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Efforts and Potential for Digitalization in the Swedish Water Industry

Master's thesis in Design and Construction Project Management & Infrastructure and Environmental Engineering

MAJA HAGBERG
KAJSA KARLGREN

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
DIVISION OF WATER ENVIRONMENT TECHNOLOGY

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MAJA HAGBERG
KAJSA KARLGREN

Supervisor: Professor Thomas Pettersson, Department of Architecture and Civil Engineering
Examiner: Senior Researcher Andreas Lindhe, Department of Architecture and Civil Engineering

Department of Architecture and Civil Engineering
Division of Water Environment Technology
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Department of Architecture and Civil Engineering
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KAJSA KARLGREN

Department of Architecture and Civil Engineering
Chalmers University of Technology

Abstract

Water is a vital resource and is therefore subject to stringent regulation in its management. With new challenges driven by climate change and population growth, more efficient and quality-assured approaches are needed for handling drinking water, sewage, and stormwater. This study focuses on digitalization of Swedish municipal water organizations, emphasizing the need for digital methods to address the industry's growing challenges. The aim of the study was to assess the status and potential for digitalization in the Swedish water industry and to identify the drivers and challenges faced by water organizations when digitalizing. Through a literature review and interviews with representatives from Swedish municipal water organizations, insights and knowledge in the field have been evaluated and analyzed. The study reveals significant potential for digitalization within the sector, but the implementation strategies vary depending on the roles and expertise of individuals within water organizations. Primary drivers for digitalization originate from dedicated individuals within the organizations, while financial limitations and time constraints impede progress. Leadership commitment and the development of a clear digital strategy are essential to facilitate organizations in navigating the digital transformation. Furthermore, a greater political focus on water as a vital resource is needed to drive legislation and standards that promote digitalization. There is also a need to review the financing of water utilities and explore opportunities for financial support allocated to innovation and digitalization efforts.

It is important to note that the participating organizations serve as examples on how to approach digitalization in the Swedish water industry. The objective was to provide an overview of digitalization efforts in the sector, rather than evaluating individual organizational approaches. Additionally, the studied organizations likely does not fully represent the diversity found throughout the Swedish water industry.

Keywords: digital transformation, digital working methods, digitalization, smart water, water industry, water management.

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KAJSA KARLGREN

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Sammanfattning

Vatten är en livsavgörande resurs och därför är hanteringen av den hårt reglerad. I samband med nya utmaningar som drivs av klimatförändringar och ökad befolkning kommer det att krävas mer effektiva och kvalitetssäkra tillvägagångssätt för hantering av dricksvatten, avloppsvatten och dagvatten. Denna studie fokuserar på digitalisering av svenska kommuners VA-organisationer och betonar behovet av digitala metoder för att möta de växande utmaningarna sektorn står inför. Syftet med studien var att undersöka statusen och potentialen för digitalisering av den svenska VA-sektorn och kartlägga de drivkrafter och hinder som svenska VA-organisationer står inför vid digitalisering av deras verksamhet. Genom en litteraturstudie och intervjuer med representanter från svenska kommunala VA-organisationer har insikter och kunskap inom området utvärderats och analyserats. Studien visar att sektorn ser stor potential med digitalisering, men tillvägagångssättet värderas olika beroende på vilken roll och kunskap individerna i en VA-organisation har. Primära drivkrafter för digitalisering inom sektorn kommer från engagerade individer inom organisationerna, medan ekonomiska och tidsmässiga begränsningar hindrar framsteg. För att underlätta för organisationer att navigera i den digitala transformationen är ledarskap och utvecklingen av en tydlig digital strategi avgörande. Dessutom krävs ett större politiskt fokus på vatten som en viktig resurs för att driva fram lagstiftning och standarder som främjar digitalisering. Det finns även ett behov av att se över finansieringssystemet av kommunala VA-organisationer och möjligheter för ekonomiska bidrag allokerade till innovation och digitalisering.

Det är viktigt att påpeka att de medverkande organisationerna är exempel på hur man tar sig an digitalisering i den svenska vattensektorn. Syftet var att ge en övergripande bild av sektorns digitaliseringsarbete, snarare än att utvärdera individuella organisationers tillvägagångssätt. Det är också viktigt att notera att de undersökta organisationerna sannolikt inte helt återspeglar mångfalden som finns i den svenska vattensektorn.

Nyckelord: digital transformation, digitala arbetssätt, digitalisering, smart water, VA-sektorn, vattenhantering.

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Maja Hagberg and Kajsa Karlgren, Gothenburg, June 2024

Glossary of Terms

Digitaliseringsnätverket	Network for digitalization within the Swedish water industry, arranged by Svenskt Vatten. Is referred to as the *Swedish digitalization network* in the report.
Digital transformation	Refers to a broader shift where an organization adopts a holistic approach to embrace digital working methods, including technological, organizational, and cultural changes.
Digitalization	The process of using digital technologies to transform and optimize processes, creating new methods of conducting business or services.
Digitization	The process of converting analog information into digital form.
Municipal water organization	The organization responsible for providing drinking water, sewage, and stormwater services within a municipality
Pipe network	Refers to all types of pipes, including water distribution pipes, sewage pipes, and stormwater pipes.
RISE	Research Institutes of Sweden, a Swedish research institute and innovations partner.
Svenskt Vatten	Swedish industry association for water and wastewater organizations.
VA-banken	A tool for managing information related to the pipe network. It includes functions for recording factual data about the network, reporting operational disturbances, planning, prioritizing, and status evaluation.
Wastewater	A collective term for sewage and stormwater.
Water management	A collective term for the management of drinking water, wastewater, and stormwater.
Water system	A collective term for all physical parts of the water infrastructure, such as pipe networks and treatment plants.

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1
Introduction

This chapter briefly outlines the significance of digitalizing water services and management to address future water needs and challenges. Additionally, the term digitalization is discussed and defined both in general and in the water industry context. Furthermore, the aim, research questions, and contribution of this report is presented.

1.1 Background

Safe and sufficiently managed water is crucial to public health and a key measure in order to prevent diseases and infections of various types (World Health Organization, 2023). World Health Organization states that an improvement of drinking water management is not only important to public health, but also a way to boost economic growth of less developed countries as well as the contribution to a reduction of poverty worldwide. In 2022, the total population lacking access to safely managed drinking water corresponded to approximately 27% of the world's population (United Nations, 2023). The United Nations (2023) Sustainable Development Goal six (SDG6) addresses this problem and implies the ensuring of available and sustainable managed water and sanitation for all until 2030. The overall goal is to accomplish global and equal access to safe and affordable drinking water, increase water efficiency, and provide a sufficient wastewater treatment. Additionally, SDG9 emphasizes the importance of establishing a sustainable infrastructure, industry, and innovations (United Nations, n.d.). It aims to encourage the construction of a resilient infrastructure of high quality to foster economic advancement and enhance human well-being, as well as fostering innovation. The Swedish representation of these sustainability goals is formulated in Sweden's 16 environmental quality objectives. The goal of Good Quality Groundwater and the goal of Good Built Environment can be considered to address the environmental aspect of the mentioned SDG's (Sveriges miljömål, n.d).

The water industry is facing several challenges, among aging infrastructure, climate change and transition to circular systems (Arnell et al., 2021). Climate change will contribute to changing the availability of drinking water and extend the areas affected by the new conditions (Strandberg et al., 2020). Sweden, among several other countries, generally have good access to water (Stensen et al., 2019). However, the country has experienced lower groundwater levels in recent years and water shortage has become apparent, placing a new stress on society. Climate change is also

expected to increase rainfall causing overflow of sewer systems which poses a risk for decreased water quality and more complicated water management (Skaland et al., 2022; Stensen et al., 2019). Adedeji et al. (2022) further highlight increasing populations and uncertainties in consumer demand as additional challenges for water utilities, and therefore argue that a transformation in water management is necessary in order to address long-term challenges.

Enhancing water-use efficiency is a crucial factor in reducing water stress (United Nations, 2023; Skaland et al., 2022). New strategies for water management, transboundary cooperation and collective effort are needed to tackle the challenges. However, pipe networks are complex underground structures that are not easily accessible and monitoring of them is challenging (Adedeji et al., 2022). To increase efficient water management and thus ensure high quality water services, Strandberg et al. (2020) propose to extend the control of water from catchment area to the water treatment plant. This can be facilitated through digitalization and utilization of new technology.

The report *Digitalisering av den svenska VA-branschen* established by the Swedish water and wastewater association, Svenskt Vatten, emphasizes the need for digitalization in the water industry to keep up with the global digital trends and to embrace new technologies (Arnell et al., 2021). Adedeji et al. (2022) states that existing technical solutions cannot supply enough capability to cope with the dynamic characteristics of the water system. Hence, a new focus is on the implementation of new digital technologies with sufficient capabilities of monitoring and control of the systems. However, Arnell et al. (2021) highlights that the transformation requires both technical and organizational changes and increased cooperation within the water industry. According to Bennich et al. (2023), Swedish municipalities face different prerequisites including financial means, competence, political governance, and physical infrastructure. Given that Swedish water services are managed by the municipalities, these factors play an essential role in addressing water management issues effectively.

Since different water organizations possess unique conditions they approach digitalization differently. Hence, voices from water organizations of various sizes can provide insight into the potential and challenges of digitalization, creating a common understanding of what digitalization means for the Swedish water industry. This highlights the relevance of investigating digitalization as a part of water management and how the Swedish water industry will undergo digital transformation collectively.

1.2 The concept of digitalization

The definition of digitalization is not unambiguous nor worldwide, but must be defined for each country and industry. Therefore, this chapter describes the definition of digitalization in this report and in the water industry context.

1.2.1 Definition of digitalization

Digitalization captures several processes, and literature from several fields of research refers to three processes in particular (Gobble, 2018; Gong & Ribiere, 2021; Gradillas & Thomas, 2023; Mergel et al., 2019; Savić, 2019; Tan et al., 2023):

- **Digitization:** the process of converting analog information into digital form.
- **Digitalization:** the process that goes beyond digitization and involves using digital technologies to extract value in new ways, by transforming and optimizing processes into new ways of conducting business or services.
- **Digital transformation:** refers to a broader concept of a technological, organizational, cultural, and relational shift where an organization is redefining their overall mindset to a more holistic approach to embrace digital working methods.

Savić (2019) elaborates on each of the processes, stating that digitization focuses on data conversion, digitalization as information processing and digital transformation emergent of knowledge leveraging. Gradillas & Thomas (2023) have examined the use of the terms digitization and digitalization and found that digitalization has been more frequently used after 2018, and is more frequently used in Europe. Further stated is that digitization could be linked to research within information management while digitalization is applied across various disciplines. The correlation between the two concepts is demonstrated by digitized data facilitating digitalization, thereby enabling continued digital advancement. The processes require adoption of digital technology which in turn calls for organizational and technological investments, making it an innovative process. These interrelationships can be captured in the concept of digital transformation.

Thus, the digital transformation encompasses the processes of digitization and digitalization, reflecting a broader journey involving technology adoption, investments, innovation, and organizational change.

1.2.2 Digitalization in the water industry context

As this report focuses on the Swedish water industry, the following section discusses the definition of digitization, digitalization, and digital transformation within the water industry.

Knudsen (2023) frames the three concepts in the context of water management. According to Knudsen digitization involves building a foundation of data saved in local databases, digitalization entails using this information in models and analyses and sharing it via the cloud with relevant parties, although the data still needs to be updated manually. Lastly, digital transformation represents the ultimate phase of transitioning work methods, utilizing AI and machine learning to reduce human involvement in operations, analyses, and decision-making, while enabling comprehensive forecasting of future scenarios for pipe networks and plants. The Swedish

water and wastewater association, Svenskt Vatten, does not distinguish between digitization and digitalization but defines it in a similar manner as in Chapter 1.2.1 (Arnell et al., 2021). They also relate digitalization and digital transformation as synonyms. The digital transformation for the Swedish water industry is described as the shift towards using the current rapid technological advancements and the extensive data collected to achieve significantly enhanced resource utilization. They emphasize the need for adopting a holistic perspective, where both technical and organizational factors of water utilities are part of the transformation.

Based on the definitions in the literature studied, the terms digitalization and digital transformation will in this report be defined as follows. The processes related to automation of digital working methods, such as; implementation of digital technologies in the operational phase, digital methods for collection, transferring and storage of data, and digital tools used to link and analyze data, will be referred to as digitalization. Digital transformation will be used when talking about the holistic view of digitalization, connecting digital ways of working with an organizational IT-infrastructure supporting information flows, decision-making processes including risk assessment and resource allocation.

1.3 Aim

The aim of this master's thesis is to explore and compare Swedish municipal water organizations' views of digitalization and what is required in order for water organizations and the industry at large to succeed with the digital transformation.

The intention is to describe the current situation of digital practices in the Swedish water industry and identify the existing perspectives on digitalization within the water industry by investigating municipalities of different sizes. Additionally, the main drivers, challenges, and success factors for increased digitalization of water organizations and their operations are identified and analyzed.

1.4 Research questions

This thesis' main research question is:

- What is needed for Swedish municipal water organizations to increase their level of digitalization in order for the Swedish water industry to undergo a digital transformation?

To answer the main research question, three sub-questions are examined:

- What views of digitalization exist among Swedish water organizations?
- What drives Swedish water organizations to digitalize, and what challenges do they encounter?
- What success factors can be identified among Swedish water organizations to proceed in their digital transformation?

1.5 Limitations

This master's thesis focuses on the Swedish water industry and how different water utilities cope with digitalizing their operations. The literature studied encompasses global sources, while the interview study focuses solely on Swedish water organizations. The study prioritizes organizational aspects and future prospects of digital transformation over detailed explanations or investigations of digital solutions.

1.6 Contribution to theory and practice

This study of digitalization within Swedish water organizations offers valuable insights for urban development practices. By comprehending the sector's perspectives on digitalization, this thesis identify industry needs across municipalities of varying sizes. Providing practical examples of success factors among water organizations, this thesis aids organizations at the initial stages of digitalization, highlighting essential considerations to kickstart their journey. While previous studies have identified the potential of digitalization to improve water management, this study highlight the organizations who undergo the digital transformation, addressing their unique drivers and challenges. Thus, the thesis situates the digitalization efforts of municipal water organizations within a national context to underscore its importance for decision-makers.

2
Theory

This chapter explores the theoretical foundations of digitalizing water management, aiming to provide a comprehensive theoretical background on topics essential for understanding the prerequisites for digital transformation of the water industry. It encompasses the technological solutions and working methods as well as organizational structures and changes needed for water utilities to digitalize.

2.1 Digitalizing water management

There are several different concepts regarding digitalization of water management mentioned in the literature, of which the three most commonly used are Water 4.0, Digital Water, and Smart Water (Sarni et al., 2018; Bennich, 2024; SWAN Forum, n.d.). These notions are all defined in a similar manner, focusing on the implementation of digital technologies when managing water services. While there is no explicitly stated difference between the concepts, they do vary slightly.

Starting with Water 4.0, it could be seen as an overall digital transformation of the water industry. The development of the water industry has been characterized by the four industrial revolutions, with one water revolution following each step of the industrial revolution (German Water Partnership, 2015). The latest industrial revolution is referred to as Industry 4.0 and it focuses on intelligent and digitalized devices. Following Industry 4.0, the latest water management revolution called Water 4.0 represents the next phase of water management evolution (German Water Partnership, 2015; Sarni et al., 2018).

Water 4.0 implies virtual and real water systems being networked together in cyber-physical systems (German Water Partnership, 2015). Smart Water Networks Forum, SWAN Forum (n.d.), relates to this as smart water networks. Both concepts refer to a system that combine the usage of sensors, real-time control and computer models with real-world water systems. This creates a connected system consisting of a set of data-driven components and solutions that are fully integrated in the water system, spanning from the treatment plants to the consumer, making it become more intelligent. The concepts Digital water and Smart water are similar to Water 4.0 but focuses more on the actual digital tools, the implementation of them and the data opportunities they entail (Bennich, 2024; SWAN Forum, n.d.). The technologies used in connected water systems include sensing and control of the water processes, methods for data collection and communication, data management, visualization,

and analysis. This combination of connected technologies leads to a more holistic approach towards the water system in general, which creates a basis for strong decision-making (German Water Partnership, 2015). To get an overview of how the different parts of a smart water network interrelate, SWAN provides a five layered model as follows (SWAN Forum, n.d.):

1. Physical assets: include the physical products of the network, enabling distribution and delivery of water (i.e. pipes, pumps etc.).
2. Sensing and control: the components which measure flow, pressure, noise and water quality and the controlling devices interfering with the physical products.
3. Collection and communication: the technologies that collect data through meters and transfer it through cable network, radio or Wi-Fi. Also technologies that stores the data in order for it to be processed and analyzed. It is useful with two-way communication in this layer, implying that commands are sent to layer two for devices to know what data to gather or tasks to perform.
4. Data management and display: this layer intends to merge data from several sources and organize it into useful information and then visualize it to the users.
5. Data fusion and analysis: these tools should combine analytics and modeling, allowing for remote and automatic management of the networks, for instance pump optimization. Machine learning and artificial intelligence (AI) can be employed to understand the network and take immediate action.

2.2 Components of digitalization

The components enabling the digitalization of the water sector can be divided into three areas. Firstly, a significant amount of data from various sources is required for controlling the pipe network, including information about water infrastructure and parameters related to water flowing through the network. This data needs to be stored and analyzed in an automated manner. Subsequently, the analyses need to be communicated and presented to relevant actors within the water organization. This chapter presents examples of digitalized methods and tools facilitating these three steps.

2.2.1 Data collection and monitoring

The ongoing digital transition of the water industry makes Internet of Things (IoT) become an important concept. IoT describes an increasingly connected world where numerous items are connected and communicate with each other, forming systems that bridge the physical world with the internet (Arnell et al., 2021; Rose et al., 2015). The interconnection and new paths of communication between different devices enable new methods to combine, control, monitor, and integrate data with less human involvement. This results in a large amount of data becoming available, often referred to as Big Data.

Big Data is defined as data that is large in quantity, could be traded in high speed, is received in diverse types, is accurate and trustworthy, and creates value for a business (Adamala, 2017). For the water industry, the type of data collected include for instance flow, water level, groundwater level, meteorological data, quality parameters, water temperature, and water consumption along the pipe network (Sarni et al., 2019; Sustainable Water Partnership, 2020; Clemens-Meyer & Lepot, 2021). Márquez & Lev (2017) and Zou (2023) agree on several benefits associated with the use of Big Data within the water industry, including how large amounts of data improves the accuracy of forecasts and provides support for decision-making. Big Data provides the conditions to move towards evidence-based rather than experience-based decision-making (Márquez & Lev, 2017).

Organizations must be sure about their purpose of using Big Data and awareness of data needed for creating a solid basis for their decision-making. The key is to compile high quality data rather than high quantity data with quality uncertainty (DIGG, n.d.). Furthermore, Zou (2023) highlights the importance of classification of data when handling this large amounts of complex data. The collected data can be stored locally in databases (data warehouses) or in cloud services (Márquez & Lev, 2017).

Tools for data collection

The large volumes of data places high demand on the technology (Gohil et al., 2021), necessitating specialized technology for data collection, ensuring data accuracy, measuring various parameters, and being affordable for purchase.

One way to collect data and monitor the status of the water system is through sensors. The sensors are placed in various components at different locations in the pipe network, such as in the raw water sources, water treatment plants, and pumping stations (Strandberg et al., 2020; Arnell et al., 2021). They measure for instance conductivity, turbidity, and flow rates of water (Arnell et al., 2021). The data can be utilized to identify variations in the water system. Additionally, there are smart sensors which are coded to alarm in case of anomalies.

The traditional mechanical water meters in Swedish households have also been smartified to no longer require manual reading and reporting of consumption to the water utilities (Göteborgs stad, n.d.). Via smart water meters, water consumption data can be transmitted instantly to the utility through remote reading by drive-by antennas or fixed networks for wireless communication (Ekström and Sivadasan, 2021). Furthermore, smart meters can provide extended capabilities beyond measuring the volume of water consumed, such as measuring temperature, flow, and pressure and locate leaks through noise data (Ekström and Sivadasan, 2021; Knudsen, 2023). Ekström and Sivadasan (2021) emphasize the advantages of smart water meters for customers as it provides them with their data of water consumption, enhancing the awareness of water consumption and improving billing accuracy. Various Swedish water utilities have started replacing analog meters within the municipality, however, there are still no regulations or laws regarding the implementation of smart

water meters.

Monitoring system

To monitor and control the water treatment processes and the pipe network, water utilities employ a Supervisory Control and Data Acquisition (SCADA) - system (SCADA International, n.d.). The SCADA-system is computer-based and connected to the equipment of the water system such as sensors and pumps, where data is collected and transmitted to its interface continuously. Within the system, control signals are specified or calculated, and compared to the real-time data to enable for reporting of anomalies in the system (Arnell et al., 2021). This enables for automatic control actions or operators to react quickly and take control of the processes (SCADA International, n.d.). Since water services are part of the critical infrastructure, the safety and control of the SCADA-systems plays a crucial role in protecting the society's water supply (Johansson, 2011).

2.2.2 Data analysis

To make sense of the collected data, proper analysis must be executed. This is where Big Data becomes demanding and the use of AI for analysis is crucial due to the capacity to find patterns and accelerated speed of which the data is analyzed (Gohil et al., 2021). AI methods are used to observe trends and correlations within large datasets to enable well-informed decisions.

AI can be utilized for real-time monitoring of the water system where algorithms fed with real-time data have the ability to dynamically adapt process actions to changed prerequisites (Kamyab et al., 2023). Combining real-time data and historical data in algorithms can facilitate the identification of trends and detection of leaks in the pipe network, which in turn help monitoring water quality and forecasts. An example of this in the Swedish water industry is an Artificial Neural Networks (ANN) model developed by the municipal company Stockholm Vatten och Avfall (Bennich, 2024; Sörensen et al., 2021). The model helps water organizations to prioritize certain areas in the searching of leakages and provides decision-support in renewal planning.

2.2.3 Data modelling

Using hydraulic models is a way to facilitate planning and design of water infrastructure. It can be used to for instance ensure accurate sizing, prioritizing interventions, and conducting flood analyses (Blomquist et al., 2021). Through modeling, various actions or deficiencies within the network and how it impacts its performance can be explored. However, to perform hydraulic modeling effectively, comprehensive data on water parameters within the network, as well as information about the water system and its components is needed as input. Well-functioning models can simulate multiple scenarios and serve as decision-making support.

Geographic Information System (GIS) programs offer a clear platform to present hydraulic modeling results, aiding in visualizing the pipe network components for

the water organization. There are additional tools that can be integrated with GIS software to manage and present both data about the pipe network and workflows. This includes information about pipe placement, age, dimension, material, flow, waterway, and elevation as well as linking work orders, planned maintenance, and warnings to the pipes (Aveki, n.d.). The systems can be utilized by water organizations to coordinate information about the water system and enable a digital workflow for the entire organization. An example of a Swedish system vendor is Aveki offering VA-banken.

Another example of a digital model reflecting the water system is digital twins, which is a three-dimensional representation of a physical object, process, or system (Arnell et al., 2021). Within the water industry, this includes models describing parts such as pipe networks and treatment plants. The model is fed with different types of data, collected from the water system, enabling real-time simulation (Manocha et al., 2024). A digital twin can be used to test scenarios in a digital environment before implementation, providing both the management and operating staff with a deeper understanding of the state of the system (Arnell et al., 2021; Manocha et al., 2024). It can also analyze different input data to increase the quality of predictions.

Augmented reality (AR) and Virtual reality (VR) technologies are additional ways to visually represent components within the water system (Sarni et al., 2019). AR seamlessly integrates digital elements with real-world video footage, allowing the digital model to be visualized in real-time onto the physical environment through a camera view (Arnell et al., 2021). Conversely, VR focuses solely on digital information, enabling detailed planning of future water infrastructure through immersive 3D views. The utilization of AR and VR in the water industry helps disseminate operational knowledge, simulate treatment processes, and create opportunities for proactive maintenance and predictive analytics, thereby enhancing operational efficiency (Sarni et al., 2019).

2.3 Information security

The increased digitalization of critical infrastructure makes the water industry more vulnerable to cyberthreats (Jansen, 2016). The work with security classification of information becomes more extensive and the organization must prioritize who needs access to the information (Svenskt Vatten, 2022a). The evaluation of sensitive information in the water industry is covered by the Public Access to Information and Secrecy Act (*Offentlighets- och sektretesslagen*, 2009:400) and Security Protection Act (*Säkerhetsskyddslagen*, 2018:585) (Svenskt Vatten, 2022c). However the assessment of classification is made by the person in possession of the information, causing the classification to vary among organizations. To support and guide the security work for Swedish water organizations, Svenskt Vatten offers a digital handbook regarding security in the water industry (Svenskt Vatten, 2023b). Drinking water distributors providing minimum 20,000 consumers also falls under the Act on Network and Information Security (*NIS-lagen*, 2018:1174) to strengthen technical and organizational measures for information security (Svenskt Vatten, 2022b).

There are primarily two categories of cyberthreats facing water utilities (Bjärkby & Värnlund, 2021). Firstly, information-based attacks which aims to manipulate information, disrupt information access, or disseminate confidential data. Secondly, operation-based attacks that seeks to seize control of devices or processes harming the water services. Generally Swedish organizations consider the consequences of cyberattacks causing operational disruptions as more critical, since they can affect water quality, than information-based threats such as data leakage (Franke, 2020; Arnell et al., 2021).

With water information becoming increasingly digital, there's been a heightened focus on ensuring information security. The European Union has taken significant steps in this regard, particularly through the implementation of the Cyber Resilience Act (CRA), which became effective in January 2024 (European Commission, 2023a). The CRA aims to safeguard consumers and businesses using products or software with digital components. This initiative introduced manufacturers and retailers of digital products to mandatory cybersecurity requirements. Additionally, the European Union updated its extensive cybersecurity legislation in 2023 with a new Network and Information Security directive, NIS2, aimed at improving cybersecurity across the Union (European Commission, 2023b). The directive seeks to achieve a high common level of cybersecurity across the Union and is expanded to also include entities that treat sewage. It includes legal measures to ensure member states' readiness and adequate preparation, including the establishment of a Computer Security Incident Response Team, CSIRT-unit, and a responsible authority. In Sweden this responsibility is assigned to the Swedish Civil Contingencies Agency, MSB, forming the unit CERT-SE (CERT-SE, n.d.). There is currently no legislation regarding how to comply with the NIS2 directive in Sweden.

2.4 Water organizations

This chapter examines the organizational structures of public water services in Sweden, highlighting the responsibility of municipalities and the various approaches to water management. Additionally, conditions for organizational change are slightly discussed.

2.4.1 Organization of public water services in Sweden

According to the Public Water Services Act (*Lagen om allmänna vattentjänster*, 2006:412), Swedish municipalities are responsible for providing public water services, including drinking water, sewage and stormwater management, within a predetermined area of operation (Sveriges Riksdag, 2006). The water management and its services are financed through tariffs paid by the drinking water customers based on their consumption. However, there are several solutions on how to organize the management of water. The most common solution is that the municipality keep the services in a water department within their own municipal administration (Svenskt Vatten, 2024a). Another way of managing the water services are by transferring the

responsibility to a municipal company. A municipal company is partly or wholly owned by the municipality with a board usually composed of politicians and experts appointed by the municipality. The company focuses solely on water services, alternatively together with other infrastructural services such as energy or waste. The company can also be owned by several municipalities in a regional cooperation form, to make use of regional expertise. Another solution is to work with the water services through an Associations of municipalities, in Swedish "Kommunalförbund". The organization of an association is similar to that of a municipality, governed by representatives from the cooperating municipalities. Regardless of the form of water management, the organization should be non-profit.

Transferring the water management to a municipal company means separating the water organization from other municipal activities. This entails clearer division between the responsibility of capital and operations for the water administration and other administrations, which in turn increases the control of the water management (Thomasson, 2013). However, an identified risk with municipal companies are that the transparency towards the political side as well as the citizens can be flawed (Thomasson, 2013; Engström & Östman, 2021). The creation of a municipal company involves new regulations for the organization and its activities, meaning that they will be regulated by both the Municipal law (*Kommunallagen*, 2017:725) and the Swedish company act (*Aktiebolagslagen*, 2005:551) (Bolagsverket, 2021). Managing the water organization as a municipal company has lately been a major institutional trend (Svenskt Vatten, 2024a). It has shown to entail increased efficiency and facilitating simultaneous work with service operations, maintenance, and capital management (Thomasson, 2013; Engström & Östman, 2021).

Public sector cooperation

In recent years, water organizations face challenges in coping with increased demands due to new regulations related to technical adoption and environmental conditions affecting water management (Thomasson, 2018). Thomasson (2018) emphasizes that due to the crucial function of water utilities in ensuring safe drinking water distribution and wastewater management, many water organizations face difficulties in managing development work alongside their day-to-day operations. This is often attributed to budget constraints and limited expertise. To address the shortage of resources and promote development, the water organizations has been required to find new ways of working and structure their organizations. One main solution to this is through cooperation between water organizations from several municipalities.

Thomasson (2013) elaborates on how a collaborative approach, such as working on common projects, is beneficial for distributing costs among several actors. It can create opportunities to make investments the municipality cannot afford on its own. Increased competence, experience, and better structure are also positive effects of cooperation. However, the management of cooperative organizations become more complex, requiring clear internal responsibility and accountability within the new structure, as well as coordination horizontally and vertically among several municipalities (Thomasson, 2018).

2.4.2 Organizational transformation

The digital transformation of the water industry includes organizational changes, change of working methods, and adoption of innovation (Arnell et al., 2021). Public organizations face unique conditions when it comes to resources, objectives, motivation, and political influence, causing different behaviors towards transformation. Typical for public organizations are political influence, a strong hierarchical decision-making structure, strict compliance with regulations, and bureaucracy, which is not beneficial for innovation and could result in organizational inertia (Thomasson, 2009; Edvardsson & Svensson, 2017; Lövenfeldt & Ohlsson, 2012; Aidanpää & Sjöberg, 2021). Bolton & Foxon (2015) state that infrastructure organizations experience technical and social constraints, due to the lack of accessible competence. They argue that this leads to a lock-in effect, favoring rapid changes over transformation. Another factor influencing the rate of change is the absence of a competitive environment in the water industry. It makes the water utilities natural monopolies which is reducing the external pressure for innovation (Bolton & Foxon, 2015; Lövenfeldt & Ohlsson, 2012). Further Nantin (2018) explains that water organizations struggle with innovation because of the challenge to create development strategies besides their day-to-day operations, since they do not experience the competitive advantages. On the other hand, the non-profit nature of public organizations can increase the open communication between departments and municipalities, helping the emergence of innovative ideas (Lövenfeldt & Ohlsson, 2012).

The size of an organization will also affect its possibility to change. Generally, larger organizations experience higher levels of inertia since decision-making processes and information flows are extended (Hällund & Torell, 2020). On the other hand, larger organization can also be beneficial for transformation due to increased resources and personnel working specifically with innovations (Damanpour & Daniel Wischnevsky, 2006). Conversely, small organizations possess fewer resources to initiate a transformation, however, they generally experience fewer steps in their decision-making process (Lorenzi & Riley, 2003). The people within the organization also influence its transformation. Srirahayu et al. (2023) emphasize that transformative leaders, a supportive organizational climate, empowerment, and teamwork foster innovative work behavior.

2.5 Drivers of digitalization

In this chapter, driving forces of digitalization within the water industry are examined, exploring the potential drivers behind a transformative shift and their impact on water management.

Crises

One driving force for digital transformation in general is the new challenges caused by for instance climate change. These shifting conditions put pressure on adapting

operations and making well informed decisions to guarantee the safety of water supply (Müller-Czygan et al., 2021). This can be enabled by increased control over the water system which is facilitated by new technology, such as sensors for real-time data. Sarni et al. (2019) describe external incidents such as demographic shifts, major flood, or water scarcity as substantial drivers for digital transformation. One example is the millennial drought in Australia, which not only brought water issues to the political agenda but also catalyzed significant transformations within the Australian water industry, positioning it as one of the most innovative globally (Bennich et al., 2023). This can reflect crises as a driving force.

Costs

Daniel et al. (2023) found economic factors, such as cost benefits, to be a major driver for digitalization efforts. However, they could not say that this driver led the organizations to successful implementations. Hietala et al. (2023) describe water organizations' digital journey as focused on receiving efficiency and could trace this back to the economic factors as well. They prioritize digital tools that boost efficiency and bring immediate economic benefits over investing in uncertain innovations.

Water organizations across the world have seen the benefits of how digital solutions can be used proactively (Park et al., 2018). They identified that investing money in digital technology and implementing smart water networks with existing infrastructure would reduce future costs. For instance, leak detection using smart sensors in existing distribution networks in Seosan, South Korea, expected to save 980 000 USD compared to replacing the leaking pipes (EBRD, n.d.). Hence, Park et al. (2018) highlights economic benefits as a driver for digitalization.

New technology

Aidanpää & Sjöberg (2021) and Grievson et al. (2022) highlight that new digital technologies serve as catalysts for digitalization. Technologies have the capacity to transform the economics of the water industry, compelling organizations to respond to the evolving digital environment. The water industry perceives that implementation of new technologies leads to direct economic savings, impacting all aspects of the water system, from treatment processes to customer relationships. Consequently, day-to-day water management improves and builds long-term resilience towards different types of crises (Grievson et al., 2022). However, Grievson et al. (2022) point out that aging technologies and outdated systems also drive the implementation of new technologies. Persson et al. (2021) highlight that a higher demand of products will lead to decreased prices, providing better opportunities to digitally transform even for organizations that are economically constrained.

Customer demand

Another driver for the digitalization of the water industry is the demand from customers. A more digitalized water industry, equipped with enhanced data assets and

advanced analytics, leads to improved customer service quality (Hietala et al., 2023). Digital working methods give customers more chances to interact with organizations (Aidanpää & Sjöberg, 2021), for instance through enhanced customer service (Magnusson et al., 2019). Further, Magnusson et al. (2019) highlights the indication that the Swedish public sector shows better innovative thinking and experimenting in areas involving external parts. This emphasis arises from the imperative to explore novel avenues effectively to address external actors' expectations and demands.

Leadership

Another key driver for digital adoption is the management's understanding of the value of change (Jacobsson & Linderoth, 2018). This may require connecting management with digitally competent employees to see and share valuable insights. Daniel et al. (2023) concurs with this viewpoint, stating that highly digitalized water utilities have observed corporate and leadership mindsets to serve as accelerators for digital transformation. Attributes for driving leadership are creativity, adaptiveness, and progressivity, which are crucial to foster a culture that facilitates flexible decision-making and acknowledges new ideas (Aidanpää & Sjöberg, 2021; Halpern et al., 2021). Furthermore, the public sector is often under significant pressure and intense scrutiny. As a result, political and top-management support is crucial for employees to feel empowered to embrace innovation (Hietala et al., 2023).

Individual commitment

Müller-Czygan et al. (2021) addresses the employees within the organization as the main drivers of digitization. They emphasize the significance of having qualified individuals who recognize the potential of digital technologies in simplifying daily tasks in the organization. These individuals play a crucial role in guiding groups towards embracing digital adoption. Hietala et al. (2023) further highlight that the drive for implementation of digital technologies should preferably arise from the individuals practicing them and not top management. Jacobsson & Linderoth (2018) suggest utilizing recent graduates' high IT-maturity to drive digital implementation. They state that pairing new graduates with experienced employees and managers will spread the drive to digitalize throughout the organization.

Grievson et al. (2022) illustrate a case wherein an enthusiastic and motivated individual within Metropolitan St. Louis Water Utilities initiated various digital startup projects due to their fascination with digital technologies. This proactive approach led the utility to embrace intelligent communication services at an early stage. This gives an example of how digital transformation can be initiated from bottom-up in an organization.

Collaboration between organizations

Organizations with limited resources might not have the opportunity to experiment with the implementation of new technologies on their own (Hietala et al., 2023), thus collaboration among various organizations can accelerate digital transformation. Hi-

etala et al. (2023) highlight that organizations would benefit from collaborating with various actors within the water industry to share valuable information, good examples and competence. The authors also point out that collaborative efforts between organizations could enhance innovation outcomes and ensure long-term sustainability. Aidanpää & Sjöberg (2021) highlights collaboration with universities, participation in innovation hubs and seeking support from the innovation agency Vinnova, as a way to maintain their regular activities while also engaging in experimentation.

Bennich (2024) highlights the significance of a professional network for sharing experiences with other organizations facing similar challenges, fostering inspiration. This perspective aligns with Magnusson et al. (2019), who observes that the public sector often engages in mimetic behavior, replicating initiatives from one organization to another in pursuit of legitimacy. Sweden possess a professional network with this purpose, the Swedish digitalization network, with members from the municipal water organizations. The network is organized by Svenskt Vatten and aims to give water organizations the opportunity to exchange knowledge and experiences in the area of digitalization to drive water industry development (Svenskt Vatten, 2023a).

Regulations

A driving force emphasized in literature is the formulation of regulations. When the state introduces new requirements and laws, they can force water organizations to look for innovative technologies and business models (Sarni et al., 2019). The regulations can be related to water quality or targeted specifically towards digital solutions. In the UK, the Water Services Regulation Authority requires utilities to provide customers with three digital communication channels. This requirement compels water utilities to adopt digital solutions, leaving them with no alternative but to digitalize. Denmark provides a concrete example of how regulations on water leakage have transformed their water industry. Since 1994, water utilities have faced penalties for exceeding 10% water loss. This has incentivized efforts to reduce losses and promote financial accountability and efficiency, catalyzing digital implementations (Ministry of Environment of Denmark, n.d.). Daniel et al. (2023) think that common regulations for the water industry would bring safety into the transformation and drive organizations adoption of digital technologies knowing critical infrastructure can be kept safe. It is also noted that regulations concerning the replacement and maintenance of technology devices can incentivize multiple hardware manufacturers to enter the market. This can lead to the introduction of new innovations and contribute to driving digitalization through their products (Daniel et al., 2023; Hietala et al., 2023).

An initiative to minimize leakage in Europe comes from the European Union, where member states are required to evaluate their water leakage levels and potential for reduction (Sveriges Riksdag, 2023; UK Government, 2020). The results of this assessment must be submitted to the European Commission no later than January 12, 2026. Subsequently, by January 12, 2028, the Commission shall establish a leakage threshold that member states must adhere to. Member states exceeding this threshold must, within two years, present an action plan with specific measures to reduce

their leakage percentage. This could potentially catalyze heightened digitalization efforts within water organizations.

Standards and government support

Persson et al. (2021) and Hietala et al. (2023) discuss the importance of national standardization when it comes to data storage and sharing to both ensure safety but also increase interoperability within and between organizations. Hietala et al. (2023) argues that standardization, serving as a method to institute rules and procedures within the water industry, could significantly facilitate opportunities for innovation.

Another factor supporting the strategic development of Swedish water service providers is the allocation of resources by politicians (Persson et al., 2021). This includes providing the necessary financial means and time to ensure the maintenance and effective functioning of the organization's assets and infrastructure over time. This is also noted by Park et al. (2018), implying that governmental financial support would serve as a facilitating step in bolstering implementation of smart water management.

2.6 Challenges with digitalization

Within the realm of water management, the digitalization journey is marked by various challenges. This chapter examines the challenges and barriers organizations may face during a digital transformation.

Lack of competence

One main challenge brought up in literature is the experience of lacking knowledge and competence to digitalize. Findings from the Finnish water industry demonstrate that insufficient internal expertise and autonomy of water organizations lead to incremental changes rather than transformation (Hietala et al., 2023). The constraints encountered by municipal water organizations, such as staffing shortages, often result in a lack of expertise within the organization. This, in turn, hampers employee involvement in digitalization efforts (Müller-Czygan et al., 2021). Dada et al. (2024) claim that water organizations have a responsibility to ensure personnel possess the required expertise for emerging technologies, either through internal means or through cross-organizational collaboration, to not hinder the technological innovation and smart water management.

Resistance and fear

Challenges that require much time and effort to overcome are the ones related to the organizational culture. O'Callaghan et al. (2020) describe the water industry as conservative by nature, hindering the adoption of innovation and technology. Furthermore, Lafioune et al. (2023) suggest that employees' fear of being replaced could lead to a resistant approach. The fear can be partially attributed to a lack of understanding regarding the benefits of transformation, which together with skepticism

and hesitation leads to a reluctance to embrace change (Ziemer & Stoffels, 2017). Oschinsky et al. (2021) further highlight employees' fear of making faulty decisions resulting from knowledge gaps as another factor that hinders digital adoption.

Financial limitations

Even if there is a present interest and motivation for digitalization in water organizations, financial limitations might still be a barrier. Digitalization requires investments in both technology and systems; hence, literature agrees that these digital solutions might become too costly for some water utilities. Small utilities in Finland experience little return on investment (Hietala et al., 2023), and Dada et al. (2024) highlight the challenge of balancing the costs with the long-term advantages of digital technologies. The knowledge gap within the industry makes room for uncertainty costs, hampering the organizations to make investments comfortably (Oschinsky et al., 2021).

There are also external factors governing the financial situation. Practitioners within the industry experience no significant demand from customers nor market readiness for digital solutions, making organizations appear hesitant to adopt digital technologies (Ziemer & Stoffels, 2017). Additionally, the context of municipalities facing heavy scrutiny means that funds must be carefully allocated, limiting opportunities for experimental initiatives (Aidanpää & Sjöberg, 2021). Bennich et al. (2023) discusses the relationship between voters and politicians, highlighting that because water services are not prioritized by voters, politicians may not focus on improving them. The lack of focus could result in limited resource allocation for digital investments in the water industry.

Time limitations

Not only are the financial limitations restricting the digital transformation, but also time constraints and work overload. There is high pressure on employees to ensure the daily operations, not giving much room for experimenting with new solutions (Hietala et al., 2023; Müller-Czygan et al., 2021). This is particularly noticeable in small organizations, where individuals often take on multiple roles, leaving them with even less time to prioritize tasks outside the daily operations (Bennich et al., 2023).

Lacking standardization and best practices

The lack of best practices and standardization for digital implementations in the water industry are widely discussed in the literature. The lack of standardization for adoption of digital technologies is not only affecting organizations opportunities to implement the technologies in their operations, but also hinders actors to introduce novel solutions to the market (Hietala et al., 2023). The absence also hinders the compatibility and scalability of technologies, affecting broader adoption (Dada et al., 2024). Müller-Czygan et al. (2021) emphasizes the lack of best practices within the area as a limiting factor in altering established working patterns and practices.

Ziemer & Stoffels (2017) believe that the lack of standardization could indicate that the market is not ready, thus creating uncertainty among organizations regarding the adoption of digital technologies.

2.7 Lessons learned from digitalizing water organizations

Interview studies, surveys, and observations made within organizations in the water industry globally have provided valuable lessons learned and experiences on how to navigate the digital journey. In this chapter the insights from the following three reports are presented and compared to get an overview of some key aspects of the digital transformation of the water industry.

- The International Water Association, Xylem (a global water technology solutions provider) and Sarni et al. (2019), have compiled insights from interviews and survey responds of 50 managers and 20 subject experts from 40 different water utilities in their report *Digital Water: Industry leaders chart the transformation journey*. The report aims to give an overview of the value and current state of digitalization as well as the way forward.
- Bindler et al. (2023) are the leading authors of the SWAN-report *How Utilities Organize for Digital Innovation* which is based on survey-responses from 38 employees from 34 diverse water utilities across 10 countries, located mainly in North America, but also in South America, Western Europe, and Oceania. Moreover, in-depth interviews contributed to gain experiences of best practices.
- Bluefield Research (an independent water research firm supplying research reports, consulting, and data analytics) & Xylem (2023) gathered insights from 18 global water experts sharing their experience on the journey of going digital to approach water challenges in their paper *Ripple Effect: A Movement Towards Digital Transformation*.

The compilation of these three reports indicates the following six key areas for water organizations to focus on in a digital transformation: the top management engagement, formulation and sharing of a clear digital strategy, prioritize innovative activities, initiate digital solutions in pilot projects, make use of existing information, and to collaborate over organizational borders.

Top management engagement

Sarni et al. (2019) highlight high management commitment in order to break traditional working patterns. They state that ambition within an organization starts at the CEO and top management level, and strong leadership is required to build consensus among the employees. They argue that "digital" must be embedded in the organization's DNA, with engaged and structured leadership being key elements.

Furthermore, implementation of new roles such as Chief Digital Officers is essential to make digitalization a priority. The three reports highlight that empowerment of employees and utilization of individual knowledge and curiosity is important. Still, they refer to the top-down approach as the key for homogeneous commitment to the digital transformation throughout the whole organization.

A clear strategy

Sarni et al. (2019) highlights the importance of a clear strategy and road map when navigating digitalization within organizations. The strategy should cover education on a broad organizational scale, including employees, politicians, and stakeholders, to understand the value of the digital journey. The goals of the digitalization should not only focus on cost benefits since it can lead to more rapid changes rather than validating a digital transformation. Bindler et al. (2023) emphasize the significance of tailoring goals to the drivers specific to each organization, as universal goals may not be applicable across all water utilities. However, there is a value in prioritizing to identify problem areas where digital solutions can be clearly shown to improve the day-to-day operations (Bluefield Research & Xylem, 2023). This means that delivering small wins can be tactical for supporting systematic transformation over time. Further stated is that involving operators along different phases of water management in early stages will benefit a solid strategy. Bluefield Research & Xylem (2023) also highlights to use authorities' expectations and regulations as guidelines for the digital strategy.

Innovation activities

The digital transformation is largely a matter of embracing new technology and working methods, hence fostering an innovative culture with high level of curiosity will help the organization exploring the digital world (Sarni et al., 2019). To facilitate the innovative culture, Bindler et al. (2023) underscore the importance of formal innovation activities. This means to allocate time for creative thinking and problem solving, for instance workshops and pitch contests. However, innovation activities can be perceived differently, and vary across organizations. Further, Bindler et al. (2023) suggest that large water utilities have advantageous conditions for acquiring and adopting new technology, as well as recruiting competence, which facilitates an innovative culture and, in turn, eases the digital transformation. This enables further attraction of digital talents and establishment of new partnerships which Bindler et al. (2023) believe leads to an innovative loop.

Pilot projects

Trying out new solutions might be costly and therefore it is important to use pilot projects as a test arena to facilitate the holistic understanding of new technologies and digital methods (Sarni et al., 2019; Bluefield Research & Xylem, 2023; Bindler et al., 2023). Smaller projects make room for experimenting with new technologies and serves as a way to learn lessons and understand the value and risks with digital working methods (Sarni et al., 2019). Bluefield Research & Xylem (2023) identified

this as a key to demonstrate the value of changes to the organization and show that the investments yield results to motivate full-scale implementation.

Make use of existing information

The digital transformation of society at large has made large amounts of data available and accessible at several departments, the water industry included. Combining this data from across divisions can help provide new insights to the organization (Bluefield Research & Xylem, 2023). Hence, beginning the digital journey does not necessarily require technology investments. Instead, initiating the process by compiling an inventory of existing data can be an effective way to extract value from data already at hand. However, enabling data accessibility for various internal and external stakeholders raises safety concerns, and increases the importance of establishing accurate policies and standards (Bindler et al., 2023). Moreover, the vast volume of data necessitates an extended IT-infrastructure, thereby indicating the essential involvement of IT expertise during the initial phases (Bindler et al., 2023; Sarni et al., 2019).

Collaboration

The water industry spans the globe, and the water organizations share the same objectives of ensuring safe and reliable water services. This means that numerous organizations face the same challenges. Hence, collaboration within the water industry is vital and support from networks will ease the journey of digitalized water infrastructures (Sarni et al., 2019). The importance of collaboration extends to data and knowledge sharing across various functions, departments, and industries (Bluefield Research & Xylem, 2023). Bluefield Research & Xylem (2023) emphasizes the significance of placing data in the right hands to unlock valuable insights and create synergy effects to foster increased collaboration. Working together across utility departments also entails financial benefits such as funding of digital innovation projects (Bindler et al., 2023).

3
Methodology

This chapter outlines the study's methodology, encompassing the research approach, data collection methods, and ethical considerations.

3.1 Research approach

The research approach for this thesis has been determined to be abductive. Dubois & Gadde (2002) describe the abductive approach as a dynamic process where the theoretical framework is continuously updated due to empirical findings and additional insights gathered throughout the process. Combining several research activities, such as a literature review and interview study, the understanding of the research area becomes broader and additional perspectives are raised. Further, this approach is pointed out as beneficial when aiming for exploring new variables and relationships within a field.

This study has also used a qualitative approach where data from literature has been used to understand the different actors in the water industry and interviews have been carried out to receive genuine experiences related to the topic. The approach focuses on verbal descriptions, generating data from interviews in combination with data generated from literature. This entails the qualitative approach to employ real life examples to the literature study, providing a holistic and wide understanding of the research area (Bell et al., 2018).

3.2 Literature review

The initial part of this study was a literature review. It encompassed what digitalization means for the water industry, the water industry's organizational and technological prerequisites and the interaction between the two. The aim was to gain knowledge about the research topic and compile findings from previous studies as well as identify the areas in need of further exploration. The literature study also aimed to find best practices and lessons learned from organizations' digitalization efforts, serving as a framework to compare the interview results with, to be able to assess the digitalization status of water organizations in relation to these practices. A major part of the literature review was performed prior to the interviews, working as a basis for identifying key issues and questions to focus the interviews around. However, as an abductive approach has been adopted, the literature study was an iterative process (Dubois & Gadde, 2002). Hence, the literature study was

performed in conjunction with the interview process, meaning that when new perspectives were observed, additional literature was studied in order to cover the new approaches and angles.

The literature was mainly received through searching for keywords related to the research area in the databases Science Direct, Google Scholar, and Chalmers Library. The keywords include *AI, digital transformation, digitalization, IoT, smart water, water industry, water management* and *water organization.* Additionally, some grey literature was found on national and global water network platforms, such as Svenskt Vatten, International Water Association (IWA), and SWAN Forum.

3.3 Interview study

The qualitative research approach of this study often combines methods of data collection (Silverman, 2006). Accordingly, the next part was an interview study. The interviews were designed to be semi-structured, incorporating open-ended questions that enable the interviewee to express themselves more freely. It allows the interviewee to dig deeper into the topics of particular interest, giving indications on what tracks to follow up on henceforth in the study. The semi-structured approach was determined due to the context-dependent nature of the research questions.

When formulating the interview questions, the research questions were used as an initial reference. The questions covered the following categories:

- Organizational change towards more digital working methods.
- Vision, goals, and strategy for digitalization.
- Drivers, benefits, and challenges with digitalization.
- Conditions needed to accelerate the digitalization of the organization and the water industry.

The aim of the interviews was to gather information about different organizations' views of digitalization, their way of working, and conditions for further digital development. The interview questions can be found in Appendix A, and were not sent to interviewees before the interview. The interviewees are representatives from Swedish municipal water organizations. Municipalities were selected based on population size to ensure various perspectives of the digitalization process in Swedish water organizations. They are categorized as small ($<$ 30,000 inhabitants), medium (30,000-100,000 inhabitants), and large ($>$ 100,000 inhabitants) municipalities. The categorization has been influenced by the evaluation of Swedish municipalities' size conducted by Sveriges Kommuner och Regioner (2022). The cooperation organizations have been categorized based on the size of the population they serve.

Table 3.1: Presentation of the interviewees.

Organization	Role	Size	Interview Date
Borås Energi och Miljö	Head of Facility Information Department	Large	March 19, 2024
Kalmar Vatten	Head of IT and Development	Medium	March 20, 2024
Göteborg Kretslopp och Vatten	Network Infrastructure Strategist	Large	March 8, 2024
Kungsbacka kommun	Water and Wastewater Engineer	Medium	March 20, 2024
Lilla Edets kommun	Operations Manager	Small	March 6, 2024
MIVA*	Development Manager	Medium	March 7, 2024
Mullsjö Energi & Miljö	Administrator	Small	March 18, 2024
NSVA**	Digitalization Strategist	Large	March 11, 2024
Skövde kommun	Network Infrastructure Manager	Medium	March 14, 2024
SVOA***	Corporate Strategist	Large	March 26, 2024
Tjörns kommun	Head of Water & Wastewater Department	Small	March 13, 2024
VA Syd	Head of Strategic Planning Project Leader & Coordinator	Large	March 26, 2024
Älmhults kommun	Head of Water & Wastewater Department	Small	March 18, 2024

Comment. *Miljö och Vatten i Örnsköldsvik AB, **Nordvästra Skånes Vatten och Avlopp, ***Stockholm Vatten och Avfall.

The interviews took place in March 2024, mainly online through Teams but three were held in person. Each interview lasted approximately 45-60 minutes and audio recordings were made. As the interviews were conducted in Swedish, the content in the report has been translated and raw interview data is not presented directly in the report. Instead, a condensed version of the interview content is provided, wherein the most important responses for this study have been summarized and approved by the interviewees for inclusion in the report. Interview results were compared with each other and to literature findings, primarily to the framework based on lessons learned.

3.4 Ethical considerations

To take ethics into consideration, the interviewees were able to remain anonymous if they preferred to do so. They also had the option to decline having the interview recorded. However, all interviewees agreed upon their professional role and municipality to be published in the report. By including the interviewees' professions and municipalities, the report can be directly linked to practical applications. Consequently, readers can gain insight into the perspectives of practitioners on the

subject. In order to guarantee accurate quotations, facts, and interpretation of the findings, interviewees reviewed the content before the report was published.

Following GDPR guidelines, the recordings and notes from the interviews were deleted upon completion of the report.

4

Results

In this chapter, results from the 13 interviews are presented. The interviewees' attitudes towards and perceptions of digitalization are concisely represented in a word cloud. Here, respondents were asked to describe the feeling they get when they hear the term "digitalization" in three terms. The result is summarized in Figure 4.1, where the size of the words represents how many times they were mentioned, from one to three times. Further on, the interview responds are evaluated from the six categories formulated in Chapter 2.7. Additionally, the results are presented in more detailed texts for each organization, divided into areas discussed during the interviews.

Figure 4.1: Word cloud illustrating the interviewees' feelings towards digitalization.

4.1 Interview results compared to the Lessons learned framework

To get an overview of how the water organizations approach digitalization, the interview results are compiled in a table based on Chapter 2.7: *Lessons learned from Digitalizing Water Organizations*. Each organization is assessed from the authors

of the thesis' insights gained from the interview study and literature, based on the following criteria:

- **Management engagement** is evaluated based on how much the top management such as political management or management team for the water organization are embracing digitalization efforts and drives the process. This may involve putting pressure through formulating goals and visions or developing new roles and teams. It is rated *high*, *medium*, or *low*.
- **Strategy implemented** is evaluated based on if the water organization has formulated a digitalization strategy for the organization or not. It is rated *Organizational* if it covers the entire water organization's operations, *Depertmental* if they have a strategy for different departments or projects but not for the entire water organization's operations, *In progress* if they are in the process of formulating one, or *No* if they lack one.
- **Innovation activities** is evaluated based on whether the organization allocates time for innovative activities that promote progress in digitalization. This category is presented by the *types of activities* involved.
- **Pilot projects** is evaluated based on the organizations' running of projects for testing the feasibility, effectiveness, and potential impact of digital methods. Both *internal* projects, involving municipal participation, and projects incorporating *external* actors, such as collaborations with other water organizations, program vendors, and research institutes are considered and presented.
- **Using existing data** is evaluated based on the organizations' approach to data management. It is rated as *embraces*, *uses*, or *don't use*. *Embraces* indicates exploration of new applications for existing data where various data is analyzed and used in a proactive manner, *uses* indicates the gathering and application of data for specific purposes, and *don't use* indicates a lack of data utilization within the organization.
- **Collaboration** is evaluated based on the water organizations' collaboration for inspiration, knowledge and experience exchange as well as collaboration for running of projects. Collaborative parts include the *municipality*, the Swedish digitalization network expressed as *SDN*, and *external* organizations in terms of other water organizations, research institutes, universities, and program vendors. *None* implies no collaboration.

Table 4.1: Overview of interview results evaluated according to the Lessons learned framework.

Organization	**Management engagement**	**Strategy implemented**	**Innovation activities**	**Pilot Projects**	**Using existing data**	**Collaboration**
Further read	Ch. 4.4, 4.7	Ch. 4.4	Ch. 4.4, 4.6	Ch. 4.6	Ch. 4.5	Ch. 4.4, 4.6
Borås Energi och Miljö	High	Organizational	Workshops	Internal	Embraces	Municipal External SDN
Kalmar Vatten	High	In progress	IT & Development group	Internal	Embraces	Municipal SDN
Göteborg Kretslopp och Vatten	Low	Departmental	No	Internal External	Embraces	Municipal External SDN
Kungsbacka kommun	High	No	Projects	No	Embraces	Municipal External SDN
Lilla Edets kommun	Low	No	No	Internal External	Uses	External
MIVA*	Medium	In progress	No	Internal	Uses	External SDN
Mullsjö Energi & Miljö	Low	No	No	No	Don't use	Municipal
NSVA**	High	Departmental	Development team	Internal	Embraces	External SDN
Skövde kommun	Medium	No	No	Internal	Uses	None
SVOA***	High	In progress	Start-ups	Internal External	Embraces	Municipal SDN SWAN
Tjörns kommun	High	Departmental	Projects	Internal External	Embraces	Municipal External
VA Syd	Medium	In progress	Differs between units	Internal External	Embraces	External SDN
Älmhults kommun	Low	No	No	No	Uses	None

*Comment.*Miljö och Vatten i Örnsköldsvik AB, **Nordvästra Skånes Vatten och Avlopp, ***Stockholm Vatten och Avfall.*

4.2 Description of participating organizations

The following section presents the structure of the water organizations and the roles of the interviewees within these entities.

Borås Energi och Miljö is a municipal company responsible for management of water services, waste, and district heating in the City of Borås. The water department has approximately 60 employees. The interviewee's role is Head of Facility Information Department, responsible for the organization's technical data.

Kalmar Vatten is a municipal company responsible for management of the water services in the municipality of Kalmar. The company has 125 employees. The interviewee's role is Head of IT and Development, responsible for IT-development and security issues.

Kretslopp och Vatten is a municipal company responsible for management of water services and waste in the City of Gothenburg. The water department has approximately 500 employees. The interviewee's role is Network Infrastructure Strategist, responsible for driving issues that need strategic development, mainly focused on digitalization.

Kungsbacka kommun's water department is responsible for the management of water services in the municipality of Kungsbacka. The water department comprises 83 employees. The interviewees were two Water and Wastewater Engineers, working with tasks like water modeling, investigations, and detailed development plans.

Lilla Edets kommun's water department is responsible for the management of water services in the municipality of Lilla Edet. The water department comprises 19 employees. The interviewee's role is Operations Manager, which is a broad role including project management and operational tasks.

MIVA is a municipal company responsible for management of water services and waste in the municipality of Örnsköldsvik. The water department comprises 78 employees. The interviewee's role is Development Manager for the company with focus on drinking water distribution.

Mullsjö Energi & Miljö is a municipal company responsible for management of water services and district heating in the municipality of Mullsjö. The organization comprises 9 employees. The interviewee performs a variety of tasks including administration, customer service, and digitization efforts.

NSVA is a municipal company responsible for managing water services cooperatively for the municipalities of Bjuv, Båstad, Helsingborg, Landskrona, Perstorp, Svalöv, Åstorp, and Örkelljunga. The organization consists of approximately 230 employees. The interviewee's role is Digitalization Strategist, working with the organizations' digitalization efforts.

Skövde kommun's water department is responsible for the management of water services in the municipality of Skövde. The water department comprises 38 employees. The interviewee's role is Network Infrastructure Manager, with multiple tasks such as network engingeering, delegating work among employees, project management of small projects, and supporting work at the treatment plant.

SVOA is a municipal company responsible for management of water services and waste in the Stockholm region. The water department consists of 650 employees. The interviewee's role is Corporate Strategist focusing on overall strategic directions for the company.

Tjörns kommun's water department is responsible for management of water services in the municipality of Tjörn. The water department comprises 28 employees. The interviewee's role is Head of Water and Wastewater Department, responsible for the water department and their operations.

VA Syd is a municipal association responsible for the management of water services, spanning the municipalities of Burlöv, Eslöv, Lomma, Lund, and Malmö. The organization comprises 500 employees. The interviewees' roles are Head of Strategic Planning, responsible for the development of the water and wastewater system and digitalization of the urban planning process, and Project Leader & Coordinator, working with managing cross-departmental projects along with assessing needs for digitalization improvements.

Älmhults kommun's water department is responsible for the management of water services in the municipality of Älmhult. The water department comprises 18 employees. The interviewee's role is Head of Water and Wastewater Department, responsible for the water department and their operations.

4.3 Views of digitalization

This section presents the results of the interviewees' responses regarding their views on the terms digitization, digitalization, and digital transformation. Additionally, it examines the current stage of these processes within their organizations compared to other Swedish water organizations.

Borås Energi och Miljö view digitalization of water management as a way to make use of data, integrate various functions, and make information more accessible. The organization consider themselves above average in their digitalization efforts compared to other utilities in Sweden.

Kalmar Vatten consider digitalization as complex and perceive digitalization as a catalyst for ensuring the provision of high-quality water services to their customers. They emphasize that it includes to establish robust communication channels with water system objects and sustainable data collection methods. Digital maturity

within the organization is highlighted as a major factor of a digital transformation, covering the human part of the transformation. Kalmar Vatten consider themselves in the middle of the digitalization process compared to other Swedish water utilities.

Kretslopp och Vatten view digitalization of water management as moving from individual to more interrelated systems, implying data being collected and sent between devices, in the long run facilitating the systems to make decisions but also make the analyses more efficient. They see that their own transformation is progressing slowly, but they cannot see that many other Swedish water utilities are further ahead.

Kungsbacka kommun view digitalization as a crucial tool for increased control of the water network. The organization considers themselves to be above average in the digitalization process compared to other Swedish water utilities.

Lilla Edets kommun's approach to digitalization revolves around SCADA-systems and automation, with a focus on achieving centralized information stored in databases, accessible without human intervention.

MIVA views digitalization as a broad concept, but the interviewee focus it around how the organization design, build and operate their systems for operational activities where data from the pipe network should be linked and analyzed together. Digitalization is viewed as a tool for further refinement of the data collected and to help streamline the operations. MIVA perceives their status of digitalization as average compared to other Swedish water utilities.

Mullsjö Energi & Miljö has a hard time coming up with a description of digitalization for the water industry but they currently focus on digitalizing their pipe network. They struggle with approaching digitalization processes and believe it is a common challenge for small organizations within the industry.

NSVA views digitalization from two perspectives. Firstly, the organizational transformation towards digital maturity which is similar across various sectors. Secondly, the technical digitalization of the water industry, involving gaining control over complex technical systems. A significant part of NSVA's digitalization process is about gaining knowledge and understanding of their water system. They highlight the diverse nature of digitalization, wherein its implications vary across different organizational roles, posing challenges in establishing a singular definition.

Skövde kommun considers that digitalization is aimed at their main systems for monitoring and GIS, and efforts to include as many operations into these systems as possible. Otherwise, little attention is paid to defining it.

SVOA highlights their main digitalization as moving from analog to digital processes primarily during the 1980s, originating from their large pipe network and organization. They contend that further digitalization is not an absolute necessity.

Instead, they see their embracement of digital solutions as far ahead in the industry and that their digitalization today revolves more around effectively managing digital workflows within the organization.

Tjörns kommun's view of digitalization revolves around gaining control over the system to efficiently plan for the future, both in terms of time and costs. The organization considers itself to be at the forefront of digitalization in Sweden, significantly ahead in digitalization efforts compared to other Swedish water utilities.

VA Syd talks about digitalization as a way to integrate digital workflows into existing operations, being able to combine and relate data to increase the use of information. It also involves integrating tools and systems to achieve a more efficient workflow, both towards the water system but also the customers. Additionally, they discuss the term smartification, referring to the use of AI and robots to make the water system become intelligent. They consider themselves to be far ahead in the development of certain aspects, but lagging behind in others due to a scattered digitalization effort.

Älmhults kommun is in their initial phase of digitalization and focuses on their SCADA-system and digitalizing the pipe network. They consider themselves at being in the middle of the digitalization process compared to other water utilities in Sweden.

4.4 Vision, strategy, and organization of digitalization efforts

The following section presents the results of questions regarding how the digitalization work is organized, their goals and visions, as well as if they have any strategy for the digital transformation.

Borås Energi och Miljö operates with a top-down approach, where their vision is to achieve a complete digital twin of their operations. The management has developed a clear digital strategy, including structured working methods and prioritization of innovation through cross-departmental workshops.

Kalmar Vatten's digitalization efforts are guided by a municipal strategy but currently Kalmar Vatten has no comprehensive digitalization strategy. However, they possess a dedicated strategy group within the company, comprising representatives from various departments, working on a common strategy. The digitalization aims to streamline operations in order to do more with the same resources. Enabling to link data for analysis to establish robust foundation for decision-making. The group for IT and development has been established to work on innovation and development efforts within the company.

Kretslopp och Vatten's digitalization is initiated by enthusiasts rather than being a centralized work, resulting in specialized knowledge linked to individual employees. The organization lacks a clear vision for their overall digitalization. However, strategies are formulated for some of the departments and their operations. While there exists a vision for digitalization within the City of Gothenburg, a specific strategy remains absent within the organization.

Kungsbacka kommun operates with a top-down approach with clear directives from municipal leadership emphasizing innovation and new approaches through meetings and education. However, the water organization has not formulated its own digital strategy.

Lilla Edets kommun's digitalization efforts are primarily initiated by the Operations Manager thanks to previous digitalization experience, thus it is emphasized to have the right personnel in place. The low level of digitalization across the broader municipality means that there is no digital strategy in place. However, the interviewee sees great potential for their small municipality to derive significant benefits from smaller digitalization efforts.

MIVA is a part of Örnsköldsvik municipality group, which possess a digitalization strategy, but is not related to the water departments' operational activities. The goals with the digitalization have not been set yet and they vary depending on the field of expertise within MIVA, which constitutes one reason to the organizations' lack of a clear digital strategy. However, the vision of the interviewee is to achieve a smart system that, where actions needed would be based on the current status of the pipe network and visualized to employees and customers daily. MIVA has a Digitalization Officer at 50% employment tasked with developing a digitalization strategy for the organization throughout this year.

Mullsjö Energi & Miljö has no specific goals, vision or strategy for the digitalization. However, the purpose of digitalizing is to facilitate the operational work, enable to work digital in the field and make it easier to share maps and information with other municipal departments. The responsibility for the current digitalization efforts are designated to the administrator.

NSVA's digitalization efforts are supported by their top management, which has formed a team of four employees dedicated to development projects, serving as support for development across the organization. Since the focus areas of units varies a lot, the visions and strategies are mainly assigned to the individual departments. Nevertheless, they emphasize that reducing leakages stands as a primary goal for the entire organization, as it impacts all facets of the operation and results in decreased costs.

Skövde kommun has no clear overall goal with the digitialization but it aims to streamline operational processes and applications towards customers. They have smaller objectives for specific applications and digitalization projects. The mu-

nicipality have a vision to implement more digital systems, to avoid unnecessary printouts, which for the water department means to have the pipe network digitally linked to a constantly updated database. Thus, they strive to have as few digital tools as possible, consolidating them into multifunctional tools. However, no clear strategy has been implemented at the water department.

SVOA's digitalization efforts are led by the IT-unit supported by two corporate strategists focusing on overall strategic direction, along with an AI specialist dedicated to AI development. Today SVOA possess a vague strategy but the AI specialist is henceforth responsible for formulation of goals and a strategy for the company's digitalization. They do also have designated roles for document management with standardized ways of working with data throughout the organization. Additionally, specialized employees work on automation (programming), focusing on continuous improvement. They are planning on establishing internal startup groups where a number of employees can dedicate time to new IT/AI/ML solutions.

Tjörns kommun prioritizes digitalization efforts across all municipal departments, with all employees having a responsibility to pursue these objectives. The organization's focus lies on digital transformation moving from analog to digital work methods, which includes training and integrating digitalization into daily work. The interviewee describes the vision for digitalization as sharing information with other departments within the municipality to create synergy effects as well as enable coordination between the departments. There are strategies and plans for specific projects, but no comprehensive strategy for digitalization across the organization.

VA Syd's digitalization work is distributed to the various departments, resulting in more progress in some areas than in others. The organization has no common vision for digitalization. However, the various departments might have their own visions and strategies. Since it is up to each unit manager to determine how much time should be allocated to development work, employees throughout the organization are involved in development as part of their roles to varying extent, but at the operations unit, very little time is allocated to work with digitalization efforts.

Älmhults kommun's digitalization relies on engaged individuals. The interviewee's vision is to create a central monitoring hub where politicians and staff can see and address the municipal water problems. However, they have not formulated a clear strategy for their digitalization work yet nor have requirements from the management focused on digitalizing the water department.

4.5 Digital working methods

This section describes the digital solutions, tools, and working methods currently utilized by the organizations.

Borås Energi och Miljö uses VA-banken for their pipe network and maintenance activities. Additionally, they use SCADA-systems and IoT sensors for data collec-

tion in the pipe network. The implementation of smart water meters in households is an on-going work in the municipality.

Kalmar Vatten uses their own hydraulic models for design and troubleshooting. They gather data from their SCADA-system and utilize historical data for various analyses and to assess the consequences of different scenarios. Sensors are integrated into the pipe network to detect anomalies and identify potential leaks but are still in a stage of exploring their possibilities. The implementation of smart water meters in households is an on-going work in the municipality.

Kretslopp och Vatten uses sensors for data collection in the pipe network and IoT technologies, SCADA-systems, and GIS-models are used for hydraulic modelling. The data and digital tools can be utilized to plan renewal or construction of pipes, early leak detection, and planning of operational changes. Additionally, AI-systems for prediction of leaks and pipe breaks are used. The organization uses smart water meters in households for measurement of water consumption.

Kungsbacka kommun utilizes VA-banken for their pipe network. They also use hydraulic models serving as digital replicas of reality, enabling scenario simulations and facilitating a design process with reduced margins. Additionally, the ongoing implementation of smart water meters in households, along with real-time data from sensors and meters, enhances network control and can be utilized for forecasting and leak detection.

Lilla Edets kommun's key initiatives for digitalization include the adoption of smart water meters in households and the integration of an updated SCADA-system. It also includes digitizing documents and systems for working orders.

MIVA utilizes a water and wastewater database where the pipe network is depicted on the municipal map alongside other municipal GIS-information. In their SCADA-system, most of their network components are connected, from which data is collected. Additionally, MIVA has hydraulic models for drinking water, wastewater, and stormwater over several urban areas and catchment areas. These models are created by consultants who also conduct simulations. The shift to smart water meters in households, with the capability to listen for leak sounds, is ongoing and predicted to be finished by 2026. Measuring devices is placed in wells in the water distribution network to establish extended control zones. There are also plans on connecting these to smart meters, to enhance real-time data collection from the network.

Mullsjö Energi & Miljö's digitalization focuses on converting information from analog to digital forms. The process to build the pipe network for drinking water, sewage, and stormwater pipes into a GIS-model is initiated, where they utilize VA-banken. This is made with support from consultants. When it comes to data management, data is manually collected and stored in Excel-sheets or binders. Operators take action on alarms through text messages triggered by anomalous data

from the networks.

NSVA utilize technical solutions including smart water meters in households, SCADA-systems, hydraulic models over the water system, and various platforms or databases for information storage and management. They have also worked with AI-models for drinking water production and made progress in developing tools for leak detection.

Skövde kommun uses their SCADA-system for data collection and real-time monitoring but also to input maintenance data for the components. They utilize VA-banken for GIS-information about the pipe network, working orders and checklists for operators that can be viewed in a mobile app. They also utilize a text message service connected to the VA database, which notifies customers when water shut-offs occur. A drinking water network model has been designed by consultants and updated by the interviewee to enable simulation of flow scenarios. The shift to smart water meters in households, with the capability to listen for leak sounds, is ongoing and predicted to be finished by 2028.

SVOA's digital work methods encompasses field personnel equipped with digital maps and working orders in mobile phones, digital operation monitoring through SCADA-systems, connected meters on the pipe network enabling collection of real-time data. They utilize GIS software and store data in an internal open-data environment to enable all personnel to take part of system information and make analyses. Additionally, hydraulic models for scenario simulations and AI-systems for prediction of leaks and pipe breaks are used. However, the implementation of smart water meters in households is not widely spread but challenging due to the large number of households to distribute.

Tjörns kommun utilizes IoT technology along with several other digital solutions, including SCADA-systems as well as smart water meters in both households and zones to enable leak detection. Additionally, they use GIS-models and hydraulic models in their work.

VA Syd utilizes IoT technologies and sensors for data collection on the pipe network. Additionally, they have implemented the usage of smart water meters in households. They focus on linking operations to create digital workflows, where GIS-models are linked with the processes in an open and easy format and results from the hydraulic models are available in an app for everyone in the organization to see.

Älmhults kommun uses a SCADA-system and VA-banken for their pipe network. The use of real-time data is not fully implemented yet and currently they need to work on collecting the right information. The implementation of smart water meters in households is an on-going work in the municipality.

4.6 Digitalization projects and collaboration

The following section presents responses to questions about internal and external projects and collaboration. It also addresses the organizations' engagement in the Swedish digitalization network.

Borås Energi och Miljö collaborates with external parts trough partnerships with Smart City Lab [1] and by engaging in dialogue with other water organizations, they share knowledge and experiences, participate in study visits, and discuss digital solutions during joint user meetings with vendors. They participate in projects with research institutes such as RISE to facilitate knowledge exchange and innovation. Currently, they are involved in a project aimed at developing standards for labeling components within the pipe network. Additionally, the company cooperates with the City of Borås and other municipal companies within the city in the initiative Smart City Borås where they explore areas for the organizations to share information and support each other. They are also a part of the Swedish digitalization network.

Kalmar Vatten is mainly collaborating with the municipality of Kalmar, and utilizes their IT expertise. Together they have established a shared data warehouse to facilitate cross-departmental data access. The project is on a small scale but aims to be fully implemented in the organization. They experience the industry as open to help each other with knowledge and experience during for instance conferences. Additionally, they are engaged in the Swedish digitalization network for exchanges of experience.

Kretslopp och Vatten collaborates in internal and external projects, including partnerships with the City of Gothenburg's IT services and other municipal departments to create a common digital infrastructure. Kretslopp och Vatten is a part of the Future City Flow [2] project. They are also engaged in the Swedish digitalization network which they see as a good way to share lessons learned and discuss guidelines with like-minded people in the industry.

Kungsbacka kommun's external collaboration is fostered through user meetings with vendors and knowledge exchange with other municipalities. Additionally, they participate in activities such as webinars arranged by the Swedish digitalization network, which they see as a good way to learn from other water organizations. The organization has not participated in any research projects regarding digitalization. However, they emphasize the advantages of testing new solutions small-scale before fully implementing them.

[1] Smart City Lab focuses on building the technical and organizational capabilities and prerequisites required in a municipality to collect and make data available in a secure, scalable, and controlled manner.

[2] Future City Flow is an innovation project that develop solutions and decision support system for urban planners, water utilities, and wastewater treatment plants to reduce flooding and the discharge of untreated sewage.

Lilla Edets kommun have some exchange of experience with local water organizations but are not involved in the Swedish digitalization network. The water department has performed a pilot project to improve their SCADA-system in collaboration with Siemens, where Siemens have provided resources and help with technology implementation.

MIVA see cooperation between local water organizations and the Swedish digitalization network as good ways of sharing good and bad experiences, but highlight that the implementation of new working methods requires huge organizational effort. The implementation of smart water meters in households could be seen as a pilot project as the technology intend to be implemented in full scale across the water distribution network as a whole.

Mullsjö Energi & Miljö does not collaborate or cooperate with other water organizations, nor engage in networks. However, they collaborate with the municipal IT-department.

NSVA is an active participant in the Swedish digitalization network, fostering knowledge exchange with external parts. The organization has taken part in the external project Future City Flow. Internally, they have performed projects on AI-models for drinking water production.

Skövde kommun collaborates mainly with surrounding municipalities and have exchanges of experiences during user meetings with system vendors. They have little time to keep track of the digital development within the water industry, leading to no engagement in the Swedish digitalization network. Several internal projects have run to implement digital working methods for field workers, such as utilization of VA-banken.

SVOA collaborates with the municipality of Stockholm for the coordination of IT resources and software. Externally, SVOA is engaged in several water industry networks such as the Swedish digitalization network and SWAN, where they share and gain insights. Additionally, they have been part of projects for developing several modelling software together with software vendors and their AI specialist also produces internal applications and software.

Tjörns kommun is performing an IoT project together with, and financed by, Vinnova. This project is a major part of the municipality's digital transformation. It is performed strategically and creates space for innovations and creativity among the employees. The organization's engagement in the Swedish digitalization network is limited due to time constraints.

VA Syd has performed internal projects to digitalize documentation and work orders used by the field workers. The organization has taken part in the external project Future City Flow. VA Syd is one of the driving organizations in the Swedish

digitalization network, and the coordinator of the network is a part of VA Syd's organization.

Älmhults kommun's water department has not been involved in any projects, neither internal nor external. Nor has the organization any collaboration with other organizations or networks.

4.7 Drivers and positive outcomes of digitalization

In this section the responses regarding the positive effects of digitalization and what drives the organizations to digitalize are presented. Figure 4.2 presents the most common drivers among the interviewed organizations where the numbers on the x-axis represent how many organizations have mentioned the driver.

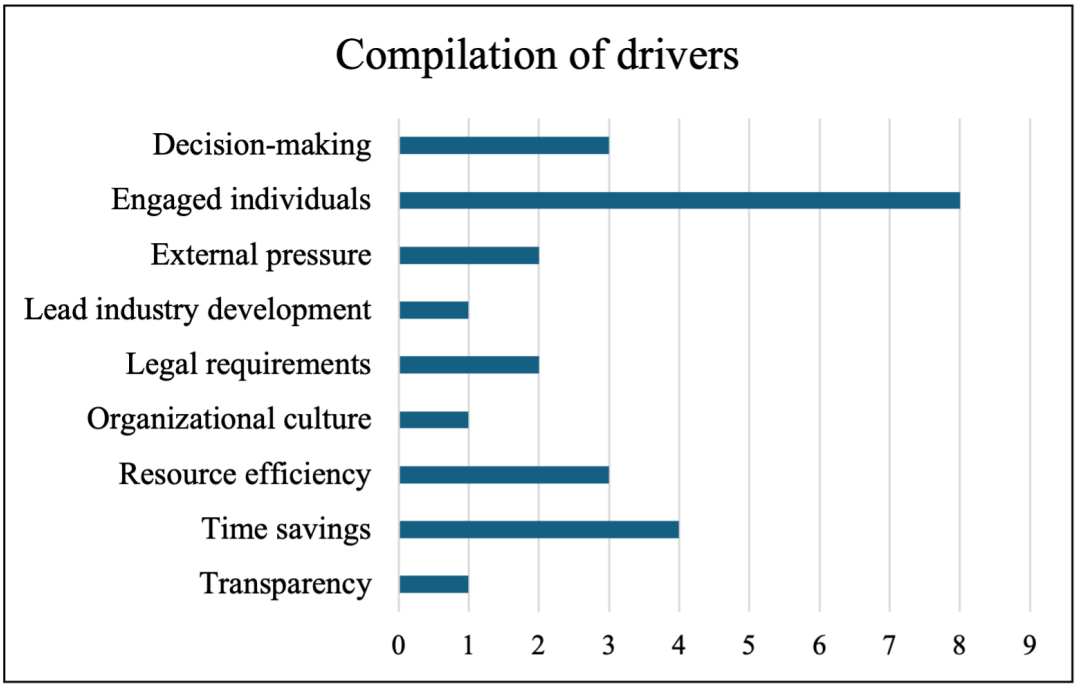

Figure 4.2: Compilation of the organizations drivers for digitalization.

Borås Energi och Miljö emphasizes factors such as data accessibility and streamlined information management as driving forces. The organization has seen notable benefits such as improved leak detection and cost savings, as well as the ability to take advantage of more information than previously. Additionally, the organization currently has a more extensive employee turnover than previously, making it vital to gather and store information digitally rather than letting the information be linked to certain employees.

Kalmar Vatten recognizes that their geographically dispersed network necessitates innovation in finding communication solutions that facilitate data collection and transmission across various locations, driving their digitalization. Other driving forces are meeting legal requirements and the potential of new methodologies to liberate time. Their position in the industry also benefits their processes by allowing them to learn from others who are ahead of them. This helps in making digital implementations less costly by avoiding potential software bugs.

Kretslopp och Vatten emphasizes interested individuals within the organization as their largest driver for digitalization. However, they have succeeded in making the issue visible and demonstrate the digitalization's potential for efficiency and cost savings to the organization and its management. The interviewee hopes that this can allocate more time to be spent on digitalization issues.

Kungsbacka kommun's digitalization is primarily driven by resource efficiency, improved data resolution, and enhanced decision-making capabilities. The organization considers themselves to be brave and emphasizes having the courage to test new methods and technologies as a successful driver.

Lilla Edets kommun's digitalization is primarily driven by engaged individuals within the organization. Successful outcomes experienced from the ongoing digitalization efforts include time-savings and a shift towards proactive operational planning.

MIVA's driving forces for digitalization are mainly enthusiasts within the organization, making it hard to digitally transform the organization in a structured way. Nevertheless, they have experienced benefits so far where digitalization has helped gain more control over the pipe network. Smart water meters across the pipe network has enhanced real-time data providing more accurate water balance between the actual amount of water delivered and the consumption of water.

Mullsjö Energi & Miljö's driving forces behind their digitalization have stemmed from management's recognition of its value recently and an individual will from the interviewee, coupled with pressure from external organizations. Mullsjö Energi & Miljö sees great potential with VA-banken to note flows at all times, to enable simulation of scenarios and to minimize handling of paper documents and maps.

NSVA's digitalization work is driven by both internal benefits, and the desire to contribute to industry development and knowledge enhancement. They also target efficiency gains in terms of time, costs, and environmental impact reduction. The individual engagement for innovative solutions and staying up to date with global industry novelties are also key drivers. Success factors identified for the organization include the courage to make mistakes and try new methods, as well as the management team seeing value in and prioritizing development initiatives. A positive outcome from digitalization is the development of tools for leak detection, allowing quick crisis response.

Skövde kommun's digitalization efforts are driven by the water organization itself, and the head of the department. Their digitalized working methods so far have benefit the organization through reduced travel and time on site, remote monitoring, better communication with customers, and simpler and more secure information flows. They have also experienced reduced usage of individual documents promoting digital platforms for sharing disturbances, actions and information.

SVOA's extensive operational area, covering both a wide geographical region and numerous households, has somehow forced the company to digitalize its processes to manage and ensure efficient water services. The initial driver for development within the company can be related to the trust-based leadership that has long permeated the organization. Together with a lot of specialized knowledge and acceptance of initial costs for improvements, the organization has been allowed to explore digital opportunities. A natural shift towards digital methods was also evident during an office relocation in 2016 when they moved towards an activity-based office. It entailed a clean desk at the end of the day and led to minimized paper usage, thus making all work methods more digital.

Tjörns kommun highlights resource efficiency and the desire to future-proof water supply by fully utilizing facilities, as well as the need to establish a solid basis for decision-making as drivers for their digitalization. Tjörn being a small municipality comes with benefits such as short decision-making processes, and the municipality tries to take advantage of these benefits. Positive outcomes of the digitalization include greater depth of knowledge about the water systems and a joint platform for data, fostering awareness regarding the utilization of collected data.

VA Syd's digitalization is mainly driven by engaged employees seeing opportunities with new technology, both in management positions and the rest of the organization. Digitalization of processes towards customer services, such as new connections to the water network have been successful as well as GIS-information about the pipe network becoming easily accessible for employees.

Älmhults kommun emphasizes engaged individuals as their main driver for digitalization. Once they start getting the right and increased amount of data, they see great potential in digitalized working methods.

4.8 Challenges with digitalization

The following section presents what challenges the organizations encounter both within their organization, with other actors and across the industry at large. Figure 4.3 presents the most common challenges among the interviewed organizations where the numbers on the x-axis represent how many organizations have mentioned the challenge.

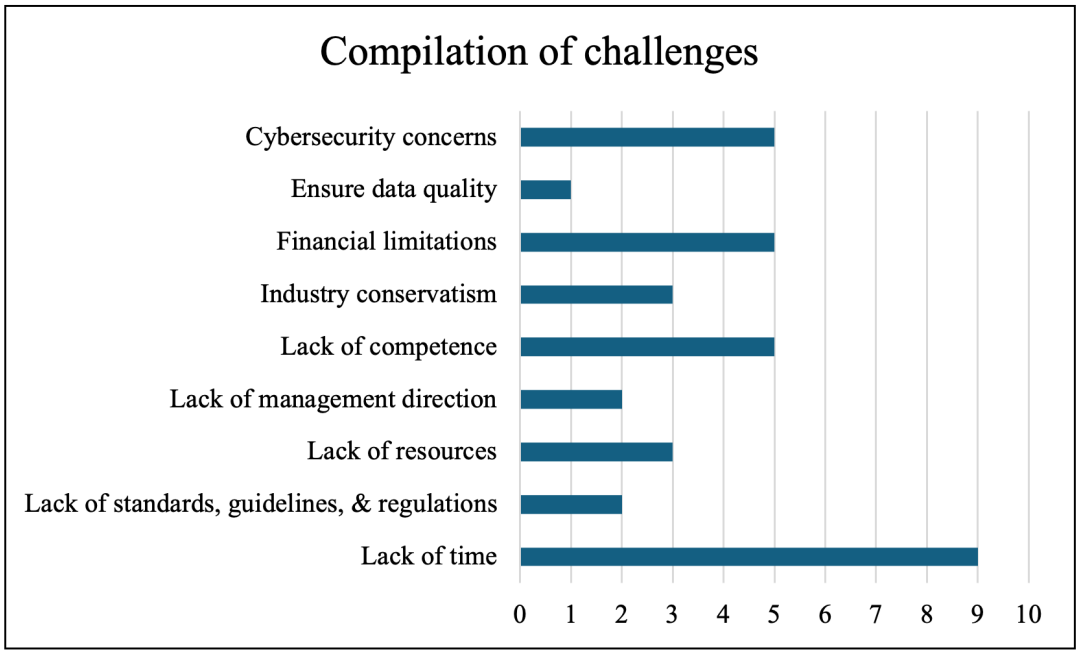

Figure 4.3: Compilation of the challenges the organizations encounter related to digitalization.

Borås Energi och Miljö highlights that challenges like cybersecurity, industry conservatism, and the need for clearer standards persist.

Kalmar Vatten and the municipality recently experienced a cyberattack, making cybersecurity a huge concern and challenge in their digital transformation. They also face challenges in shortage of particular skilled personnel, especially in the domain of cybersecurity. Another main issue is the lack of interoperability between different data platforms, which creates a need for various specific solutions for different areas causing problems with data availability.

Kretslopp och Vatten emphasizes not seeing immediate benefits, making it very abstract for employees when time and expertise are not sufficient to achieve adequate understanding. Thus, it is emphasized to use practical examples, such as pilot projects, to show progress in small steps. Their pipe network is big and widespread which entails thorough infrastructure of sensors and meters to get the results wanted from digitalization. The work behind getting sensors and systems to function should also not be underestimated, requiring both competence as well as a thorough security mindset.

Kungsbacka kommun faces barriers to digitalization including technical limitations such as connection for receiving data from meters across the municipality, data quality issues causing inadequate analyses, time and financial limitations for keeping the models updated.

Lilla Edets kommun faces barriers including conflicting interests, particularly between the water organization's IT and municipal IT, alongside security concerns.

Additionally, they highlight the lacking municipal engagement as challenging for further digitalization.

MIVA acknowledges a will to work on digital issues but also a lack of time allocated for this. Instead, the municipality is dealing with aging infrastructure, which requires prioritization of effort and resources. Further, employees diverse roles makes MIVA lack expertise needed for digitalization progress. Their extensive pipe network also presents a challenge, making changes expensive and often resulting in projects ending as pilots rather than being fully implemented. As for several water organizations, they see data security concerns and highlight the lack of industry standards, leading to diverse approaches.

Mullsjö Energi & Miljö experience a lot of challenges where the small organization have a hard time focusing on specific areas, making it difficult to monitor and cope with the state of the art of digitalization within the water industry. This leads to little knowledge about what technology and systems exist on the market as well as the benefits and value of implementing them. It is emphasized that the tariff funding makes it difficult to raise money for improvements. For instance, one reason for not implementing smart water meters in households are the costs for dual systems during meter replacement.

NSVA faces challenges such as creating a balance between development and daily operations, information security, as well as costs for implementation of new systems. The interviewee highlights that traditional working methods still persist, with knowledge being linked to individuals and personal experience holding considerable importance in the water industry, hindering the adoption of digital working methods.

Skövde kommun faces challenges in getting all employees to embrace the new technology, mostly because of difficulties proving the value of them but also due to a conservative approach within the water industry. They also face obstacles such as lack of time to develop and learn new working methods as well as expertise for new technology. However, they are currently reviewing and mapping the needs within the organization.

SVOA face challenges related to decentralized decision-making, risking contradictory decisions and non-standard practices that does not facilitate the digital working methods. They use a wide array of software, which presents the challenge of avoiding unnecessary costs and administration.

Tjörns kommun face challenges such as lack of resources, time, and varying willingness among employees to embrace change.

VA Syd encounter barriers for digitalization such as resource and competence deficiencies where daily operations takes up most of the resources. Furthermore, water digitalization issues receive low priority at both the internal management and political levels, resulting in vague directions for the process.

Älmhults kommun face several barriers for digitalization, emerging from lacking time where the day-to-day operations take up most of the time, making little room for education of new ways of working and new systems. Additionally, they do not have the ability to dedicate one person to work with digitalization. Further challenges in the organization is lack of financial means, and not seeing the benefits of the change, which creates a lack of interest among the employees.

4.9 Needs for accelerating digitalization

The last result section presents the organizations prerequisites for initiating their digital transformation and the support needed to advance their progress. This includes the key stakeholders to involve and the potential role of standards in facilitating their process.

Borås Energi och Miljö advocate for support from organizations like Svenskt Vatten to drive development and provide clearer examples to facilitate employee understanding of digitalization benefits. Borås Energi och Miljö highlights the importance of driving development from where the organization currently stands, which involves understanding their data and using a language that is understandable for the entire organization. Additionally, they underscore the necessity of having the right personnel in place to drive digitalization forward.

Kalmar Vatten recognizes the need for investing in employee training and skill development, particularly in IT, to accelerate digitalization. They foresee collaborative efforts between water organizations and their own municipality as crucial for facilitating the necessary investments in both digitalization and physical infrastructure enhancements. Addressing interoperability issues, they emphasize the importance of standardization in IT services within the water industry and advocate for Svenskt Vatten to lead these initiatives. Furthermore, they advocate for government funding to support smaller organizations in meeting the increasing demands, as those outlined in NIS 2.

Kretslopp och Vatten highlights an overarching responsibility from the internal management and more resources with the right competence in the organization to accelerate digitalization. They emphasize that the water industry in general would benefit from common basic structures for data management, addressing both security aspects as well as searchability and shareability. They see Svenskt Vatten as an actor driving this effort, but the legislation could also be stricter with national requirements for open data. Increased collaboration between municipalities would also help enhance the efficiency of smaller municipal water organizations and drive the water industry forward.

Kungsbacka kommun highlights that accelerating digitalization would benefit from dedicated digitalization roles within the organization. Further highlighted is water industry standards for digital working methods to ease collaboration between

water organizations, as well as regulations and laws on the field of smart water meters and leakage limitations. It is also crucial for water organizations to understand the power of using digitalization to meet the regulations. They experience the water industry as open for collaboration and knowledge sharing, leveraging diverse organizational strengths for mutual benefit. However, there's a need for political recognition and support for digitalization initiatives within the municipality to fully utilize its potential.

Lilla Edets kommun believes that collaboration within the water industry to develop industry guidelines for the digital journey and a forum to discuss digitalization issues would be beneficial for accelerating sectoral digitalization. For the own organizations acceleration, Lilla Edet highlights new competences, as well as municipal managers and politicians understanding of the issue as the largest needs for accelerating their digitalization.

MIVA emphasizes that since water industry organizations are non-profit, there are no inherent demands for development. Therefore, for the industry to undergo digital transformation, regulatory bodies must impose more stringent requirements, citing Denmark as a good example. They also see the need for a shift in traditional organizations meaning implementation of new roles, such as digitalization strategists. Additionally, sharing of competence between organizations through for instance regional resource hubs could be a form of cooperation to address the lack of resources. Svenskt Vatten is proposed as an actor to develop recommendations to support the transformation. They believe that since Svenskt Vatten's suggestions often become water industry standards, their publications could aid smaller organizations in navigating the digital journey.

Mullsjö Energi & Miljö consider legal requirements as crucial for digitalizing the water industry, expressing that the lack of requirements for smart water meters in households, leave them without plan on implementing them. To accelerate their internal digitalization, they must find good water industry examples to look at in order to see the benefits, learn and find interested parties who can drive their process. They are also in need of a clear vision regarding real-time data from their municipal IT-organization.

NSVA believes that specialized expertise, primarily AI skills, and an expanded network for knowledge sharing are necessary to accelerate water industry digitalization. Although, the organization highlights that there is a culture of knowledge sharing in the water industry. Moreover, clear standards and guidelines regarding information classification, security, and cloud services are identified as essential for accelerating the transformation. It is suggested that the development of such standards and guidelines can be driven by the Swedish Civil Contingencies Agency, MSB. NSVA highlight cooperation, both nationally and internationally, and to take advantage of the fact that different organizations are proficient at different parts of digitalization, as important for progress.

Skövde kommun see the value in water organizations utilizing the same systems, such as VA-banken, as this is believed to enhance expertise and facilitate the sharing of experience within the water industry, ensuring that organizations speak the same language. Further stated is that digital development should be driven by those who work close to reality, and not be too centralized, to enhance implementation.

SVOA believes that the need for digitalization will require water organizations to adopt new formats, necessitating cooperation among several water organizations. They argue that such collaboration would be beneficial for the development of smaller water organizations. It is also emphasized that the organizations themselves must look for challenges and opportunities, but collaboration with academia to discover new technology and talents are also advantageous. Management must also challenge the organization with requirements, such as traceability of data. Finally, water industry associations could develop standards for databases and enforce strict requirements from the government, similar to the ones in Denmark, to drive digitalization of the water industry.

Tjörns kommun believes that to accelerate digitalization in the water industry, common standards for data communication and storage are required. Independent institutions such as universities and RISE will be important to engage when creating standards of this type. Due to the conservative nature of the industry and the varying conditions among municipalities, collaboration within the industry is highlighted as necessary for digitalization progress. Clear directions from policymakers will also be required, given the non-competitive nature of the water sector.

VA Syd emphasizes the engagement of the entire organization as well as recruiting employees with IT and water industry expertise as needs for accelerating their digitalization. Additionally, there is a need for regional political directives for digitalization investment. However, digitalization of the water industry is also pointed out as a national matter in need for national initiatives and standardizations from Svenskt Vatten. VA Syd believes that awareness, understanding and the status of water issues in the urban planning process must be raised in order to drive digitalization. This could be aided by closer cooperation with the municipalities.

Älmhults kommun highlights recruiting personnel with the right competence, underscoring GIS knowledge as crucial, and be given time to educate the employees, as needs to accelerate the digitalization within the industry. However, they need enough financial means to purchase it as well as setting the right requirements for system vendors. It emerges that different water organizations excels in different parts of the process and that the industry is open to exchange experiences, still Älmhult experience no natural place for this exchange to take place. However, it is argued that larger municipalities should drive the process thanks to more resources.

5
Discussion

In this chapter the responses and experiences of 13 utilities along with the literature are discussed. It provides an overview of the current digitalization state of the Swedish water industry. Overall, much of the findings from the literature are reflected in the water industry in Sweden, but the interview study has provided a more nuanced understanding of how the industry views digitalization, its development, the driving forces and challenges involved, and what the sector needs to digitally transform together.

5.1 Varying views of digitalization

In the Swedish water industry, the definition of digitalization lacks a clear consensus. However, there is recognition of the potential it holds for establishing a more robust foundation for decision-making processes. Additionally, it is recognized that digitalization serves as a mean to improve data and information sharing. It revolves around consolidating various functions within a single platform or system, fostering connectivity among different systems, and enabling smoother digital information flows to prevent information from being tied to individuals. When it comes to perceptions of digitalization, the word cloud in Figure 4.1 reveals a prevalence of positive feelings. It is important to acknowledge a sense of uncertainty associated with it as well. However, each water utility representative contributed minimum one positive word, which gives an indication that Swedish water organizations see the potential with digitalization even though efforts to proceed might be lacking. It is clear that different municipalities are at various stages of digitalization, but this does not pose a problem for the water industry. Rather, it is an opportunity for organizations to excel in different areas and then learn from each other.

Digitalization manifests differently for individuals with diverse expertise and experience, both within organizations and across the industry. This diversity surfaced during interviews, leading to the conclusion that digitalization varies in its implementation and impact. For the interviewees closely involved in operational activities, digitalization focuses around implementing solutions that enhance efficiency and are easily embraced by field workers. This often involves digitizing documents, work orders, and fieldwork practices. For them, SCADA-systems offer valuable capabilities for remotely monitoring and controlling operations, framing digitalization as a tool for operational enhancement. For interviewees operating at a strategic level, digitalization involves gaining insights into the water system. The SCADA-system serves

as a crucial tool for data collection and accessibility. Emphasizing the significance of utilizing larger volumes of data for more precise predictions is also highlighted within the context of digitalization. However, they did also include aspects as digital maturity, linking various digital workflows together and information accessibility throughout the organization when discussing the concept of digitalization. Related to the definitions found in literature, this view aligns more closely with the concept of digital transformation. It expands beyond the confines of specific operational tasks, instead taking a holistic approach to digitalization efforts. This approach not only involves the adoption of new technological tools but also encompasses broader organizational changes.

5.2 Digitalization status in the Swedish water industry

In the Swedish water industry, the status of digitalization varies significantly, influenced by the size of the organization and the engagement and expertise of individuals within it. Larger organizations, benefiting from their resources and time, find it easier to undertake extensive digitalization projects and engage in innovation. Additionally, for them, it is not just about a desire to be at the forefront of digitalization but it is an absolute necessity to operate their business due to the large operational area and pipe network. Conversely, smaller organizations often experience more tangible improvements, such as increased time efficiency and cost-effectiveness, compared to larger organizations. The smaller scale allows for better oversight of individual work efforts, facilitating the identification of areas for improvement. For these organizations, such as Lilla Edet, Skövde, and Mullsjö Energi & Miljö, digitalization could be seen as a more valuable opportunity for change than for larger organizations. However, they struggle to initiate these changes and attribute limited digital implementations to poor monitoring of digital industry practices rather than to not seeing the value of investments.

In terms of digital working methods, the industry commonly utilizes GIS software systems like VA-banken to manage and present data regarding the pipe network and workflows. These tools are considered essential in the digitalization journey, facilitating the accessibility of information and data for all members of the organization. The majority of municipalities do not seem to encounter problems with technologies for data collection; instead, challenges arise in the utilization and analysis of data. Difficulties are experienced in storage, lack of analytical skills, data integration, and security aspects. Additionally, it has become apparent that digitization poses a greater challenge than previously assumed. Many organizations have extensive digital solutions but still find areas where they lag behind, particularly in digitizing knowledge and information dependent on individual expertise. This indicates that the water industry still relies on individual experience and knowledge of systems and operations gained from many years within the water organization. Thus, the organization becomes vulnerable to employee turnover, which digital transformation

can address by standardizing workflows, ensuring that information resides in shared systems rather than in individual employees' minds.

The shift to smart water meters is widespread in the studied municipalities. This transition will generate more data valuable for mapping water consumption in the area of operation. It creates opportunities for enhanced control of the pipe network and for predicting consumption, thereby increasing the assurance of consistent water supply. It also improves the customer experience by phasing out their manual meter reading and providing access to consumption data. It has become evident that although customers do not exert external pressure for change, water organizations prioritize employing digital solutions to improve customer experiences and efficiency for end-users.

> *"Our vision is that if we were a company in a competitive market, customers would want to choose us."*
>
> – Head of IT and Development, Kalmar Vatten

> *"We are not aiming to generate any profit, but we should be at least as efficient as a private company, if not more so."*
>
> – Corporate Strategist, SVOA

This focus extends beyond merely enhancing organizational effectiveness and time-saving measures. This contrasts with the picture literature suggests of the water industry, suggesting that the lack of competitive advantages and absence of external pressures lead to inertia. However, this study demonstrates that the lack of competition contributes to a slower pace of change but not a lack of change.

5.3 Financial limitations and time constraints

The tariff system financing water organizations is highlighted as a major barrier to prioritize investments not directly linked to network maintenance and expansion. Much of the water infrastructure, built over 50 years ago and largely financed by the state, now requires substantial reinvestment. Consequently, the water tariff system constrains water organizations capacity to prioritize non-network-related investments, such as digitalization efforts. This means that the issue of digitalization also lies in the hands of politicians, where there may be a need to re-evaluate the funding of the water industry at the political level to create space for prioritizing large-scale digitalization. It is noted that it is necessary but financially unfeasible for small organizations to dedicate someone with both IT and water management skills to work with digitalization efforts full-time to proceed digital transformation. Addressing these limited resources, solutions such as resource pooling and intra-collaborative projects are emphasized. The study shows that Vinnova-funded projects and collaborations with suppliers have proven beneficial for individual organizations' digital development, providing both funding and expertise. For instance, projects like the one performed by Tjörn has transformed their operations entirely,

while collaborations like Lilla Edet and Siemens projects showcase similar outcomes.

The primary barrier to digitalization identified in this study is time limitations. Just as the literature presents, the time limitation is evident in smaller organizations where professional roles encompass significant responsibilities and where work must be notably value-creating to the greatest extent possible. Many of the interviewees testify that it is more a matter of time constraints to find the right new solutions and to train their personnel, rather than a resistance to trying out new approaches.

> *"The willingness to work on digital issues exists, but there is a lack of allocated time for this, and to some extent, the right expertise."*
>
> – Development Manager, MIVA

> *"We get a lot of great ideas and inspiration to build on, but I don't have the time to keep up. We really want to, but it is really difficult to find the time."*
>
> – Network Infrastructure Manager, Skövde kommun

However, there still exist a conservative approach in the sector, thus showcasing the benefits of change before implementation is crucial. Looking at the literature and examples from interviewees, numerous international examples and valuable insights from the Swedish digitalization network are available for water organizations to learn from. Thus, it is suggested that conservatism may stem from time constraints to keep track of and implementing new digital solutions.

5.4 The challenge of dispersed municipalities

The size of a municipality, both in terms of geographic area and population, creates unique conditions for water organizations. In this study, it is noted that medium-sized or smaller water organizations often face challenges related to extensive infrastructure in relation to a small work force. This is primarily attributed to a more dispersed population in these municipalities than in larger ones. This presents a challenge when implementing new technology and ensuring connectivity, communication, and data quality within the pipe network. However, a more dispersed pipe network also leads to longer travel times for maintenance and similar activities. Hence, digitalization can entail significant time savings for these municipalities.

5.5 Leadership for empowerment

The strong hierarchical and decisive structure inherent in public organizations also manifests itself in the context of digitalization. It is essential for top management to show leadership that advocates for digitalization to achieve broader organizational impact, which is highlighted by several interviewees as well as in Chapter 2.7 *Lessons learned from digitalizing water organizations.* Presently, the drive for digitalization

largely lies on individual level, often driven by enthusiasts within the organizations. However, when digitalization initiatives are spearheaded solely by enthusiasts, the implementation tends to be narrow in scope, often involving only interested individuals rather than transforming the entire organization. Therefore, management needs to promote competent and engaged individuals to decision-making positions to demonstrate that digital transformation is a priority within the organization. However, Kretslopp och Vatten highlights the importance of enthusiasts showcasing the benefits of digitalization to garner support from management, since their journey has progressed in this manner. Taken together, this suggest that both a top-down approach and a bottom-up approach are effective in initiating a digital transformation. However, the top-down approach results in more organization-wide digital initiatives, where the delegation of tasks in the digital transformation is clearer, thus creating less resistance for involved individuals.

As suggested by Bindler et al. (2023); Bluefield Research & Xylem (2023); Sarni et al. (2019), management that encourages employees and provides time and resources to experiment with new ideas will advance their digitalization efforts, which is also evident in practice. Organizations with high management engagement, such as Borås Energi och Miljö, Kalmar Vatten, Kungsbacka kommun, NSVA, and SVOA, leverage the commitment of their employees effectively. These organizations are in the process of formulating some kind of digitalization strategy and tend to embrace their data more comprehensively, as seen in Table 4.1. This study also emphasizes the importance of involving diverse roles, encompassing both strategic and operational measures, in the development of the digital strategy, alongside allocating time for innovation activities. Borås Energi och Miljö exemplifies an organization with a clear, long-term vision and short-term goals which is reflected in their digitalization strategy. They include direction for the entire organization and facilitate workshops engaging participants from all parts of the organization to educate staff and foster knowledge exchange. Their strategy encompasses all facets of operations, from production facilities to distribution networks, implementing uniform standards to ensure consistency and efficiency. Moreover, they prioritize providing accessible tools for all employees to access data, models, and plans equally. Borås Energi och Miljö actively collaborates internally throughout the organization and externally with the municipality, showcasing a holistic and organized approach to digitalization.

5.6 Collaboration within and across organizations

Both literature and practice agrees on collaboration as essential for water organizations to navigating their digitalization, serving as knowledge and experience exchange. The non-profit nature of the Swedish water industry is perceived by several interviewees to have fostered a culture where sharing lessons learned is willingly embraced. However, the individual engagement and commitment of employees within the organization is also decisive, as much collaboration hinges on these individual engagements and networks of contacts. As a consequence, organizations with smaller contact networks and difficulties engaging in networks may lag behind

in digital development. This study indicates a need to clarify the purpose of the Swedish digitalization network as well as disseminate information about the network. Making room for embracement of initiatives from a diverse range of municipalities and water organizations would help the sector to capitalize on several organizations unique strengths.

Not mentioned in literature but evident in practice is the importance of small water organizations collaboration with other municipal departments. Such collaboration proves essential for optimizing IT resources, addressing security concerns, and aligning digitalization efforts. However, effective collaboration hinges on engaged municipal management capable of recognizing these needs. The process could be facilitated by formulation of a common strategy to achieve a homogeneous approach throughout the municipality, supporting the water organization in digital matters. This collaborative approach is particularly important for water utilities, as they operate under different conditions due to their tariff-based financing compared to other municipal departments.

5.7 Political initiatives

Swedish water organizations advocate for prioritizing water management on the political agenda. This entails directing investments and elevating the status of water as a vital resource. Efficient infrastructure for water management should be recognized as a national concern. This advocacy is closely linked to the digitalization of the water industry, which has demonstrated its ability to streamline processes and significantly improve early-stage leak detection, as well as identify weak points in the pipe network. Such efforts contribute to conserving water resources and ensuring safe access to water, aligning with the achievement of United Nations' Sustainable Development Goals 6 and 9. Therefore, promoting and supporting initiatives at the national level for the digitalization of water management should be considered a priority in Sweden's pursuit of both global and national sustainability goals.

5.7.1 Legal requirements

The Swedish water industry is governed by the Public Water Services Act (Lagen om allmänna vattentjänster), but to increase the level of digitalization in the sector, legal requirements need to be strengthened and expanded. Noted by several interviewees, Denmark is a pioneering country in digital transformation of the water industry. Their use of digital technologies partly origins from stringent legislation on leakage, pushing Danish water utilities to continuously adopt new technologies for extended control and prevention of water leakages in their pipe network. They have reduced water leakage to an average of 7,2% (Ministry of Environment of Denmark, n.d.), compared to the Swedish 17% (Svenskt Vatten, 2024b). Drawing inspiration from Denmark, setting elevated requirements compels organizations to meet legal requirements, leading to savings in water resources and cost efficiencies for individual organizations, thus driving digitalization.

Another specific legal requirement to implement is related to smart water meters in households. Several interviewees have mentioned the electricity industry as an example, where legal requirements compel the installation of smart electricity meters for consumers. While most interviewees are currently in the process of installing smart water meters in households, the absence of corresponding legal requirements may have slowed down the process. This is evident in the case of Mullsjö Energi & Miljö which has not implemented the smart water meters mainly due to the absence of legal requirements. Suggesting national requirements for smart water meters could serve as an accelerator for increased adoption of the technology within the Swedish industry.

5.7.2 Establishing standards

However, meeting new demands and navigating digital transformation necessitates the establishment of standards. Three categories of standards have been identified covering water organizations' needs to accelerate and coordinate digitalization within the industry.

- Standards for data management to facilitate common labeling of components within the pipe network. Should cover directives for storage, enhancing accessibility and organization of information.
- Standards for interoperability. Should be directed towards software providers to develop systems that are compatible with other vendors but also tailored to the specific needs of the water industry.
- Security standards, including classification of data, sharing of data, and compliance with the NIS2 directive, safeguard sensitive data and infrastructure, bolstering the industry's resilience against cyber threats.

The absence of standards may be attributed to the complexity facing the water sector, where each water organization is unique. It makes it challenging to apply standards and could potentially result in lock-in effects. However, evidence from both literature and interviews suggests that the digital journey could be undertaken with greater confidence when standards are established as guidelines. There appears to be a consensus, both in the literature and among interviewees, that organizations benefit from data sharing. Standards for data management could thus promote greater equity among water organizations, facilitating comparable data transparency and enhancing collaboration opportunities. Currently, it is not clear who should undertake this responsibility but most organizations emphasize that the development of standards should be led by Svenskt Vatten, but also stress the importance of involving actors such as universities, RISE, MSB, system providers, and the municipalities themselves in the process.

5.8 Evaluation of methodology

The methodology for this master's thesis has been beneficial for the study on digitalization within the Swedish water industry. The abductive approach in combination with qualitative data from interviews have given practical examples supporting the literature findings. Multiple interviewees are in agreement on various aspects discussed during the interviews, which are also supported by findings in the literature. This suggests that the interview results can be deemed trustworthy. However, minor improvements in the constituent parts of the methodology could have been made. Firstly, the potential benefits of interviewing equivalent roles in each municipality to ensure representative and comparable results are acknowledged, though this may pose a challenge due to organizational differences. There is a limitation in interviewing only one person per municipality, as it potentially hinders a comprehensive understanding of the entire municipality's view on digitalization. Interviewing several people from different parts of the organization would provide insights from various operations, offering a more holistic view of the organization's approach to digitalization and potentially highlighting needs in larger parts of the organization. This approach would yield more extensive results and enable the thesis to provide clearer recommendations on how to initiate digitalization. Consequently, the thesis would also offer valuable insights for those working closer to daily operations. Additionally, interviewing more municipalities to provide a broader representation of the views of digitalization within the Swedish water industry is suggested as an improvement of the study.

6
Conclusion

The work of this master's thesis have investigated how water utilities across the Swedish water industry view and approach digitalization. The study has revealed what drives the digitalization efforts and what challenges are encountered as well as what is required for further progress. The following conclusions address the research question and its three sub-questions.

The view of digitalization

- There is a lack of clear consensus on the definition of digitalization in the Swedish water industry.
- There is mainly a positive outlook on digitalization as a facilitator for water management.
- Digitalization manifests differently based on individuals' expertise and roles within water organizations.

Drivers for digitalization

- In most water organizations, digitalization initiatives are primarily driven by enthusiasts passionate about advancing digital technologies.
- Increased use of digital solutions is a natural necessity for large municipalities with a large operational area.
- The significant time and cost savings that digital working methods can bring partially drive small organizations.

Challenges hindering digitalization

- Water organizations generally lack clear direction for digital transformation from top management.
- Time limitations, especially for small municipalities.
- Water organizations lack competence for data analysis, IT, and information security.
- The tariff-based funding limits the room for investments in digitalization efforts.

Success factors for digital transformation

- Formulating a strategy for digitalization.
- Engagement in the Swedish digitalization network and actively collaborate with water organizations and vendors.

- Cooperate with the municipality to work in a standardized way.
- Clearly target resources to work on digitalization efforts, such as formulating specific roles or teams.
- Present data in an easily understandable format for the entire organization to recognize and utilize.

Recommendations for the Swedish water industry

There are both internal and external needs for change and support. Therefore, the conclusions are divided into what the water organizations need to do, and what the industry needs to do to further drive digital development.

Organizational wise:

- The commitment to digitalize a water organization should start at management level.
- Exercise leadership that empowers digitalization enthusiasts to make use of the internal competence.
- Formulate a clear digital strategy on how to approach the digitalization.
- Facilitate the digital transformation by gathering expertise within the municipality collaborating on cross-municipal issues such as IT.

Industry wise:

- The sector must agree on an arena to showcase the value of digitalization to several water organizations to increase their drive to digitalize. This study suggests to increase organizations' participation in the Swedish digitalization network.
- The water industry must collectively develop standards for digitalization efforts, suggestively coordinated by Svenskt Vatten.
- Water management must be prioritized by politicians.
- The government should formulate stricter legal requirements and target financial support to the water organizations.

6.1 Future research and development

The overall feeling from this study is that the Swedish water industry sees themselves in the beginning of the digital transformation, advocating for large areas of improvement. Hence, a potential topic for future research is to look at practices in other industries similar to the water industry, such as the electrical industry or similar process industries, to identify valuable insights applicable to the water industry's digital development. Thus, investigate what practices can be implemented to ease the digital transformation of the Swedish water industry.

A main barrier to digital development identified in the study is the financial limitations water organizations experience. Also the wide-spread infrastructure posing as a challenge for digitalization. Therefore, a future study could examine how tariff-based financing impacts innovation within water organizations, encompassing the

size of the infrastructure in relation to paying customers as well as size of the water organization. The study would address the varying conditions across municipalities and shed light on how these factors affect digital experimentation and innovation initiatives.

Given that this study has indicated that smaller municipalities face greater challenges to digitalize compared to larger ones, it would be interesting to investigate the prerequisites for digitalization among smaller organizations specifically. Investigating these factors could reveal correlations between digitalization and municipal size, as well as shed light on the influence of motivated individuals within certain organizations.

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A

Interview Guide

The questions below have served as the foundation for the interview study. They have been adapted based on the progression of the conversation.

Roll och inställning
Role and attitude

- Vilken roll har du i vattenorganisationen?
  What is your role in the water organization?
- Beskriv känslan du får i kroppen när du hör ordet digitalisering (inom VA-sektorn) med tre ord.
  Describe the feeling you get when you hear the word digitalization (of the water industry) in three words.
- Hur skulle du beskriva digitalisering inom VA?
  How would you describe digitalization within the water industry?
- Skiljer ni på begreppen digitisering/digitalisering/digital transformation? Hur?
  Do you differentiate between the terms digitization/digitalization/digital transformation? If so, how?

Organisationens digitala arbete
The organization's digital work

- Har ni påbörjat arbetet med att digitalisera er verksamhet? Hur och varför?
  Have you initiated the process of digitalizing your operations? If so, how and why?
- Vad driver er digitaliseringsprocess?
  What drives your digitalization process?
- Vilka digitala lösningar/system använder ni?
  What digital solutions/systems do you use?
- Har ni någon plan på att implementera smarta mätare?
  Do you have any plans on implementing smart water meters?
- Har ni varit involverade i några projekt, både interna och/eller externa?
  Have you been involved in any projects, both internal and/or external?
- Finns det några ni samarbetar/samverkar med?
  Do you have any collaboration with other organizations?
- Vad anser du att ni lyckats med?
  What do you consider you have succeeded in?

- Vilka utmaningar och hinder upplever ni?
  What challenges do you experience?
- Vilka positiva effekter har ni sett av er digitalisering?
  What positive effects have you seen from your digitalization?

Vision och strategi
Vision and strategy

- Har ni någon vision/några mål för er digitalisering?
  Do you have any vision/goals for your digitalization?
- Har ni en strategi kopplat till visionen och målen?
  Do you have a strategy linked to the vision and goals?
- Hur är digitaliseringsarbetet organiserat?
  How is your digitalization work organized?

Förutsättningar för fortsatt digital utveckling
Needs for a continued digital development

- Vilka förutsättningar behöver ni för att accelerera ert digitaliseringsarbete?
  What prerequisites do you need to accelerate your digitalization efforts?
- Hur tror du att branschgemensamma standarder skulle påverka den digitala utvecklingen i branschen?
  How do you think industry standards would impact digital development in the sector?
- Vilka aktörer tror du blir viktiga att involvera för att ta fram standarder?
  Which stakeholders do you think will be important to involve in developing standards?
- Vem/vilka tycker du ska driva den digitala utvecklingen av sektorn?
  Who do you think should drive the digital development of the sector?
- Hur ser du på Svenskt Vattens roll?
  How do you view the role of Svenskt Vatten?

Branschens utveckling
Industry development

- Har du koll på hur andra vattenorganisationer arbetar med digitalisering?
  Do you have insight in how other water organizations are working with digitalization?
- Hur skulle du ranka ert digitaliseringsarbete i förhållande till övriga i branschen?
  How would you rank your digitalization efforts compared to others in the industry?
- Anser du att det är viktigt att vattenorganisationer ligger i ungefär samma fas i den digitala utvecklingen? Varför?
  Do you think it is important for water organizations to be in roughly the same phase of digital development? Why?

- Vems ansvar är det att organisationer inom sektorn hänger med i digitaliseringen?
  Whose responsibility is it to ensure that organizations within the industry keep up with digitalization?

Avslutande fråga
Concluding question

- Finns det något du vill lägga till?
  Is there anything you would like to add?

Kompletterande fråga som skickats över mail efter intervjun
Additional question sent via email after the interview

- Finns det avsatt tid eller initiativ till att organisationen ska jobba med innovation/kreativt tänkande/utvecklingsarbete gällande just digitala frågor, eller finns det planer på att implementera detta på något sätt?
  Is there allocated time or initiatives for the organization to work on innovation/creative thinking/development work regarding digital issues, or are there plans to implement this in any way?

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
DIVISION OF WATER ENVIRONMENT TECHNOLOGY
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2024
www.chalmers.se

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