced algorithms that provide holistic optimization of the sewage system and treatment plant. As a modular offer, customers select the optimization algorithms that fit the process specificities and the optimization objectives to guarantee the best return on investment.

Implement

The biggest challenge was demonstrating the advantages of the cloud.

Challenges and Opportunities

- The project is a learning journey for all the stakeholders. The onboarding of novel users is crucial.
- Data quality and consistency are crucial to build user trust.
- Uncertainty at the beginning of the digital journey in moving to the cloud. All necessary measures needed to comply with cybersecurity guidelines (e.g. ISO/IEC 27001:2013, ISO/IEC 27017:2015, NIST SP 800-210) and allow customers to benefit from the advantages of cloud software (monthly releases, no software updates, freedom to unsubscribe, etc.)

Lifecycle Phase:

- 2007: Server on premises at main WWTP of BlueKolding
- 2011-13: Expanded to sewer network and three additional WWTPs
- 2014-16: Sewer expansion and deployment of energy spot pricing optimization
- 2017: Transition to standardized, modular SaaS and cloud technology.
- 2017-20: Holistic optimizations
  - Energy market demand/response control
  - Weather forecasting implemented
  - Sewer network optimizations

Each key feature of the Digital Twin supported each of the key objectives set for the implementation.

Digital Twin Key Features

- A powerful digital tool to optimize operation through informed insights according to the objectives of savings, performance, or capacity that were set.
- User Interface that enable users to decide on optimization objectives; holistic prioritization among cost saving, increased capacity, compliance, and climate impact.
- User experience (analytical and GIS) deign to access data from the entire wastewater system (historical data and real-time data from sensors, meters, SCADA systems, etc.) combined with weather forecasts and rain radar data.
- Robust algorithms and data-driven models already tested and validated, customized dashboards and predictive early warnings.
- Data integration, data schemas, data quality control, sensor maintainance notifications, mobile interface

Benefit

Included improved operations, increased maintenance staff efficiency, and enhanced data handling and reporting.

Improved Operation

- Better system stability
- Control of compliance
- Minimized environmental footprint

Staff Advantages

- Notifications on performance issues
- Easier operation - 24/7 autopilot
- Improves the understanding of the system
- Motivates - analysed, actionable information

Data Handling and Reporting

- KPIs, in-depth analysis, and benchmarking

Additional Benefits

- 27%: decrease of the total nitrogen in the effluent
- 23%: reduction of the energy consumption
- 46%: reduction of the chemical consumption
- 83%: reduction of the combined sewer overflows
- 80%: increase of hydraulic capacity of the entire wastewater system
- Increased level of information security
- Provision of balancing to the demand-response electricity market

Expand

The robust Digital Twin allows for expansion and further development moving forward.

Future Plans

- Enhance algorithms to provide the best optimization possible and reduce CO2 and H2O emissions.
- Sewer optimization by helping cities to avoid inflow and infiltrations and developing flooding alerts.
- Improve user interface to adapt to the needs of expert engineers and operation teams considering the diversity and uniqueness of our customers
- Effective e-learning and live assistance to quickly onboard and train users

"We work continuously to energy-streamline our processes. Setting up an advanced SMARTGrid system with close interaction between the treatment of wastewater and electricity market tariffs is a huge step forward for us."

—Per Holm, CEO, BlueKolding

CASE STUDY 5 Wastewater Treatment

Gruppo CAP, Italy

The Digital Twin focused on real-time monitored data to verify and validate a mathematical whole plant model.

Scope

Gruppo Cap, water service utility of Metropolitan City of Milan, has always been at the forefront in the management of digital platforms for water service and decided to install a digital twin structure in Bresso-Niguarda WWTP (250 000 PE) in 2020 last quarter in collaboration with DHI.

Digital Twin Architecture Components

Sensing / Control

- [ ] Sensors
- [ ] Actuators
- [ ] Advanced Monitoring

Data Collection and Sources

- [ ] Business & Operational Systems
- [ ] Automation Systems
- [ ] Attributes

Data Integration

- [x] Data ingestion and integration
- [x] Data Management

Analytics

- [ ] Data Driven Models
- [x] Physics Based Models

Visualization

- [x] Simulation and Decision Support Tools

User Experience

- [x] What-if Scenarios
- [x] Real-time Performance Dashboards
- [ ] Augmented /Virtual Reality
- [ ] Mobile Alerts
- [ ] Advanced Automation

Identify

Build a reliable tool that enable the operators to evaluate, in a virtual environment, the impact of operational choices.

Additional Goals

- Reduce chemicals
- Improve operational choices to increase biogas production and biomethane separation

Assess

The existing SCADA was leveraged in the development of the Digital Twin.

Digital Twin Design Approach

- The structure of the digital twin started from the implementation in Activation Sludge Model (ASM) scheme of the whole plant. Web service connection to SCADA data from 60 sensors have been implemented in a database avoiding lack of data using interpolation.
- The user-friendly interface has been proposed by DHI in order to obtain a clean overview of utility needs: scenario KPI comparison, real data (SCADA) trends with simulation trends comparison results
- The SCADA system was already present in the WWTP. The whole plant model, connection with core system of the database for the digital twin and interface has been built in 5 months
- The system proposed by DHI has been bought with a direct order to the company DHI in order to test such a system on a single WWTP. Gruppo CAP is now considering expanding the digital twin to other plants. We are ready with license for three other WWTPs.
- The team working on the solution had knowledge on WWTP ASM modelling, PLC programming, and interface creation. The experience regarding the communication problems at the beginning of signals processing allowed us to obtain the full results we expected.

Implement

Creating a Digital Twin is not just something related to IT and control logic aspects…lab data, process aspects, and operator experience too, are mandatory.

Challenges and Opportunities

- SCADA data dead bands and interpolation to fill gap
- Representation of layout plant structure
- Calibration of the ASM needed concentration dynamic pattern wastewater characterization campaign
- Connection between software developer and internal company network
- Aeration control strategies is complex to model and replicate
- Definition of daily based KPIs

The agile implementation approach allowed for the integration of real-time data to provide accurate monitoring.

Digital Twin Key Features

- The DT included integration of real-time monitored data from more than 60 sensors coupled with signal from 18 energy meters to verify and validate a mathematical whole-plant model.
- The Digital Twin thus implemented is therefore proposed as a full-scale tool for monitoring, DSS, and early warning (to identify and respond to possible risk situations) using scenario analysis. The compatibility of SCADA signals has been tested with the database interface created in order to run ASM family model.

> "We have a powerful tool capable of monitoring the actual status of the system and planning operating scenarios for the whole plant in a simple and user-friendly interface. We are now able to plan by means of KPIs forecast."
>
> —Roberto Di Cosmo, Process Eng. North Area Gruppo CAP

Benefit

As the Digital Twin is leveraged, more decision support results in more knowledge of the process dynamics.

- Monitoring and DSS to influent load variation effect on process, energy consuption
- KPI monitoring and forecasting
- Implementing new control strategies (from external carbon dosing by means of NO3 N control in predenitrification outlet to redox potential control)
- DO set point variation to set up best fuzzy logic strategies.
- Check of offline measured parameters such as oxidation tank and recirculation TSS wih Lab spot analysis

Expand

The implementation allows for different layouts, new control strategies, and additional plants in the future.

Future Plans

- Fill the discrepancies between real energy meter value and simulated energy consumption
- Add new control strategies implemented during the Digital Twin case study
- Add scenario results to Utility control room
- Start other three Digital Twins on different sized WWTP
- Pass to the fully automated control action of the system using best set point for pumps or DO directly from the scenario analysis defined final value
- Implement different layout (such as granular biomass reactor) to understand process possibilities

CASE STUDY 6 Wastewater Network

Waterschapsbedrijf Limburg, The Netherlands

The Digital Twin takes real-time measurement data from the 149 pumping stations (flow, pressure and velocity) and rainfall data from weather company. The data are fed to machine learning algorithms that generate insights and alarms regarding the performance of the wastewater transportation systems.

Scope

The Digital Twin solution implemented delivers decision support for the operators in the Central Control Room, for monitoring and managing the performance of the wastewater transportation systems of all 17 wastewater treatment plants.

Digital Twin Architecture Components

Sensing / Control

- [x] Sensors
- [ ] Actuators
- [x] Advanced Monitoring

Data Collection and Sources

- [ ] Business & Operational Systems
- [x] Automation Systems
- [x] Attributes

Data Integration

- [x] Data ingestion and integration
- [x] Data Management

Analytics

- [x] Data Driven Models
- [ ] Physics Based Models

Visualization

- [x] Simulation and Decision Support Tools

User Experience

- [ ] What-if Scenarios
- [ ] Real-time Performance Dashboards
- [ ] Augmented /Virtual Reality
- [ ] Mobile Alerts
- [ ] Advanced Automation

Identify

The ambition of the utility is to establish truly data-driven operations and maintenance of the wastewater transportation and treatment infrastructure (incl. biosolids handling), by implementing state-of-the-art digital technologies and solutions (digital twins being one of those technologies).

Additional Goals

- A better understanding of the normal behaviour of the wastewater transportation systems, and to detect deviations from this normal behaviour as early as possible, to be able to prevent failures in the transportation systems as much as possible. With knowledge that the system has:
  - Aging workforce leading to an accelerating loss of operational knowledge
  - Increasing complexity in the infrastructure due to (amongst others) sustainability goals and new legislation
  - More pressure on the infrastructure due to climate change.

Assess

Through agile implementation, the Digital Twin leveraged real-time data to provide an effective user experience.

Digital Twin Design Approach

The digital twin solution takes measurement data from the wastewater transportations system (flows, pressures, velocity) and rainfall data from a weather company. These data are fed to machine learning algorithms that have 'learned' the normal behavior of the system, and that generate performance indicators that describe the expected behavior at any given time. It generates early warnings in case of unexpected deviations in the normal or optimal behavior of the system. This is all done continuously, in real time.

The user experience/interface was developed during the pilot phase, in close cooperation with the end users (operators in the Central Control Room).

This was done using the Agile/Scrum sprint methodology in the development: developers and end users had a review session every 2 weeks, over a period of 3 months.

The architecture of the Digital Twin consists of two main components. The first, called the Big Data Platform, was built in Microsoft Azure Cloud using a set of Azure building blocks (like IoT Hub, Event Hub, Asset Model, ADLS Gen2). The second, doing the data analytics and visualization, was built using Aquasuite®, RHDHV's Virtual Operator software suite. This is deployed through Microsoft Azure as well.

Buy-in from the WBL stakeholders was primarily achieved through the aforementioned Agile/Scrum way of working during the pilot phase.

Implement

The main challenge was the buy-in from the end-users (the operators in WBL's Central Control Room, and their colleagues in operations and maintenance).

The agile implementation approach allowed for a successful implementation and enhanced user experience.

Challenges and Opportunities

The main challenge was succesfully mitigated with the Agile/Scrum development approach during the pilot phase, in which all potential issues were continuously monitored and evaluated weekly by the operational stakeholders of WBL and the hydraulic specialists, data scientists, and data engineers of RHDHV.

Another challenge/risk for WBL was the use of Microsoft Azure Cloud as the main platform for development and deployment of the solution, both from a technical and a financial point of view. This risk was mitigated by choosing RHDHV as the partner that combines in-depth knowledge of wastewater technology with high-level experience in developing Azure Cloud solutions for the water domain.

Lifecycle Phase

The development started with a successful Proof of Concept, after which a pilot was done on one of WBL's transportation systems (containing six pumping stations). After the successful pilot, the solution was rolled out to the transportation systems of all 17 wastewater treatment plants (149 pumping stations in total).

Context of Application

Waterschapsbedrijf Limburg (WBL), a Dutch regional water authority, owns and operates 17 wastewater treatment plants and 149 sewage pumping stations. With this infrastructure, WBL serves 500,000 households and 30,000 businesses, processing 150 million m3 of wastewater annually. WBL's core processes are wastewater transportation, wastewater treatment, and sludge treatment.

Digital Twin Key Features

- WBL and RHDHV successfully applied Aquasuite (RHDHV's Virtual Operator software suite) and Microsoft Azure Cloud for developing and implementing an operational Digital Twin that, through advanced data analytics, provides operators with:
  - real-time insights in the actual behaviour of WBL's wastewater transportation systems, compared to 'normal/optimal' behaviour
  - early warnings on anomalies and deviations in the expected behaviour of various parts of the wastewater transportation system.
- This enables WBL to manage the transportation systems more efficiently, and to prevent sub-optimal performance of the transportation systems
- It is key to acquire the buy-in of the end-users. An Agile/Scrum way of working during a pilot in which these end-users structurally participated (during a small-scale pilot phase) proved successful in achieving this.

User Experience

The Digital Twin delivers insights and early warnings of deteriorating performance to operators in the WBL's Central Control Room. When necessary, the operators evaluate these insights/warnings with colleagues like process engineers, pumping station specialists, maintenance engineers, the asset manager, etc.

The Digital Twin has a threefold focus:

- Catchment contribution analysis, identifying dry weather contribution, rain weather contribution and unaccounted for contribution (e.g., due to illegal spills)
- Pipe condition analysis, identifying sudden failures like pipe breaks and blockages, and more gradual deterioration of the performance due to, for example, clogging buildup
- Pump performance analysis, identifying deteriorating pump performance (e.g., due to wear) in an early stage

In all cases the Digital Twin clearly visualizes unexpected behavior compared to normal behavior and alerts the operator in case of urgent anomalies.

Over the years to come, WBL will take an essential next step in the development of data-driven business operations. By choosing Royal HaskoningDHV Digital, we have gained a partner with a valuable combination of expertise: in-depth knowledge of wastewater treatment management and digital know-how.""

—Remy Sleijpen, WBL Board Member

Benefit

The primary outcome is the implementation of a digital twin that gives the operators in WBL's Central Control Room accurate real-time insights in the performance of the entire wastewater transportation system.

- Detects unexpected or deteriorating performance at a very early stage, which enables WBL to optimize operations and maintenance of the wastewater transportation systems.
- Enables operational staff to gain a better understanding of their assets, thereby empowering them in their daily work.
- Allows for easily adding new Digital Twin functionalities in the near future. This refers to the 'Big Data Platform' component that was set up in Azure Cloud, not as a point solution for the current machine learning functionalities, but as a generic scalable data provisioning service for any future data analytics service.

Expand

The Digital Twin implementation allows for future enhancement and flexibility moving forward.

Future Plans

The future plans of WBL regarding the application of Digital Twin technology relate to themes such as (in random order):

- Extending the current monitoring functionalities of the Digital Twin to advanced automatic control of the pumping stations
- Scaling the current Digital Twin application to (eventually) 3,500+ more municipal pumping stations (in the sewer systems)
- Machine-learning-based data analytics for optimization of wastewater treatment processes
- Machine-learning-based data analytics for predictive maintenance purposes for the wastewater treatment plants
- Data-analytics-based advanced control of wastewater treatment plants
- Applying catchment-wide predictive control to optimise wastewater flows and treatment holistically
- Data analytics for optimization of sludge logistics
- Data-analytics-based advanced control of sludge treatment

CASE STUDY 7 Wastewater Treatment

PUB, Singapore's National Water Agency, Singapore

A Digital Twin providing advanced analytics and process control for wastewater treatment.

Digital Twin Architecture Components

Sensing / Control
- [x] Sensors
- [x] Actuators
- [ ] Advanced Monitoring

Data Collection and Sources
- [ ] Business & Operational Systems
- [x] Automation Systems
- [ ] Attributes

Data Integration
- [x] Data ingestion and integration
- [x] Data Management

Analytics
- [x] Data Driven Models
- [ ] Physics Based Models

Visualization
- [ ] Simulation and Decision Support Tools

User Experience
- [ ] What-if Scenarios
- [x] Real-time Performance Dashboards
- [x] Augmented /Virtual Reality
- [x] Mobile Alerts
- [x] Advanced Automation

Context of Application

Royal HaskoningDHV's (RHDHV) Aquasuite software was deployed at PUB's Integrated Validation Plant (IVP) at Ulu Pandan Water Reclamation Plant (UPWRP) in March 2019

Treatment capacity: 12,500 m3/day

The software underwent a 2-year trial to validate the reduction of energy consumption in water reclamation processes, chemical use, and reliance on manpower while increasing water quality.

Aquasuite is now integrally implemented at IVP for advanced process control (APC) and analytics for actionable insights.

Identify

Driven by growing water demand, rising operational costs, manpower constraints, and new challenges like climate change, PUB was looking for a way to leverage innovative digital technologies to improve wastewater treatment processes, strengthen operational resilience, improve productivity, and deliver better services to customers.

Additional Goals

- To optimize process control and monitoring, innovative technologies have been applied to IVP through development of a data-driven predictive Digital Twin, which consists of:
  - on-premise predictive control
  - cloud-based advanced analytics
- PUB's goals were two-fold: on-premise predictive control and cloud-based advanced analytics
- Predictive control:
  - Stable operations
  - Achieve product water quality
  - Optimize nutrient removal
  - Reduce aeration energy
- Advanced analytics:
  - Early-stage anomaly detection
  - Determine aeration deviation
  - Verify potential instrument drift
  - Predict poor equipment performance

Assess

The Digital Twin design approach provided in implementation of control and co-development of analytics.

Digital Twin Design Approach

- The DT uses a data-driven approach for both predictive control and anomaly detection.
- The following approach was used: First, the control part of the DT was implemented on premise. Second, the analytics part of the DT was co-developed and deployed in the cloud.
- For the co-development, an agile way of working was proposed with functional development sprints and software deployment sprints allowing continuous customer validation.
- All main stakeholders participated during design and implementation. Final users were targeted with specific training.

Implement

Determining the right level of technical detail for the Digital Twin implementation to meet the needs of the end user was a primary challenge.

Challenges and Opportunities

Taking the end user along in the process of developing and deploying the Digital Twin:

- Need to provide guidance, training, and a different way of working to embed the new digital solutions.

The approach of the Digital Twin might become too technical driven and not problem driven:

- First investigate the tasks, pains, and gains of the client. What do they really need?
- This also directly connects to the need for both artificial intelligence and domain knowledge.

Several technical challenges:

- Data quality must be ensured. Pre-processing of the data can be necessary to obtain useful info.
- Interoperability is essential; however, security and privacy policies can be obstacles to deal with.

The agile implementation approach of the Digital Twin allowed for effective use of AI for APC and decision support system.

Key Features

By incorporating our domain knowledge, robust process automation, and artificial intelligence techniques (predictive control and advanced analytics), we created a data-driven predictive Digital Twin that provides an autopilot for advanced process control and operation and actionable insights for the operator by autodetection of anomalies.

PUB's operators and plant managers now have visibility across the entire process, which allows for better monitoring and control to mitigate risk, cut costs, and ensure the most efficient approach to water management.

> This pilot trial demonstrates how digital solutions like Aquasuite can seamlessly digitize and automate our water reclamation operations"
>
> —Dr. Kelvin Koh, General Manager, Ulu Pandan Water Reclamation Plant

Benefit

The Digital Twin provided a wide range of benefits and scalable solutions in an extendible platform for actionable insights and operational support.

- Predictive control:
  - ~88% accurate load prediction
  - ~15% aeration amount reduction with corresponding energy reduction
  - Autopilot system enables stable operation and effluent quality due to load prediction-based control functions
- Advanced analytics:
  - Ability to autodetect several deviations
  - Early warning as operational support
- Anomaly detection models deployed for:
  - Processes, instruments, equipment
- Together with the autopilot system, early warnings minimize manual intervention

Expand

The implementation allows for future refinement and enhanced functionality.

Future Plans

- Refine implemented functionality and visualization.
- Extend the analytics platform so that the user will be actively notified on persistent anomalies/events.
- Explore additional functionality besides the current anomaly detection models for the aeration process, instrumentation, and equipment in close cooperation with PUB.

CASE STUDY 8 Urban Drainage

BIOFOS, Copenhagen, Denmark

SWAN SMART WATER NETWORKS FORUM

The Digital Twin focused on building trust while facilitating implementation.

Utility

Within the EU Horizon 2020 project "Digital Water City," BIOFOS, operator of the WWTPs in Greater Copenhagen, will implement the ML tools in a decision support system to build trust and facilitate implementation of advanced ML within BIOFOS's control system.

Digital Twin Architecture Components

Sensing / Control

- [x] Sensors
- [x] Actuators
- [x] Advanced Monitoring

Data Collection and Sources

- [ ] Business & Operational Systems
- [x] Automation Systems
- [x] Attributes

Data Integration

- [x] Data ingestion and integration
- [x] Data Management

Analytics

- [x] Data Driven Models
- [x] Physics Based Models

Visualization

- [x] Simulation and Decision Support Tools

User Experience

- [ ] What-if Scenarios
- [ ] Real-time Performance Dashboards
- [ ] Augmented /Virtual Reality
- [ ] Mobile Alerts
- [ ] Advanced Automation

Main Findings

The machine learning approach was seen to work well, providing fast forecasts with competitive accuracy relative to the current production model.

Identify

The main objective was to ensure that capacity available in urban drainage systems is leveraged optimally.

Additional Goals

- Quick inflow prediction based on machine learning at lead times up to 3 hours.
- Leverage near real-time data to obtain near real-time predictions.
- Political requirement to decrease combined sewer overflows and bypass at the WWTP.
- Stay within allowed limits in discharge permit.

Assess

A custom implementation approach plan allowed for each goal to be addressed.

Digital Twin Design Approach

- Combination of two data-driven models.
- Deep learning model predicts rain intensity based on weather radar images.
- Gradient boosting model predicts inflow based on rain intensity predictions and volume, level, and flow sensor measurements.
- Predictions are shown in existing front-end.
- Opportunity to develop solutions under the EU Horizon 2020 Digital Water City project.
- Short payback time due to savings in infrastructure investments.
- The existing grey-box model needed improvement.

Implement

To address each challenge, BIOFOS understood the importance of estimating the effort and time to complete the project to build up trust and integrate in operation.

Challenges and Opportunities

Data

- Retrieval of historical data. Extended time series of rainfall and inflow rates to the plant is needed to train the ML engine. Preferably 1 year or more, to include seasonal variations in catchment response.
- Quality. While an abundance of data may be available, poor qaility data will result in an equally bad model.
- Data accessible from cloud. In general, the use of cloud storage offers a stable and reliable repository, but it may come with a relatively high cost.
- Sufficient data to predict the interesting events. It is important that the training data set includes events that match the occurring events.

Trust

- Transparency of model, why are predictions as they are. Unexpected results reduce the faith in the models, and from an overall trust viewpoint, unexpected results should be quantifiable.
- Buy-in from operational personnel is crucial. No system will run for extended time without maintenance and engagement from stakeholder. Hence, it is important that a continued buy-in is present, which again calls for value creation.
- Readiness of people for digital solutions. Digitalization is still a young phenomenon in the wastewater business segment, calling for special attention to this potential barrier.

Each key feature supported trust in the system.

Digital Twin Key Features

- Engagement from stakeholders and end users is necessary to complete and roll out system
- Data quality and availability essential for all sources:
  - Sensors (flow, level, volume)
  - Gauges (rain)
  - Weather radar
- Transparency in which observations are important in determining the predicted value is important for trust in the system
- Fast calculation of forecasts provided by data-driven machine learning models

> End user engagement is essential to implementing a digital twin."
>
> —Barbara Greenhill, BIOFOS

Benefit

Fast and reliable forecasts facilitate better utilization and optimal operation. Future investments can be more efficient – saving environmental and monetary costs.

- Ease of retraining with new data (for example, in case of infrastructure changes).
- Extendable to other plants for control purposes.
- Forecast expected to be better than current.
- More reliable inflow forecasts allow the operators to improve performance from the treatment plant, both in terms of reduced pollution in the effluent and in saved energy.

Expand

The implementation was a success that allows for future extensions and future phases.

Future Plans

BIOFOS currently uses a simple forecast model and control points in the catchment to change from dry to wet weather operation. BIOFOS expects ML to deliver better forecasts, reduce unnecessary wet weather operation starts and improve integrated control between the WWTP and the catchment, and achieve better operation and environmental benefits.

- Extend to other plants
- Extend to other locations in network
- Integrate with existing frontend
- Improve robustness of code and services

CASE STUDY 9 | Urban Drainage

VCS, Denmark

SWAN
SMART WATER NETWORKS FORUM

Utilitywide implementation of the Digital Twin

Context

Urban drainage system containing rainwater, wastewater, and combined pipes: Increasing the transparency of the system and the models supporting the Digital Twin.

- LIFECYCLE PHASE: Operational phase
- LEVEL: Utilitywide system
- SPECIFICS OF APPLICATION: VCS Denmark

Digital Twin Architecture Components

Sensing / Control

- ☐ Sensors
- ☐ Actuators
- ☐ Advanced Monitoring

Data Collection and Sources

- ☐ Business & Operational Systems
- ☐ Automation Systems
- ☐ Attributes

Data Integration

- ☑ Data ingestion and integration
- ☑ Data Management

Analytics

- ☑ Data Driven Models
- ☑ Physics Based Models

Visualization

- ☑ Simulation and Decision Support Tools

User Experience

- ☐ What-if Scenarios
- ☑ Real-time Performance Dashboards
- ☐ Augmented /Virtual Reality
- ☐ Mobile Alerts
- ☐ Advanced Automation

Identify

Increased transparency and understanding of the system and models, as well as improved planning models, were key goals of the Digital Twin implementation.

Additional Goals

- As urban drainage models have a wide impact on what is going to be designed, there is a large need to increase transparency of when and where the model performs well, and also to understand the "real" system better.
- A goal is to improve the understanding of the current system and understanding of the models, so called error-diagnosis, of when and where the physic-based models behind Digital Twins can and cannot simulate the behavior of the system.
- Higher awareness of the uncertainty of the planning models as well as improvements (by learning from the operation model) will lead to better investments in new design and renovation in the areas that needs it most.

Assess

A detailed implementation approach allowed for a Digital Twin design that met each key goal.

Digital Twin Design Approach

- Data from +400 in-sewer observations is stored in a cloud-based datalake, being analysed for sensor-anomalies, equidistant time-resolution and structured in a database for exploitation in other visualization applications. An operational simulation model (DHI/Mike Urban) is run daily with observational data from +15 rain gauges in the area. The model is updated quarterly with new information from the asset database. Advanced statistical analysis will be performed to compare timeseries from the results of the simulation model and the observational data.
- An interface is developed to show all locations, and the corresponding timeseries are visualized.
- The current development of the solution is made as flexible as possible to avoid proprietary systems. The solution is thereby ready to include new innovation solutions in the setup along the way.
- The current system – running for now – has been under development since 2008, but due to outdated software requirements the solution needs to be changed.
- The Digital Twin initiated several processes to find an optimal solution with a combination of in-house knowledge building and what is done by consultants.

Implement

Understanding the challenges allowed VCS to make the best conclusions to successfully implement a Digital Twin.

Challenges and Opportunities

- Raw data is not always just raw data – there are many steps to get the quality data you need, and some processes may not be ignored. Remember to be transparent about these steps.
- Make a visual easy system interface to increase the broader applicability
- Having a Digital Twin used by many provides 'easy access' but also requires training of people as well as exploitation of the uncertainty of the results.

Conclusions

- Think flexibility into the solution, and be aware not to use proprietary systems where future solutions cannot be incorporated.
- The simulation model may not replicate your system. Be aware of the uncertainty.
- Take ownership of the Digital Twin and learn how you can use it with all its limitations.
- There is not only one Digital Twin but a Digital Twin Environment with several Digital Twins within. Think data links into this solution.

> "Confidence in digital twins is crucial for future use, and can be achieved by being transparent about uncertainty."
>
> —Agnethe N. Pedersen, Hydraulic modelling specialist

Benefit

Multiple benefits will be realized with the knowledge gained from the Digital Twin in the upcoming years.

- Greater transparency of the system performance (for more colleagues in the utility)
- Greater transparency of the model performance simulating the real system
- Better design and planning models – and with more certainty in where to prioritize new investments in the service area.
- Greater collaboration across the departments in the utility company
- Greater use of the data collected
- Increased insight in the performance of the targeted design criteria
- Better communication tools to the regulators

Expand

Future enhancements will be prioritized together with colleagues to best address Digital Twin goals moving forward.

Future Plans

- Optimization of simulation models based on output from the error-diagnostics
- Expand the error-diagnostic tool to several types of sensors and sites
- Include more model results in the Digital Twin environment
- Improve the supportive toolbox for operation with the Digital Twin environment

CASE STUDY 10 Pump Station Optimization

Kempner Water Supply Corporation, United States

SWAN SMART WATER NETWORKS FORUM

The Digital Twin focused on pump station optimization, energy reduction, and asset management.

Scope

To provide a Digital Twin to minimize pump lifecycle costs, track changing pump conditions, and operate pump station as designed. Take the guesswork out of pump design and operation to provide data-driven insights for better decision making.

Specifics of the Application

- Predictive asset management
- Automate stations for energy efficiency
- Extend pump life
- Reduce leaks and increase resiliency

Digital Twin Architecture Components

Sensing / Control

- ☑ Sensors
- ☑ Actuators
- ☑ Advanced Monitoring

Data Collection and Sources

- ☐ Business & Operational Systems
- ☑ Automation Systems
- ☑ Attributes

Data Integration

- ☑ Data ingestion and integration
- ☑ Data Management

Analytics

- ☑ Data Driven Models
- ☑ Physics Based Models

Visualization

- ☑ Simulation and Decision Support Tools

User Experience

- ☑ What-if Scenarios
- ☑ Real-time Performance Dashboards
- ☐ Augmented /Virtual Reality
- ☑ Mobile Alerts
- ☑ Advanced Automation

Identify

The Specific Energy Digital Twin operated pump stations optimally by controlling variable-frequency drives (VFD) and pumps to maximize efficiency while accounting for dynamic system conditions.

Additional Goals

- Optimize the use of investment on newly installed VFDs
- Run pumps to positive net present value using measured pump curves and historical operating data, instead of running to failure
- Minimize energy expenditure of the WSC's largest energy user, a pump station pumping to an uphill tank

Assess

A clear design approach paved the way for effective Digital Twin implementation.

Digital Twin Design Approach

- Edge analytics are used to compare the most up-to-date physics-based model (hydraulic) and the actual data collected.
- User interface was created with the help of the customer. Operators needed a simple graphic to show current operating condition and recommended setpoints.
- Architecture (sensors) already existed; specific energy needed to add an edge device and program the high-fidelity hydraulic model
- Buy-in was achieved by performing a trial run (pilot program) using an existing pump station to show the benefits, particularly with energy savings.
- Uncertainty was addressed via the hydraulic model since the live data had a comparison metric.

Assessment Outcomes

- Kempner WSC learned that their lead pump was severely worn and operating at a peak efficiency of 57%, which is almost 30% lower than the peak efficiency of a new pump
- Software recommended a pump repair project with an NPV of $12,488 and a return on investment of 50%
- An average of 23% energy savings realized
- Digital Transient Control functionality has reduced peak pressure transients during pump starts and stops by 77%, from 152 to 35 psi

Implement

Getting the organization to adopt the technology using training so all can understan, while maintaining a straightforward approach was a key challenge.

Challenges and Opportunities

- Risks
  - Lack of operator buy-in. Silo effect among operations, engineering, maintenance and IT.
- Challenges
  - Combating status quo
  - Inaccurate instrumentation – Requires accurate flow, pressure, power measurements
- Adoption/training
  - Management must support a shift in operational behavior

The agile implementation approach allowed for the Digital Twin to focus on clear, attainable key features.

Digital Twin Key Features

- Asset Management
  - Tracks pump health over time
  - Ensures reliability of key assets
- Optimization
  - Energy savings
  - Ensures operation at peak efficiency, accounting for wear

> The Dynamic Pump Optimizer has made it much easier to run our pump station and allowed us to get the full benefit out of our VFDs."
>
> —Rodney Seaver, Distribution System Manager

Benefit

Clear benefits included energy and cost savings, reduced failures, and improved asset management.

- Average 23% energy savings (~$40,000/yr)
- 77% peak transient reduction (reduced pipe failures)
- Pumps run to positive NPV (better asset management)
- Expanding the implementation
  - Dynamic Pump Optimizer (DPO) implemented at other stations
  - Water plant high service pumps (1200 hp): (2) 600 hp pumps, installed 2015
  - Northeast Pump Station (150 hp):(2) 75 hp pumps, installed 2019

Expand

The implementation was a success that allows for future expansion to other stations and an enhanced SCADA system.

Future Plans

- Dynamic System Optimizer in the works
  - Includes multiple pump stations, tanks, and pressure-regulating valves to optimize the tank-filling sequence
- Lift Station Guardian
  - Standardized build blueprint for small developer stations to enable as many features of DPO as possible.
- Tagger
  - Cellular SCADA system, the foundation for DPO and Tagger. Allows customers to connect any PLC to the cloud and allow control and/or trending, bringing edge analytics to remote locations.