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Undersökning av digitaliseringens värde inom vatten- och avloppsbolag

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Abstract

As water utilities encounter growing challenges, many are adopting new digital technologies and adjusting their digitalization strategies accordingly. However, despite potential benefits, digitalization efforts may be hindered by various challenges within the organization. This thesis investigates how value is created and captured through digitalization in water utilities. It also examines the specific challenges encountered during the digitalization process within this sector.

This study employs a qualitative approach, involving interviews with individuals within a water utility to understand their perspectives on value creation and value capture from digitalization. To gain an external viewpoint, interviews were also conducted with individuals outside the utility. In addition, several meetings were observed to examine how digital technologies were used and developed in practice.

The study identified how value was created and captured through digitalization in the water utility, as well as the challenges associated with these processes. These challenges not only constrained value creation and capture but also influenced how digitalization was perceived within the utility. The findings illustrate the complexity of digitalization within the water utility and how the integration of digital technologies can make value creation and capture more challenging. The study also emphasizes the importance of effectively managing and optimizing these processes to maximize the benefits gained from digitalization.

The study suggests several directions for future research, including how digitalization evolves based on factors such as the size or geographical location of the water utility. Further research could also focus on developing methods to evaluate the performance of digitalization in this context. Additionally, the study recommends that water utilities carefully consider the complexity of digitalization and the resources necessary to effectively manage and achieve strategic goals.

Key-words: *Digitalization, water utilities, value creation, value capture, integration, digital technologies, digital transformation*

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Undersökning av digitaliseringens värde inom vatten- och avloppsbolag

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Godkänt	Examinator	Handledare
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Sammanfattning

Vatten- och avloppsbolag står inför omfattande utmaningar i sitt uppdrag och förvaltning. Digitala verktyg och strategier för ökad digitalisering presenteras ofta fram som potentiella lösningar för att hantera dessa utmaningar. Digitaliseringen kan dock hämmas av olika barriärer inom vatten- och avloppsbolag. Denna studie undersöker hur värde skapas och utvinns genom digitalisering, samt vilka barriärer som begränsar framgång inom dessa bolag.

Denna studie använder en kvalitativ metodik och bygger på intervjuer med personer inom ett vatten- och avloppsbolag för att förstå deras perspektiv på värdeskapande och värdeutvinning genom digitalisering. För att få ett externt perspektiv genomfördes även intervjuer med personer utanför bolaget. Dessutom observerades flera möten i syfte att undersöka hur digitala verktyg används och utvecklas i praktiken.

Studien visar hur digitalisering bidrar till både värdeskapande och värdeutvinning inom ett vatten- och avloppsbolag, samtidigt tydliggörs de hinder som kan uppstå vid digitalisering. Resultaten visar att digitalisering inom vatten- och avloppsbolag är en komplicerad process. Dessutom upptäckts att integrationen av digitala verktyg kan göra det svårare att uppnå önskade effekter. Studien betonar vikten av att aktivt arbeta med att styra och effektivisera dessa processer för att fullt ut kunna ta vara på digitaliseringens potential.

Vidare föreslås framtida forskning som undersöker hur digitaliseringens utveckling påverkas av faktorer som organisationsstorlek och geografisk kontext. Det finns också ett behov av att utveckla metoder för att följa upp och utvärdera digitaliseringens effekter inom vatten- och avloppssektorn. Studien rekommenderar att organisationer inom branschen tar hänsyn till digitaliseringens komplexitet och säkerställer att resurser finns för att nå uppsatta strategiska mål.

Nyckelord: *Digitalisering, vatten- och avloppsbolag, värdeskapande, värdeutvinning, integration, digitala verktyg, digital transformation*

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List of Abbreviations

SCADA system - Supervisory Control And Data Acquisition system
HMI - Human-Machine Interface
PLC - Programmable logic controllers
GIS - Geographic information system
CIS - Customer information system

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Yonis Osman Bileh
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1. Introduction

This section of the report outlines the challenges faced by water utilities, followed by the problem statement, purpose, research questions, and delimitations.

1.1. Background

Water utilities in Sweden are responsible for supplying drinking water to consumers and transporting wastewater to treatment plants (Svenskt Vatten, 2023). Each municipality manages its own water utility, which oversees the maintenance and expansion of the pipeline and pump station network that supports these services. Water utilities deliver a vital service to society, which requires their asset management systems to be reliable, resilient, and safe, with the ability to respond effectively to system failures (Bennich, 2024b; Mounce, 2020). Although unexpected incidents can occur, water utilities are still required to maintain service delivery in accordance with legal requirements, and customer expectations (Bennich, 2024b). However, this is becoming increasingly difficult due to a growing range of challenges that constrain their ability to provide their services.

Water utilities face a variety of challenges in both operations and service delivery. These include the impacts of climate change, aging infrastructure, social pressures, population growth, urbanization, and ongoing policy reforms (Bennich, Engwall, and Nilsson, 2023; Garrido-Baserba et al., 2020; Mounce, 2020). Garrido-Baserba et al. (2020) emphasize that maintaining a reliable and sustainable water supply is essential for meeting future demands. However, as infrastructure continues to age, effective asset management becomes increasingly difficult. According to Bennich, Engwall, and Nilsson (2023), budget limitations, lack of incentives, and knowledge loss due to retirements hinder reinvestment and long-term planning. Svenskt Vatten (2023), the Swedish industry association, supports this view in its annual report, estimating that approximately 560 billion SEK will be needed for water infrastructure investments by 2040. The report also notes an annual shortfall of about 12 billion SEK, largely attributed to a substantial maintenance backlog. Mounce (2020) further argues that addressing these complex challenges requires a shift toward more flexible and adaptive operational approaches.

To address these challenges, the literature suggests using digital technologies and digitalization to support more efficient asset management (Bennich, 2024b; Mounce, 2020; Okwori et al., 2021). However, as Hoolohan et al. (2021) note, digital assets can also introduce new issues, including unintended consequences from data-driven decision making, cybersecurity risks, and difficulties in integrating new tools with legacy systems. As water utilities continue to adopt digital technologies and expand their digitalization efforts, new may emerge (Okwori et al., 2021). Furthermore, the complexity of managing these challenges increases as more processes become digitized (Gong and Ribiere, 2021; Okwori et al., 2021).

Previous research suggests that projects focused on improving data insights in the water sector are often difficult to justify, as infrastructure upgrades tend to be prioritized (Mounce, 2020). Capturing value from digitalization becomes more difficult when digital technologies and data are insufficient or poorly managed, as this can result in incorrect assumptions and potentially costly decisions for the organization (Arnell, Miltell, and Olsson, 2023).

In addition, Grover et al. (2018) highlight that organizations often encounter difficulties in creating value from digitalization projects. They observe that many fail to progress beyond the experimental stage of big data initiatives, with pilot projects frequently being discontinued. Similarly, Boyle et al. (2022) note that water utilities face significant challenges in both developing and implementing digital initiatives. Bennich (2024a) further observes that introducing new solutions that differ from the existing operational environment is challenging, especially since water utilities often face difficulties with system integration and data sharing.

The cycle of challenges in creating and capturing value from digitalization presents major problems for water utilities that are either beginning or advancing their digitalization efforts.

1.2. Problem formulation

The importance of digitalization as a solution to the challenges faced by water utilities is growing. To enhance the efficiency of asset management, water utilities are adopting new digital technologies to help address operational challenges. These technologies support utilities in meeting service expectations and complying with regulation within their specific operating contexts (Bennich, 2024a; Boyle et al., 2022; Mounce, 2020). However, water utilities continue to struggle with adopting digital technologies and successfully navigating their digitalization journey (Bennich, 2024a; Mounce, 2020). Additionally, validating digitalization initiatives is challenging due to their perceived uncertainty (Mounce, 2020). Although previous studies have addressed this topic to some extent, further research is needed to explore the value of digitalization in water utilities and the specific challenges they face in creating and capturing that value.

Earlier research on value, data, digitalization, and digital transformation such as Chesbrough, Lettl, and Ritter (2018), Grover et al. (2018), Günther et al. (2017) and Correani et al. (2020) offer insights into how organizations can create and capture value from technology and innovation. However, these studies primarily focus on customer-facing, private sector organizations with capabilities that differ from those of water utilities.

Water utilities in Sweden operate under public governance as nonprofit entities managed by municipalities (Bennich, 2024a; Svenskt Vatten, 2023). This organizational structure and business model differ significantly from those of private, profit-driven organizations. As a result, there is a need for further research into the value digitalization can create within public organizations such as water utilities.

1.3. Purpose

This study aims to explore the value of digitalization in a water utility and to identify the challenges associated with capturing and realizing this value.

1.4. Research question

To achieve the purpose of the study, the following two research questions will be answered:

1. **How does a water utility create and capture value from digitalization?**

2. **What challenges do water utilities face in creating and capturing value from digitalization?**

Given the challenges water utilities face and the complexity of digitalization, it is crucial to understand how these organizations create and capture value from digitalization. To investigate this, a case study was conducted at a water utility.

1.5. Delimitation

This study examines the perceived value of digitalization among representatives of a water utility in a Swedish city with a population of approximately 100,000. It also acknowledges that broader perceptions of digitalization may be influenced by environmental, social, and geographic factors. The findings are primarily based on insights from operations and maintenance teams responsible for delivering drinking water and managing wastewater transport. Treatment plants are excluded from the study due to their distinct operational characteristics, and capabilities.

2. Literature review

This chapter presents the literature used to analyze digitalization and
the value of digitalization, in the context of water utilities. It explores frameworks that define the phenomenon of digitalization and examines how value creation and capture can occur from it.

2.1. Digital technologies in water utilities

Digital technologies are defined in similar terms in most business, management or information systems literature. Vial (2019) refers to the SMACIT acronym (Social, mobile, analytics, cloud and internet of things - IoT) when defining these technologies. Legner et al. (2017) uses a similar acronym, SMAC (social, mobile, analytics and cloud computing) when describing digital technologies. Fitzgerald et al. (2014) defines digital technologies in similar terms (social media, mobile technology, analytics, or embedded devices). The slight variations in these acronyms across the articles may reflect the evolving context in which they were written. In later years IoT has gradually gained greater recognition alongside other digital tools over time (Vial, 2019). This is similar for water management literature that discusses digital technologies. The SMACIT acronym is referred to in water management literature such as Bennich (2024a), Boyle et al. (2022), and Aivazidou.

However, the SMACIT acronym is not referred to in certain water ICT and Science & Technology literature. In Garrido-Baserba et al. (2020) article digital technologies are not defined with the SMACIT acronym. Instead, each component of the acronym or similar linked terms are used such as “communication technologies, and social media”, “big data analytics”, “cloud services” and “affordable sensors”. In Mounce (2020) article the SMAC acronym isn’t used however terms such as “Data Analytics”, “Cloud Computing”, “Internet of Things and Edge Computing” and “Blockchain, Data Sharing and Web 3.0” are discussed in depth. Despite the differences in these articles, the literature agrees on what is defined as “digital technologies” as these technologies continue to change industries and society.

In this study, digital technologies are defined in alignment with definitions found in both water business and management literature, following the SMACIT acronym. When these technologies are applied within specific organizational contexts, they are referred to as digital tools.

Digital tools are used to manage assets in water utilities. They are for example used to optimize processes, obtain data, enhance information, knowledge, collaboration and communication in organizations, science and society (Legner et al., 2017, Mikalef et al., 2017; Vial, 2019). Mikalef et al. (2017) note that digital tools can connect people, devices and sensors which can transform how organizations operate. In the water industry, digital tools can be used to amass data, analyze, and optimize, facilities, processes and operations. According to Mounce (2020) digital technologies can be used to improve visualization of information, automate tasks, and enhance decision making in water utilities.

Digital technologies continue to be developed and utilized at a greater pace in organizations and society. Vial (2019) writes that disruptions (for incumbent market leaders) and changes become more common with digital technologies, as these technologies continue to develop. According to Legner et al. (2017) "*...miniaturization, combined with ever-increasing processing power, storage capacity, and communication bandwidth…*" in digital technologies has led to significant changes in organizations and society. These technologies continue to develop and change water utilities and their operations (Garrido-Baserba et al., 2020). Bennich (2024b) writes "*…digital technologies, impact various sociotechnical systems in distinguishable ways depending on the transformative capacity of the new technologies themselves and the adaptability of the existing system at hand…*". Meaning the impact and outcomes of digital technologies depend not only on the technologies themselves but also on the adaptability and flexibility of water utilities. Therefore, digital technologies give rise to a broader phenomenon.

2.2. Digitization, digitalization and digital transformation in water utilities

Digitization, digitalization and digital transformation (DT) are phenomena that are often brought up when describing the impacts and outcomes digital technologies bring to organizations and society (Gong and Ribiere, 2021; Kraus et al., 2021; Plekhanov, Franke and Netland, 2023; Vial, 2019; Verhoef et al., 2021). These phenomena are discussed across a wide range of research fields, including but not limited to business, strategy, technology, material science, manufacturing, management, finance etc. In the water literature, these phenomena are widely explored to illustrate the impact and outcomes of digital technologies (Aivazidou et al.,2021; Bennich, 2024a; Boyle et al., 2022; Garrido-Baserba et al., 2020; Mounce, 2020). Depending on the context, these phenomena are described using both similar and divergent terms (Gong and Ribiere, 2021; Gradillas and Thomas, 2023).

Digitization refers in literature to the process of changing analog information to digital data (Gong and Ribiere, 2021; Kraus et al., 2021; Legner et al., 2017; Plekhanov, Franke and Netland, 2023; Vial, 2019; Verhoef et al., 2021). This corresponds with the way it is described in some water management literature (Bennich, 2024a; Boyle et al., 2022). However, Aivazidou et al. (2021) use the terms digitization and digitalization interchangeably. Simultaneously in water ICT and Science & Technology literature such as Mounce (2020), the two terms are also described interchangeably. Garrido-Baserba et al. (2020) do not mention the term digitization. The importance of this term is that it explains the outcome of using digital technologies in a single process or operation (Verhoef et al., 2021).

Digitalization describes the outcome of reinforcing existing value propositions, either by integrating digital tools or using them as a network of processes (Vial, 2019; Verhoef et al., 2021; Gong and Ribiere, 2021). Verhoef et al. (2021) highlight that digitalization consists of using digital tools, agility and capabilities, pointing to the fact that digitalization is not only focused on cost savings but also the efficiency of several processes. According to Gong and Ribiere (2021) digitalization can automate processes, reduce costs, errors, and increase customer experience.

Digitalization in water utilities is described in similar terms (Aivazidou et al.,2021; Arnell, Miltell and Olsson, 2023; Bennich, 2024a; Boyle et al., 2022; Garrido-Baserba et al., 2020;

Mounce, 2020). According to Boyle et al. (2022) digitalization in water utilities leads to increased efficient processes by "digitalization of technologies" (Boyle et al., 2022). Further highlighting that managers need to be careful "not underestimating the cost, and risk associated with digitalization of technology" (Boyle et al., 2022). Bennich (2024a) also describes the increased efficiency in processes due to digitalization. Aivazidou et al. (2021) also note that "*digitalization improves efficiency and flexibility*" (Aivazidou et al.,2021). However, Boyle et al. (2022) is the only source to highlight the monetary value of using digital tools in water utilities, emphasizing the push for greater impact and outcomes from digitalization.

Digital transformation (DT) is often defined as an all-encompassing change on a societal level, due to digitalization of technologies (Gong and Ribiere, 2021; Kraus et al., 2021; Legner et al., 2017; Plekhanov, Franke and Netland, 2023; Vial, 2019; Verhoef et al., 2021). Vial (2019) defines DT as, "... *a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies…*" (Vial, 2019). The definition of DT Gong and Ribiere (2021) introduce is also similar, "*A fundamental change process, enabled by the innovative use of digital technologies accompanied by the strategic leverage of key resources and capabilities, aiming to radically improve an entity and redefine its value proposition for its stakeholders.*" (Gong and Ribiere, 2021). Some water research use similar terminology to describe DT. According to Bennich (2024b) "*digital transformation is used to denote the process of (significant) change.*" citing Vial (2019). Boyle et al. (2022) argues that DT encapsulated a large transformative change in water utilities. Garrido-Baserba et al. (2020) and Mounce (2020) don't define DT but indicate the larger outcome that occurs compared to digitalization, by describing more stakeholders and figures outside water utilities partaking in the transformation. According to Hoolohan et al. (2021) DT can bring negative effects to water utilities. As the responsibility of the infrastructure can become obscure and marginalized groups can suffer from decision making that happens due to existing systems that might miss the needs of these groups. Thus, so far the outcome of DT appears to be complicated and hard to describe.

This uncertain definition of DT affects the assessment of the phenomena. Kraus et al. (2021) writes "*The DT concept needs to be differentiated from digitization. Also described as 'digitalization' in some research … DT refers to changes arising from digital technologies, whereas digitization refers to the conversion of information from analog to digital form, and the automation of processes through information technologies*" (Kraus et al., 2021). Which shows another way to define DT.

The varying definitions and conceptual ambiguities make it challenging to evaluate the outcomes of these phenomena. Researchers in business, management or information systems emphasize that multiple interpretations of digital transformation exist (Vial, 2019; Verhoef et al., 2021; Gong and Ribiere, 2021). Vial (2019) notes "unclear terminology, and the conflation of the concept and its impacts, among other challenges, hinder the conceptual clarity of DT". Parviainen et al. (2017) write "*According to literature, digitalization, or digital transformation, refers to 'the changes associated with the application of digital technology in all aspects of human society'...*" (Parviainen et al., 2017). However, Parviainen et al. (2017) note that DT is an outcome of digitalization as organizations position themselves to digitalize in their proposed framework for "tackling digital transformation".

Given the complexity of these phenomena, it is important to clarify how they are understood within the context of this thesis. Not only are they technically intricate, but they are also conceptually ambiguous, making them difficult to define and interpret. The existence of multiple perspectives in both research and industry further contributes to this confusion. As Vial (2019) notes, such ambiguity can hinder efforts to clearly define the impact of these concepts.

For the purpose of this study, digitalization is defined as the enhancement of existing value propositions through the integration or coordination of digital technologies. In contrast, digital transformation is understood as a broader, organization- or industry-wide change enabled by digital technologies. Therefore, this study focuses on digitalization to examine the value it creates and how that value can be captured in the context of a water utility.

2.3. Creating and capturing value from digitalization

Defining the value of implementing, coordinating or integrating digital technologies is challenging, like the valuation of other intangible assets. Depending on the context, the outcomes of digital technologies can be understood as value-in-use, or as value-in-exchange when traded for other resources (Bowman and Ambrosini, 2000; Chesbrough, Lettl, and Ritter, 2018; Vargo, Maglio, and Akaka, 2008). From a resource-based perspective, value-in-use and value-in-exchange are distinguished by the point at which the value is realized (Bowman and Ambrosini, 2000). While value is traditionally created and exchanged at the point of sale, this resource-based view falls short when applied to digital technologies and digitalization in water utilities.

According to Chesbrough, Lettl, and Ritter (2018), value is defined as "*actor-perceived consequences arising from the deployment of a resource in a process*". They emphasize the various dimensions of these consequences, extending beyond monetary evaluation, particularly in the context of open innovation. Chesbrough, Lettl, and Ritter (2018) also highlight that value can be categorized as either *value-in-use* or *value-in-exchange*, depending on the context and timing of the process. These forms of value are then either created or captured.

The concept of value-in-use from digitalization is intended to enhance the existing value proposition within the organization. In contrast, value-in-exchange is often more relevant to external stakeholders, such as technology developers and consultants, who operate outside the water utility. This study focuses specifically on value-in-use from digitalization, as it holds greater significance for water utilities, which in this case provide public services and operate as non-profit entities in Sweden.

As previously stated in Chapter 2.2, water research by Aivazidou et al. (2021), Bennich (2024a), and Boyle et al. (2022) highlights that digitalization enables water utilities to enhance decision making and improve process outcomes, particularly through increased efficiency. Following Grover et al.'s (2018) model for assessing value created from big data analytics, the value from digitalization can be understood as strategic value, which is further categorized into symbolic and functional value (see figure 1).

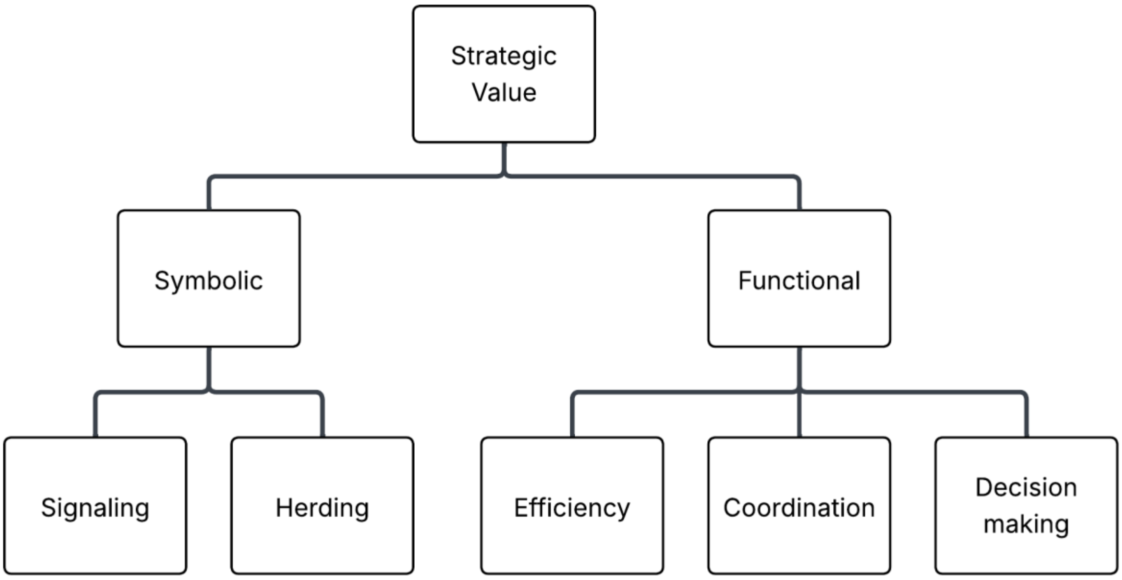

Figure 1 The functional and symbolic value factors that form the strategic value of data analytics (Grover et al., 2018).

Using Grover et al. (2018) as a framework, digitalization can create both functional and symbolic value for the organization. This value-in-use enhances efficiency, coordination, and decision making. While also contributing to symbolic outcomes such as signaling the organization’s strategic direction and fostering herding behavior, where stakeholders align with that direction. Drawing on the resource-based view presented by Bowman and Ambrosini (2000), customers of a water utility may experience an increase in consumer surplus because of efficiency gains that might enable lower prices.

Another key aspect of value-in-use from digitalization is the portability and interconnectivity of data, which is integrated and coordinated in different ways. According to Günther et al. (2017), portability refers to the ability to transfer and remotely access digitized data across different application contexts, while interconnectivity involves the synthesis of data from multiple big data sources. The ability to repurpose data beyond its original intent, as well as to integrate data from multiple sources, is a significant advantage enabled by digitalization.

In the context of water utilities, value-in-use from digitalization can be captured through ongoing activities, processes, and the involvement of human operators who deliver services (Ben-Dak Valtzer, 2023). According to Vargo, Maglio, and Akaka (2008), value-in-use is particularly relevant as it can be defined as system improvement within a specific context or the enhancement of capabilities. In the service-dominant logic, this is also considered a form of value creation. This corresponds with Ben-Dak Valtzer (2023) description of the digitalization journey of water utilities as it involves people, processes and digital technologies.

To capture value from digitalization, Parviainen et al. (2017) propose a model that addresses how to effectively benefit from digitalization and digital transformation in practice. The first step of this model involves analyzing the potential impact and determining the organization's desired position based on its context. The second step is to assess the current state of the organization and identify gaps between the present situation and the desired future. The third step involves reviewing the actions required to bridge the gap, which includes analyzing different scenarios, evaluating the feasibility of these scenarios based on risks, current capabilities, and necessary actions. The fourth step focuses on implementing and validating actions, with the possibility of revisiting earlier steps if needed. The model is designed to be iterative, with a focus on gradually refining and assessing digitalization goals and strategies.

According to Correani et al. (2020), effective implementation of digitalization and digital transformation requires a strong alignment between strategy formulation and strategy implementation within the organization. In this model Correani et al. (2020) identify building blocks that enable capturing value, in the context of DT. These building blocks include: the scope of the transformation, data sources (both internal and external), data platforms, people, partners, artificial intelligence, information and knowledge, processes and procedures, transformed activities, and customers. Their model serves as a guiding framework to help organizations capture value from digitalization, acting like a checklist to ensure that all critical aspects are considered and addressed. What sets the model by Correani et al. (2020) apart from the one introduced by Parviainen et al. (2017) is its stronger emphasis on people, partners, and customers.

To conclude this section, the value of digitalization in the context of water utilities is best understood as value-in-use. Organizations can capture this value by strategically planning and implementing changes in their processes and activities as described by Parviainen et al. (2017) and Correani et al. (2020). For the water utility, this can result in the creation of value, as described by Grover et al. (2018). Digitalization can also lead to compounding effects, where increased portability and interconnectivity of data enable additional value creation and capture, as outlined by Günther et al. (2017).

Despite the benefits of digitalization, many organizations have struggled to achieve their intended outcomes, even after investing significant resources in data-driven decision making (Grover et al., 2018). Therefore, it is important to understand the challenges of capturing and creating value from digitalization.

2.4. The challenges of creating and capturing value from digitalization

According to Correani et al. (2020), many digital transformation projects fail due to a lack of alignment between strategy formulation and strategy execution. They emphasize that a digital strategy must be closely integrated with the firm’s business model to ensure that changes are driven by actual organizational needs. The scope of the transformation should reflect these needs, and the strategy should be designed accordingly. Correani et al. (2020) argue that organizations cannot realize the benefits of DT unless the strategy is effectively implemented.

An important consideration is that Correani et al. (2020) conducted their case studies on three global, publicly traded, for profit companies: Vodafone, CNH Industrial, and ABB. These organizations also received support from Microsoft during their DT initiatives. This raises the question of whether the guidelines derived from these cases are applicable to contexts such as Swedish water utilities, which are municipally operated and run as public organizations.

Poláková-Kersten et al. (2023) emphasize that for high reliability organizations (HROs) to fully benefit from DT, they must understand their position in the process and coordinate their efforts effectively. They point out that HROs need to adopt a risk-aware mindset, demonstrate strong leadership, and consider the pace of transformation, including a willingness to tolerate failure and embrace new working methods. However, the authors also caution that digitalization may conflict with the core identity of these organizations, potentially hindering the successful implementation of digital solutions.

As digitalization demands new ways of working, it may conflict with the established practices of water utilities. Garrido-Baserba et al. (2020) point out that digital tools and technologies introduce a level of complexity that these organizations may have limited experience managing. They also note that the water sector deals with inherently complex challenges "due to its multidisciplinary nature," which can influence the effectiveness of implementing digital technologies within such organizations (Garrido-Baserba et al., 2020). Hoolohan et al. (2021) argue that the insights generated by digital technologies in the water sector should be critically examined, as the solutions themselves may be flawed. For instance, they suggest that these technologies might simply reinforce existing assumptions rather than offering new perspectives. Such limitations can hinder the value that water utilities are able to capture and create from digitalization.

Parviainen et al. (2017) note that for their model to be successful organizations need to analyze their current state thoroughly, conduct a risk and scenario analysis, build a roadmap and implement and evaluate their journey. They emphasize that a lack of clarity about the organization's position can result in a failure to recognize whether the current business model is at risk of becoming obsolete or what actions might be necessary to prevent this. It may also lead to a misunderstanding of the potential impacts, costs, and risks associated with digitalization. Without proper scenario planning and risk analysis, it becomes difficult to define meaningful goals based on the organization's current state (Parviainen et al., 2017).

Nevertheless, it's important to recognize that water utilities typically do not view their business as being at risk of becoming obsolete. Instead, their focus is on optimizing operations and enhancing resilience and flexibility (Okwori et al., 2021). While Parviainen et al. (2017) argue that organizations should assess their digitalization positioning to avoid having their business models rendered obsolete by new entrants, this concern may be less relevant for water utilities, given the nature of their role and market structure.

Parviainen et al. (2017) also stress that without first assessing a baseline of the digitalization strategy, it becomes difficult to evaluate progress or future developments. They further emphasize that digitalization is not a one-time effort but an ongoing process that requires continuous adaptation and refinement to keep pace with evolving demands in the business environment. Poláková-Kersten et al. (2023) highlight a tension between the demands of digitalization and DT initiatives and the traditional ways in which HROs operate.

Another important consideration, as noted by Günther et al. (2017), is that creating value from data becomes difficult if issues of portability and interconnectivity are not addressed. For example, data confined to a specific context and not easily transferable or applicable across different settings can limit its usefulness and broader impact. Okwori et al. (2021) highlight that key challenges preventing water utilities from adopting data-driven decision support tools include limited data availability and a lack of interoperability between existing and new data models. However, they also note that not all systems or datasets need to be fully interoperable and caution that greater interoperability could increase the exposure of municipal systems to cybersecurity threats and risks.

Grover et al. (2018) emphasize that understanding the root causes of problems is essential for implementing effective solutions that create value from data. Factors such as data quality, integration, security, analytics capabilities, and human expertise all play a critical role (Grover et al. 2018). This is also highlighted to be important in the digitalization journey in water utilities (Bennich, 2024b; Boyle et al., 2022; Garrido-Baserba et al., 2020; Mounce, 2020).

Water utilities continue to struggle with capturing and creating value from digitalization. Mounce (2020) points out that investment in physical infrastructure often takes precedence in water utilities, making it difficult to justify efforts to improve data quality. Similarly, Parviainen et al. (2017) argue that the identity of HROs may conflict with the demands of digitalization. The challenges highlighted in literature focused on private, for profit organizations may not fully reflect the context of water utilities, potentially limiting our understanding of how these organizations create and capture value from digitalization. This underscores the need for a clearer understanding of how water utilities create and capture value from digitalization.

3. Method

This chapter outlines the selection of the case study and details the chosen methodology, explaining the research approach and execution. This chapter also describes data collection and data analysis methods. In addition, it assesses the research quality of the study and considers ethical and sustainability aspects.

3.1. Research Design

This study adopted a qualitative, exploratory case study approach to gain a deeper understanding of digitalization within the water utility. The research was divided into two phases: a pre-study phase and a main study phase. This structure reflected the evolving nature of both the literature review and the research problem.

The pre-study phase, through initial interviews, helped to frame and clarify the research problem, while the literature review identified gaps in existing knowledge and refined the study's focus. The main study phase built on this foundation, providing a more in-depth exploration of the research problem (Saunders et al., 2015). Together, these phases offered a comprehensive view of the water utility's current position in its digitalization journey.

The findings from the exploratory study were primarily grounded in empirical evidence and aimed to contribute to theory through analytical interpretation rather than through the data alone (Blomkvist and Hallin, 2015). The empirical findings served as a foundation, but it was the reasoning and analysis built upon them that generated theoretical insights.

To support this analysis, a review of existing literature on digital transformation, digitalization, value, and the water sector provided a reference point for understanding the academic landscape. By drawing on these bodies of literature, the study enabled a synthesis that contributes to ongoing theoretical discussions in the field.

An exploratory qualitative approach offered the potential to contribute new empirical insights into a phenomenon that has been previously under-researched. Following the recommendation of Blomkvist and Hallin (2015), this study adopted an abductive approach, which was well-suited for research where empirical findings played a central role in shaping understanding. This approach involved alternating between inductive and deductive reasoning throughout the research process, allowing new explanations to emerge or be examined in greater depth as the study evolved. It also supported a flexible approach to data collection, enabling adjustments to be made in response to new insights gained through observations, interviews, or informal meetings.

The qualitative aspects of this study involved conducting interviews to explore organizational challenges, internal processes, and the key enablers of digitalization. These interviews also provide insight into how digital tools were developed, adopted, and perceived within the water utility following their implementation. In addition, participation in meetings allowed direct observation of stakeholder interactions and decision making processes, offering valuable context for how digital initiatives are introduced and discussed in practice.

For these reasons, a single case study was an appropriate research design for the study, as it enabled a deep understanding of the implementation of digitalization, the value it created, and how that value is captured. It also provided insight into the changes that occur over time as digitalization develops in the water utility. As highlighted by Eisenhardt and Graebner (2007) and Blomkvist and Hallin (2015), a single case study was particularly suitable when significant change occurred under unique conditions that may not be easily replicated. This approach allowed for a rich, in-depth analysis of a water utility's actions, supporting the development of detailed empirical insights.

3.1.1. Selection of the case

The barriers and enabling factors for digitalization in the Swedish water sector represented an area of cross-disciplinary collaboration. Which involved private companies, public organizations, government-funded research institutions, and municipalities. The case selected for this study was a water utility that recently implemented several digital tools. These tools could sometimes serve as pilot initiatives for future digital tools as part of the utility's broader digitalization.

Previous studies, such as Arnell, Miltell, and Olsson (2023), had recommended the use of pilot projects to promote further digitalization in water utilities. Additionally, research by Bennich (2024a), Hoolohan et al. (2021), and Mounce (2020) had shown that water utilities were increasingly adopting a variety of digital tools and that the sector was actively undergoing digitalization in different contexts.

This ongoing digitalization made water utilities a relevant and timely subject of study for understanding digitalization within the sector. As they continue to implement new digital tools and adapt their organizational practices accordingly (Hoolohan et al., 2021).

A distinctive aspect of this study was that the water utility only recently began implementing several digital tools: Smart Reports in late 2023, VA-banken at the end of 2024, and Leak Detector in early 2025. This provided an opportunity to gain deeper insight into the changes introduced by these digital tools and how they had been integrated into everyday practices. Unlike studies focused solely on pilot phases, this case study captured the post-implementation stage. Where evaluation, adaptation, and ongoing improvements took place to better understand how the full value of such digital tools could be captured.

3.1.2. Pre-study phase

The pre-study phase involved gathering data from the water utility's internal documentation, as well as collecting qualitative data through interviews and meeting observations. This phase began with participation in an informal introductory meeting with key individuals within the organization, followed by attendance at a project meeting focused on the "Smart Reports" tool, which included external technology suppliers. Additionally, weekly maintenance group meetings were observed, which offered valuable insights into ongoing digitalization efforts and the operational challenges faced by the utility.

Alongside this data collection, a review of relevant literature was conducted to better define and refine a research problem that aligns with the context of the study.

3.1.3. Main study phase

The main study phase built upon the insights gained during the pre-study, incorporating additional findings from interviews, meeting observations, and literature review to further explore digitalization within the water utility. This phase is designed to deepen the understanding of the research problem, enabling more focused and insightful interviews as the study progresses and the research focus becomes more refined. Interviews were conducted using semi-structured interview guides.

The literature review was conducted concurrently to help interpret emerging findings and adjust the research focus as new insights developed during the study.

3.1.4. Literature review

A critical literature review formed the foundation of this study, linking key theories and debates relevant to digital transformation, digitalization and value creation/capture in water utilities. As Saunders et al. (2015) highlights that a literature review should not merely summarize past research but critically assess its relevance, value, and sufficiency.

Literature was selected using boolean search logic to ensure precision and relevance. Throughout the review process, key questions that originate from Saunders et al. (2015) guided the analysis: Why is this source relevant? What is the author conveying? How convincing is the argument? How does it apply to this research? Each source was assessed based on relevance, value and sufficiency (coverage of key debates). The literature review was conducted using a range of academic databases, including Web of Science, Google Scholar, and Elsevier.

The search phrases used were:

First iteration
digitalisation OR digitalization OR digital transformation

Second iteration
water utilities OR water management OR water infrastructure OR smart water systems

Third iteration
"digitalisation" OR "digitalization" AND "water utilities" OR "infrastructure" AND "value creation" OR "economic impact" OR "efficiency gains" OR "performance"

Fourth iteration
"digitalisation" OR "digitalization" OR "digital tools" OR "data base" AND "water utilities" OR "infrastructure" AND "predictive maintenance" OR "proactive maintenance" OR "performance"

Fifth iteration
"digitalisation" OR "digitalization" OR "digital tools" OR "data base" AND "water utilities" OR "infrastructure" AND "value" OR "benefits" OR "performance" OR "digitalization benefits" OR "resource based view" OR "service dominant logic"

By synthesizing insights from prior studies, this review established a theoretical basis for understanding digitalization in water utilities. Identifying gaps in existing research, it also provided the necessary foundation for exploring how digitalization and digital transformation influence water utilities and their decision making and strategies.

3.2. Data Collection

Data was collected through meeting observations, interviews, and documents. This approach aimed to map the changes resulting from the implementation of digital tools and to understand how these tools and related changes impact both the sub-unit and the broader organization.

3.2.1. Meeting observations

Meetings were used in this study to gain insight into the organization's ongoing digitalization, how digital tools are implemented and used across different teams, and how these tools were received and discussed by various stakeholders. In most meetings, I took on the role of a silent observer, sitting in the background and taking notes while participants interacted and engaged with the tools in real time. The table below provides an overview of the meetings.

Table 1: Meetings overview

Meeting	**Type of meeting**
M1	Introduction meeting
M2	Operational development
M3	Peer-to-peer training session
M4	Supplier meeting
M5	Operational development
M6	Maintenance strategy planning
M7	Weekly maintenance group meeting
M8	Weekly maintenance group meeting
M9	Weekly maintenance group meeting
M10	Weekly maintenance group meeting
M11	Operational development

Observing these meetings provided insight not only into how users interacted with digital tools, but also into how the group collectively perceived their benefits and impact on the organization.

3.2.2. Interviews

A total of 14 interviews were conducted across the two phases of the study. During the pre-study phase, interviews primarily followed unstructured and semi-structured formats. While in the main study phase, semi-structured interview guides were predominantly used.

Participants were selected based on the subunits they worked in, particularly those involved in maintenance and operations. Individuals involved in the digital infrastructure needed for digital asset management, such as automation technicians responsible for sensor installation and participation in tactical and strategic meetings, were also included.

In addition, one external process engineer from the supplier that developed digital tools for the water utility was interviewed. Engineers from other subunits within the organization were also interviewed to gain broader perspectives on the digitalization underway in the water utility and how these changes were perceived internally. To provide an external comparison, a development engineer from another water utility in a different municipality was also interviewed to explore how digital tools were being used in their context.

3.2.2.1. Pre-Study Phase Interviews

Six exploratory interviews were conducted during this phase, using a combination of unstructured and semi-structured formats to gather insights on maintenance operations, asset management, automation, and the adoption of new technologies. These interviews also helped refine the interview guide, as some questions proved to be either irrelevant or unclear to participants and were adjusted accordingly. See the table below for more information.

Table 2: Pre-study interviews

Interview number	**Participant**	**Role/s**	**Organization**	**Date (YYYY-MM-DD)**	**Location**	**Approx Duration (minutes)**
1	PSP1	Maintenance Manager	Utility A	2025-01-31	Digital/Teams	45
2	PSP1	Maintenance Manager (following a leak) incident)	Utility A	2025-02-05	Digital/teams	20
3	PSP2	Automation Technician	Utility A	2025-02-07	Digital/Teams	60
4	PSP3	Automation Manager	Utility A	2025-02-07	Digital/teams	50
5	PSP4	Maintenance Technician	Utility A	2025-02-12	Digital/Teams	30

6	PSP5	Process Engineer	Technology supplier	2025-02-25	Digital/teams	60

PSP=Pre-study participant

3.2.2.2. Main Study Phase interviews

During this phase, the interviews offered deeper insights into organizational dynamics, digitalization, and the tools and processes supporting maintenance and asset management. See the table below for details.

Table 3: Main study interviews

Interview number	Participant/s	Role/s	Organization	Date (YYYY-MM-DD)	Location	Approx Duration (minutes)
7	WUA1, WUA2	Development Engineer, GIS Engineer	Utility A	2025-03-28	Digital/teams	60
8	WUA3	Maintenance Technician	Utility A	2025-04-02	Digital/teams	55
9	WUA4	Automation Technician	Utility A	2025-04-03	Digital/teams	60
10	WUA5	Maintenance Engineer	Utility A	2025-04-03	Digital/teams	70
11	WUA6	Maintenance Manager	Utility A	2025-04-08	Digital/teams	70
12	WUA7	Maintenance Engineer	Utility A	2025-04-09	Digital/teams	50
13	WUB1	Development Engineer	Utility B	2025-04-15	Digital/teams	60
14	WUA8	Maintenance Technician	Utility A	2025-04-16	Digital/teams	35

DS = Digital solution provider, WUA = Water utility A, WUB = Water utility B

To provide context for the digitalization within the water utility and the tools being used, a paired interview was conducted (Interview 7) with engineers from other subunits. This group setting allowed for a deeper understanding of how digital tools are used in different contexts within the organization and offered the opportunity to observe how the participants discussed and reflected on digitalization together.

3.2.3. Informal observations

Informal, non-participant observations were carried out throughout the course of this thesis during a 20-week insider placement at the water utility in the spring of 2025. During this period, I held informal conversations with key individuals across various departments, discussing their use of digital tools and their understanding of the organization’s digital strategy. I also spoke with technicians during periods of downtime to gain insights into how they perceived the ongoing digitalization based on their experiences within the organization.

While note-taking was generally not conducted during these informal interactions, I occasionally documented key points afterward when the information was considered relevant to the study. These notes served to establish a chain of evidence supporting the study’s findings.

3.2.4. Documents

The water utility’s maintenance and digitalization strategy document (referred to as MDSD in this report) was obtained for this study. It was developed throughout 2024 and finalized at the end of 2024. The document outlined plans and development strategies for the period 2025 to 2030 and presents a long-term vision extending from 2036 to 2050. Its framework is based on the recommendations provided by Svenskt Vatten (Swedish Water) in publication P113, *“Effektivt underhåll av VA-system”* (*“Effective Maintenance of Water Utility Systems”*). The 16-page document includes sections on background, methodology, strategic direction, and priorities for 2025–2030. It also includes a discussion of the implementation phase, and a summary.

3.3. Data Analysis

The abductive approach facilitated a flexible interaction between literature and empirical findings. Data collected through interviews, meetings, and observations was continuously compared with existing research and analyzed throughout the data collection process. This adaptive methodology allowed for the identification of several unexpected and insightful discoveries.

The qualitative data and documents were analyzed using thematic analysis, which is particularly effective for understanding the outcomes of themes from a phenomenon (Braun and Clarke, 2006; Saunders et al., 2015). These themes were identified systematically from key concepts in literature, interviews, and documents.

Data analysis began with the initial coding and categorization of information gathered from meetings, interviews, and document analysis. The value captured and created from digitalization was analyzed using the frameworks proposed by Chesbrough, Lettl, and Ritter (2018), Correani et al. (2020), Grover et al. (2018), Günther et al. (2017) and Parviainen et al. (2017). The result and analysis then focus on the consequences of digitalization as perceived by different actors. Additionally, the challenges that limited the creation and capture of value from digitalization were identified through themes expressed by study participants. These themes were further supported by value related literature mentioned above and water sector literature such as Bennich (2024a), Garrido-Baserba et al. (2020), Mounce (2020), and Okwori et al. (2021).

The themes identified from the qualitative data were subsequently categorized as either value created from digitalization, value captured from digitalization, or challenges that hinder the creation or capture of value. In chapter 5.1 the value created from digitalization, based on the perspectives of various individuals within the water utility was explored. Chapter 5.2 examined how the water utility captured value from digitalization, based on strategic planning, internal documents, and stakeholder perspectives. Chapters 5.3 and 5.4 examined the challenges that hindered the creation and capture of value. The findings were then re-coded and organized into second order categories within their respective chapters.

This approach provided a comprehensive understanding of the connections between literature and qualitative data.

3.4. Research Quality

The quality of the methods employed, and the analysis of the findings had to be assured. Therefore, the study's validity and reliability were carefully considered when evaluating its overall quality (Blomkvist and Hallin, 2015).

3.4.1. Validity

This case study involved a single water utility, and it is important to acknowledge this as a limitation. The limited scope may restrict the inclusion of perspectives from other water utilities with different organizational cultures and contextual factors, potentially affecting the representativeness of the findings.

Despite these constraints, the study offers valuable qualitative insights. The in-depth experiences and perspectives contribute meaningfully to understanding the strategic value of digitalization, as well as the barriers that hinder its realization. The detailed focus of the case study enabled forms of analysis that are often difficult to achieve, such as observations of weekly and strategic meetings. Combined with the review of strategic documents, this approach provided a comprehensive and nuanced understanding.

Additionally, input from a development engineer at Water Utility B and a representative from the technology supplier introduced external viewpoints that enriched the qualitative data. This diversity of perspectives, both internal and external, enhanced the validity of the findings and strengthened the overall understanding of the case.

3.4.2. Reliability

Standardized procedures for data collection and analysis were implemented to ensure high reliability throughout the case study. During the pre-study phase, consistent interview questions were used, informed by an initial review of the literature. As deeper insights were gained, the questions were refined to better capture relevant information.

To minimize participant bias and error, measures were taken to guarantee anonymity and clearly communicate the study's purpose. These efforts encouraged participants to share information openly and honestly. While the use of semi-structured interviews may have introduced some variability, steps were taken to maintain consistency and accuracy in the interview process. These safeguards were crucial for enhancing the trustworthiness and credibility of the study's findings, thereby providing a strong foundation for drawing meaningful conclusions.

3.5. Research Ethics and Sustainability

Ethical considerations were central throughout this study. Guidelines from the Swedish Research Council (*Ethics in Research and Good Research Practice*, 2019) and Sveriges Ingenjörer (*Vår Hederskodex*, 2024) informed the ethical conduct of the research. Core principles such as reliability, honesty, respect, and accountability were upheld. All participants were invited to take part in the study voluntarily and were informed about how the information collected would be used. Interview participants provided consent for the interviews to be recorded, transcribed, and included in the research. They were also assured of confidentiality, and informed that the recordings would be accessed only by the author.

Methodological considerations were also carefully addressed to ensure that the findings of this case study were accurately and meaningfully represented, thereby upholding the integrity of the research process. Efforts were made to align with principles of reliability, honesty, and responsible data use by maintaining transparency throughout the methodological process and clearly articulating the study's objectives. All data collected from participants and documents adhered to these ethical standards and were used solely for the stated purposes of the study.

Sustainability is a critical concern for water utilities, which increasingly face complex challenges related to climate change that complicate asset management and operational planning.

This study seeks to expand existing research to support more informed decision making in water utilities, enabling them to realize the potential value of digitalization. When effectively implemented, digitalization can enhance efficiency, contribute to more sustainable operations, improve workplace safety, and reduce environmental pollution. However, digitalization alone is not sufficient to drive these improvements. A deeper examination of the barriers that hinder creating and capturing value from digitalization is essential to support water utilities in their pursuit of more sustainability.

4. Empirical context

The empirical context of this study is presented in this chapter. The basis of these findings has been gathered from documents, interviews, documents and observations. The organization, along with its physical infrastructure for drinking water delivery and wastewater transport, is described in this chapter. This chapter also outlines the strategic goals for maintaining these assets and the digital tools used to monitor and manage them.

4.1. Organization structure

This study’s focus was a municipal water utility in a mid-sized Swedish city that was responsible for the production and distribution of drinking water, as well as the collection and treatment of wastewater. The utility was divided into several subunits that were responsible for maintaining the infrastructure and meeting future demands.

4.2. Physical infrastructure

Drinking water was produced in treatment plants, then transported through pipelines to customers. Wastewater was transported through pipelines to pump stations, where pressure was built up in a well in the pump station before it was pumped to the next station, eventually reaching the treatment plant for processing. Maintenance technicians were responsible for performing maintenance and conducting routine inspections throughout this system of “pipes, pipelines, pumps and pump stations” (M1; Bennich 2024b).

4.3. Organizational strategic goals

The water utility had also developed a maintenance and digitalization strategy document (MDSD) where overarching goals were defined as:

- Improved understanding of maintenance work
- Continuous improvement through planning, follow-up, and analysis
- Consistent maintenance practices across the water and wastewater organization
- Clearer responsibilities for maintenance at different stages
- Traceability maintenance costs within the utility operations
- Increased efficiency across all processes

These goals served as a guiding framework for the operation and maintenance of the utility (PSP1, WUA3 and WUA5).

4.4. Digital tools

The water utility employs a wide range of digital tools, making it difficult to list them all. However, several key tools relevant to achieving the utility's strategic goals had been identified.

The SCADA systems consisted of sensors that measured physical conditions and transmitted signals to PLCs, control computers, and local HMIs. These components were used to monitor and control various processes in real time.

The SCADA system could also transmit data to various information systems. Data from the SCADA system could be integrated with other systems, applications, and models such as iFIX, aCurve, GIS, MIKE (by DHI), Leak Detector (Kamstrup), and IDUS. These systems were further integrated with additional tools, for example Smart Reports, and VA-banken. Communication tools such as customer information systems (CIS) and Teams were also used in the water utility.

5. Results and analysis

The findings of the case study based on empirical data are presented in this chapter. The basis of these findings has been gathered from interviews, documents and observations. These findings are presented by examining the value created from digitalization in the water utility (Chapter 5.1), the value captured from digitalization (Chapter 5.2), and the challenges that limit value capture (Chapter 5.3) and value creation (Chapter 5.4).

5.1. Creating value from digitalization in the water utility

Digitalization created value for the water utility by enabling impactful outcomes that benefited the organization, its employees, various subunits, and external stakeholders. The following subchapters present the different ways in which digitalization created value in the water utility by enabling various outcomes.

5.1.1. Automated processes

Digitalization had led to automated processes and activities in the water utility. The integration of sensor data with PLCs and control computers enabled automated responses to predefined conditions according to participants in this study (PSP1, PSP3 and WUA6). For example, the SCADA system could shut down a pump if a blockage was detected, preventing damage to the motor without requiring human intervention (PSP1 and WUA4). It could also attempt to clear obstructions in the pump or inlet pipe by reversing the pump's direction (PSP1, WUA4 and WUA6). The system could also alert a pump to start pumping once a certain level was reached in the well (SPS1, SPS2 and WUA6). According to users these functions allowed the system to operate autonomously even under critical conditions, preserving components while saving time and resources.

5.1.2. Faster access to information

Digitalization also led to faster access to information in the water utility. The integration of SCADA systems and IT systems allowed users to access information quickly from various systems. Digital tools such as iFIX allowed users to monitor real time data, receive alerts in case a pump was not working and the pipeline system was overflowing (PSP1, PSP3, WUA4 and WUA7). Users were also able to monitor processes such as pump starts and stops, electricity consumption, and well pressure. This access to information allowed for remote diagnostics, reducing the need to visit the pump station or physically lift the pump (WUA3).

> *"With the smart reports you get a fast good overview of the whole thing."*
> *- Maintenance engineer WUA5*

The integration of data from the SCADA system and aCuvre enabled users to quickly understand the processes in facilities and components (PSP1, M1, PSP5, WUA1, WUA2 and WUA6). Tools such as Smart Reports had improved the maintenance/operations subunit's ability to detect anomalies across hundreds of pumps more efficiently, by providing a streamlined overview of large data sets (PSP1, WUA3, WUA5 and WUA6). Users noted that presenting pump performance indicators in rows of Excel data provided a quick overview of facility conditions, eliminating the need to click through each individual pump, as required in other tools. Given that the utility operated over 500 pumps, this approach significantly reduces the time spent during meetings, which is highlighted by users in interviews and meetings (M1, WUA6, M7, M8, M9 and M10).

5.1.3. Effective internal and external communication

The integration of communication tools with employee information or customer data facilitated easier internal and external communication. Digital communication tools such as Teams and CIS enabled employees and customers to address issues and coordinate efforts to resolve them (PSP1 and WUA1). These tools could also be used to coordinate resources for incidents such as an oil leak into the storm water system faster, according to the maintenance manager in the water utility (PSP1). Tools such as Teams, CIS, VA-banken, and iFIX supported communication and collaboration with residents, colleagues, and contractors (PSP1, WUA1, M9 and WUA5). Users noted that these tools provided easier access to a wider network of people. One maintenance manager highlighted that tools such as Teams enabled cross functional units to collaborate on various projects, share ideas, and discuss the challenges they encountered (PSP1).

"With digital tools, we can very easily inform those affected via SMS, instead of having to put paper notices on every house impacted by, for example, a closed valve." - Development engineer WUA1

Digitalization made it easier for all parties to access and stay aware of important information. An engineer noted a reduced risk of overlooking important details when tools such as GIS and CIS were integrated, as more information became available to support both internal and external coordination (WUA1).

5.1.4. Improved coordination

Smart Reports aided meetings in the utility according to its users (M7, M8, M9, M10 and WUA3). The maintenance manager highlighted that these reports made weekly meetings easier to coordinate and collaborate by shifting the focus from intuition to pump data (WUA6). According to him, enhancing the value of the meetings and simplifying coordination efforts to assess pump conditions within the maintenance team. Likewise, a maintenance engineer pointed out that collaborations and priorities became more optimized since more people understood the situation in the pumpstations (M7 and WUA7).

The integration of digital tools helped establish clearer priorities both within the water utility and in interactions with external partners (PSP1, M2, M6, WUA3, WUA5, and WUA7). For example, Smart Reports made it easier to signal critical issues not only to technicians and engineers, but also to senior leadership outside the maintenance group (PSP1, PSP3, M1, M2, M6, WUA5, and WUA6). According to a maintenance manager and several engineers, this supported clearer agenda-setting in strategy meetings, weekly team meetings, and supplier interactions (M1, PSP1, PSP5, M6, and WUA6).

The Smart Reports also helped establish a shared understanding of priorities, making it easier for more people to recognize what was important and should be of primary concern (M1, M2, M7, WUA3, WUA5 and WUA6). The reports also enabled more people to investigate concerns systematically, as their use was regularly discussed in weekly meetings (M7, M8, M9, and M10).

“We use iFIX during nighttime leak detection because it provides real-time data and allows us to see changes in operations.” - Maintenance engineer WUA5

By integrating tools such as iFIX and Leak Detector, engineers and technicians could identify the location of leaks (WUA5 and WUA8). They could then analyze real-time flow data to determine where flow changes were least impacted by actions such as closing valves (WUA5 and WUA8). This enabled them to coordinate leak detection efforts more easily, without relying on more complex methods that required more people (WUA5). A technician highlighted that Leak Detector could for instance detect noise from circulation pumps (WUA8). Despite these false flags she pointed out that this method made it easier to coordinate leak detection with only two people.

5.1.5. Improved documentation

According to a maintenance engineer VA-banken improved their ability to document maintenance activities and analyze the pipeline network (WUA5). Improved documentation was considered important due to its broad impact across many otherwise unrelated activities. According to an automation technician, it significantly reduced time and effort while simplifying various processes (PSP3).

“If it had been well documented, there wouldn’t have been a need to go out there, like 20 minutes to get there and then 20 minutes back. Instead, I could just check it in a minute in a documentation system.” - Automation technician PSP3

Additionally, VA-banken helped ensure that ongoing maintenance activities on the pipeline network were not overlooked (WUA1, WUA2, WUA6 and WUA8). VA-banken also allowed for better coordinated maintenance plans and actions according to a maintenance engineer (WUA5). By allowing more people to follow maintenance logs and real time data of the pipeline network it became easier to coordinate projects using both real time data and information from GIS (WUA1, WUA2 and WUA5).

5.1.6. Enhanced transparency

Digitalization led to more transparency and new opportunities with external stakeholders. The SCADA system allowed the utility to report pollution to the environment in cases of overflows (M1, PSP1 and WUB1). According to technicians, engineers and managers, the data collected by sensors was used to report in cases of pollution from pipelines and pump stations but also if certain substances were found in the wastewater or freshwater to authorities (M1, PSP1, PSP3 and WUB1). Faulty sensor data could also lead to wrong information being reported. A development engineer in Water Utility B noted that when they discovered their sensor data was faulty they would report this to authorities so they could make their own assessment of past reports (WUB1). He further highlighted the importance of transparency in the sector as this had an effect on addressing issues related to pollution.

“You learn more about the system when working with smart reports. You're forced to engage at a certain level in order to understand it fully and gain deeper insight into how the system works. I think that's a very significant benefit.” - Maintenance engineer WUA5

According to its users, Smart Reports increased the visibility of pump station issues to a broader audience during meetings (PSP1, M7, M8, M9 and M10). By displaying rows of pump data during weekly maintenance and operations meetings, these reports enhance understanding of pump station conditions, not only among technicians but also among engineers, coordinators, and managers who may not be familiar with specific equipment. Some pumps have even become known as “infamous pumps” due to their recurring problems and reduced performance (M9). A maintenance technician noted that the reports had allowed them to decide if certain pumps should be replaced with input from more people that were now familiar with these issues (WUA3).

5.1.7. Improved analysis

According to managers, technicians, and engineers, digitalization facilitated easier analysis (PSP1, PSP2, PS3, WU1 and WU2). Digitalization provided a clearer overview of conditions in facilities in the field, ongoing operations, and potential future states due to the integration of real-time data with models and simulations (PSP3, WUA1 and WUA2). They noted that various tools such as MIKE, Smart Reports and aCurve allowed them to “guess” what the future conditions would be based on historical data (PSP4, M1, WUA1, WUA2, WUA6 and WUA7).

Digital tools such as iFIX enabled users to analyze real-time data and detect anomalies in processes related to pumps and wells (PSP3, WUA4 and WUA6). For example, technicians could monitor the volume of wastewater being pumped, (if such data was available) or assess the pump’s energy consumption during operation. This supported more accurate and efficient monitoring of processes according to users (PSP3, WUA3 and WUA3). Users also highlight that this allowed them to understand more about processes in facilities, thereby allowing them to take better maintenance actions when needed (WUA3).

“aCurve has made it easier to visualize SCADA data.” - Automation technician PSP3

Other digital tools such as aCurve enabled more in-depth analysis (PSP5 and WUB1). Unlike iFIX, it could incorporate soft sensor data, such as laboratory results, and it also supported regression analysis among other forms of analysis (PSP5 and WUB1). Many users, including one of the maintenance engineers interviewed, preferred using aCurve over iFIX due to its more visually appealing interface (WUA5).

“My vision to avoid complications was to have a web-based solution.” - Development engineer WUB1

In line with this, aCurve offered the advantage of avoiding issues commonly associated with locally installed software, as it is web based (WUB1). Users noted that they are able to share their analyses with other users, such as colleagues, consultants and researchers (M2, PSP3, PSP5 and WUA5). An automation technician highlighted that seeing other users' saved analysis methods made it easier for them to decide how they could analyze processes they were unfamiliar with (PSP3).

"…you can also gain more insight about a facility, and in a more efficient way, than driving around to do visual inspections, especially when we have such a geographically dispersed set of facilities…" - Maintenance manager WUA6

Digitalization made participants more informed in their decision making. Integrated data from tools such as GIS, VA-banken, Leak Detector, and MIKE enabled technicians, engineers, and managers to make more informed decisions with the support of accessible and relevant information within these systems (WUA1, WUA2, WUA6, WUA8 and WUB1). Engineers pointed out that these tools allowed them to find faulty pipelines that might affect their planned downtime of other parts of the system (WUA7). These tools also helped users explore the links between certain maintenance actions and how they affected the pipeline network (WUA1, WUA2 and WUA5). In addition to these engineers and managers highlighted how these tools allowed them to plan for future needs by simulating and calculating how increasing needs might affect the current set up (WUA1, WUA2, WUA5, WUA6 and WUB1).

Modeling and simulation programs made it possible to identify irregularities in sensor data and detect potential anomalies within the pipeline network, which helped coordinate finding faulty sensors (WUA1, WUA2 and WUB1). A modelling engineer highlighted that programs allowed users to follow processes and see if certain infrastructure was dimensioned in a wrong way or if sensor data did not make sense (WUA1). In another case, a development engineer pointed out that simulation programs highlighted when physical inputs from sensors were faulty and helped clean up such faulty sensors (WUB1).

"Smart reports have allowed us to find anomalies faster, faster than the SCADA application." - Maintenance technician PSP4

Technicians, engineers and managers also pointed out that the Smart Reports enabled them to prevent more serious consequences, such as pump breakdowns (PSP1, PSP3, M1 and M2). By finding anomalies as fast as possible, serious consequences could be avoided by acting before these abnormalities developed into a full breakdown of components (M1). According to users they are also able to prioritize anomalies based on intuition and the potential severity of a pump failure. Maintenance managers, engineers and technicians all pointed out how Smart reports allowed them to avoid environmental consequences that might have occurred without the reports (PSP1, M1, M2, PSP3, WUA3, WUA5, WUA6 and WUA7). By reacting to anomalies technicians were able to service pumps, clear any obstructions and avoid wastewater overflow (WUA3 and WUA7).

5.1.8. Internal and external opportunity recognition

An automation technician noted that digitalization had helped more people recognize the value of digital tools (PSP3 and WUA4). As awareness and use of these tools grew, he observed that it helped set the tone for broader initiatives within the organization (PSP3). A maintenance manager had also noted that tools such as Smart Reports allowed more people to explore the possibilities of integration of digital tools within the organization (PSP1 and WUA6).

"… there are also two different levels of benefit here, one is simply getting the facilities to function as it does today, and the other is enabling more advanced capabilities, like modeling, digital twins, and some of the machine learning and other emerging technologies that are hot right now."- Development engineer WUB1

Several individuals noted that digitalization not only signaled potential solutions to existing challenges but also highlighted new possibilities and ways of working (M1, M2, PSP3, WUA4, and WUB1). According to the development engineer from Water Utility B digital tools had become more widely understood within the organization, and more people were likely to be open to adopting new digital tools (WUB1).

Digitalization also signaled to external parties, such as customers, suppliers and the municipality, that the water utility was undergoing a change (PSP1, PSP3, WUA5, WUA6 and WUA8). A maintenance manager noted that installing water meters for customers allowed Leak Detector to function signaled to these customers that their water service was undergoing a change that could benefit them (M1, PSP1 and WUA6). The adoption of Smart Reports also signaled to suppliers that the utility was making changes in its operations (M4). The maintenance manager pointed out that the Smart Reports and the integration of data from aCurve signaled that major changes were underway in the maintenance units, both to their group and other units in the water utility (M1, PSP3 and WUA6).

Digital tools like aCurve helped shape practices within the water utility by demonstrating how anomalies could be detected over extended time periods across multiple subunits (M1, PSP3, and WUA6). Unlike SCADA systems like iFIX, aCurve provided a more accessible way to visualize pump performance over extended periods, weeks, months, or even years (PSP5 and WUB1). Initial use of aCurve took place within the water utility's production unit (M1, M3, M4, PSP3 and PSP5). As awareness of its benefits grew, the tool gradually spread to other subunits including the maintenance unit (M3, PSP3, PSP5, and WUA4).

5.2. Capturing value from digitalization in the water utility

The following subchapters present how value from digitalization was captured through strategic planning and implementation. These processes illustrate how the water utility assessed its situation, formulated strategy, and carried out its implementation.

5.2.1. Strategic goals review

The operations and maintenance group at the water utility developed a maintenance and digitalization strategy (M1, M2, PSP1, and WUA5). This strategy was formulated over the course of 2024 and documented in the Maintenance and Digitalization Strategy Document (MDSD). The participants that planned and formulated the strategy analyzed current and emerging digitalization trends and identified a need to adopt a more proactive approach to maintenance by leveraging new technologies such as AI and machine learning in the future (M1, M2, WUA5, and MDSD). According to a maintenance engineer, they also recognized several key drivers for digitalization, such as feedback from other subunits, addressing aging infrastructure that demanded more resources than were available, and improving predictability in both reporting and operational needs (WUA5 and MDSD).

The group that formulated the strategy outlined a plan to shift from reactive maintenance in 2024–2026 to proactive maintenance between 2027–2035 (MDSD). By 2036–2050, they aim to implement a predictive maintenance model (MDSD). This progression was driven by the goal of becoming more predictive to enhance reporting accuracy and increase predictability in both operational performance and financial planning (WUA5). According to the document, as well as the maintenance manager and engineer, this approach would also enable them to manage their aging infrastructure more efficiently (MDSD, PSP1, WUA5, and WUA6). Based on their drivers, this scenario was chosen to be the best alternative for their organization (MDSD and WUA5).

5.2.2. Current state and gap analysis

The water utility's maintenance and digitalization strategy addressed the state of maintenance practices and the integration of digital tools at that time (MDSD). This involved evaluating which digital tools were in use and how they were being applied (WUA5 and MDSD). The strategy also discussed and calculated the resources required to achieve their maintenance goals, particularly by comparing the available working hours within the maintenance unit to the estimated effort needed to implement the desired changes (MDSD). The calculations primarily focused on the cost of performing maintenance tasks. That said, the strategy did address the integration of existing systems. It also emphasized the need for a preliminary study to explore how these systems could be integrated to optimize maintenance operations and overall service delivery (MDSD).

The water utility's maintenance and digitalization strategy identifies a gap between the current reactive approach and their goal of becoming proactive by 2027 and predictive by 2036 (MDSD). The document outlines the digital tools currently in use and highlights the need for their integration to optimize operations. It also discusses a lack of clearly defined responsibilities for this integration and proposes a preliminary study to explore how these tools can be effectively integrated. To bridge these gaps, the strategy recommends increasing automation and implementing new data collection methods, such as monitoring water flow, pressure, and well levels. These initiatives are to be tested on a small scale before broader implementation (MDSD).

5.2.3. Implementation

The water utility has implemented several digital tools, including Smart Reports and VA-banken in 2024, and Leak Detector in 2025 (M1, M2, PSP1, WUA5, WUA6, and WUA8). These tools were initially introduced on a small scale and gradually expanded. For instance, Smart Reports were rolled out throughout 2024 and calibrated over time to address the specific conditions of individual pump stations (M1, M7, PSP1, and WUA7). Leak Detector, however, is still in its early stages. Signal receivers for the water meters are not yet widely installed, as they are currently only available in the vehicles of technicians who specialize in leak detection (WUA8). As a result, if more up-to-date data is needed, rather than waiting for the two-week cycle of garbage trucks to collect signals the technicians must manually drive through areas to retrieve the data (WUA8).

Changes were actively taking place, new tools were being implemented, and more sensors were being installed than before (M1). According to managers, engineers, and technicians, there had been a noticeable shift over the past two years, with increased focus on the digitalization strategy (M1, PSP1, PSP2, PSP3, WUA5, WUA6, and WUA7). As part of the Smart Reports implementation, one municipal district was selected where all pump stations were equipped with flow meters, energy meters, and modern control systems (M1, PSP1, PSP2, PSP5, and WUA7). In this district, new and more detailed reports were developed, surpassing the standard Smart Reports used elsewhere to demonstrate the potential of the system (PSP1).

By using these tools in meetings, diagnostics, automated processes, decision making, and collaboration, the utility was able to create value from digitalization, as outlined in chapter 5.1. Despite these efforts, it remained unclear how the actions that had been implemented would be evaluated. The MDSD did not outline any evaluation methods, nor was this topic discussed in strategy meetings (M6).

5.3. Challenges of capturing value from digitalization in the water utility

To effectively capture value from digitalization, the water utility relied on its digitalization strategy and implementation. However, challenges remained that limited the value captured, largely due to insufficient analysis in several areas of planning and execution. This lack of in depth analysis made it difficult to determine the value being captured, how it was being captured and whether sufficient value was being captured.

5.3.1. Analyzing feasibility of strategic goals

A key challenge was determining whether the planned roadmap and actions were realistic and achievable for the water utility, given its circumstances. This was due not only to the complexity of the task but also to the lack of sufficient data needed to carry out this type of analysis. It also remained unclear whether the data the water utility had available could evaluate the feasibility of proactive maintenance for their organization or defined specific goals based on that assessment (MDSD). The strategy document did not address how realistic the scenario of going from reactive to proactive was based on the utility's conditions. Nevertheless, it outlined the following goals for their digitalization process (MDSD):

- Improved understanding of maintenance work
- Continuous improvement through planning, follow-up, and analysis
- Consistent maintenance practices across the water and wastewater organization
- Clearer responsibilities for maintenance at different stages
- Traceability maintenance costs within the utility operations
- Increased efficiency across all processes

Although these goals were outlined, identifying performance indicators to assess progress against the current situation remained challenging due to the complex nature of the water utility's operations (MDSD). Additionally, it was difficult to determine how future improvements would be measured.

5.3.2. Analyzing current and future states

Comparing the current digitalization state with the desired future was both complex and resource intensive. Although the current state of maintenance processes was thoroughly examined, the utility's specific approach to digitalization and how it aligns with their stated goals remained unclear. While the document provided a detailed analysis of maintenance tasks, current and projected costs, it focused primarily on operational aspects (MDSD).

Several engineers and managers noted that they would need to develop new competencies to address the complex challenges posed by digitalization (PSP1, PSP2, WUA3 and WUA5). Analyzing the current digitalization architecture required extensive knowledge of both operational and informational technology, which few had in the water utility (PSP3 and WUA4). Gaining insight into the future state of digitalization required in-depth knowledge of emerging digital technologies and systems.

It was difficult to compare and evaluate progress within the water utility, as unexpected incidents could occur at any time. Most data collection focused on daily operations, with limited information available to assess progress toward a future state. This made it harder to reflect on and evaluate past developments. Furthermore, the lack of a clear vision for the desired future of digitalization limited the ability to capture value. As a result, it was challenging to create an effective roadmap and identify appropriate actions to reach the utility's goals.

5.3.3. Reviewing actions and practices

The sequence of actions were not clearly defined in the strategy document, nor was their relative importance discussed. Responsibility for digitalization was assigned collectively to several subunits, including maintenance/operations, planning, automation, and production. While the document stated that these subunits shared responsibility, it remained unclear what this entailed in practical terms for the digitalization process (MDSD). The document did not specify which system functions could be affected by the changes from digitalization, or which processes would benefit most. It also did not reassess performance indicators, as these had yet to be established.

The document included a detailed review of maintenance costs, covering aspects such as working hours, salaries, workwear, computers, and physical tools. Nonetheless, it lacked an assessment of how digitalization would have impacted existing practices (MDSD). Although pilot programs were suggested to test the feasibility of proposed changes, dependencies between actions and stakeholder perspectives were not considered. The organization's capacity for change was also not clearly addressed

Reviewing the actions and practices implemented by the water utility was challenging due to the lack of clearly defined responsibilities and allocated resources. This difficulty was further intensified by the ad hoc nature of how digital tools were implemented (PSP3 and WUA5). These challenges limited the water utility's ability to capture value from digitalization.

5.4. Challenges of creating value through digitalization in the water utility

The following subchapters present the challenges of creating value through digitalization in the water utility. These challenges show how the water utility had issues with maintaining data quality, ensuring operability, sustaining interest, overcoming complexity and legacy systems, and understanding benefits.

5.4.1. Maintaining data quality

The most frequently mentioned challenge was data quality and the challenge of maintaining it during operations. An automation technician noted that there was insufficient governance to ensure a systematic approach to installing sensors, programming PLCs/control computers, and linking them to iFIX (PSP1 and WUA6). He explained that technicians sometimes named sensors or PLCs inconsistently within the system, making it difficult to trace issues such as faulty sensors that affect data quality (PSP1). A maintenance engineer also echoed these concerns and emphasized the need for standardized procedures. This was particularly important for installations related to the SCADA system (WUA5). He warned that carelessness during these installations could significantly impact decision making, which could lead to costly errors (WUA5).

Another challenge related to data quality was raised by the development engineer at Water Utility B, who pointed out the difficulty of implementing effective measures to improve data quality (WUB1). He noted that addressing these issues was not only technically complex but also complicated by the difficulty of assigning clear responsibility for data quality tasks (WUB1). Several engineers, technicians, and managers also highlighted this concern (WUA4, WUA5 and WUA6). They pointed out that defining responsibility for data quality related tasks was challenging because resources were often being redirected to other areas.

A related concern to data quality and governance was the difficulty in collecting and analyzing important data. An automation technician noted that consultants, authorities, or internal stakeholders often requested specific types of data, which were not always available. In such cases, sensors had to be installed, and data collected manually, resulting in unplanned workloads (PSP3 and WUA4). He also noted that there was no established governance for defining expected data points, which made it difficult to carry out this work in a structured and manageable way (WUA4). This lack of focus on systematic data collection of data that was not important to operations also made it challenging to track progress over time.

> *"…people tend to overestimate the quality of the data. You must understand that data isn't just abstract 'data'; it comes from a physical machine somewhere, where someone has been working and maybe had to deprioritize it for a long time because other things were more urgent. " - Development engineer WUB1*

Despite the faster access to information due to digitalization, sensors could log incorrect data which affected the quality of the available information (M1, PSP3 and WUA4). This negatively impacted the operability of digital tools such as Smart Reports, aCurve, or iFIX. Because it was assumed that the data feeding into the digital tools was correct, their functionality was impacted. As a result, the digital tools did not create value as intended, and the operability of any tools integrated with them was also impacted.

5.4.2. Ensuring operability

An important challenge was understanding how the digital tools used in the water utility solved problems and whether they did so in the most effective way. Persistent anomalies in Smart Reports caused frustration among technicians, who point out that certain anomalies remained unchanged despite repeated efforts to service the affected pumps (M7, M8, M9, M10). In all weekly meetings (M7, M8, M9 and M10) technicians pointed to the fact that in some cases it was only a small "rag" that was stuck inside or sometimes nothing at all leaving them confused as to why the Smart Reports were still detecting anomalies. According to the maintenance engineer this was most likely due to the fact that the calculations in the cells for those pumps needed to be recalibrated (M7 and WUA7). This raised questions about whether Smart Reports method of detecting anomalies was accurate or appropriate.

"...manually tuning in the relationship between the pumps in order to then find a new baseline from which deviations should be assessed, that's something I currently find a bit complicated. And my own trust in the reports has been somewhat affected by that." - Maintenance manager WUA6

Several technicians, managers, and engineers questioned whether there was an alternative to constantly recalibrating the Smart Reports to ensure their operability (WUA3, WUA5, WUA6 and WUA7). Recalibrating to maintain operability and normal function required significant resources, which in turn limited the value created from digitalization.

"The technician shouldn't have to write things manually, because even a small typo or two people writing slightly different things can result in poor statistics. That makes it difficult to follow up properly." - Maintenance engineer WUA5

According to a maintenance engineer VA-banken required significant reconfiguration to operate (WUA5). For example, he highlighted that avoiding the need for technicians to manually record their maintenance actions manually required adapting the program for their organization. This involved allocating resources to enable maintenance actions to be selected from a dropdown menu which took time and resources.

Each digital tool required reconfiguration to align with the water utility's specific context. This not only limited the value that could be created and slowed down implementation but also affected users' trust in the solutions.

5.4.3. Sustaining interest and trust

According to a technology supplier, it was challenging to get operational personnel in water utilities to have confidence in data-driven processes and adjust their ways of working (PSP5). The maintenance manager in the water utility noted that many within the water utility wanted to first understand the reliability of these digital tools before fully accepting them (PSP1). During the initial rollout of Smart Reports, the tool produced several errors, particularly in its anomaly detection. These errors led to skepticism among technicians, managers, and engineers (PSP1, PSP3 and WUA6). However, as the reports were gradually calibrated and users developed a better understanding of the tool, acceptance increased over time (WUA3 and WUA7).

Nevertheless, resistance to digital tools persisted. As one automation engineer noted, some individuals felt no need to change and relied on established routines (PSP2). Managers in maintenance and automation attributed this resistance to factors such as security concerns and established processes (M1, M2, PSP1, PSP2, and WUA6). There were also challenges of communicating the reason for these digital tools and the needs they fulfilled (WUA6). During several weekly meetings, the maintenance manager requested technicians to document the status of facilities in an excel document but the technicians didn't understand the purpose of this (M8, M9 and M10).

Several technicians, engineers, and managers noted that they were uncertain whether the decisions they made based on the available data were entirely correct (PSP1, M2, M7, WUA6). They also noted that many of the new systems required extensive recalibration and reconfiguration of existing infrastructure. This impacted decision making, as several technicians reported during weekly meetings that they allowed certain anomalies to persist in the hope that these would "self-heal" and disappear. This practice contradicted the thinking behind early anomaly detection, which is intended to prevent breakdowns (M7, M8, M9 and M10). Nevertheless, the manager emphasized that the reports helped clarify expectations for technicians and engineers, promoting more data-driven decision making over reliance on tacit knowledge (M1, M2, M7, and WUA6).

There were also several individuals that continued to work with digital tools they perceived as more beneficial and had previous experience with rather than work with newer digital tools. Despite its introduction, the adoption of aCurve within the maintenance unit remained limited, particularly among technicians. Many continued to prefer real-time analysis in iFIX, which they perceived as more beneficial for their needs (M1, WUA4, WUA5, and WUB1).

According to an automation technician, despite ongoing efforts, effectively communicating the potential of digitalization to more individuals in the organization remained difficult (PSP3 and WUA4). A major hurdle was not only the lack of interest but also the complexity involved in gaining expertise in both information systems and operational technology, such as aCurve and SCADA.

5.4.4. Overcoming complexity and risk

A key priority for water utilities is minimizing risk and avoiding the costs associated with system failures (M1, PSP1 and PSP2). An automation manager highlighted that one of their greatest challenges was establishing safe and secure communication with facilities through the SCADA system (PSP2). He also noted that cybersecurity regulations, such as the NIS2 Directive, restricted their available options (PSP2). As a result, certain digital solutions, particularly those requiring cloud infrastructure were not considered due to limitations in data management and concerns over storing data in other countries (PSP2). For these reasons, several potential digital tools were excluded from consideration altogether.

“Of course, you introduce a certain level of complexity when transitioning from visually inspecting your facility to analyzing data. It does require a shift in competence.” - Maintenance manager WUA6

The use of data and new digital tools introduced new complexities they had not encountered before (M1, PSP1, PSP2, PSP3, WUA5 and WUA6). A maintenance engineer pointed out how digitalization required new competencies they did not have yet (WUA5). The development engineer at Water Utility B noted that complexities related to data quality required a different approach to staffing (WUB1). He indicated that conducting in depth analyses of data quality was currently challenging to implement effectively. Despite this he pointed out that data quality despite its complexity was an important subject. According to an automation technician, more individuals within the water utility were beginning to realize the importance and complexity of integration, data quality and analysis (PSP3).

"The easy part was probably creating the strategy document."- Maintenance engineer WUA5

As the water utility continues to adopt new tools and modify existing processes, the complexity of these changes has increased. This was emphasized by several managers, engineers, and technicians (PSP1, PSP2, PSP3, WUA5, WUA6, and WUA7). One maintenance manager noted that recalibrating the Smart Reports was both complicated and time consuming (PSP1 and WUA6). Another maintenance manager echoed this, stating that as more digital tools were introduced, it became increasingly difficult to determine the best course of action and identify areas for improvement (WUA5). He also pointed out that the necessary resources for implementing and integrating digital tools were lacking. This perspective aligned with the automation manager’s observation that it was challenging to find solutions compatible with their existing systems (PSP2). Despite these difficulties, the implemented changes in maintenance and operations had a positive impact, according to managers, engineers, and technicians (WUA3, WUA4, WUA5, WUA6, and WUA7).

5.4.5. Understanding benefits

Digitalization was seen as enabling the water utility to create value that would not have been possible otherwise. However, there were concerns about whether the time and resources required for certain initiatives were truly justified. For example, there was at times a lack of consensus regarding the importance of documentation in certain tools. This was illustrated when one technician questioned the need to log maintenance actions in VA-banken (M6), prompting a maintenance engineer to explain its purpose and how it could be beneficial in the future.

“It might not deliver a big bang for the buck right away, and many people probably want immediate value for their money.” - Maintenance engineer WUA5

Another issue highlighted by engineers and managers was the uncertainty of the value of introducing new digital tools or integrating existing tools created (PSP1 and WUA5). A maintenance engineer pointed out that it was difficult getting decision makers on board on new opportunities since it was hard to predict the outcome of new opportunities (WUA5). This was in line with what an automation technician had pointed out that, due to people not being knowledgeable in digital tools certain opportunities were ignored (PSP3). This challenge was amplified by the difficulty of getting more people to understand the architecture of the operational technology and the information systems in place at the water utility (PSP3 and WUA4).

5.4.6. Overcoming legacy systems

The water utility had a complex architecture of both physical and digital infrastructure, developed over several decades. These legacy systems limited value creation through digitalization. Technicians, managers, and engineers pointed out that the legacy systems made it challenging to adopt new digital tools (PSP1, PSP2, PSP3 and WUA5). The water utility's facilities had been developed over several decades, and were built with long-term use in mind. As a result, the utility had inherited control computers and sensors so outdated that some manufacturers no longer existed (PSP1 and PSP2). This significantly limited the scope of new implementations, as they were constrained by the capabilities of existing systems. An automation manager noted that in some districts in their municipality, they had begun replacing older control computers because they were too outdated to integrate with current systems (PSP2). However, he also emphasized that this process was time-consuming and had an impact on other ongoing activities (PSP2).

The limitations of these legacy systems impacted the implementation of new digital solutions like Smart Reports. One key consequence was the heavy emphasis on reporting only operating time, as this was the one data point consistently available across all stations (M1, PSP1, PSP3 and PSP5). As a result, even pump stations equipped with flow meters or water level sensors were limited to reporting operating time to maintain consistency in the analysis (PSP1 and WUA7). The development engineer from Water Utility B pointed out the risk of overcomplicating processes due to the limitations of their existing systems (WUB1). New tools had to be adapted to these legacy conditions, which often led to unique challenges that were difficult to resolve and would require significant resources to address.

Older water meters at customers' pipelines were also unable to detect the sound of water and as a result, could not transmit data to Leak Detector (WUA8). A maintenance technician noted that these outdated meters were being replaced, but the process was slow and had a negative impact on her daily work (WUA8). Despite the delays, there were plans to scale up the replacement effort as leak detection became an increasingly important priority for the water utility (PSP1 and WUA8).

6. Discussion

This chapter discusses the results and data presented in the preceding chapters. Its purpose is to connect the empirical findings with literature, while also offering recommendations in relation to the report's research question.

6.1. Summary of findings

This study investigated the value of digitalization in a water utility by exploring how value is created and captured, as well as the challenges that hinder these processes. This was addressed through the following research questions:

1. **How does a water utility create and capture value from digitalization?**
2. **What challenges do water utilities face in creating and capturing value from digitalization?**

The study reveals that digitalization in a water utility creates significant perceived value. This value comes from the automation of processes and faster access to information. It also enables more well informed and simplified communication, documentation, and analysis. Additionally, digitalization improves transparency on both operational and strategic levels, by allowing for pollution levels or operational anomalies to be reported to more stakeholders.

The study also reveals that the water utility captures value-in-use from digitalization through strategic planning and implementation. This involves analyzing and reviewing their goals, assessing the current state, and the future state of digitalization within the organization. Ultimately, they capture this value by effectively executing their digital strategy.

Nevertheless, capturing and creating value from digitalization presents challenges for the water utility. Value creation, for example, is limited by factors such as legacy systems, unclear benefits of digitalization, lack of interest and trust, operability, and poor data quality issues. On the other hand, value capture is limited by an insufficient analysis of the current situation within the utility. In areas such as data governance and digital integration, a lack of clarity complicates efforts to analyze the feasibility of the envisioned goals. This also makes it difficult to develop performance indicators for the goals, as they are not assessed for feasibility. As a result, there are no clear metrics to evaluate the implementation of the digitalization strategy. Without reviewing the execution of digitalization strategy and the actions taken, it becomes difficult to assess the utility's progress and adjust strategies accordingly.

Digitalization in water utilities remains a significant challenge, so does the ability to create and capture value from it. The findings show that these challenges can influence the water utility's experience with digitalization. The literature review highlights that digitalization is a complex subject, requiring deep understanding of how digital tools integrate and coordinate to strengthen an organization's value proposition. The findings show that water utilities face specific contextual challenges. These differ from the more general challenges discussed in literature on value, digitalization, and innovation. Therefore, it is important to further examine these challenges to gain a deeper understanding of the outcomes of digitalization in water utilities.

6.2. Reviewing digitalization in the water utility

Digitalization in the water utility is a complex topic that can be difficult to define clearly. As Vial (2019) notes, some literature lacks a precise definition of digitalization. Other sources, as highlighted by Kraus et al. (2021), use the term interchangeably with digitization. Water research sometimes does not distinguish between digitization and digitalization and treat them as synonymous. This lack of clarity can obscure the specific challenges that water utilities and related organizations face because of digitalization. For example, studies in water ICT and sustainability, such as Mounce (2020) and Aivazidou et al. (2021), use the terms interchangeably. This can lead to misunderstandings about the scope of change required for a successful project. Unlike digitization, which involves converting a specific process from analog to digital, digitalization requires bigger organizational changes.

As the findings in this study indicate, digitalization in the water utility requires new competencies, increased attention, trust, and coordinated use of resources to be able to strengthen the organization's value proposition. Much of the literature in management, business, technology, information systems, and the water sector highlights that many organizations struggle with digitalization and big data initiatives due to misalignment between strategy planning and execution (Grover et al., 2018; Günther et al., 2017). It is possible that the ambiguity of terms might lead to confusion regarding the resources and planning required for successful digitalization efforts in organizations.

A significant aspect to consider is that water utilities might differ from the types of organizations commonly discussed in business, information systems, and management literature on digitalization. These studies typically focus on for profit, private sector organizations, which operate in contexts that are not directly comparable to water utilities. Water utilities tend to prioritize risk management and reliability, which contrasts with recommendations that emphasize taking risks and pursuing innovation in new ways. According to Vial (2019), a recurring theme in DT literature is the importance of an organizational culture that supports risk taking and experimentation. This creates tension between the expectations placed on water utilities and the recommendation found in business management literature. A notable example of this risk awareness is an automation manager explaining that certain digital solutions are avoided due to concerns about their reliability (PSP2). This aligns with the findings of Poláková-Kersten et al. (2023), who note that HROs are highly risk aware and tend to view themselves as cautious.

It is important to consider that the failure of digital tools, leading to breakdowns in water utilities asset management, could result in serious consequences. Concerns about cyberattacks causing infrastructure damage, loss of facility oversight, or loss of control are significant issues for water utilities. These risks represent a potentially existential threat to water utilities services (Bennich, 2024a; Poláková-Kersten et al., 2023). Concerns about the increased risks associated with integrating digital tools that rely on certain digital solutions are valid. However, addressing these challenges is difficult without examining how the water utility creates and captures value from digitalization. A lack of understanding of how the water utility creates value from digitalization can result in overlooking key factors such as data quality, integration, change management issues, and analytical capabilities, as noted by Grover et al. (2018) and Günther et al. (2017). Additionally, value capture may be limited if aspects such as risk, potential scenarios, feasibility, and long-term performance are not thoroughly analyzed, as highlighted by Parviainen et al. (2017) and Correani et al. (2020).

Despite this however, the findings show that it is complicated to get a full grasp of how the water utility creates and captures value from digitalization. Most of the data collection is focused on the daily operations, which makes it difficult to assess the performance of the digitalization strategy in a systematic way as suggested by Parviainen et al. (2017) and Correani et al. (2020). At the same time, the requirements of water utilities and the presence of legacy systems can hinder value creation. These factors may limit data quality, analytical capabilities, integration, and data portability, which Grover et al. (2018) and Günther et al. (2017) identify as essential for creating value.

6.3. Research implications

First, this study contributes to the understanding of digitalization in water utilities by emphasizing its complexity in this context. Some of the existing literature highlights the benefits of digitalization but does not clearly define the concept, making it difficult to identify and evaluate its outcomes. By defining digitalization, this study highlights the complexity of integrating and coordinating digital tools to improve the value proposition. A clear definition supports a better understanding of the digitalization process, its requirements, and its expected outcomes. As Correani et al. (2020) suggest, when the requirements of digitalization are not clearly understood, it can lead to misaligned strategies and potential failure. For example, if individuals within an organization view digitalization as a short-term process like digitization, it can cause confusion and lead to an underestimation of the planning and resources required. This may impact the organization's ability to successfully deal with digitalization.

Secondly, this study enhances the understanding of how value is created and captured through digitalization in water utilities. While previous research has focused on the benefits and value of digitalization in this sector (Arnell, Miltell, and Olsson, 2023; Bennich, 2024a; Boyle et al., 2022), this study builds on that work by introducing value creation and value capture frameworks. These frameworks provide further insight into how the digitalization process can be more optimized in water utilities. The findings from this study show how water utilities create and capture value but also the challenges they face while doing so.

Previous literature on value has identified strategies for addressing value creation and capture in the context of innovation and digitalization, mainly focusing on organizations that differ from water utilities (Chesbrough, Lettl, and Ritter, 2018; Correani et al., 2020; Grover et al., 2018; Günther et al., 2017; Parviainen et al., 2017). This study extends that knowledge by discussing the specific contextual challenges that organizations like water utilities may encounter. It highlights the importance of considering the organizational context when capturing and creating value from digitalization. This is illustrated by acknowledging that water utilities operate under unique conditions that can affect the outcomes of digital efforts. Taking these contextual factors into account is crucial, as they may limit the ability to create or capture value from digitalization.

Finally, this study contributes to the broader research on digitalization by exploring how it can be optimized in a context that differs from those typically discussed in business management literature. It introduces contextual factors that are often overlooked, particularly in sectors like water utilities. For example, water utilities often continue using legacy systems while integrating new technologies, which can influence their ability to create value. Due to resource constraints and their focus on reliability, they may rely on technologies that no longer fully meet their current needs. Furthermore, factors such as interest, trust, and responsibility can affect their capacity to generate value from digitalization. This process may also be affected by the portability and quality of data within the water utility. Analyzing digitalization, including its risks, feasibility, and past actions, is often challenging in the context of water utilities. As water utilities tend to focus primarily on collecting operational data (Mounce, 2020). Which corresponds with the findings from this study. At the same time, it is important to recognize the complexity of defining performance and measuring progress resulting from digitalization investments in water utilities.

6.4. Practical implications

It is important to understand the nature of digitalization in the water utility sector, including its complexity and the significant resources it demands. Digitalization is a complex process that requires long-term planning and should not be mistaken for short term efforts such as the digitization of individual processes. Integrating digital tools can lead to unforeseen situations that may introduce new challenges. It is important to consider how different scenarios could impact the organization. A lack of understanding in this area may hinder the ability to create or capture value from digitalization, as highlighted in the literature (Correani et al., 2020; Grover et al., 2018; Günther et al., 2017; Parviainen et al., 2017).

Another important aspect is understanding performance over time. It is essential to establish appropriate performance indicators to assess the effectiveness of value creation and value capture from digitalization in the water utility. However, this is a complex task that is challenging to implement effectively under the current circumstances. This is mainly because data collection in the water utility is focused on operational data, a pattern that also appears to be common in other water utilities (Bennich, 2024a). While recognizing the complexity of measuring performance, it is important to note that the portability of operational data may be limited in the context of performance analysis. Such data may require extensive analysis to determine the impact of digitalization on the organization.

Understanding integration and data flow requires effort, but it is essential for identifying the risks the organization may face in specific situations. It also supports assessing the feasibility of planned initiatives and determining the most appropriate actions based on the current context.

Finally, water utilities may use the challenges identified in this study to reflect on their own organizational context. These reflections should consider factors such as the existing systems in use, user readiness to adopt new digital tools, the complexity of system integration, or the current level of digital competencies. All these factors play an important role in the digitalization process in the water utility.

6.5. Limitations of the study

While this study provides important insights into the value from digitalization and barriers to creating and capturing value from digitalization, several limitations must be acknowledged. These limitations affect the generalizability of the findings and should be considered when interpreting the results.

A potential limitation of this study is its primary focus on a single water utility, with additional input from one engineer at another utility and several technology developers. This limited scope makes it difficult to assess which perspectives may be missing, especially considering the differences in size, structure, and organizational culture among water utilities. Since utilities vary in the scale and complexity of their asset management, some important contextual factors may not have been fully captured.

Another limitation to consider is the qualitative nature of this study, which relies heavily on participants' honesty and their ability to accurately recall their experiences. Although efforts were made to minimize bias, there remains a risk that some participants may have unintentionally omitted important information or misrepresented certain aspects. Additionally, some responses may reflect what participants believed to be the expected or preferred answers, rather than their genuine perspectives. Digitalization is a complex topic, which may have caused confusion among participants. Despite efforts to frame questions around their personal experiences, it is possible that some participants misunderstood certain questions or provided responses that did not fully reflect their intended meaning.

It is also important to recognize that this study offers an in depth view of a water utility at a specific point in time. Longitudinal studies that follow organizations over extended periods may provide a more nuanced understanding of the contextual barriers water utilities face and how these challenges evolve over time.

Finally, it is important to acknowledge the limited scope of this study's research question and its potential impact on identifying barriers to creating and realizing strategic value from digitalization. While efforts were made to include a wide range of perspectives and phenomena, some relevant factors may have been overlooked, which could affect the completeness of the findings.

For these reasons, it is important to recognize that the findings of this study may not be applicable to all organizations or industries. Because the identified barriers are context-specific, they may appear differently in other settings. Therefore, the results should be interpreted with caution and may need further validation through additional research.

6.6. Future research

Given the limitations of this study, further research is needed to deepen the understanding of digitalization in water utilities. One potential avenue is to explore how these barriers manifest across utilities of different sizes, or whether they are consistent across a broader range of organizations. Future studies could also investigate how factors such as geographic location, workforce size, and organizational age affect the nature and impact of digitalization in the organization. Another potential area of research could be to examine the effectiveness of value creation and value capture from digitalization in water utilities. By focusing on performance indicators specific to the water sector, a more detailed and context specific understanding of the challenges faced during digitalization can be developed.

Additional factors worth exploring include the work experience of employees in water utilities and how it affects their ability to overcome barriers to realizing value from digitalization. Exploring how factors such as age, educational background, and attitudes toward digital technologies influence employees' responses to digitalization barriers could provide valuable insights. These variables help highlight the human aspects of digitalization and how they affect the success of such initiatives.

Finally, future research could examine how value creation and capture from digitalization is approached in different types of organizations or industries. Insights from various contexts would help researchers better understand the factors that contribute to challenges or failures in digitalization efforts.

7. Conclusion

The purpose of this study was to examine the value derived from digitalization and to identify the challenges to value creation and capture. Although the benefits of digitalization are well documented, there is limited research specifically addressing value creation and capture in the context of water utilities. The benefits and barriers of implementing digitalization in water utilities have been examined in previous studies. However, some of this research adopts a definition that is closer to digitization, while in other cases, digitalization is not clearly defined. Therefore, this study aimed to define digitalization within the context of water utilities. While also clarifying how value is created and captured from digitalization and identify the challenges that limit this process.

The findings of this study illustrate the ways in which value is created and captured within the water utility sector, highlighting its importance to overall operations and strategy. Several value creation processes are enabled by digitalization, which plays a critical role in their implementation. However, the effectiveness of digitalization is limited by challenges that are specific to the context of water utilities. These challenges may include legacy systems, complexity, risk, trust issues, or concerns about data quality specific to water utilities. This study contributes to the digitalization literature by providing insight into how digitalization evolves in less commonly explored contexts.

These findings also challenge the assumption that digitalization in water utilities follows a similar path to that of consumer oriented, private sector organizations. The challenges identified in this study are context specific and complex, indicating that they require further analysis and tailored approaches to water utilities. The value creation and value capture processes indicate that the water utility is actively engaged in digitalization and that a substantial level of integration is necessary to achieve meaningful results.

While the study was limited by its small sample size and short time duration, it still provides a foundation for a large scale longitudinal research. Many of the findings are based on the actor's perceived value, as suggested by existing literature. However, this approach may have limitations, as participant inaccuracies could influence the results of the study. Nevertheless, various steps were taken to minimize potential bias and inaccuracies, such as incorporating multiple perspectives from a large and diverse data sample.

Future studies could explore how challenges in creating and capturing value vary across different water utilities, considering factors such as age, size, and geographical location. Another area of interest could be the development of performance indicators to assess the progress of digitalization within water utilities. Additionally, future research could investigate how other industries perceive the strategic value of digitalization and the barriers they encounter in creating and realizing that value.

This study also examined the practical implications of digitalization and provided recommendations for addressing related challenges. It is suggested that water utilities develop frameworks to assess their current digital maturity and establish performance indicators to track progress. Implementing these kinds of measures can support the identification of realistic goals and actions and enable ongoing evaluation of digitalization in the utility.

In the current context of rapidly evolving digital technologies, understanding digitalization is essential for organizations that rely on such technologies.

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Appendix A Selected interview questions

The following are sample questions used during semi-structured interviews. The complete list was adapted during each interview based on participant responses.

Introduktion

Beskriver kort vad studien handlar om och ber om tillåtelse att spela in.

Beskriv din roll och arbetsprocess.
Vilka verktyg använder du?
Vilka utmaningar står du inför?

Strategi

Kan du berätta om er underhållsstrategi och digitaliseringsstrategi? Hur har dessa strategier planerats och implementerats?
Vad är viktigast för er grupp?
Hur samlar ni in data på det ni gör? Vad får ni för återkoppling? Varifrån får ni återkoppling?
Hur går du tillväga för att uppnå era mål?
Vilka utmaningar står ni inför?

Digitala verktyg

Vilka digitala verktyg använder du?
Hur kan dina analyser bli bättre? Varför tror du det?
Kan du berätta om [Smarta Rapporter, Leak Detector, aCurve]? Hur introducerades det verktyget? Hur använder du det?
Vad skulle du vilja se i liknande verktyg?
Vad för förändringar har verktygen lett till? Har ditt arbetssätt förändrats?
Har du stött på några utmaningar när du använder verktyget? I så fall, vilka?