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AQUALECTRA

Bachelor Thesis

Strategic Outsourcing of Water Disruptions

A new operational model for outsourcing water grid disruptions

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Colophon

Title	**Strategic outsourcing of water disruptions**
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Summary

This bachelor thesis defines outsourcing as when companies delegate tasks to external providers to reduce costs, access expertise and improve efficiency. Currently, Aqualectra's water distribution network struggles with control over outsourced corrective maintenance activities. There is no clear contractual procedures, leading to issues in evaluating performance and processing payments. The objective is to develop a modern contractual procedure for outsourced corrective maintenance through immersive theoretical reviews, current situation analysis and gap analysis. Aqualectra N.V. is a government-owned utility company in Curaçao supplying water and electricity. To support its operations, Aqualectra utilizes SAP (System Analysis Program Development) as its enterprise-wide system for registering and managing information. The department Grid Operations Water (GOW) handles water distribution activities. GOW handles approximately 6000 customer complaints annually. The department is experiencing delays in outsourcing breakdowns and has an over-reliance on manual processes. The problem was identified through a cause and effect (Ishikawa-diagram) analysis and states that: *Grid Operations Water is suffering from several operational inefficiencies that hinder organized outsourced corrective maintenance.*

The main research question is: *What are the current best practices in contractor management, and how can these practices be applied to optimize contractual services in response to emergency water grid failures within Grid Operations Water?* The sub-research questions focus on analyzing current outsourcing processes, identifying best practices and bridging gaps. The research model consist of the three phases: (1) Literature Review, (2) Current Situation Analysis and (3) Solution Development. The key stakeholders are the contractors, Servicemen Interruptions Water, field technicians, supervisors, Head of Department GOW, Control Center Dispatchers and the Customer Relation agents. To enhance the reliability of the findings, data triangulation is applied (interviews, literature review and document analysis).

The theoretical review highlights Water Distribution Networks (WDNs) as vital infrastructures tasked with delivering safe water to diverse users. The best method to manage outsourced activities in these networks lies in selecting the right contractors for the right job, drafting effective contracts and maintaining control over outsourced activities. Global technological advancements, such as blockchain technology and smart contracts, are transforming outsourcing management. In the trend of smart contracts, smart payment procedures are in the mainstream. Reactive maintenance (RM), though fundamental in addressing immediate equipment failures, has limitations when compared to more proactive maintenance strategies like predictive and preventive maintenance. Emergency Response Plans (ERPs) and Disruption Management Frameworks play crucial roles in maintaining the reliability and resilience of the water distribution network. The Disruption Management Framework proposes a promising approach to address disruptions through three phases: Discovery, Recovery and Redesign. The theoretical review concludes that the focus must be on an information management model that drives disruption management, emphasizing the dynamic interplay of external and internal factors.

The current situation analysis in this thesis analyzes how GOW manages outsourced disruptions and how payments are processed separately. These processes were benchmarked through interviews with the water company (WEB) on the sister islands: Aruba & Bonaire. The objective of the outsourced disruption management process is to review current outsourced disruption response workflow and identify inefficiencies in the process. The results present the following major shortcomings: lack of ERP application training, over reliance on manual approvals & paperwork and poor contractor & performance monitoring. The objective of the outsourced disruptions payment process review is to analyze contractor payment workflow and identify inefficiencies. The results indicate a delay in payment processing caused by manual data entries in SAP and high administrative workload for contractors. There is also poor transparency in financial processes.

The solution comprises reorganizing the process of outsourcing water disruptions. The new process must be systematic, modernized, transparent and efficiently monitored. To set up the new process, a new approach is used that consist of assessing shortcomings, identify alternatives based on best practices, develop operational guidelines, review & validate with stakeholders and restructure and validate the final process. The developed operational guidelines serve as a directory to integrate smart contracts for automatic payments, standardize data collection & storage, improve real-time tracking of contractor jobs, reduce paper-based documentation and develop a GIS-integrated disruption tracking system.

This bachelor thesis presents a detailed analysis of the challenges, inefficiencies and solutions for outsourced corrective maintenance in Aqualectra's water distribution network. The proposed model integrates technology, automation and best practices to improve efficiency, reduce delays and enhance contractor management.

Table of Contents

Terms and Abbreviations

Terms	
Corrective (Reactive) maintenance	Corrective maintenance is a maintenance task performed to identify, isolate and rectify a fault so that the failed equipment, machine or system can be restored.
Disruption management	The process of detecting and reacting to disruptions in a system by making changes to its structure or operation to improve supply chain resilience.
Outsourcing management	A business practice in which services or job functions are hired out to a third party on a contract or ongoing basis.
Pipe fitting work	Installing, assembling, and maintaining piping systems for water, gas, oil or industrial fluids.
Smart contract	A smart contract is a computer program or a transaction protocol that is intended to automatically execute, control or document events and actions according to the terms of a contract or an agreement.
Abbreviations	
AQ	Aqualectra
CM	Corrective Maintenance
ERP	Emergency Response Plan
GIS	Geographic Information System
GOW	Grid Operations Water
OWD	Outsourced Water Disruptions
PM	Preventive Maintenance
RM	Reactive Maintenance
SAP	Systems, Applications and Products. (The organization's Enterprise Resource Planning system)
WDN	Water Distribution Network
WSC	Water Supply Chain

List of Figures

List of Tables

List of Infographics

Acknowledgement

Dearest gentle reader,

I am proud to welcome you to this acknowledgment, in which I reflect on my enriching experience at Aqualectra N.V. from September 2024 to January 2025. During this period, I had the opportunity to immerse myself in the fascinating world of water distribution networks and gain practical experience within this dynamic company. Completing my graduate project at Aqualectra has been a unique opportunity to apply my theoretical knowledge in a real-world setting.

I am deeply grateful for the warm and unforgettable welcome of Mrs. N. Boeldak-Theodora, who embraced me from the very first moment with open arms and a heart full of kindness. Beyond her warm reception, she has been a constant source of encouragement and guidance, always ready to provide insightful advice and support.

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This project has not only provided me with valuable practical experience but has also deepened my passion for the technical sector. I am confident that the knowledge and skills I have acquired will enable me to make meaningful contributions to the future of technology.

I hope that this dissertation offers you a clear insight into my experiences and achievements during this exciting period.

With gratitude,

Tanisha de Windt

1. Introduction

Outsourcing is a business practice where companies hire external providers to perform tasks or processes that would typically be managed in-house (Thomas Smale, 2017). Outsourcing can provide organizations with greater budget flexibility and control by enabling them to pay for services and business functions only as needed. It is often seen as a way to reduce the costs of hiring and training specialized staff, access specialized expertise and lower capital and operating expenses as well as to mitigate risks (Olive, 2019).

Companies primarily outsource to reduce “non-core” business expenses (Lockwood, 2011). Other reasons for outsourcing include reducing and controlling operating costs, improving company focus, accessing world-class capabilities, obtaining tax credits, freeing internal resources for other purposes, streamlining or increasing the efficiency of time-consuming functions and maximizing the use of external resources. (Luxner, 1989)

A category of outsourcing is maintenance outsourcing. Maintenance outsourcing refers to the practice of contracting an external service provider to oversee and execute maintenance tasks for an organization. This approach transfers the responsibility for maintenance operations to a third-party provider (What is Maintenance Outsourcing, n.d.). When it comes to maintenance in Distribution Network Service Providers (DNSPs) five different maintenance strategies are applied: Corrective maintenance, Preventive maintenance, Predictive maintenance, Proactive maintenance and Perfective maintenance (Márquez, 2009).

DNSPs use corrective maintenance (CM) to address and mitigate issues that lead to the degradation of services on the network (Márquez, 2009). Just like any other maintenance activity, corrective maintenance can also be outsourced. When outsourcing it is important to not lose control over the outsourced activity. To prevent this, the client needs to have capable and active employees to manage the vendor. Vendor management and technological skills are here very important to not lose control, otherwise outsourcing is bound to fail (Barthélemy, 2003).

Currently Aqualectra’s department responsible for water distribution is facing challenges with control over outsourced activities specially outsourced corrective maintenance activities. According to the Water Grid manager (Monte, 2024) the lack of control over the outsourced corrective maintenance activities and no clear contractual procedures are causing major issues when evaluating process performance and executing on-time payments for the activities. Most of the outsourced activities are being supervised by employees with little contractor management skills and there are still parts of the contractual procedure that are manual e.g. the service entry sheet. Therefore this research project has been commissioned by Aqualectra’s Water Supply Chain department to develop clear and technological advanced contractual procedures when outsourcing corrective maintenance activities.

Chapter 1 introduces Aqualectra N.V., its vision, mission and the context of the study. In chapter 2 the research methodology is presented where the problem definition, research questions, methodology, boundaries, objectives, key stakeholders and study reliability are specified. Chapter 3 provides a theoretical review of the topic. To do so, it examines water distribution networks, outsourcing management, trends, challenges, maintenance strategies, emergency response plans and frameworks for disruption management and contractor payment processing.

The current situation analysis is covered in Chapters 4. Chapter 4 focuses on the operational procedure to outsource and resolve water grid disruptions and it also examines the contractor payment process. Chapter 3 and 4 answer the first two sub-research questions.

Chapter 5 answers the final sub-research question and proposes a structured approach to improve the outsourced water disruption (OWD) process, including assessing shortcomings, exploring alternatives, formulating guidelines and validating the final process. Chapter 6 presents the study's key findings and answers the main research question. It also provides recommendations for optimizing disruption management and payment processing.

Additional supporting materials, including advocacy for an up-to-date water distribution network, transitioning from reactive to predictive maintenance and an in-depth analysis of the current situation, can be found in the appendices.

1.1 Company description Aqualectra N.V.

Aqualectra(AQ) is a private utility firm owned by the government of Curaçao that produces and distributes water and electricity to more than 80,000 households and businesses on the island. The existing Water Distribution Network on Curaçao is part of a water supply chain network with components that carry drinking water[1] from Aqualectra's water production plant to consumers.

At Aqualectra, the Water Supply Chain (WSC) department is responsible for the overall production and distribution of drinkable water. Within WSC, the Plant Operations Water department handles the production, while the Grid Operations Water (GOW) department manages the distribution. The water treatment plant improves the quality of seawater through Reverse Osmosis (RO) by removing and reducing contaminants and other undesirable components so that the water becomes safe for consumption. The Water Distribution Network (WDN) carries the drinkable/potable water through pipes, valves and pumps.

The department of Grid Operations Water (GOW) experiences an average of 6000 client complaints per year. These complaints are typically breakdowns about potable water with high or low pressure, brown water, unpleasant water taste, a complete lack of water or burst/teared pipes that are causing water leakage. The Servicemen Interruptions Water in WSC are the individuals

[1] Water that is safe for consumption.

that arrive first at a breakdown and are to an extent responsible for performing corrective maintenance. When performing corrective maintenance, Servicemen Interruptions Water are authorized to excavate 1.0 x 0.4 x 0.4 meters in soil. CM that requires excavation beyond this measurement, including in asphalt, concrete or brick removal if necessary, are outsourced.

1.2 Vision and mission Aqualectra

Aqualectra's:

Vision

"To lead Curaçao into the future by transforming its utilities."

Mission

"To fundamentally contribute to the wellbeing of the citizens of Curaçao."

Values

Service, Excellence and Passion

2. Research Methodology

This chapter outlines the research methodology employed in this study beginning with an in-depth definition of the problem followed by a comprehensive problem statement. The research problem is investigated by performing a cause-and-effect analysis on the two key stakeholders: The GOW department and the in-house contractors. This analysis serves as the foundation for deriving the main and sub-research questions that guide the research.

The research scope is also defined in this chapter, delineating the boundaries of the project. This includes a clear articulation of the assumptions made throughout the research process and an acknowledgment of the limitations that may impact the findings.

2.1 Problem definition

To define the problem, the initial effects are outlined and a cause-and-effect analysis is presented. This analysis is illustrated in Figure 2-1. For a more extended and detailed definition of the problem refer to the research proposal report (Windt, Process optimization of civil work within Aqualectra water: Research proposal, 2024).

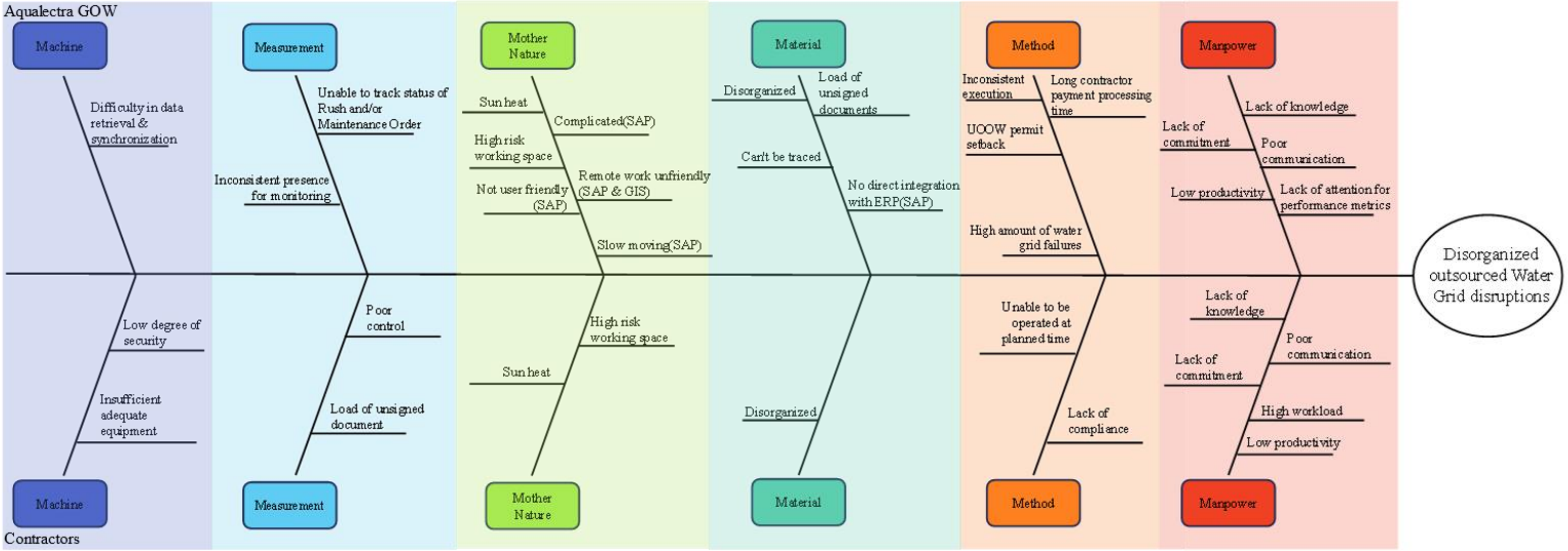


Figure 2-1 - Cause and effect analysis

2.2 Problem Statement

The problem statement materializes from the cause-and-effect analysis described previously and can be framed as follows:

Grid Operations Water is suffering from several operational inefficiencies that hinder organized outsourced corrective maintenance.

2.3 Research Questions and Method

Main research question:

What are the current best practices in contractor management, and how can these practices be applied to optimize contractual services in response to emergency water grid failures within Grid Operations Water?

Sub-research questions:

To answer the main research question, the following sub-questions will be explored using the corresponding methods:

1. *What are the best practices for managing contractual services during emergency grid failures, and how can these best practices be applied to redesign the existing workflow of contractors in Grid Operations Water when resolving emergency water grid failures?*

   The research method will begin with a literature review about best practices in managing contractual services, followed by an analysis on its application in Grid Operations Water when resolving emergency water grid failures.

   The research methodology is composed of:

   - Desk research; this will involve reviewing existing literature, reports, and case studies related to best practices in contractual service management and emergency response.

2. *How are contractual services in Grid Operations Water currently being managed when resolving emergency water grid failures?*

   This will start with interviews with key stakeholders about current processes.

   The research will consist of:

   - Observation; analyzing the current workflow and work behavior of key stakeholders, documenting the interactions between stakeholders and contractors and noting real-time adjustments that are made. This is done to be able to develop a resilient system that can better withstand emergencies.
   - Qualitative research; this involves conducting interviews to understand the stakeholders' experiences, perspectives and behaviors. The findings will include insights from stakeholders regarding their experiences with the current processes and proposed changes.
   - Document analysis; Reviewing internal documents related to processes and protocols currently in place for managing emergency water grid failures.

3. *How can the gap between the current management of outsourced disruptions and the desired best practices identified in the research be effectively bridged?*
   The research methodology for this question consists of:
   - Desk research; this involves reviewing organizational documents and policies related to contractor services and management within Grid Operations Water.
   - Focus group; discussions with various stakeholders to explore collaborative insights and generate collective recommendations for bridging the gap.
   - Gap analysis; identify specific areas where current practices fall short of best practices by conducting interviews with stakeholders to gather their perceptions of how specific gaps affect performance and analyzing performance metrics to identify instances where gaps may have contributed to inefficiencies or failures.

2.4 Research Model

A research model is a structured guide that outlines how a research study will be conducted. It serves as a guide for researchers to organize and integrate the various components of the research, so that they are more focused in the scope of the research project (Oluwatobi Ayodeji Akanbi, 2015).

This research is divided into three phases (Refer to Figure 2-2), each addressing a distinct sub-research question to systematically investigate the challenges and opportunities to develop a strategy for disruption preparedness.

In phase I a comprehensive literature review is conducted to establish a theoretical foundation. The focus is on synthesizing theories related to disruption management, outsourcing management, Water Distribution Networks, Emergency Response Plans and reactive maintenance.

Phase II focuses on understanding the current state of processes, roles and interactions among stakeholders. The key methods employed are interviews, observation on process and stakeholder behavior and a qualitative research regarding the stakeholders' insights on current procedures.

Phase II seeks to explore existing knowledge to address the challenges identified in Phase I and to provide information for the development of a structured approach for managing outsourced disruptions.

The final phase proposes a response plan for outsourced water grid breakdowns.

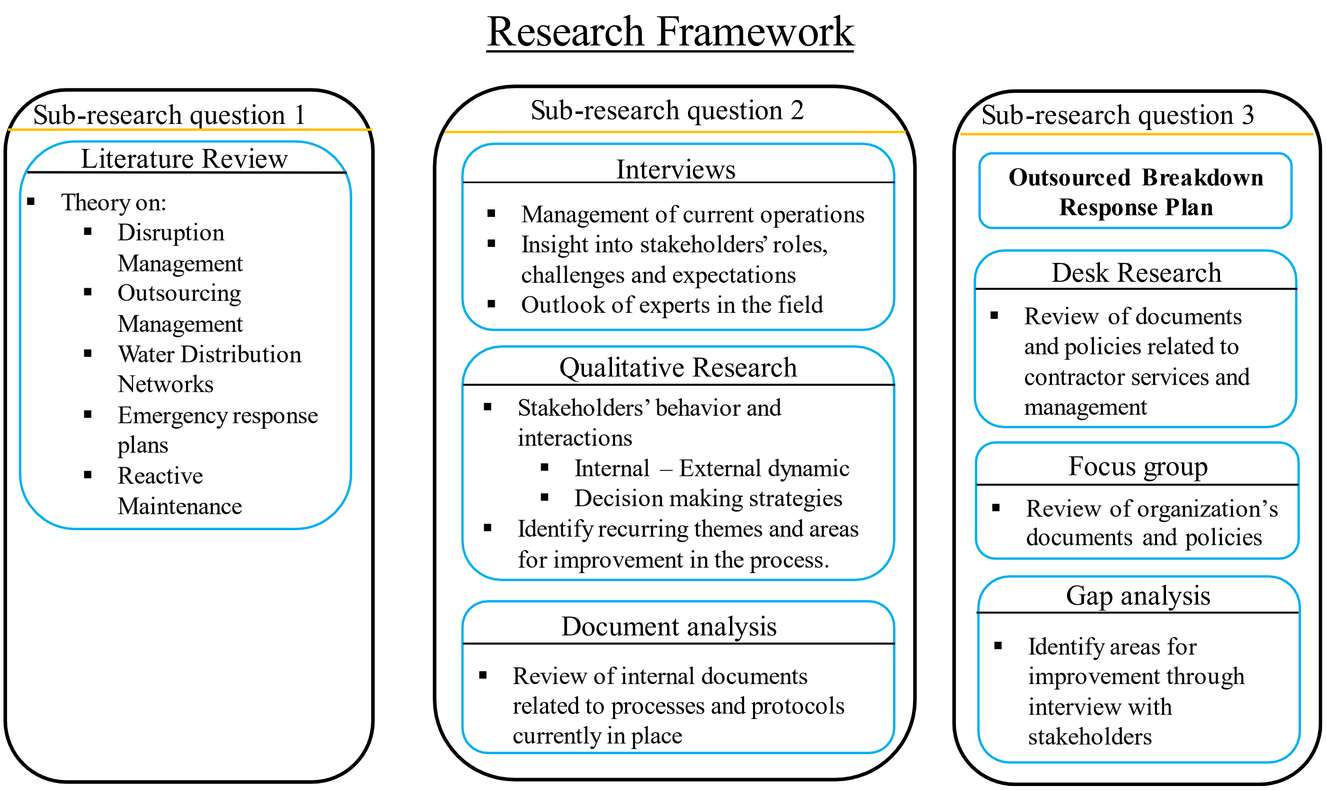


Figure 2-2 Research Framework

2.5 Research Boundaries

As mentioned in paragraph 1.2, Aqualectra uses multiple contractors for a variety of activities. This research is limited to the activities of resolving water grid breakdown/emergency water grid failures such as fixing leaks and partial replacement of pipes within Grid Operations Water. This does not include follow up (maintenance) activities after a breakdown or breakdowns that require water grid inspection and/or engineering work .

2.6 Research Objective

The objective of this graduate project is to provide recommendations for optimizing the efficiency and effectiveness of civil, excavation and pipe fitting work performed by contractors for Grid Operations Water. The aim is to develop a process that reduces bottlenecks and improves overall performance. This will be achieved through literature review of state-of-the-art contractor management practices, an analysis of the current situation and critical evaluation of the results, while also exploring the integration of the new process into the existing ERP system. The analysis will lead to practical recommendations for improving contractor workflows, monitoring and reporting, supported by optimized procedures and implementation plans.

2.7 Interested Parties

Interested parties are individuals, groups, or organizations that are involved in, affected by, or have an interest in the process (BCM Institute, n.d.). They either directly participate in or are impacted by the operations and outcomes of the process, which includes repairing and maintaining the water grid through outsourcing. The following table gives oversight of the stakeholders:

		Role	Interest	Concern(things they keep an eye on.)
1	**Contractors(Stakeholder)**	Perform outsourced repair/maintenance work on the water grid.	Receiving timely job assignments, approval for completed work and payment.	Delayed payment processing
2	**Servicemen Interruptions Water**	On-site personnel who identifies Water Grid breakdown and assess whether a contractor is needed.	Quick verification of their assessments and efficient assignment of contractors when needed.	Ensuring clear communication about job status.
3	**Field Technicians(Stakeholder)**	Monitor the contractor’s work on-site to ensure that the contractor’s work meets the technical, safety and quality standards set by AQ.	1. Ensuring that the work performed by the contractors is up to standard and completed efficiently without requiring further rework. 2. Clear and timely report of Work Order status.	1. Communicating the Work Order Status effectively. 2. Ensuring high work quality
4	**Supervisors(Stakeholder)**	Review and verify the Servicemen Interruptions Water’s assessment, approve the use of contractors and oversee the completion of outsourced jobs.	Maintaining quality control to ensure quality work, oversee that only necessary jobs are outsourced and approving completed Work Orders.	Quick verification and allocation of contractor, proper job tracking and ensure good correlation between fieldwork and the data reported(in SAP).
5	**Dispatchers(Stakeholder)**	Receive job requests from Servicemen Interruptions Water and dispatch them to Supervisors on shift for verification.	Facilitating smooth communication between Servicemen Interruptions Water, supervisors and contractors and tracking job status.	Minimizing delays in dispatching Work Orders to Supervisors/Field Technicians.
6	**Technical Clerk**	Create a Purchase Request (PR) out of performed outsourced repair/maintenance work and receive to be created PO.	Ensuring timely and accurate PR-to-PO conversion, so contractors can be paid promptly.	Accuracy in the documentation process and compliance with procurement policies.
7	**Head of Department GOW(Stakeholder)**	Provides final sign-off on the completed jobs, approving them to move to the financial stage.	Ensuring the work meets the necessary standards.	
8	**Procurement Department**	Ensure the smooth processing of POs, once the PRs are generated and signed by the HOD.		Avoiding errors and delays in processing POs, and ensuring all approvals are in place before payment.
9	**Finance Department**	Process contractor payments once the PO has been received by the PR creator and after receiving Contractor’s invoice.	Ensuring timely and accurate payments to contractors.	Timely payments to avoid disputes.
10	**Clients**	Benefit from the repair (and maintenance) work done on the water grid.		
11	**Water Supply Chain Management**	Oversee the overall operations, ensuring efficiency, quality and cost-effectiveness in handling outsourced work.	Maintaining service reliability, operational efficiency, and budget control.	Controlling costs, minimizing downtime, ensuring transparency in contractor management and maintaining good service levels.
12	**UOOW(Public Authorities)**	Issue the necessary permits, so that the water department can operate legally.	Compliance with laws, regulations, and safety standards.	Issuing the permit on time, so that the jobs can go on seamlessly.
13	**IT Department**	Maintain the systems(SAP & GIS) to support the process.	Providing a reliable, user-friendly and secure system.	Seamless system integration with the process.

2.8 Reliability of the study

To enhance the reliability of the findings, data triangulation (Bhandari, 2022) will be applied. This involves gathering data from multiple sources, such as interviews, document analysis and literature review. All research procedures and results will be thoroughly documented to ensure transparency.

To minimize researcher bias, regular feedback will be sought from stakeholders and experts in the field. Additionally, critical reflection will be employed to assess any potential biases and how they might influence the research outcomes.

3. Outsourcing Water Disruptions: Theoretical Review

3.1 Introduction

This chapter reviews the literature on managing outsourced water grid breakdowns and answers the first sub-research question: What are the best practices for managing contractual services during emergency grid failures, and how can these best practices be applied to redesign the existing workflow of contractors in Grid Operations Water when resolving emergency water grid failures?

In order to gather a volume of literature on this specific subject, a narrative approach was used. A narrative literature review provides a comprehensive background for understanding current knowledge on the subject at hand (Cronin P., 2008). This literature review is structured thematically. To provide clear answers to the research questions, the literature search was conducted using mainly the next six electronic databases; *Institute of Electrical and Electronics Engineers (IEEE)*, *Google Scholar*, *ResearchGate, the University of Curacao LRS*, *Consensus* and *Emerald Insights*. The investigation was conducted utilizing various terms and free text phrases, which were appropriately combined and was managed by filtering full text peer-reviewed articles from the year 2013 and onward. However, after evaluating the available literature on the topic, the search criteria were broadened to include all relevant studies, with a preference given to recent publications.

The research questions were inspired by a prior additional narrative literature review on this topic which revealed distinct gaps in the existing body of literature. While considerable scholarly work has addressed (organizing) outsourcing as a broad concept and there is a moderate volume of research concerning water grid breakdowns in the context of corrective maintenance, as well as significant discussion on the transition from corrective to preventive maintenance, the intersection of these domains remains notably underexplored.

To address these gaps, the research questions will be explored through a synthesis of the existing literature, an examination of comparable case studies and interviews with experts in the field. To conduct the literature review in a structured manner, the search will focus on the following key areas:

1 Water Distribution Networks; to gain a detailed understanding of water distribution networks and the challenges associated with their maintenance.
2 Outsourcing management[2]; reviewing literature on outsourcing management helps clarify best practices and common challenges when external providers are responsible for

[2] Given that excavation forms the foundation of most outsourced tasks in this context, research on construction contracts will be particularly relevant, as it often addresses the complexities associated with excavation activities.

corrective/reactive maintenance. It is meant to also shed light on how to establish effective partnerships with vendors and ensure that outsourced tasks related to underground piping systems meet quality and safety standards.

3 Corrective/Reactive Maintenance; to understand both the benefits and limitations of corrective maintenance and to identify effective strategies for managing failures that occur (within water distribution systems) after they have happened.
4 Emergency Response Plans(ERPs): to explore response strategies that prioritize swift water grid repairs, resource readiness and effective communication.
5 Disruption Management; this area explores strategies and methodologies to manage disruptions within water distribution networks.
6 Framework for Smart Payment Processing: This section will explore innovative approaches to enhance the efficiency, accuracy and transparency of payment processing for outsourced maintenance services.

3.2 Water Distribution Networks

A Water Distribution Network (WDN) is an integrated system comprising interconnected pipes, pumps, storage tanks, valves and water meters. These components work together to transport potable water from treatment facilities or natural water sources to a variety of end users, including residential, commercial, industrial and emergency services. According to Christodoulou et al. (2018), the purpose of WDNs is to ensure that water reaches these users reliably and safely, meeting both the demand and quality standards required by modern communities.

Christodoulou et al. (2018) add that as infrastructure ages, water utility companies are increasingly tasked with developing and implementing innovative methods for monitoring, repairing and, when necessary, replacing WDN components. They are also expected to proactively design strategies to maintain continuous operation. This need for innovation arises from the growing complexity of effectively assessing pipe networks while managing them in ways that maximize reliability and minimize both operational and maintenance costs.

Heino et al. (2015) identify WDNs as critical infrastructures. Heino proceeds to explain that risk assessment of these infrastructure are a major problem for the engineering community, because they are underground infrastructures.

Christodoulou et al. (2018) proceed to explain that various factors contribute to a WDNs vulnerability, including time-invariant and time-dependent risk factors that impact the likelihood

However, this does not imply that the literature review will exclusively center on construction contracts. While such contracts acknowledge the challenging working conditions associated with excavation work, they also encompass broader aspects of construction that fall outside the scope of this research.

of pipe breakage and overall system reliability. Key factors include a pipe's age, diameter, material composition and history of previous breaks. Additionally, operational conditions such as network pressure and water flow rates are critical in determining the performance and longevity of WDN components. These risk factors serve as indicators and are instrumental in guiding maintenance decisions. They originate from:

1. The network's topology and the reliability of the system's basic components.
2. The diversity of the components with unique design specifications and operational requirements.
3. A scarcity of historical data on the components' performance over long-term and under varying operating/loading conditions.
4. The inaccessibility of the network for direct inspection, making it difficult to assess their physical condition.

This vulnerability, though, is not static. A water distribution network functions somewhat like a living organism. The behavior of its components is constantly changing. This makes it dynamic in nature and which with every failure its survival as a whole is affected.

Pipe deterioration can result in pipe breakages, which in turn causes water loss and allows for the infiltration of pathogens into the network. These pathogens lead to water contamination, posing significant health risks to the population served by the Water Distribution Network (Christodoulou, 2018).

3.3 Outsourcing Management

As monopolies, water utilities must demonstrate their efficiency to both customers and decision makers (Esfahani, 2005). Water utility companies face great challenges in recruiting young workers to replace those who are retiring (Takala, 2013). This is a factor that encourages them to increase their outsourcing operations. Nevertheless, that does not signify that outsourcing always leads to success. It can create extra costs, service disturbances and more challenges if not carefully implemented (Heino, 2015).

Outsourcing is referred to as the dispensation of non-core business operations to a third-party organization (Akbari, 2017). Companies decide to outsource for different type of reasons. The majority choose to outsource mainly to reduce costs of business operations, production and for an enhancement in financial performance (Roussel, 2005).

Outsourcing decreases business operations costs by shifting the fixed cost to variable costs and it provides more chances to discover skills that the organization does not currently have. Contracting with an outside organization should be considered a possible improvement to achieve a higher and better service level (Akbari, 2017).

In recent years, three types of outsourcing have been established by Oshri, Kotlarsky, and Willcocks (2015); total outsourcing, selective outsourcing and transitional outsourcing (Akbari, 2017):

- Total outsourcing; This is the transfer of over 80% of the company's operations or business functions to a third-party supplier.
- Selective outsourcing; refers to managing 20–80% of internal business while assigning a selected task to one or more outside providers.
- Transitional outsourcing; is the temporary outsourcing of a major organizational change, such as introducing new technology.

This research focuses on a utility company's water department, which outsources water grid breakdown repairs when the required civil or pipe fitting work falls outside the scope of the Servicemen Interruptions Water. This practice is common in the utility sector as it allows companies to leverage specialized expertise.

Repairing the water distribution network often requires excavation work to access the affected areas. Excavation work is regarded as a component of the construction industry, as it necessitates adherence to construction work standards and regulations during its execution (Safe Work Australia, 2024). Therefore, this section on outsourcing management draws partially on research from the construction industry related to underground infrastructure projects, specifically the installation of water pipelines, rather than the construction or modification of physical structures like buildings, roads or bridges.

When an organization wants to outsource, thus delegating certain tasks to third parties, a legal agreement is set in the form of a contract. Contracts are of great importance. The contract sets out the conditions for the services to be provided and protects the rights of all parties while regulating interpersonal exchanges.

Research has categorized construction contracts into two main types: payment-based contracts and delivery-based contracts (Abdul-Ghani, 2021).

Contracts according to the **payment** are:

- Lump-sum contracts
- Measure and value contracts
- Cost-plus contracts
- Unit price contracts

Delivery contracts are:

- General contracts
- Design-build contracts
- Separate contract method
- Management contracts

The main difference between these two types of contracts lies in their focus and structure.

Contracts according to the payment are concerned with how the contractors will be compensated for their services. They define the payment structure, whether it be a fixed amount (lump-sum), based on measured work (measure and value) or other methods like cost-plus or unit price.

The focus here is on the financial arrangement and the terms of payment, which can affect the contractor's risk and the owner's financial exposure.

In a lump sum contract, the contractor agrees to complete the entire project for a fixed total price. This price is agreed upon before the work begins and does not change unless there are significant changes to the project scope.

In a unit price contract, the work is divided into specific items or tasks, and each task has a predetermined price per unit (such as per meter, cubic meters or piece). The total contract price is determined by multiplying the unit prices by the quantities of work actually completed. The contractor is paid a fixed price for each unit of work completed.

After this the contractor needs to submit its invoices based on the actual quantities completed.

The advantages are that the owner is allowed to make changes during the implementation phase and the units of the work are accurately detailed and the owner has some flexibility.

The disadvantages are the high risk on the owner in the case of an “unbalanced bid” . An unbalanced bid refers to when the contractor puts unreasonable prices for the units and this price does not represent the actual cost for the units.

On the other side we have delivery contracts which are centered around the method of delivering the project. They outline the responsibilities of the contractor in terms of project execution, design and overall management. The contract specifies a fixed price for the entire project, which includes all labor, materials and overhead costs. This price is agreed upon before the work begins.

In summary, the main difference is that payment contracts are primarily about the financial arrangements and how payments are structured, while delivery contracts focus on the execution and management of the construction project itself. This distinction influences the risk allocation, quality control and overall project management strategies employed in construction projects (Abdul-Ghani, 2021).

3.3.1 Challenges in outsourcing civil and pipe fitting work

Research indicates that outsourcing offers numerous advantages when strategically implemented (Barthélemy, 2003). However, it also presents various challenges that organizations must navigate. Barthélemy J. found seven “deadly sins” that are the underlying cause of most failed outsourcing efforts. These seven “deadly sins” are unique in their own concept, but they remain interconnected and it is likely that each organization will encounter each one at some time during the outsourcing process. The seven “deadly sins” are:

1. Outsourcing activities that should not be outsourced
2. Selecting the wrong contractor
3. Writing a poor contract
4. Overlooking personnel issues

5. Losing control over the outsourced activity
6. Overlooking the hidden costs of outsourcing
7. Failing to plan an exit strategy

Barthélemy suggests to manage what activities should be outsourced by determining which business activities can be best performed by contractors and which ones should be kept in-house. It is important to notice that, for companies outsourcing water utilities, sufficient capacity to maintain and perform basic operations should be retained in-house (Heino, 2015). Barthélemy explains that activities which their resources and capabilities are valuable, rare and difficult to imitate e.g. core activities should not be outsourced because firms risk losing competitive advantage and becoming “hollow corporations”. Nevertheless, this “deadly sin” may not fully apply for water utility companies, as they are often monopolies and do not face competitive pressures.

Moreover, when a contractor is chosen primarily based on e.g. offering the lowest bid despite lacking the necessary capabilities and expertise to effectively manage the assigned activities, the project is likely to fail. Coleman et al. (2015) explain that this is often the cause of selecting an unsuitable contractor. The most effective way to spot the best contractors is through first-hand experience. A useful technique to choose the top third-parties is to entrust a large number of contractors with commodity activities before outsourcing more sensitive activities. However, first-hand experience requires both time and financial investment whether or not a contractor is efficient and trustworthy. An alternative is to use second-hand experience i.e. by evaluating the contractor’s reputation.

A good contractor is necessary for outsourcing success. Not adequately negotiating the contract and assuming that the partnership relationship will take care of everything is a mistake. A good contract must be precise, complete, compensation based, balanced and flexible. Involving contractors early in the project builds trust and gives them the opportunity to contribute ideas and increase productivity (Loosemore, 2014).

Coleman and Bashir (2015) both support Barthélemy’s fourth deadly sin: Overlooking personnel issues. They emphasize that at the beginning of a contractor partnership, management should prioritize good communication, clearly defined plans and ethical behavior towards employees.

It is also important for management to avoid losing control over outsourced activities. Management must ensure a skilled and confident onsite team to handle the contractors and the hidden costs of outsourcing must not be overlooked.

An exit strategy is also crucial for instances where the contractor must be switched or the outsourced activity is reintegrated.

3.3.2 Trends in outsourcing management

According to Ezeh (2024), leveraging technology for better contract management can transform how utility companies manage their contracts. As mentioned, this section on outsourcing management draws partially on research from the construction industry. Looking ahead, several key trends and innovations are expected to redefine construction contracts. These innovations offer greater efficiency, transparency and collaboration (Ezeh, 2024). Two concepts will be explored: using trust to strengthen relationships with contractors and the emerging trend of smart contracts, a feature of blockchain technology.

3.3.2.1 Building Trust as a Solution for Successful Partnership

Heino et al. (2015) introduce the trust approach to manage contractual relationships. The research explains that due to challenges such as those mentioned above, including the significant issue utility companies face in finding young workers to replace the large number of retirees, designing and implementing outsourcing protocols becomes a complex process. These complexities affect the outcomes, particularly when outsourcing introduces new stakeholders, leading to changes in working routines.

Adapting to these changes requires new ways of thinking, as well as flexibility in people's mindsets. This is why human-related perspectives should not be overlooked in transformative approaches to managing contractual relationships.

Heino et al. (2015) surveyed 71 managers of water utilities, who observed that all of the uncertainty in outsourcing process cannot be eliminated by increasing the technical elements of the contract. Contracts are always more or less imperfect. Therefore Heino et al. (2015) emphasized that trust is essential to prevent these imperfections from being exploited. However, five of the managers indicated that private firms sometimes operate irresponsibly and perform low quality work whenever possible. This highlights that a strong atmosphere of trust does not always exist between utility companies and service providers.

Organizations sometimes treat contractors as underlings rather than partners, which leads to the management of mistrust rather than a true partnership. This results in ongoing inefficiency, weakened cooperation and it blocks innovation from the contractor’s side. A good contract should be specific enough to ensure high-quality of work, yet flexible enough to accommodate future needs and changes.

While outsourcing has elements that can be managed using mechanistic approaches, there are aspects that go beyond the mechanistic way of thinking. To develop trusting relationships management must avoid forcing non-mechanistic challenges into mechanistic structures and instead seek ways to effectively address these challenges.

3.3.2.2 Blockchain Technology and Smart Contracts

AIA Contract Documents (2024), an online portal that provides a comprehensive set of forms and contracts used in the design and construction industries explains that when it comes to the future of underground infrastructure projects, the adaptation of digital tools and smart contracts are one of the most impactful trends. Legal technology, including contract management software is transforming how the contracts are drafted. These tools offer features like automated contract generation, real-time collaboration and they ensure greater process tracking (Documents, 2024).

Smart contracts are a feature of blockchain technology. Blockchain Technology is an advanced database mechanism that enables transparent information sharing within a business network. This technology is an innovation that was initially developed to support cryptocurrencies like Bitcoin. It has now significant implications through various sectors. It's principles hinge on decentralization, immutability and transparency. These principles make it a transformative tool when managing contractors (Abdelghany, 2024). Smart contracts are self-executing contracts where the terms and conditions are directly written into code and embedded within a program or software. These contracts automatically execute actions when predefined conditions are met, eliminating the need for intermediaries. It can be concluded that outsourcing management has evolved to a strong focus on leveraging technology and fostering trust.

3.4 Corrective (Reactive) maintenance

Reactive maintenance (RM), sometimes referred to as corrective maintenance, is a type of maintenance strategy where maintenance is done once an equipment has broken down (IBM, 2024). This review on reactive maintenance is concise. It reflects the limited scope of recent research on its effective implementation. When examining reactive maintenance in the context of outsourced projects, the research becomes even scarcer. The predominant focus in existing studies is on transitioning to other maintenance strategies, such as predictive or preventive maintenance, which are perceived to offer greater reliability, efficiency and cost-effectiveness in the long term.

In an article from Ali et al. (2002), they propose an improvement for reactive maintenance projects that are outsourced, through information technology. They identify 3 major problems when outsourcing RM that are due to a lack of knowledge and poor communication between stakeholders:

1. Assigning the right problem to the right contractor.
2. Double handling of data entry
3. Information transfer

Ali et al. (2002) also identified the usage of paper in certain parts of the process as a problem, specifically highlighting, among others, the worksheet and feedback form. These forms require Operators within the organization (the client) to fill in the work undertaken, complete the assessment section and obtain a signature from the contractor. Paper usage causes delays in which RM is handled.

The study provided the following improvement points:

- Knowledge capturing – use IT tools to provide a central archive that is able to capture and update both tacit and explicit knowledge.
- Electronic storage of information – provide easy retrieval of information for users.
- Improving communication – make full use of internet and other ICT solutions to reduce the use of paper.
- Easy-to-use- interface – accommodate non-technical user with an easy-to-use interface.
- Controlled accessibility – an accessible system for all parties with their capabilities controlled by job responsibilities.
- Automated data entry systems – facilitate automatic transfer of information across various systems.

Ali et al. highlights that the more knowledge the system can capture, the better it will be at identifying the type of repair work needed. This is greatly useful when the organization is using or is going to use a system that has AI capabilities.

3.4.1 Transitioning from reactive to predictive maintenance

In a recent article published by Power & Motion, Jensen (2024) highlights the trend of transitioning from reactive maintenance to predictive maintenance in fluid power systems. While fluid power systems and water distribution networks differ in their primary purposes, they can still be compared in terms of shared engineering principles and key components, as they are both grounded in the fundamental principles of fluid dynamics.

In both systems, fluid is transported from one location to another under pressure. The flow and pressure in each system are carefully regulated by valves to ensure efficient operation. Additionally, both rely on conduits, such as pipes or hoses, to transport the fluid.

These shared features underline the potential for cross-disciplinary insights, where advancements in one field, like predictive maintenance in fluid power systems, could inspire innovations in water distribution networks and vice versa. For further details on this topic, refer to Appendix I: Shifting from Reactive to Predictive Maintenance.

3.5 Emergency Response Plans

An Emergency Response Plan (ERP) is a mindfully written series of planned actions that will help the organization to respond to emergencies of all types (Arasmith, 2014). The focus of literature on ERPs will be specifically directed toward understanding and managing routine, recurring breakdowns within water distribution networks, rather than large-scale natural disasters. These breakdowns such as pipe bursts, valve failures and water pressure inconsistencies represent the everyday operational challenges that disrupt water services to the customer. For the critical-aspects of an effective ERP in water distribution networks, please refer to Table 3-1.

	Critical-aspect	Description
1	Technical information	The ERP should include essential technical details to support personnel responding to emergencies.
2	Roles and responsibilities	Communication procedures should specify who is responsible for what actions, what information must be shared and when actions should be taken.
3	Safety precautions and training	All personnel should be regularly trained on organizational safety protocols.
4	Action plans for specific emergencies	The ERP should have step-by-step guidance on responding to different scenarios.
5	Adaptability	It should be considered a "living" document that is regularly reviewed and updated to reflect new insights or shifts in operational priorities.

Table 3-1 Critical-aspects for a successful Emergency Response Plan

The organization should also consider record keeping systems. These systems facilitate the storage and retrieval of critical data, enhance process control by providing data for informed decision-making and ensure consistent delivery of high-quality water services. According to Zografos (1998) and Messina et al. (2020), an information system solution will enhance emergency response effectiveness and reduce the duration of utility interruptions.

3.6 Disruption Management Framework

To respond to operational disruptions Messina et al. (2020) considers two type of strategies:

(i) Mitigation strategies – this strategy is about having countermeasures preventively in place to respond to disruptions and;

(ii) Recovery strategies – here you have actions in place to apply during disruptions for fast recovery.

Messina et al. highlight how an effective information management model can significantly improve supply chain visibility. Enhanced visibility, in turn, accelerates the recovery phase. The proposed conceptual model (Refer to Figure 3-1) for this research project consists of 3 phases: Discovery, Recovery and Redesign. Each of these phases are influenced by external factors such as social, political, economic, industrial and technological influences and internal factors such as organization structure and culture. The framework is supported by an information management model that provides a structured approach to handle information across all 3 phases. This model has seven stages, namely: identifying needs, creating, organizing, storing and maintaining, processing, sharing and using information.

In the Discovery phase, the focus in on recognizing and analyzing the disruption by looking at the disruptive event and the disruption cause. Here, two critical types of information need to be assessed to make sense of the disruption before moving on to the recovery phase (Folkman, 1987). They are the primary and secondary appraisal. The primary appraisal checks the potential of the harm, threat or challenge. The depth and breadth of the recovery phase will depend on the severity of these factors. The secondary appraisal evaluates the resources and capabilities of the organization to restore the disruption. In the Recovery phase, the focus is solely on the recovery practice and the organizations strategies for disruption recovery.

The 3rd phase is Redesign, which reviews how the organization measures the success of their recovery efforts and derive lessons to improve future disruption recovery.

The conceptual research framework was adapted from the frameworks in Figure 3-2, Figure 3-3 and Figure 3-4 to tailor existing theoretical models to the specific context and objectives of this study. While the original frameworks provide valuable foundations on how to cope with (supply chain) disruptions and manage the information related to these disruptions, they do not fully address the unique operational challenges faced by Grid Operations Water in managing outsourced water disruptions. Figure 3-3 illustrates an information management approach for supply chain disruption recovery (Dario Messina, 2020). Messina et al. introduced an information management model of nine-steps that serves as a support system for the conceptual framework outlined in Figure 3-2. Davenport (1997) suggests that the information management process is a series of sub-processes that involve determining information requirements, capture information, distributing and utilizing it effectively.

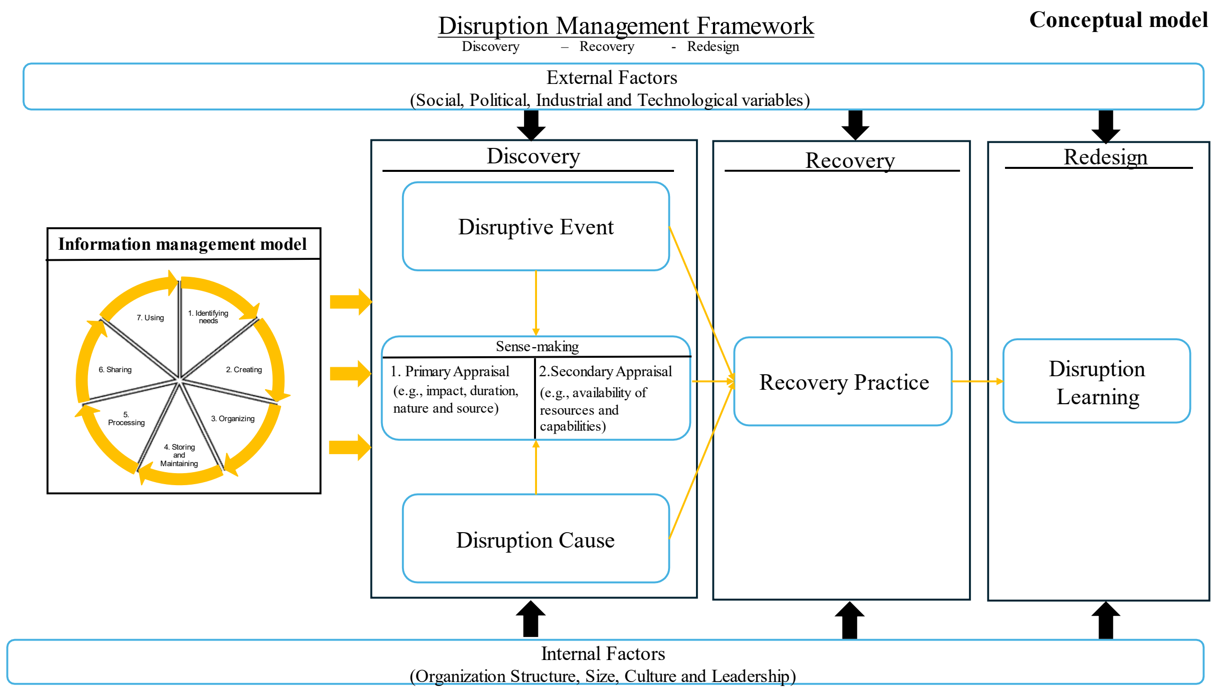


Figure 3-1Disruption Management Framework adapted from (Dario Messina, 2020) and (Pal, 2022)

Figure 3-4 illustrates disruption recovery through the lens of coping theory, where the disruption is viewed as a stressor (Pal, 2022). This proposed coping process is not tied to a specific context and will change according to variables such as the impact, duration, nature and source of the disruption.

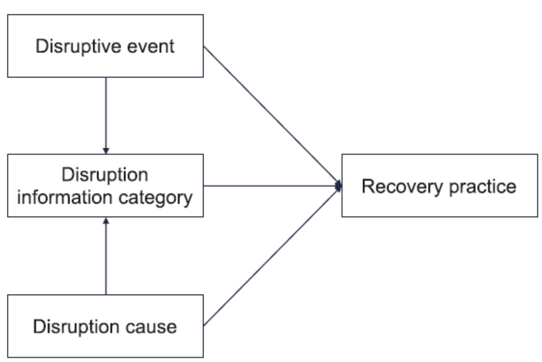


Figure 3-2 Disruption Management approach

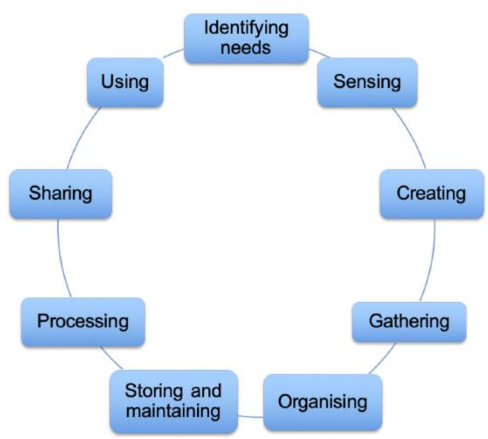


Figure 3-3 Information Management Model

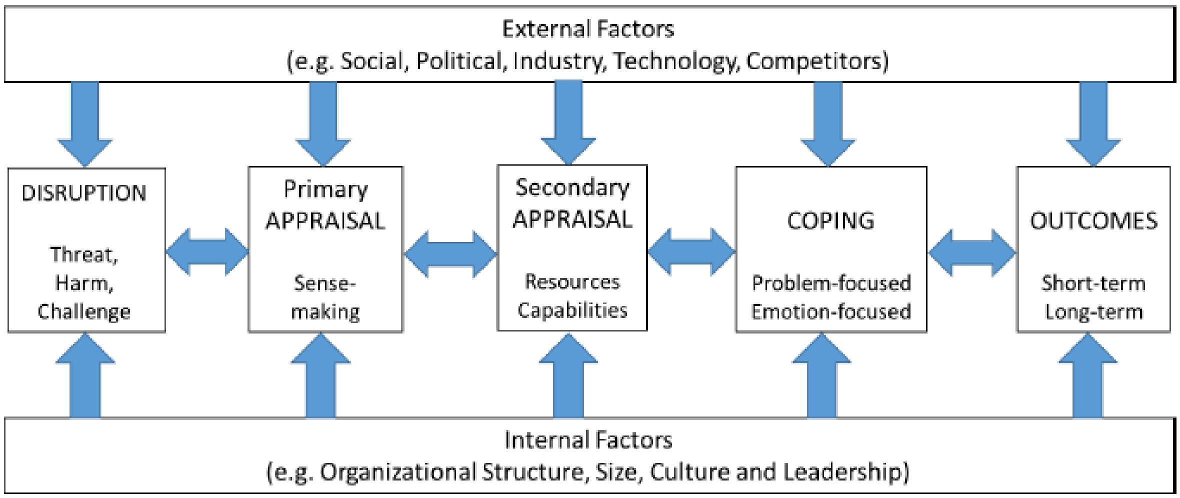


Figure 3-4 Coping Theory

3.7 Framework for smart payment processing

In the trend of smart contracts Ahmadisheykhsarmast (2020) proposed a smart payment procedure using blockchain technology. The purpose of this framework is to ensure security of payments for service that fall in the scope of construction service through smart contracts. In the procedure, the employer of the company and the contractor first agree on the terms of security of payment. Through a smart contract that is implemented on the blockchain, the agreed terms are displayed as a computerized protocol (refer to Figure 3-5**Error! Reference source not found.**).

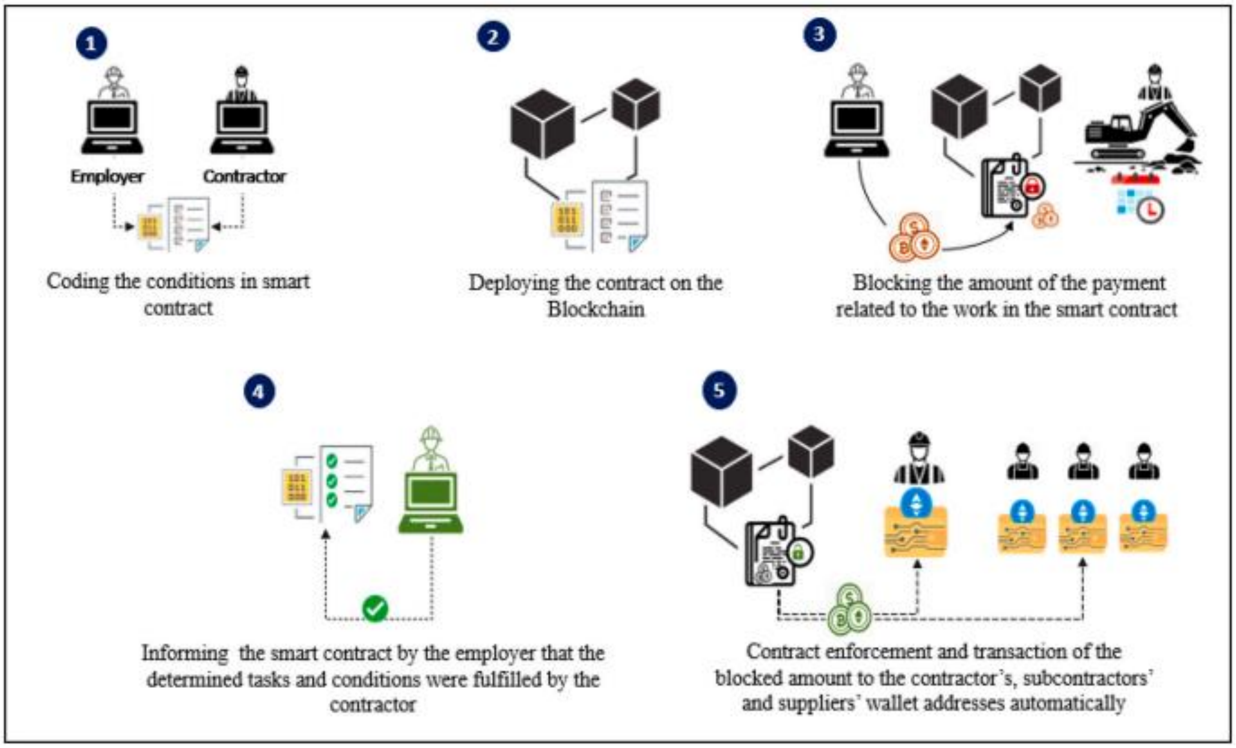


Figure 3-5 Smart payment procedure using blockchain technology (Salar Ahmadisheykhsarmast, 2020)

3.8 Conclusion

Water Distribution Networks (WDNs) are vital infrastructures tasked with delivering safe water to diverse users. These systems face significant challenges due to aging infrastructure, operational complexities and the dynamic nature of the networks. The best method to manage outsourced activities in these networks lies in selecting the right contractors for the right job, drafting effective contracts and maintaining control over outsourced activities. Global technological advancements, such as blockchain and smart contracts, are transforming outsourcing management. In the trend of smart contracts, smart payment procedures are in the mainstream. Reactive maintenance (RM), though fundamental in addressing immediate equipment failures, has limitations when compared to more proactive maintenance strategies like predictive and preventive maintenance. Ali et al.'s study highlighted the importance of IT tools for enhancing RM workflows. Emergency Response Plans (ERPs) and Disruption Management Frameworks play crucial roles in maintaining the reliability and resilience of the water distribution network. The Disruption Management Framework proposes a promising approach to address disruptions through three phases: Discovery, Recovery and Redesign. The Discovery phase involves analyzing the disruption and assessing its potential impact and organizational resources. The Recovery phase emphasizes executing strategies to restore operations, while the Redesign phase captures lessons learned to improve future responses. The focus shall be on an information management model that drives disruption management, emphasizing the dynamic interplay of external and internal factors.

4. Outsourcing Water Disruptions: Empirical Review

This chapter reviews Grid Operations Water's outsourced disruption management and answers the second sub-research question: How are contractual services in Grid Operations Water currently being managed when resolving emergency water grid failures?

The process review report about the management of outsourced disruptions can be found in Appendix II: Current situation analysis 1 and the process review report about the payment procedure for outsourced disruptions can be found in

Appendix III: Current situation analysis 2. The following chapter summarizes the findings of those analyses.

4.1 Objectives

The analyses focused on the current management of outsourced disruptions within Grid Operations Water, as well as the payment procedures related to these disruptions, which are carried out in collaboration with the Procurement & Contracting Out department. While a portion of the payment process is handled by Procurement & Contracting Out, whose internal procedures fall outside the scope of this research project, these processes remain relevant for understanding how contractors ultimately receive payment. The objectives were to:

- Identify current processes completed;
- Identify the responsibilities of each role/department;
- Determine the current disruption management framework implemented in Grid Operations Water
- Determine the current payment process for contractors;
- Benchmark the current process with likewise industries.
- Identify shortcomings and challenges in the current disruption management framework;

4.2 Water Distribution Network

The water distribution network of Curaçao consists of various pumps, storage tanks, valves, transport- and distribution meters located across the island. These components work together to distribute potable water from the water plants located at Mundu Nobo and Fuik to residential, commercial and industrial consumers.

After the water is treated and stored in storage tanks, it enters the distribution network where it is directed toward different regions of the island. As the water flows out of the tanks, it passes through the distribution meters. These meters accurately measure the volume of water being delivered. From the meter, water is distributed to that zone's service pipelines, serving residential, commercial or industrial consumers. These subsequent meters repeat the same function: they measure the incoming water and distribute it further into more localized subregions (See Figure 4-1 Section of Domi's Water Distribution Network).

To maintain the water distribution network, above-ground components, such as distribution meters and pumps, are typically maintained on a scheduled, periodic basis. In contrast, underground infrastructure, particularly water pipelines, presents more challenges and is generally maintained on a reactive basis, often triggered by the frequency and nature of client complaints.

When a specific area exhibits a recurring pattern of complaints, such as low pressure, brown water, or repeated water leakages, this may indicate structural degradation of the pipeline infrastructure. Upon reaching a predefined threshold of complaints, a pipe replacement project is initiated. This project involves replacing a defined segment of the water distribution network within the affected area and includes excavation, removal of old piping and installation of new sections.

To ensure compliance with public health and safety standards, water quality is continuously monitored at designated sampling points throughout the distribution network to enable the timely detection of potential contaminants. These sampling points are determined based on factors such as population density, historical water quality data and identified risk zones.

As the designated water utility company serving the island, GOW carries a significant responsibility in ensuring a reliable and safe water supply. In light of this, Grid Operations Water is currently seeking innovative ways to improve the operation of the water distribution network. The department is in the process of implementing predictive maintenance strategies. These strategies aim to anticipate equipment failures and optimize maintenance efforts by leveraging data analytics and sensor inputs.

The water grid is mapped in a Geographic Information System (GIS), but its accuracy is limited, with some pipelines either absent or incorrectly placed. An update of the water grid in GIS does not occur immediately. Currently, a request for an update of the water grid passes through 3 departments, including the Grid Operations Water, the Utility Engineering and the ICT department, which takes about 10 business days.

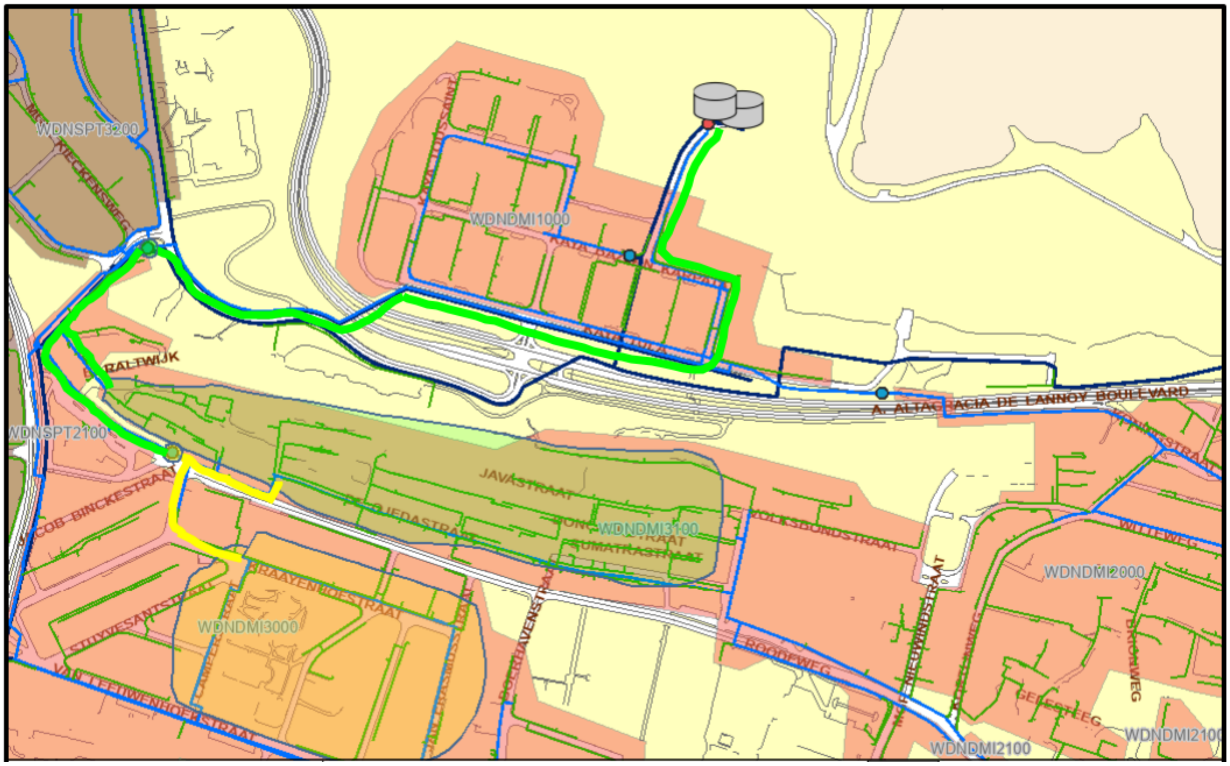


Figure 4-1 Section of Domi's Water Distribution Network

4.3 Outsourcing Management

Grid Operations Water (GOW) outsources certain tasks that fall outside the authorized scope of resolution by the Servicemen Interruptions Water, most commonly excavation work. The primary reason for outsourcing is to leverage the specialized expertise of external contractors. GOW follows a selective outsourcing strategy, meaning it chooses which interruptions are assigned to external providers and which are handled internally.

The department operates using unit price contracts to compensate contractors (refer to paragraph 3.6 for details on the payment procedure). Contractors are supervised by the on-shift Supervisor present at the time of the interruption. This Supervisor oversees and evaluates the completed work before proceeding with financial settlement. This process includes, as mentioned, filling out a service entry sheet and a separate evaluation sheet, the latter of which is not tied to payment but is used to assess the contractor’s performance.

However, the outsourcing process is currently managed insufficiently. In practice, the contractor often dictates the delivery timeline. Due to a scarcity of skilled contractors on the island, GOW lacks the flexibility to easily replace a contractor, giving contractors significant leverage in scheduling jobs. This presents a challenge, as Grid Operations Water operates under a Key Performance Indicator (KPI) requirement that mandates the resolution of interruptions within an

8-hour timeframe. However, due to contractors frequently being engaged with other assignments(including those for other departments), adherence to this target is often not achieved.

Moreover, Supervisors and Field Technicians from the shift team are not always able to remain on-site throughout the resolution process. GOW, therefore, relies somewhat on trust, assuming the contractor is performing as expected. A final quality check is done by the Supervisor and/or Field Technician once the job appears complete, before payment is approved.

Contractors themselves often prefer the presence of a Field Technician on-site to avoid disputes during the completion of service entry forms. However, the management of mistrust is a recurring challenge within the department, an issue echoed in theoretical frameworks on outsourcing in civil and engineering projects. Efforts to modernize the process often result in the introduction of additional steps intended to manage mistrust, which inadvertently increases the overall complexity and duration of the process.

4.4 Corrective Maintenance

The type of maintenance performed when an interruption occurs is corrective maintenance, which is logical given the reactive nature of these events. However, this strategy is generally not preferred and is typically avoided when possible. That said, interruptions that occur repeatedly serve as indicators for underlying issues and often trigger predictive maintenance activities, such as the pipe replacement project referenced in section 3.2.

In the theoretical review, one of the referenced articles discusses the outsourcing of corrective maintenance. The interested parties considered are: the client, the contractor, the facilities management (FM) team and the suppliers. In Aqualectra, Grid Operations Water covers the role of the client, FM team and the supplier. The process described in the article, bears similarities to the one in GOW. While both share common departments, a key distinction emerges in the method by which the details of the work to be performed are communicated.

Many of the challenges highlighted in the theoretical review are also present within GOW, particularly the reliance on paper-based processes for service entry sheets and feedback forms. These manual systems cause delays, especially when contractors are required to physically visit the department to sign service sheets. This step is widely seen as unnecessary and inefficient, a frustration shared by both contractors and GOW staff, who would prefer a more streamlined, digital solution.

4.5 Emergency Response Plan

The department has established internal procedures to support the team in the event of an interruption, along with defined criteria for determining when an issue should be outsourced. The theoretical review identified five critical aspects essential for an effective emergency response plan for a water distribution network: technical information, clearly defined roles and responsibilities, safety precautions and training, specific action plans for different types of emergencies, and adaptability. Table 4-1 outlines how the department currently performs in each of these five areas.

	Critical-aspect	**Description**	**Department Performance**
1	Technical information	The ERP should include essential technical details to support personnel responding to emergencies.	SAP is used to record and track service notifications, Rush Orders and malfunctions with technical information like customer details, address, meter number, and malfunction type. However, delays in updating final malfunction resolution impact technical data accuracy and KPIs.
2	Roles and responsibilities	Communication procedures should specify who is responsible for what actions, what information must be shared and when actions should be taken.	Roles and responsibilities are well defined in *WSC's Functieboek*. The *WSC "functieboek"* is a document that outlines the specific roles and responsibilities assigned to each position within the department
3	Safety precautions and training	All personnel should be regularly trained on organizational safety protocols.	Periodical safety training sessions on organizational safety protocols are provided to all relevant personnel.
4	Action plans for specific emergencies	The ERP should have step-by-step guidance on responding to different scenarios.	The general workflow for disruption response is structured, but the documentation lacks specific step-by-step protocols tailored for different type of disruptions.
5	Adaptability	It should be considered a "living" document that is regularly reviewed and updated to reflect new insights or shifts in operational priorities.	There is recognition of inefficiencies in KPI reporting and disruption closure. However, the current process lacks a formal mechanism for regularly reviewing and updating procedures based on lessons learned or operational changes.

Table 4-1 Emergency Response Plan review in Grid Operations Water

4.6 Disruption Management

The following section outlines GOW's structured approach to manage water grid disruptions, from initial detection to resolution and process improvement. This framework highlights the key phases: information management, disruption discovery, recovery, and redesign.

4.6.1 Information Management

The disruption information management cycle begins when the malfunction is reported by the client and concludes when the situation no longer requires immediate or urgent attention. This process starts in the Customer Relations department and ends within GOW. Consequently, this research project examines the flow and management of information from Customer Relations to GOW. Further details of this review can be found in Appendix IV: IMM review.

4.6.2 Disruption Discovery

The proposed framework illustrates disruption discovery as the first stage in resolving a disruption. The discovery phase is centered on understanding the disruptive event, its underlying cause and the process of sense-making, which involves both primary and secondary appraisals.

At Aqualectra N.V., disruptions are initially detected through customer complaints, typically via a phone call to the Customer Relations department, through internal alerts generated by employees and sent directly to the Control Center or through the identification of recurring patterns of client complaints originating from specific regions. This marks the initiation of the disruption discovery process. During the discovery phase, the Servicemen Interruptions Water are dispatched by the Control Center to the site of the malfunction to perform a primary appraisal. This involves a comprehensive assessment of the disruption's impact, duration, nature and source. Based on their initial findings, they determine whether the issue can be resolved immediately on-site.

The primary appraisal is done by the Servicemen Interruptions Water who make a through a thorough evaluation of the disruption's impact, duration, nature and source. If the primary appraisal reveals that the solving of the malfunction falls inside the scope of the Servicemen Interruptions Water's authorized corrective maintenance activities, the necessary corrective measures are taken. However, in cases where the resolution falls outside this scope, the Servicemen Interruptions Water may conclude that outsourcing (or further investigation, such as a pipeline inspection) is required.

In instances where outsourcing is required, the discovery phase progresses to a secondary appraisal. During this phase, the Supervisor plays a pivotal role in evaluating the resources and capabilities available within the organization to adequately respond to the disruption. This involves assessing available contractors, their expertise, equipment and capacity to address the issue effectively.

4.6.3 Disruption Recovery

Aqualectra recovers from disruptions by deploying the necessary technicians, engineers and/or inspectors, all of whom possess the required expertise and knowledge of the water grid, to the site of the malfunction. When the scope of the disruption recovery exceeds the capabilities of these internal experts, the malfunction is outsourced to external service providers who have the right equipment and expertise (refer to Appendix VII: Examples of contractual services). Aqualectra has established procedures to guide its technicians, engineers and inspectors in their operations and decision-making. However, in an interview with the Head of Department GOW (HoD) and Grid Manager, it was highlighted that while the GOW team is encouraged to adhere to these procedures, they often rely more on their experience and situational judgment to determine the most appropriate course of action.

4.6.4 Disruption Redesign

The redesign phase focuses on identifying the company's efforts to enhance the efficiency of its current disruption response plan. Aqualectra utilizes an Executive KPI Dashboard to measure the effectiveness of its disruption response. When this dashboard indicates inefficiencies or areas for improvement, the company revises the existing plan and implements changes to optimize the process.

One of the executive KPI’s is the Average Total Water Fault Repair Time, which monitors malfunction response time. Over the past year, this KPI has consistently fallen short of its target due to employees not properly registering malfunctions (refer to Figure 4-). To address this issue, the company established standardized work procedures to ensure accurate malfunction registration.

However, employees do not actively use the existing plans to support the recovery phase, as they do not perceive the direct impact of failing to meet KPI targets.

These KPIs also serve as indicators for identifying areas with frequent disruptions, allowing for targeted maintenance interventions. Additionally, as said in section 4.2, the department is currently in the process of implementing predictive maintenance strategies, aiming to anticipate failures and optimize maintenance efforts across the water distribution network.

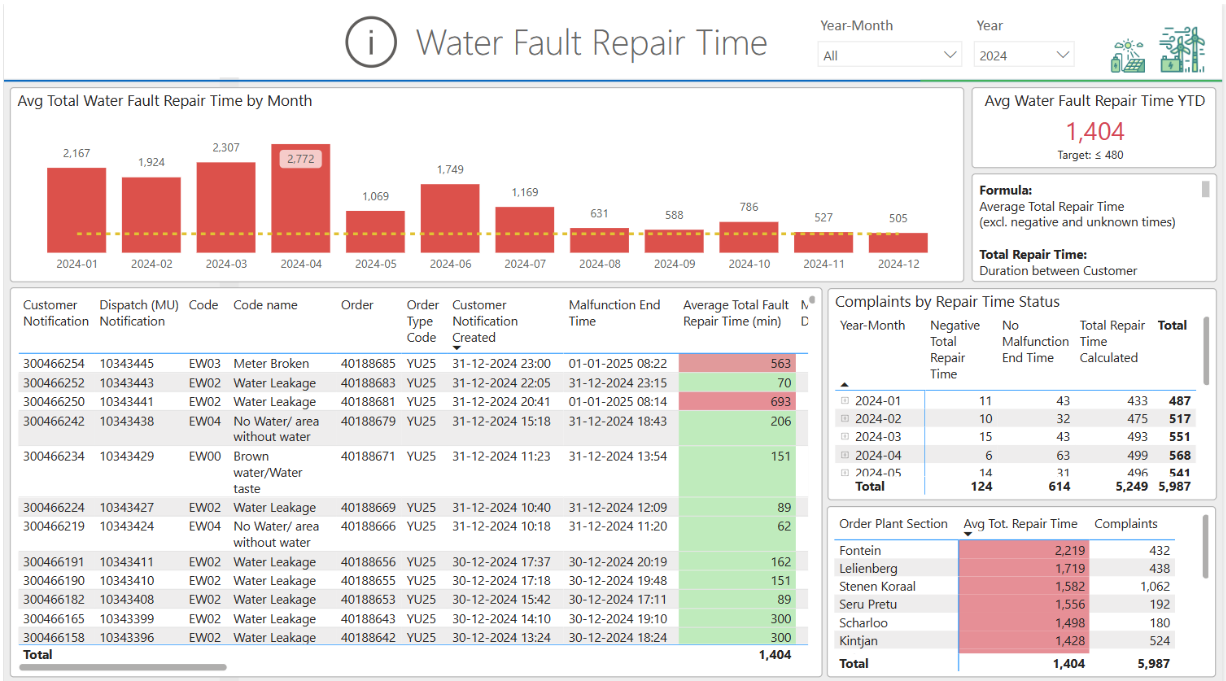


Figure 4-2 - Average Total Water Fault Repair Time 2024

4.6.5 Internal and external influences

The process of managing outsourced disruptions in Grid Operations Water is shaped by various internal and external factors that influence how the team responds to disruptions

4.6.5.1 Internal

Organization Structure and size

The company is a large organization with over 500 employees and operates within a mechanistic organizational structure, where decision-making is centralized at the top. Mechanistic organizations are characterized by vertical communication systems. However, when managing disruptions, the company adopts a more horizontal communication approach to ensure efficient information flow. The disruption management team operates as a cross-functional unit (refer to Figure 4-3 - Disruption Management Unit), bringing together individuals from customer service, water supply chain and external service providers.

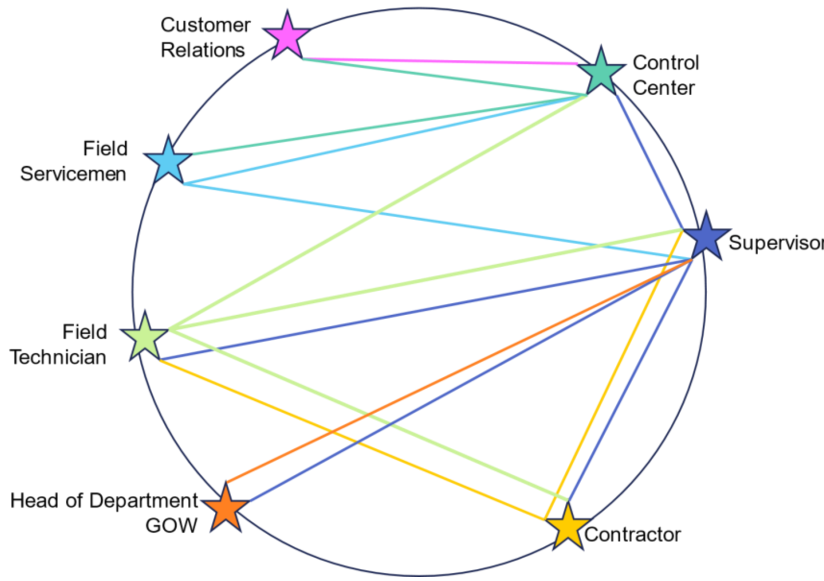


Figure 4-3 - Disruption Management Unit

Despite existing deficiencies in information management, the team maintains strong coordination and ensures effective response to disruptions.

Organization Culture

Aqualectra has a high-performance culture where managers put high emphasis on both culture and solid business performance as drivers of organizational success.

Leadership

The company's leadership fosters a participative environment where team input is valued, encouraging innovation and driving change. A strong emphasis is placed on cross-functional collaboration. Additionally, leadership prioritizes employee well-being, professional development and continuous training to enhance skills and expertise. At the same time, they maintain a results-driven approach, focusing on performance, efficiency and achieving organizational goals.

4.6.5.2 External

Social

Regarding the social influences on disruption response, as the sole provider of water and electricity on the island, Aqualectra faces significant pressure to restore services promptly. Prolonged disruptions can severely impact daily life, business operations and even public health. The residents of the island expect quick and efficient resolution of disruptions and any delays can lead to dissatisfaction, more customer complaints and potential reputational damage for the company.

Political

One of the key political influences on disruption management at Aqualectra is the excavation permit application process, which can be time-consuming and restrictive. In order to carry out certain repair and maintenance activities, the company must obtain permits from UOOW[3]. The process of securing these permits take a significant amount of time that prolong the malfunction response time.

To mitigate delays, Aqualectra can apply for a quarterly permit (kwartaalvergunning), which allows for more flexibility in executing planned maintenance and emergency repairs. However, these quarterly permits come with specific limitations and conditions such as for work within city areas, on road surface and/or excavating more than 25 meters, additional permits must be requested on a case-by-case basis at the time of the required intervention. According to GOW Supervisors, the 25-meter limit is insufficient, as many outsourced disruptions require excavations exceeding this distance.

Industrial

There is a scarcity of skilled contractors on the island, particularly those with expertise in maintaining and repairing water distribution systems.

The Advanced Metering Infrastructure (AMI) project, which aims to develop an intelligent distribution network for both water (WSC) and electricity (PSC[4]) is causing industrial challenges. While the deployment of smart water meters has been largely successful, post-installation challenges have emerged, particularly with an increase in water leakage incidents at the water meters reported by customers. These issues have led to the need for frequent interventions by the GOW team.

Technological

A technological factor influencing disruption management is the abrupt integration of the ERP-system, SAP. While SAP has become the primary system for processing and managing operations,

[3] UOOW, formerly known as DOW, is the governmental organization on Curaçao that coordinates excavation and suspension activities.

[4] Power Supply Chain

the lack of adequate training has resulted in employees having limited understanding of its functionality and purpose. Although the system does not directly impact how the team responds to disruptions, it significantly affects oversight—tracking which disruptions have been resolved, which require further attention and which have been fully completed.

Another technological challenge is the inefficient functionality of the Geographic Information System (GIS[5]). The GOW team experiences frequent connection losses, particularly during critical moments, which significantly hinders their ability to accurately locate and assess disruptions.

4.7 Outsourced Disruptions Payment Procedure

The following section summarizes key issues in the contractor payment process, as identified in Appendix III: Current situation analysis 2 which outlines the current procedure.

The service approval procedure involves multiple levels of authorization, which significantly slows down the Purchase Order (PO) release process. Contractors are required to visit the department in person to sign service entry sheets—a time-consuming task that conflicts with their already demanding schedules. Given the shortage of skilled contractors on the island, as highlighted in the disruption management analysis, their time is primarily dedicated to resolving disruptions for GOW and other departments, leaving little room for administrative tasks.

Compounding this issue, a lack of organized information management has been identified. Contractors often do not have clear records of the disruptions they have resolved or which services they have already received payments for, leading to frequent payment disputes. This lack of visibility creates inefficiencies and misunderstandings between stakeholders.

Internally, GOW also lacks a centralized real-time tracking system for monitoring payment statuses. As a result, some payments are delayed, while others are completely lost in the system, with outstanding invoices remaining unpaid for years.

4.8 Stakeholder Insights & Process Benchmarking

This chapter focuses on understanding the perspectives and experiences of key stakeholders involved in the outsourced disruption management process at Aqualectra. By analyzing feedback from both internal and external stakeholders, the chapter seeks to gain valuable insights into best practices from their point of view. Additionally, the chapter integrates process benchmarking to compare Aqualectra's practices with other utility/outsourcing management industries, offering valuable insights into potential enhancements to manage disruptions.

[5] GIS is a system used for mapping and analyzing spatial data. It plays a crucial role in infrastructure management by providing real-time insights into the water distribution network.

4.8.1 Objectives and desired outcomes

Understanding what success looks like from the perspectives of different stakeholders is crucial in creating a comprehensive vision for any project or initiative. Each stakeholder group(Refer to section 2.7) has unique goals and expectations that shape their understanding of an ideal situation. To capture these diverse perspectives interviews were conducted with representatives from each stakeholder group.

Hereby everyone was asked***: "What would the ideal approach be for handling disruptions, from your perspective?"***

Customer Relation Agent
To always have enough information provided by the client about disruption type and location.

Control Center Dispatcher
A streamlined information management in SAP, with the ability to bypass redundant steps. For example, when making notifications for other departments in SAP, the process should be simplified to save time and reduce potential delays.

Servicemen Interruptions Water
The ideal approach would ensure that all team members are aligned and have access to the same information. Improved material availability and better tools would also help enhance operational efficiency.

Field Technician
Contractors should be well-organized and capable of managing their executed services efficiently. Ideally, there would be a sufficient number of well-equipped contractors dedicated to disruption resolution, as the lack of availability hinders field technicians' productivity. Field technicians also prefer a clearer division of disruptions between eastern and western teams. They see the need for a more digital, centralized and streamlined process with less hierarchy. Additionally, communication must improve to provide real-time updates on changes in the water grid, ensuring that they are always informed.

Supervisor
The ideal approach would involve everyone adhering to standardized procedures to ensure consistency.

Head of Department Grid Operations Water
From the Head of Department's (HoD) perspective, an effective and timely review of fieldwork and service entry sheets would significantly improve operational flow.

Contractor

The ideal approach would involve the digitization of the payment process, as the current requirement to physically visit the headquarters is tiresome. It would also be more efficient for technicians to remain on-site throughout the entire resolution process, allowing them to take necessary measurements and complete service entry sheets on-site. Furthermore, ensuring that contractors have the required materials readily available on-site would improve the overall disruption management process.

To conclude, the diverse perspectives gathered from the stakeholders that form part of Grid Operations Water paint a clear and detailed picture of what an ideal disruption management process could look like. While each role brings its own set of needs and frustrations, there is a strong common thread: the desire for more streamlined, transparent and digital processes.

From the Customer Relation agent to the Head of Department Grid Operations Water, everyone emphasized the importance of improved communication, real-time information sharing and the removal of unnecessary bottlenecks in both administrative and operational processes. Contractors, in particular, highlighted how outdated processes like manual signing of payments undermine efficiency.

4.8.2 Process Benchmarking

To benchmark the process, interviews were conducted with WEB Aruba and WEB Bonaire. As Curaçao’s sister islands, Aruba and Bonaire share similar infrastructure, legal frameworks, time zone, climate, culture and traditions. These similarities make them suitable references for comparison. The interviews focused on their procedure for outsourcing water grid breakdowns and how they pay the outsourced activities. The interview questions used in this benchmarking study can be found in Appendix V: Interview Questions.

4.8.2.1 WEB Bonaire

WEB Bonaire is responsible for ensuring the sustainable, reliable and affordable supply of drinking water and electricity on Bonaire.

The malfunction response team consists of technicians who work full-time from 7:30 AM to 4:30 PM, with any work beyond this considered overtime. Emergencies related to the main pipeline are given the highest priority. The key stakeholders in the disruption management process include technicians, the call center, team leaders and contractors. Communication across departments is primarily coordinated via telephone.

Unlike other organizations, WEB Bonaire does not have a specific target response time. Their main challenge lies in the availability of contractors; however, apart from this, they do not face significant operational difficulties. They utilize unit price contracts and ensure strict control over outsourced activities through continuous monitoring by the Head of Department. This includes overseeing the placement of sand layers and all necessary groundwork before finalizing repairs.

WEB Bonaire has a well-established relationship with highly skilled contractors, built on mutual trust and long-term collaboration—some contractors have been working with the company for over 15 years. During the interview, the Head of Department emphasized that the success of their process is largely due to the trust between the company and its contractors. The contractors have a clear understanding of what is expected of them, which contributes to the efficiency and effectiveness of their operations.

At WEB Bonaire, the contractor payment process involves multiple levels of review to ensure accuracy and accountability. The Head of Department and/or team leaders assess the services provided by the contractor, documenting the work completed. Simultaneously, the contractor submits an invoice detailing the services rendered. Both the internal review and the contractor's invoice are then forwarded to the head office for final processing and payment.

4.8.2.2 WEB Aruba

WEB Aruba's emergency water breakdown response is coordinated by the call center during regular office hours and by a supervisor after office hours, ensuring that scheduled technicians are promptly notified. Mainline leaks are given top priority, while smaller leaks are assigned to a dedicated team for resolution.

Communication between departments is conducted via a two-way radio, and the target response time ranges from 30 to 40 minutes, which is typically achieved unless delayed by external factors like traffic or weather conditions. Outsourcing is primarily used for large pipe repairs exceeding 6 inches in diameter, requiring excavation, heavy equipment and additional workforce, with an in-house contractor engaged on a yearly contract.

Quality and safety are ensured through direct WEB supervision, while contractor performance is monitored based on WEB Aruba's standards for safety, excavation and workforce. The main challenge in outsourcing is the time required to mobilize workforce and equipment, which WEB Aruba mitigates by clearly defining work expectations, providing detailed location information and ensuring repair materials are readily available.

Recent improvements include acquiring new equipment for the technicians to reduce reliance on outsourcing and optimizing GIS mapping to enhance network visibility and breakdown efficiency. Future strategies focus on further equipping and training personnel to optimize response times, with an emphasis on strong internal communication to maintain operational effectiveness.

At WEB Aruba, disruptions are recorded in a system through work orders, which document the duration, type of disruption, involved technicians and materials used. Payments are processed via invoices that specify the number of hours worked and the equipment used. Approval for payments is granted by a Supervisor and payments are made through an open purchase order (PO) that remains valid for the entire year.

After interviewing the stakeholders, benchmarking and thoroughly analyzing the process several shortcomings were identified. Please refer to Table 4-2 Shortcoming and challenges regarding the current Disruption Management

1	**WATER DISTRIBUTION NETWORK**
1a	Over-reliance on reactive maintenance
1b	Insufficient use of data analytics and sensor inputs
1c	Limited accuracy of GIS Mapping
2	**OUTSOURCING MANAGEMENT**
2a	Lack of onsite control
2b	Mistrust between internal and external stakeholders
2c	Overly complex modernization attempts
2d	Dependence on manual evaluation and paper-based systems
3	**CORRECTIVE MAINTENANCE**
3a	Lack of standardized communication
3b	Payment processing delays due to manual sign-off
3c	Lack of digital solutions
4	**EMERGENCY RESPONSE PLAN**
4a	Delays in updating final disruption information.
4b	No formal detailed step-by-step protocols tailored to specific types of disruptions (e.g., water leakage vs. low water pressure).
4c	Process lacks adaptability. There is no formal mechanism to review and learn from operational experiences (e.g., feedback loops).
5	**DISRUPTION MANAGEMENT**
A	Information Management
5a.a	Control Center Dispatchers, Servicemen Interruptions Water, Field Technicians and Supervisors lack adequate SAP training.
5a.b	Approval process for the service entry sheet and making of purchase requisitions is largely manual.
5a.c	Lack of a centralized communication hub.
5a.d	Over-reliance on manual data updates in SAP.
5a.e	Inconsistent storage of information.
5a.f	Field Technicians, Supervisors and Contractors exchange critical information verbally.
5a.g	Customers do not receive real-time updates on disruption status unless they call in.

5a.h	Lack of organizing, storing and maintaining information by Field Technicians, Supervisors, Contractors and Head of Department.
5a.i	Decision-making by all stakeholders relies occasionally on dubious data.
5a.j	Malfunction end time is not being processed accurately.
B	Discovery
5b.a	GIS-mapping challenges
C	Recovery
5c.a	Control Center Dispatchers, Servicemen Interruptions Water, Field Technicians and Supervisors rely heavily on experience and situational judgement rather than on established guidelines.
5c.b	Lack of real-time performance monitoring caused by inconsistent use of standardized work procedures.
5c.c	Lack of experienced contractors specialized in water distribution maintenance.
5c.d	Decision-making relies on delayed and/or incomplete data
5c.e	Long processing time for excavation permits when necessary.
D	Redesign
5d.a	No systematic review of past disruptions to improve response efficiency.
E	Internal
5e.a	Resistance to change
5e.b	Varying levels of SAP expertise
F	External
5f.a	Permit delays from UOOW
5f.b	Shortage of skilled contractors on the island
6	**OUTSOURCED DISRUPTIONS PAYMENT PROCEDURE**
6a	Manual data entry & processing delays
6b	Administrative workload on Contractors
6c	Lack of organized Information Management
6d	Absence of a centralized payment tracking system
6e	Limited transparency & communication gaps

Table 4-2 Shortcoming and challenges regarding the current Disruption Management

4.9 Conclusion

The analysis of water disruption management within Grid Operations Water has revealed critical inefficiencies driven by outdated systems, fragmented communication and over-reliance on manual processes.

The water distribution system is hindered by widespread operational gaps, including over-reliance on reactive maintenance, poor use of data analytics and inaccurate GIS mapping. Outsourcing challenges such as lack of onsite oversight, mistrust and paper-based evaluations further reduce efficiency. The corrective maintenance suffers from non-standardized communication and manual payment approvals, while the emergency response plan lacks tailored protocols and adaptive feedback mechanisms. Disruption management is undermined by SAP training gaps, manual workflows, fragmented communication and unreliable data. Operations rely more on experience than standardized procedures, with long permit processes and contractor shortages compounding delays. Internally, resistance to change and uneven SAP expertise persist, while externally, permit restrictions and a lack of skilled contractors add to the strain. Payment procedures for outsourced disruptions remain largely manual, untracked and burdensome, lacking transparency and centralized control.

5 Reorganization Of Outsourced Water Disruptions

This chapter reorganizes the Outsourced Water Disruptions(OWD) in Grid Operations Water by answering the third sub-research question: How can the gap between the current management of outsourced disruptions and the desired best practices identified in the research be effectively bridged?

5.1 Design specifications and boundary conditions

In order to reorganize Outsourced Water Disruption (OWD) in Grid Operations Water, it is important to set draft specifications and boundary conditions. These are set based on the literature reviewed in Chapter 3 and the analyses in Chapter 4 and 5. These specifications and boundary conditions are described in the following section and will be substantiated while strategies are being formulated.

I. The process needs to be systematic

For the process to be systematic it must be defined within the disruption management framework (Dario Messina, 2020) and it should have a complete information management cycle (Pal, 2022) where data about disruptions are accurately recorded, processed and communicated. Every stakeholder needs to be aware of what information category they are responsible for, when and how they should manage that information.

II. Modernized

The new process should leverage technology to align with the trend of smart contracts and automated payment procedures. These functionalities minimize human error, replacing time-consuming manual processes with a faster, more reliable system (Ezeh, 2024). Additionally, they enhance trust and transparency in managing contractual relationships by ensuring that transactions are executed automatically based on predefined conditions.

Furthermore, digitalizing information management is essential to keep up with modern technological advancements. A more automated and integrated system will not only streamline operations but also reduce administrative workload, allowing employees to focus on higher-value tasks rather than repetitive data entry and verification.

III. Transparent

For the design to offer transparency it needs to ensure that all stakeholders are aware and have access to real-time information about the status of the water distribution network. Real-time data accessibility allows stakeholders to make informed decisions based on accurate and up-to-date information. Transparency reduces disputes between the contractor companies and Aqualectra and it also enhances trust. Trust is necessary to ensure smooth collaboration between all parties involved in managing disruptions in the water distribution network (Heino, 2015).

IV. Offer opportunities for effective monitoring

For effective monitoring the process should clearly define responsibilities across the different stakeholders to ensure each party knows what information they are responsible for and how they should report this.

5.2 Approach to reorganize OWD process

In this section the approach to reorganize outsourced water disruptions will be discussed. The approach to reorganize the process involves the following steps (Refer to Figure 5-1 - Approach to reorganize OWD process):

1. Assess shortcomings and challenges (Refer to Table 4-2);
2. Identify alternatives based on specifications and boundary conditions;
3. Formulate operational guidelines and structure a coherent OWD process;
4. Conduct review and consultation with stakeholders and experts;
5. Restructure and validate final OWD process.

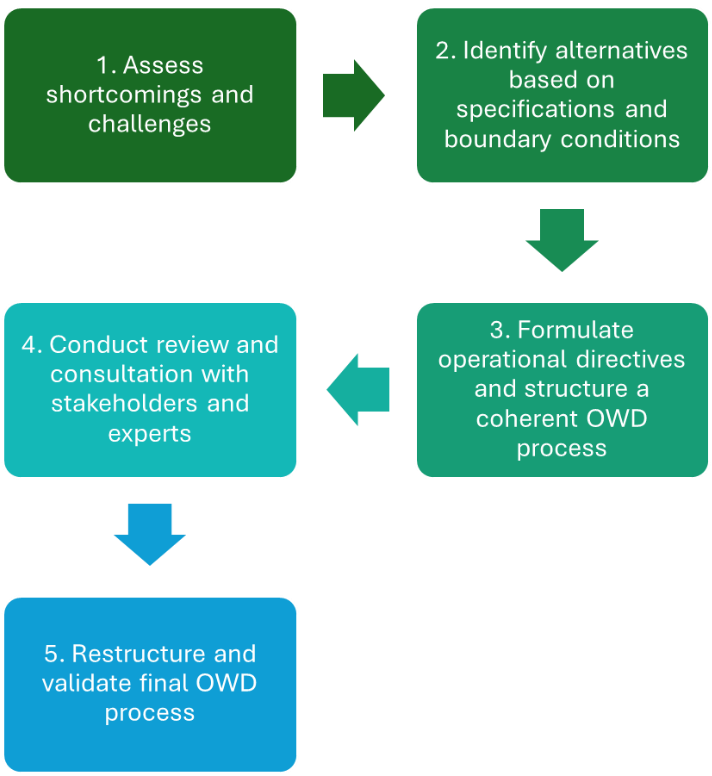


Figure 5-1 - Approach to reorganize OWD process

Step 1: Assess shortcomings and challenges

The first step to start reorganizing the OWD process is to assess the shortcoming and challenges of the current OWD process discussed in chapter 4. These are then compared to best practices derived from the theoretical review in chapter 3.

Step 2: Identify alternatives for a reorganized OWD process

In this phase alternatives will be identified by consulting the theoretical review carried out in chapter 3. In identifying alternatives for a reorganized OWD process the theory, best practices and critical success factors for proper disruption management are discussed. These alternatives will lead to operational guidelines for an organized OWD process.

Step 3: Formulate operational guidelines and structure a coherent OWD process

The 3rd step will formulate the strategies and a first version of the OWD process is developed. In order to bridge the gap between the current situation and the improved situation it is necessary to set out actionable guidelines.

Step 4: Conduct review and consider stakeholders perspectives

It is crucial to involve all relevant stakeholders and experts in the field during the new process review to gain valuable contributions and establish consensus at an early stage. This approach ensures that stakeholders provide input, fostering a sense of ownership and collaboration. As a result, the reorganization of the current process can be implemented with greater alignment and reduced resistance.

Step 5: Reorganize and validate final OWD process

In this final step the reorganized process will be validated by a group of Aqualectra experts in water supply chain and operation management. Based on their reviews on the process design concept, the final process will be structured with more detailed information.

5.3 Development of OWD process

In this section the process of reorganizing outsourced water grid disruption is described by considering the reviewed literature, the current situation process review accompanied by generated alternatives and specifications and boundary conditions. In the reorganization phase critical thinking will be applied to come to the best alternative solution. The shortcoming and challenges illustrated in Table 4-2 will serve as a starting point for formulating the operational guidelines. Refer to Infographic 1 for a visual summary of the current shortcomings, proposed transformative actions, and the anticipated future strengths for Grid Operations Water.

5.3.1 Assessment of shortcomings and challenges

This section discusses the gaps between the current situation and the reviewed theory. The operational guidelines formulated need to overcome the shortcoming and challenges illustrated in Table 4-2.

Water Distribution Network

The shortcomings of GOW's water distribution network stem primarily from its over-reliance on reactive maintenance, driven by client complaints and service disruptions, to manage and maintain the network. While GOW is working towards implementing predictive maintenance strategies, the full potential of data analytics and sensor technology remains untapped, limiting the ability to proactively monitor and address infrastructure issues. Additionally, the water distribution network's mapping in the Geographic Information System (GIS) is hindered by inaccuracies, such as missing or incorrectly placed pipelines, which undermine the effectiveness of decision-making and resource allocation.

Outsourcing Management

The current outsourcing process in GOW reveals several critical shortcomings. A key issue is the limited control GOW has over contractor scheduling, largely due to a scarcity of skilled contractors on the island. This imbalance of power allows contractors to dictate timelines, often resulting in delays and non-compliance with GOW's KPI of resolving interruptions within an 8-hour window. Compounding this challenge is the inability of Supervisors and Field Technicians to remain on-site throughout the resolution process, which forces GOW to rely heavily on trust that contractors are delivering work to standard. As much as Supervisors and Field Technicians strive to maintain oversight, the volume of interruptions exceeds the capacity of the available contractors, further weakening GOW's ability to maintain timely and effective control over outsourced work. Attempts to modernize the process by introducing new controls to manage the present mistrust have increased procedural complexity. Additionally, the use of manual, paper-based systems such as the service entry and contractor evaluation sheet contributes to administrative burden.

Corrective Maintenance

While corrective maintenance is appropriate for unplanned interruptions, its reactive nature demands ad hoc decision-making. It presents several shortcomings and challenges, particularly in outsourced contexts. Key challenges identified are duplicated data entry and poor communication among stakeholders, issues that often stem from inadequate knowledge sharing and lack of centralized systems. The current reactive approach overlooks opportunities to transition into predictive maintenance by failing to capture and analyze failure patterns.

Emergency Response Plan

GOW’s Emergency Response Plan (ERP) reveals several shortcomings when compared to best practices outlined in the literature. While technical information is recorded using SAP, delays in updating the final malfunction resolutions negatively impact the accuracy of technical data and the KPIs. Although roles and responsibilities are clearly defined and safety training is provided on a periodic basis, the defined process for disruption resolution lacks detailed, step-by-step protocols tailored to different types of disruptions, resulting in less standardized responses. Additionally, while inefficiencies in KPI reporting and disruption closure are recognized, there is no formalized mechanism for systematically reviewing, updating and adapting the ERP to reflect lessons learned from past disruptions. The absence of a structured and proactive review cycle weakens the ERP’s adaptability, which is critical for maintaining its relevance and effectiveness over time.

Disruption Management

Information management

As outlined in the Disruption Management Framework, an effective information management system is essential for achieving visibility across the supply chain and facilitating informed decision-making in disruption resolution. However, the current information management practices are highly fragmented and lack standardization.

In the Customer Relations (CR) and Control Center (CC) departments, the primary objective is to create Service and PM(Plant Maintenance) notifications. While variations in how individual employees create these notifications may seem inconsequential, the lack of standardized procedures results in inconsistent data entry. Employees often store data in SAP without a clear understanding of its purpose or its role in subsequent decision-making processes. When faced with challenges in data entry, employees frequently resort to alternative approaches that, while easier, may not be the most accurate or appropriate. Consequently, decisions are being made based on incomplete or unreliable data compounded by insufficient SAP training.

Similarly, the Grid Operations Water (GOW) department does not systematically store data related to contractual services. Once a contractor completes a task, they submit a service entry sheet, which is then forwarded for payment processing. However, this transactional history is not integrated into the Water Supply Chain (WSC) system, resulting in a significant gap in data traceability. WSC lacks a centralized repository to track which contractor performed specific tasks, which field technician or supervisor was involved, the exact date of service and the location. Retrieving this information requires a cumbersome and time-consuming search across multiple departments, often yielding incomplete or imprecise data. There is no structured process to correlate contractor activities with regional water grid maintenance, leading to a disconnect between operational activities and administrative records.

Moreover, in the payment processing phase, once the service entry sheet leaves Grid Operations Water, the department loses visibility and oversight of its status. GOW is unable to track whether the document has been processed, misplaced or if the contractor has received payment—despite being the department responsible for assigning the job to the contractor.

To establish a highly effective information management system, a standardized information flow for disruptions must be implemented. Each department must have a clear understanding of how to manage the seven categories of information, supported by adequate SAP training to ensure accurate and consistent data handling. Furthermore, SAP requires an urgent upgrade, as the current version is inadequate for today's dynamic and fast-paced operational environment.

Discovery

The discovery phase occurs rapidly, as consumers promptly report disruptions upon detection. However, a key challenge arises in accurately registering the disruption’s location within the Geographic Information System (GIS). While the consumers strive to provide precise location details, the accuracy of these reports is often compromised due to outdated GIS data. The system contains pipes that no longer exist in the field, while some active pipelines are missing from the GIS records. This misalignment between the GIS database and actual field conditions complicates the identification and resolution of disruptions.

Recovery

As stated throughout this project, Grid Operations Water (GOW) outsources disruptions when their resolution exceeds the expertise of the Servicemen Interruptions Water. However, there is no accurate quantitative data indicating what percentage of disruptions are outsourced. Currently, outsourced activities contribute to 17% of disruptions that exceed 480 minutes (Windt, Werkinstructies voor GOW, 2024).

This lack of quantitative data stems from poor information management. Also the contractors employed by GOW are not exclusively dedicated to water disruption resolution, they provide services across the entire organization and are extremely overloaded.

Redesign

The redesign phase is hugely influenced by the information management cycle. Currently, GOW has KPIs in place to help redesign and refine its disruption response strategies by identifying inefficiencies and areas for improvement. These KPIs serve as a benchmark for performance evaluation. The effectiveness of these KPIs depends on accurate data input.

Internal factors

Despite existing information management deficiencies, GOW's horizontal communication approach during disruption management, combined with cross-functional collaboration, provides a strong foundation for effectively addressing disruptions.

The management team's open approach to innovation, training and promoting growth ensures the company can adapt to new challenges while continuously improving its processes. However, there are varying levels of SAP expertise across departments, which may hinder the seamless implementation of changes. This variability highlights the need for targeted SAP training to ensure that all employees have the necessary skills.

External factors

Socially, the company faces immense pressure to restore services promptly. Politically, delays in the excavation permit application process create significant setbacks, although quarterly permits provide some flexibility. Industrially, the shortage of skilled contractors complicate rapid disruption resolution. Technologically, the abrupt integration of SAP, combined with inadequate training, limits employees' understanding. Additionally, the GIS system suffers from frequent connection losses, hindering accurate disruption assessments.

Payment Procedures

The current payment procedure for outsourced disruptions at Grid Operations Water (GOW) reflects a structured and compliance-oriented approach. The inclusion of both technical and procurement departments in the process demonstrates cross-functional collaboration.

However, the system also exhibits critical inefficiencies. Manual data entry and paperwork-heavy steps slow down the process, especially in the creation and release of Purchase Orders. Contractors are required to physically sign service entry sheets, which adds administrative burden at the cost of their operational availability—particularly problematic given the local shortage of skilled contractors. The absence of a centralized, real-time tracking system for payment status limits transparency and creates avoidable disputes. Contractors often lack clarity on which services have been paid for, and GOW struggles with delayed or lost payments due to fragmented information management. These issues not only disrupt workflow but also affect trust and reliability in contractual relationships.

5.3.2 Identify alternatives based on specifications and boundary conditions

This paragraph presents alternatives and aspects to consider when formulating the operational guidelines for an organized outsourced water disruption management.

Water Distribution Network

According to Christodoulou et al. (2018), water distribution networks (WDNs) are dynamic systems, where the condition of components is constantly changing. As such, predictive maintenance strategies are essential to anticipate equipment failures and maintain continuous operation. Christodoulou et al. (2018) also stress that accurate and regularly updated Geographic Information System (GIS) data is critical for assessing risks and managing the performance and reliability of WDNs, particularly given the challenges posed by underground infrastructure. Further details on the importance of a up-to-date WDN can be found in Appendix VI: Advocacy for an Up-to-date Water Distribution Network.

Outsourcing Management

To strengthen contractual relationships, Grid Operations Water must balance mechanistic approaches with human-centered strategies, focusing on building trust and treating contractors as partners. It is essential for GOW to have a skilled and confident onsite team capable of effectively overseeing and supporting outsourced activities. Additionally, involving contractors early in digitalization projects fosters trust and allows them to contribute to innovative ideas.

To manage the contract, automated or self-executing smart contracts are gaining popularity, especially in infrastructure-related projects. These contracts help reduce administrative burdens and protect contractors from delayed payments by executing terms automatically based on pre-defined conditions.

Although Aqualectra does not currently utilize blockchain-based systems, like literature suggests, to support smart contracts, it is advisable to explore how the principles of self-executing contracts could be integrated within the existing ERP system (SAP). This would enhance transparency and accountability in the execution of outsourced activities.

When considering the adoption of this technology, it is important to address human-centered factors, not just the technical aspects. This includes designing contracts that are understandable, fair and supportive of collaboration between all parties involved.

Corrective Maintenance

To address the shortcomings associated with corrective maintenance, it is recommended to implement IT tools that facilitate the capture and integration of both tacit knowledge (experience-based, informal insights from the GOW team) and explicit knowledge (formal, documented procedures and data). This management of internal knowledge will lay the groundwork for a transition toward predictive maintenance.

Emergency Response Plan

Grid Operations Water should explore ways to make its emergency response plan more adaptable and responsive to the dynamic nature of water disruptions. A key improvement would be enhancing the accuracy of technical information in SAP by giving greater attention to updating final disruption information promptly and completely.

Additionally, feedback loops should be systematically incorporated into the emergency response plan, allowing the team to submit insights and suggestions based on their operational experiences. These insights and suggestions should be reviewed regularly and used to update procedures

Disruption Management

Information management

GOW would benefit from establishing a new, systematic and transparent process for managing disruptions, with clear and defined pathways that guides disruptions from identification through resolution. By introducing an information management model, GOW can gain visibility over disruptions to effectively track the status of both in-house and outsourced disruptions, as well as monitor the subsequent payment process. It is essential to provide stakeholders with clear instructions on how to manage the seven information categories in SAP to ensure consistency and accuracy in data handling.

To further improve efficiency, GOW should adopt a comprehensive disruption management framework within a unified system that allows seamless monitoring, organization and management of information in real time. The use of multiple communication platforms such as telephone, manual methods, and email to manage information leads to fragmentation, causing delays and inaccuracies. By consolidating the process within a single system, GOW can improve both the speed and visibility of disruption management across all stages of the process.

Discovery

GOW could significantly improve its operations by implementing a faster method to receive updates on GIS data to have faster allocation of the WDN's underground assets.

Recovery

The recovery stage at GOW would benefit from the deployment of dedicated contractors solely responsible for managing disruptions. This would improve response times. Additionally, giving all stakeholders adequate SAP training will help GOW meet its KPIs by ensuring that accurate and consistent information is recorded to support decision-making.

Redesign

Bode (2017) found that the integration of internal and external information positively impacts the speed and ability of decision makers to process information in order to discover quickly the disruption and act upon it. Hereby, GOW should develop a system where both internal and external information can be entered and updated to centralize these two information sources in one place.

Internal factors

To improve internal circumstances, GOW needs to provide all stakeholders with comprehensive SAP training and raise awareness about how the information they manage impacts performance indicators. This will ensure that stakeholders understand their roles and responsibilities in the data management process.

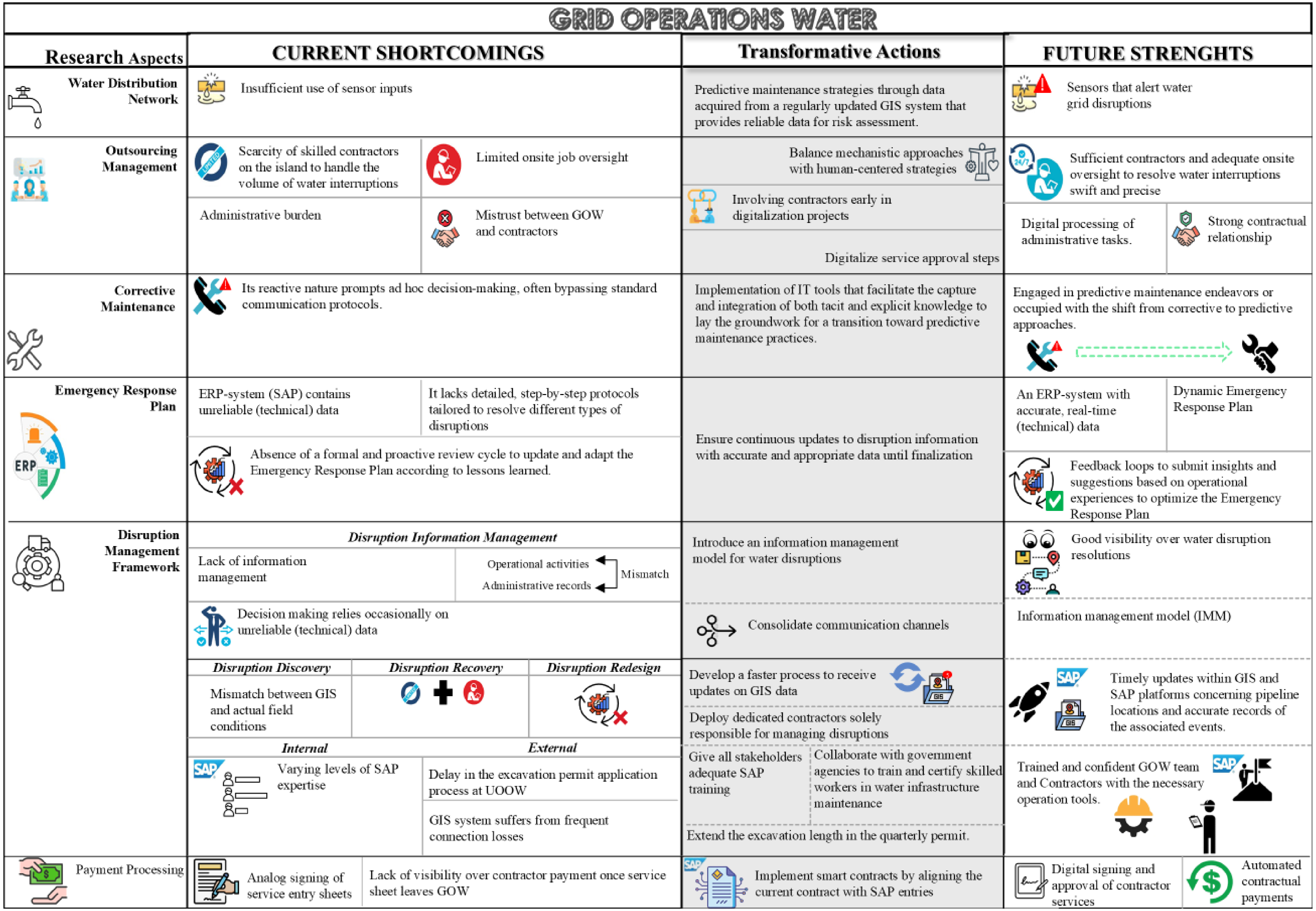
External factors

The most influential external factors is the lack of contractors specialized in water distribution systems on the island. A way to mitigate this challenge is to invest in local workforce development. Aqualectra can collaborate with government agencies to train and certify skilled workers in water infrastructure maintenance. GOW should also consider submitting a petition to extend the excavation length in the quarterly permit.

Payment Procedures

To improve the contractor payment process for outsourced disruptions at Grid Operations Water, one promising approach is, as said, the implementation of smart contracts as proposed by Ahmadisheykhsarmast (2020). This would automate payment execution once agreed-upon conditions are met, enhancing transparency, security and efficiency while reducing manual intervention. Additionally, the adoption of mobile platforms for real-time service confirmation would alleviate administrative burdens on contractors and reduce delays in SAP updates.

Enhancing information management systems by digitizing contractor records and aligning them with SAP entries would also create a more organized and reliable database. Finally, redesigning the internal approval workflow to include automated processes, would significantly streamline service approvals and reduce bottlenecks.



Infographic 1 - Illustration of gap analysis for Grid Operations Water

5.3.3 Formulate operational guidelines and structure a coherent OWD process

Based on the assessment and identified alternatives for the shortcomings, a concept for an organized outsourced water disruption management framework is developed (Refer to Table 5-1).

Operational guideline 1	*Complete and centralize information cycle in one system.*
Operational guideline 2	*Minimize reliance on paperwork.*
Operational guideline 3	*Develop a smart payment procedure.*
Operational guideline 4	*Develop operational procedures for consistent data storage and disruption management.*

Table 5-1 Operational guidelines for organized OWD

OPERATIONAL GUIDELINE 1: COMPLETE AND CENTRALIZE INFORMATION CYCLE IN ONE SYSTEM.

Objective: Establish a single digital platform for managing disruption-related information.

Actions:

- Integrate a system for centralized data management;
- Develop a structured process for creating, processing and sharing information;
- Ensure all relevant stakeholders have access to real-time data.
- Provide contractors with the necessary tools to access information.

Major changes and benefits:

- ✓ Improves information reliability.
- ✓ Eliminates information silos and reduce miscommunication.
- ✓ Encourages informed decision making and transparency.
- ✓ All stakeholders can access (authorized) information in SAP.

OPERATIONAL GUIDELINE 2: MINIMIZE RELIANCE ON PAPERWORK.

Objective: Digitalize as many steps as possible with the goal of reducing paperwork and administrative workload.

Actions:

- Implement a digital system for the submission and approval of contractual service requests;
- Transition contractor evaluation to a fully digital platform;
- Provide comprehensive training for the stakeholders on the utilization of digital tools.

Major changes and benefits:

- ✓ Reduces delivered contractual services processing time
- ✓ Reduces administrative workload.
- ✓ Increases document security and accessibility.
- ✓ Introduces information organization and storing in Grid Operations Water.

OPERATIONAL GUIDELINE 3: DEVELOP A SMART PAYMENT PROCEDURE.

Objective: Implement an automated, transparent and secure payment system to streamline contractor payments and reduce delays.

Actions:

- Explore the integration of smart contracts;
- Establish a clear communication channel for contractors regarding payment procedures and delivered services.

Major changes and benefits:

- ✓ Reduces delays and disputes in contractor payments.
- ✓ Enhances transparency and accountability in the payment process.
- ✓ Minimizes manual errors.

OPERATIONAL GUIDELINE 4: DEVELOP OPERATIONAL PROCEDURES FOR CONSISTENT DATA STORAGE AND DISRUPTION MANAGEMENT.

Objective: Establish standardized operational procedures to ensure consistent data storage and optimization of outsourced disruption management processes for improved decision-making and operational continuity.

Actions:

- Create and implement clear protocols for data storage.
- Ensure integration of all relevant data into a central system for easy access and retrieval.
- Provide training to stakeholders on data management best practices and disruption response processes.

Major changes and benefits:

- ✓ Streamlines the management of disruption-related information.
- ✓ Enhances the consistency and reliability of operational data.
- ✓ Improves inter-departmental communication and collaboration during disruption events.

A schematic overview of the proposed design including all the above discussed operational guidelines is illustrated in Figure 5-2.

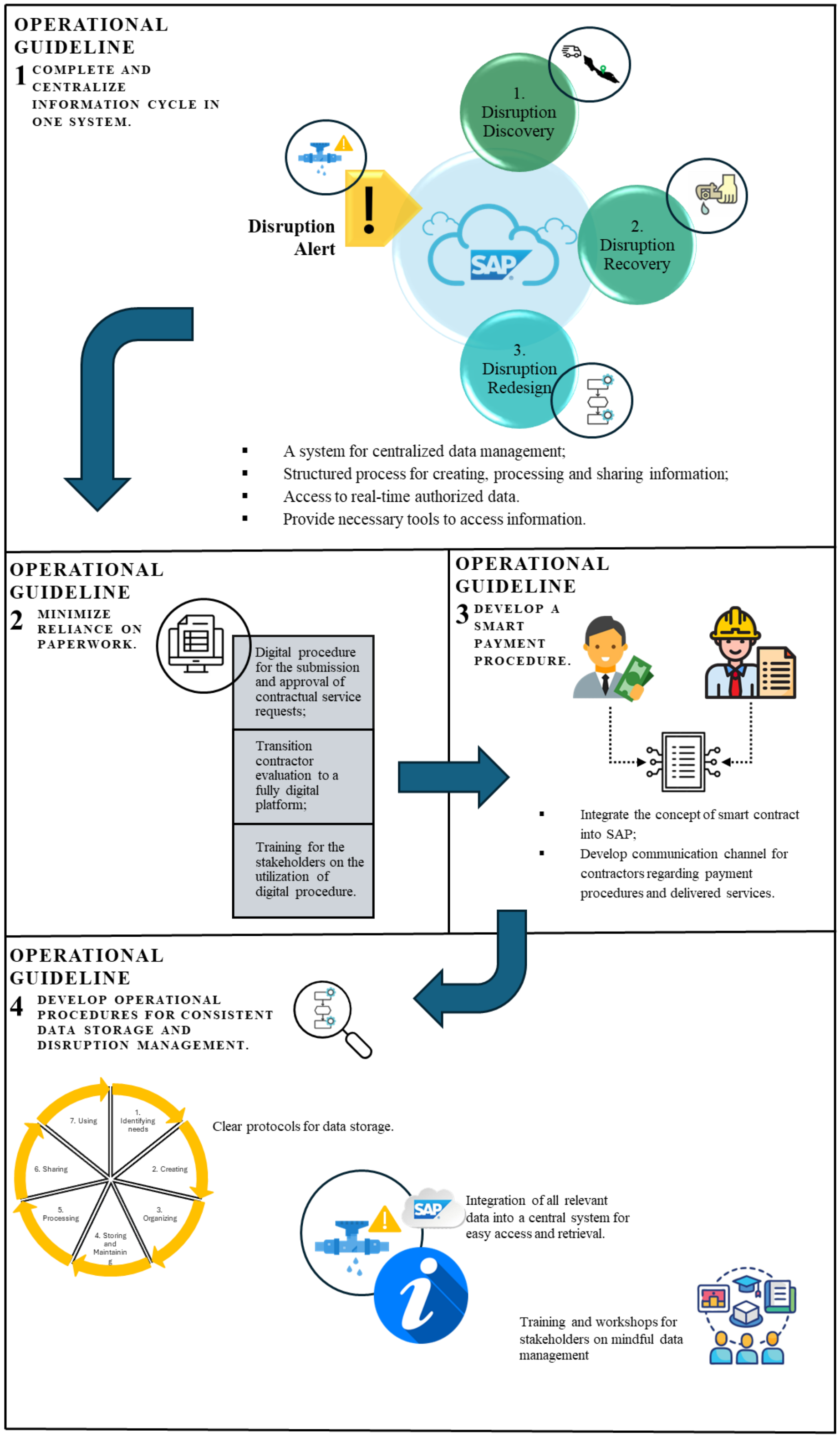


Figure 5-2 - Approach for an organized outsourced water disruptions management

5.3.4 Conduct review and consider stakeholders perspectives

In this paragraph, the proposed process is reviewed by experts at Aqualectra, taking into account the perspectives of the various stakeholders who were interviewed. From the proposed design a concept process has been developed. This process was reviewed by the departments Operational Analyst and the company's business process functional analysts.

During the review phase, the main concern raised was the number of steps in the process. It was noted that a strong atmosphere of trust does not currently exist between GOW and the contractors involved. Additionally, employees sometimes deviate from procedures to serve their own interests, leading to the inclusion of numerous steps in the process to ensure accurate data capture for the Key Performance Indicators (KPIs) and to effectively monitor the status of disruptions. To address these issues, GOW should consider organizing workshops and team-building activities to foster trust in the contractual relationships. Additionally, it would be beneficial to make stakeholders aware that the focus is on tracking the efficiency of disruption management, rather than monitoring individual employee performance. This approach will help align expectations and enhance collaboration between all parties involved.

Additionally, the proposed system to centralize the process is SAP and due to the limitations of the current version of SAP, additional steps had to be incorporated into the process. These extra steps were necessary to work around SAP's restrictions, ensuring that accurate data could still be captured and the status of disruptions monitored effectively. The system's limitations highlighted the need for a more modern SAP version for further improvements and to better support the efficient management of disruptions.

5.3.5 Restructure and validate final OWD process

Based on the interview, the perspectives of stakeholders and analysts were taken into account. Incorporating their suggestions, a final process was structured.

The process was validated by Aqualectra's Business Process Functional Analysts, SAP Applications Expert and Grid Manager Water. They recommended automating the procedure within SAP by integrating the service entry sheet into a contract that will be linked to the corresponding Rush Orders for water disruptions. In broad terms, once the contractor resolves the disruption and the GOW Supervisors and Head of Department approve the process in SAP, an automatic Purchase Order (PO) is generated. All POs from a given week are then consolidated, enabling weekly payments to contractors for completed services—replacing the current system where payments are delayed for months. The implementation phase has commenced and the process is currently being tested.

The foundation of the process was built following Operational Guideline 1, while the implementation of Operational Guidelines 2 and 3 are currently in progress. Initially, a pilot test was planned to evaluate the process; however, the implementation of Guidelines 2 and 3 has been ongoing for four months due to its complexity.

The analysts and stakeholders have determined that the process is well-organized and successfully digitalized. As a result, the research project will conclude here, and Operational Guideline 4 will be implemented once Guidelines 2 and 3 are fully developed and tested.

6 Conclusion & Recommendations

This chapter covers the conclusions and recommendations drawn from the research study which had the objective to provide insight, knowledge and information on the current findings, developments and approaches on the management of outsourcing the resolution of water disruptions within a water distribution network on the island of Curaçao. This chapter answers the main research question: What are the current best practices in contractor management, and how can these practices be applied to optimize contractual services in response to emergency water grid failures within Grid Operations Water?

6.1 Conclusion

As stated above this research has been conducted to reorganize outsourced water disruptions within Aqualectra's department Grid Operations Water.

It can be concluded that the objective of the research has been achieved, as the main research question has been answered. This has been accomplished by:

- Conducting an extensive theoretical review, current situation and gap analysis. The theoretical review focused on water distribution networks, best practices, challenges and trends in outsourcing management, a concise dive in the theory of corrective maintenance and emergency response plans. Additionally, a key area of disruption management was examined, followed by a final review on smart payment procedures.
- Analyzing the current situation by conducting two separate process reviews: one focused on the management of outsourced disruptions, while the second examined the payment process of outsourced disruptions. The process mapping method was used to visualize the workflow, identify stakeholders, and understand their roles in outsourcing water disruptions. This analysis revealed the shortcomings and challenges within the disruption management procedure and the shortcomings in financial processing, with some issues affecting multiple processes.
- Carrying-out a gap analysis, that discusses the development of a structured and organized approach to managing water disruptions. Operational guidelines were developed to enhance efficiency and stakeholders' perspectives were considered in the final process.

The study concludes that Grid Operations Water needs to:

- Establish a structured information management model and centralize all data within a single system to increase visibility over the supply chain.
- Reduce paper-based administration by digitizing processes and utilizing cloud storage to significantly improve information management and accessibility.
- Develop clear operational procedures, as stakeholders tend to follow the path of least resistance rather than what is necessary for accurate data storage.
- Strengthen trust and collaboration between Contractors and Aqualectra to improve workflow efficiency.

- Organize workshops and training sessions to enhance communication and overall partnership when resolving water grid disruptions.

To conclude, addressing the inefficiencies through digital transformation, standardized procedures and improved stakeholder collaboration, GOW will create a more streamlined and transparent outsourcing framework for water disruption management and contractor payment with attention for performance metrics.

6.2 Recommendations

To improve the efficiency, coordination, and performance of outsourced corrective maintenance within Grid Operations Water (GOW) department, the following actionable recommendations are proposed:

- Develop a structured SAP training program tailored to the various stakeholders.
- Establish formal communication protocols between internal staff and contractors, like standardized SAP-based reporting formats.
- Create a dedicated cross-functional team within GOW responsible for managing and monitoring outsourced maintenance activities.
- Explore SAP Work Manager capabilities to enable contractors and the GOW team to update work orders and obtain digital approvals directly in the field using tablets. Start with a pilot project using one GOW team and one contractor to assess feasibility before full deployment.
- Introduce a quarterly or semester-based *Top Contractor Recognition Program*, where the highest-performing contractor is rewarded based on key performance indicators such as response time, quality of execution, SAP compliance and communication effectiveness. Rewards may include financial bonuses or priority access to high-value operations.
- Strengthen communication and trust with contractors. Introduce collaborative problem-solving workshops to help address pain points and build mutual accountability.
- Streamline excavation permit approvals by working with UOOW to implement a more inclusive quarterly pre-approved permit

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Appendix I: Shifting from Reactive to Predictive Maintenance

The article "Preventative and Predictive Maintenance in Fluid Power: The Technologies and Benefits" discusses the transition from reactive to predictive maintenance in fluid power systems. Traditionally, maintenance has been reactive, addressing issues only after failures occur, leading to unplanned downtime and cascading operational disruptions. The article highlights that integrating sensors, telematics and other technologies enables a shift toward predictive maintenance. That allows real-time monitoring and proactive issue resolution before failures happen. This approach not only minimizes unplanned downtime but also optimizes the lifespan and performance of equipment.

Applying these principles to Grid Operations Water (GOW) can significantly enhance the reliability and efficiency of the water distribution network. By implementing sensor technologies and data analytics, GOW can monitor the condition of its infrastructure in real-time, detecting anomalies such as pressure fluctuations or leaks before they escalate into major disruptions. This proactive approach would reduce service interruptions, lower maintenance costs and extend the lifespan of critical assets.

Incorporating predictive maintenance into GOW should involve key action related to equipping critical components of the water distribution system with sensors capable of monitoring parameters such as flow rate, pressure and water quality and utilizing advanced analytics to process the data collected, identifying patterns that indicate potential failures or maintenance needs.

Appendix II: Current situation analysis 1

OUTSOURCED DISRUPTION MANAGEMENT

PROCESS REVIEW

Appendix III: Current situation analysis 2

OUTSOURCED DISRUPTIONS PAYMENT PROCEDURE

PROCESS REVIEW

Appendix IV: IMM review

	Identifying needs	
	Identifying needs involves identifying what and why information is needed to address the disruption and which attributes will improve the information's value, quality and usefulness. The following departments/roles identify the next information to address disruptions:	
		Communication Tool:
A	Customer Relations	
1	Requesting detailed information about the malfunction's symptoms and exact location. The following client-provided information enhances the quality: - Water meter number - Malfunction location - Detailed description of malfunction's symptoms	Telephone
B	Control Center	
1	Processing Service Notification for water meter number to analyze GIS to identify malfunctioned pipeline's equipment number.	SAP GUI
2	Grid Operation's schedule to fathom which team is responsible for handling disruptions in the eastern and western regions for the day.	-
C	Servicemen Interruptions Water	
1	Malfunctioned pipeline, emergency type and water meter number to find exact location of the malfunction.	SAP Work Manager
D	Field Technician	
1	Malfunction's location, type and Servicemen Interruptions Water's findings.	SAP GUI, Work Manager and/or telephone
E	Supervisor	
1	Malfunction location, emergency type, Servicemen Interruptions Water and Field Technician's findings, available contractor company during the shift and contractor equipment availability.	SAP GUI, Work Manager and/or telephone
F	Contractor	
1	Malfunction type and location	Telephone
2	The allocated budget or agreed-upon compensation for the services provided(Unit services and prices, Memo Ref. Nr. 2023-35319).	-
G	Head of Department GOW	
1	Malfunction details, including location, type, start and resolution date/time(Malf. Stat and end time), as well as the assigned GOW team and contractor responsible for the repair.	SAP GUI and/or telephone

Appendix 6. 1 Identifying information needs

	Creating	
	Creating information involves generating and producing new information about disruptions. The following departments/roles create information by:	
		Communication Tool:
A	Customer Relations	
1	Producing client-related information such as the client details mentioned in Appendix II: Current situation analysis 1 and the type of water emergency.	SAP GUI
B	Control Center	
1	Registering which water grid asset is suffering from a malfunction.	SAP GUI
C	Servicemen Interruptions Water	
1	Entering malfunction details (verifying client's complaint) in SAP Work Manager.	SAP Work Manager
2	Noting follow-up steps to resolve water grid breakdown (outsourcing and/or water grid inspection).	SAP Work Manager
3	If necessary, specifying the type of follow-up preventive/restorative maintenance required on the affected water pipeline/location.	SAP Work Manager
D	Field Technician/Supervisor	
1	Providing details about reactive maintenance activities (verifying Servicemen Interruptions Water's findings).	SAP GUI, Work Manager and/or telephone
2	Documenting Contractor's delivered services.	Service entry and contractor's evaluation sheet
3	Supporting information on duration of reactive maintenance.	SAP GUI or Work Manager
4	Providing details on temporary water outage to perform maintenance work in the water grid.	WhatsApp Messenger
E	Supervisor	
1	Documenting Contractor's delivered services.	Service entry and contractor's evaluation sheet
2	Supporting information on duration of reactive maintenance.	SAP GUI or Work Manager
F	Contractor	
1	Reporting information about delivered services.	Telephone
2	If necessary, providing information about necessary follow-up restorative maintenance.	Telephone
	Not applicable to role/department:	
	Head of Department GOW	

Appendix 6. 2 Creating information

—	**Organizing**	
	Organizing information is about indexing, classifying and linking information to support its retrieval in case of a disruption. The following departments/roles organize information by:	
		Communication Tool:
A	Customer Relations	
1	Linking client complaints to Service Notifications in SAP.	SAP GUI
B	Control Center	
1	Bringing the PM and Service Notification in SAP together in a Rush Order.	SAP GUI
2	Connecting all disruptions to a specific water pipeline by linking all disruptions to that pipeline's equipment number in SAP.	SAP GUI
	Not applicable to role/department:	
	Servicemen Interruptions Water	
	Not within the scope of the role/department's activities:	
	Field Technician	
	Supervisor	
	Contractor	
	Head of Department GOW	

Appendix 6. 3 Organizing information

	Storing and Maintaining	
	Storing and maintaining information involves keeping the information in databases or file systems to prevent redundant data collection, while ensuring that the information is regularly updated to provide the most accurate and current data available. The following departments/roles store and maintain information by:	
		Communication Tool:
A	Customer Relations	
1	Constantly updating SAP every time a malfunction occurs by linking all disruptions to the client's address and water meter number.	SAP GUI
B	Control Center	
1	Storing technical details about the malfunctions provided by the Servicemen Interruptions Water.	SAP GUI
2	Regularly updating SAP every time a malfunction occurs on the pipeline by linking all disruptions to the malfunctioned pipeline's equipment number.	SAP GUI
	Not applicable to role/department:	
	Servicemen Interruptions Water	
	Not within the scope of the role/department's activities:	
	Field Technician	
	Supervisor	
	Contractor	
	Head of Department GOW	

Appendix 6. 4 Storing and maintaining information

	Processing	
	Processing information involves accessing, analyzing, and presenting information about disruptive events in a manner that facilitates informed decision-making. The following departments/roles process information by:	
		Communication Tool:
A	Customer Relations	
1	Analyzing the client's complaint to determine the type of emergency they are experiencing.	SAP GUI
B	Control Center	
1	Analyzing Service Notifications to determine to which department in WSC they should forward the malfunction. E.g.: • Grid Operations: - Water Leakage - Low or high water pressure • Inspection & Troubleshooting - High water consumption • Maintenance department - Broken water meter	SAP GUI
2	Present information received by the Customer Relations department in a technical context for the Servicemen Interruptions Water	SAP GUI
C	Servicemen Interruptions Water	
1	Access information from Control Center to make a decision on how to resolve the malfunction.	SAP Work Manager
D	Field Technician/Supervisor	
1	Analyze findings from Servicemen Interruptions Water to support final decision regarding follow-up reactive/preventive maintenance or inspection activities.	SAP GUI, Work Manager and/or visual inspection
2	Processing the services and field work delivered by the contractor to determine which services, along with their specifications, will be noted on the service entry sheet and contractor evaluation sheet.	SAP GUI, Work Manager and/or visual inspection
E	Contractor	
1	Process information received via telephone from Field Technician/Supervisor to make a decision on how to resolve the malfunction.	Telephone
F	Head of Department GOW	
1	Processing information on service entry sheet to approve initiation of contractor's payment.	Service entry sheet

Appendix 6. 5 Processing information

	Sharing	
	Sharing involves distributing or communicating information to the relevant stakeholders involved in the affected process. The following departments/roles share information by:	
		Communication Tool:
A	Customer Relations	
1	Releasing information about client's complaint and emergency to the Control Center.	SAP GUI
B	Control Center	
1	Sharing information about disruption type and location to the concerning department	SAP GUI and telephone
C	Servicemen Interruptions Water	
1	Entering information about findings on malfunction site to support both the storage and maintenance of data, as well as informed decision-making.	SAP Work Manager
D	Field Technician	
1	Distributing information about analyzed findings of the Servicemen Interruptions Water and own onsite evaluation to support Supervisor's decision making.	SAP GUI, Work Manager and/or telephone
E	Supervisor	
1	Informing the contractor about the malfunction details and providing instructions to address it.	Telephone
F	Contractor	
1	Share information about the services delivered and any necessary steps required to restore the infrastructure, if needed.	Telephone
G	Head of Department GOW	
1	Informing the Technical Clerk of Contractor's delivered service for Purchase Requisitions(PR) generation.	Service Entry Sheet

Appendix 6. 6 Sharing information

	Using	
	Using involves applying the available information to facilitate informed decision-making for a swift recovery from supply chain disruptions. The following departments/roles use information by:	
		Communication Tool:
A	Customer Relations	
1	Use client's information to create Service Notification	SAP GUI
2	Use information received by Control Center to determine if the disruption is already registered or not.	SAP GUI
B	Control Center	
1	Use information provided by Customer Relations to provide the Servicemen Interruptions Water with the adequate technical context to operate.	SAP GUI
C	Servicemen Interruptions Water/Supervisor	
1	Use information from onsite inspection to make a decision on how to resolve the malfunction.	-
D	Field Technician/Supervisor	
1	Analyzing information from Contractor to fill out service entry sheet and to make decision about need for follow-up preventive and/or restorative maintenance.	-
E	Supervisor	
1	Processing information from Field Technicians and Contractors to approve the service entry sheet and request a corrective order from the Control Center.	SAP GUI, Work Manager and/or telephone
F	Contractor	
1	Use information(instructions) received from Field Technicians/Supervisor to resolve water grid breakdowns	-
G	Head of Department GOW	
1	Accept information on service entry sheet and in SAP to determine if breakdown has been decently resolved and to approve the service entry sheet.	-

Appendix 6. 7 Using information

Appendix V: Interview Questions

1. Can you briefly describe your company's emergency water breakdown response process?

2. What are the key steps involved from the moment an issue is reported until it is resolved?

3. How do you prioritize different types of emergencies (e.g., mainline breaks vs. smaller leaks)?

4. Who are the key stakeholders involved in managing emergency breakdowns?

5. How do you coordinate communication between departments during an emergency?

6. What is your target response time for addressing water breakdowns, and how often is this achieved?

7. What challenges do you face in responding to breakdowns promptly?

8. Do you outsource any part of your emergency water breakdown process? If so, which components?

9. What factors influence your decision to outsource versus handle tasks in-house?

10. What type of contracts do you use for outsourcing emergency work (e.g., fixed-term, on-call services)?

11. How do you ensure that outsourced work meets your quality and safety standards?

12. What is the process for monitoring and evaluating the performance of outsourced contractors?

13. What challenges have you encountered with outsourcing emergency breakdown services?

14. Can you share any best practices or lessons learned from outsourcing emergency responses?

15. Have you had to bring any previously outsourced services back in-house? If so, why?

16. What improvements are you considering for your emergency response or outsourcing strategies in the future?

17. Is there anything unique about your approach that you believe sets your process apart?

18. How is the payment process?

Appendix VI: Advocacy for an Up-to-date Water Distribution Network

The analysis done on the Water Distribution Network (WDN) breakdowns within WSC has revealed poor documentation quality of the water distribution network. Critical data about the network is missing, and the Geographic Information System (GIS) used for analyzing and displaying geographical information is outdated. As a result, there are significant delays not only in resolving WDN breakdowns but also in carrying out routine preventive maintenance of the water grid. This section provides key recommendation for Supervisors of the Water Grid when performing maintenance activities.

In addition, (Maare, 2021) highlights that the high amount of damage caused to underground utilities due to excavation work warrants serious attention. Having an updated and well-documented system is essential to ensure quick response times and prevent further disruptions.

Bilal et al. explained that the diverse network of buried utilities makes it challenging to perform excavation work in these areas (Bilal, 2018). The risk of damage increases particularly when comprehensive and accurate documentation of the location of these utilities is not present.

The key to preventing underground damages depends on how efficient and effective the key stakeholders such as Dispatchers, Supervisor, Field Technicians and Inspectors operate (Al-Bayati, 2019).

Mostly, the root cause of damages done to the underground utilities is due to the poor quality of information held of the utilities before starting a project. The information is either non-existent, incomplete or inaccurate.

Furthermore, (Taba, 2015) addresses the human element as another famous cause. Poor data entry, documentation and stakeholder behaviors result in bad communication and poor operating conditions. More human causes are: lack of care around services, rushed jobs and poorly planned projects (Maare, 2021).

Maare conducted a study to find reasons and solutions for utility damages during excavating projects. The study suggests that proactive investments should be made in the gathering, monitoring and updating of the existing utility network. Innovative Ground Penetrating Radar (GPR) and Electromagnetic Locate (EML) detection tools that are based on GIS-systems are encouraged.

To improve the WDN registry more suggestion have been made that involve improved training and education of operators and their supervisors and more collaborative initiatives between all stakeholders. Without these improvements, the risk of prolonged breakdowns and operational inefficiencies will continue to grow, impacting service quality.

WSC can significantly reduce utility damages by prioritizing accurate documentation and adapting modern technologies. These efforts will help to ensure a more resilient and effective Water Distribution Network.

Appendix VII: Examples of contractual services