Navigating Delays in Green Water Projects:

Identifying Sustainability-Related Challenges and Mitigation Strategies

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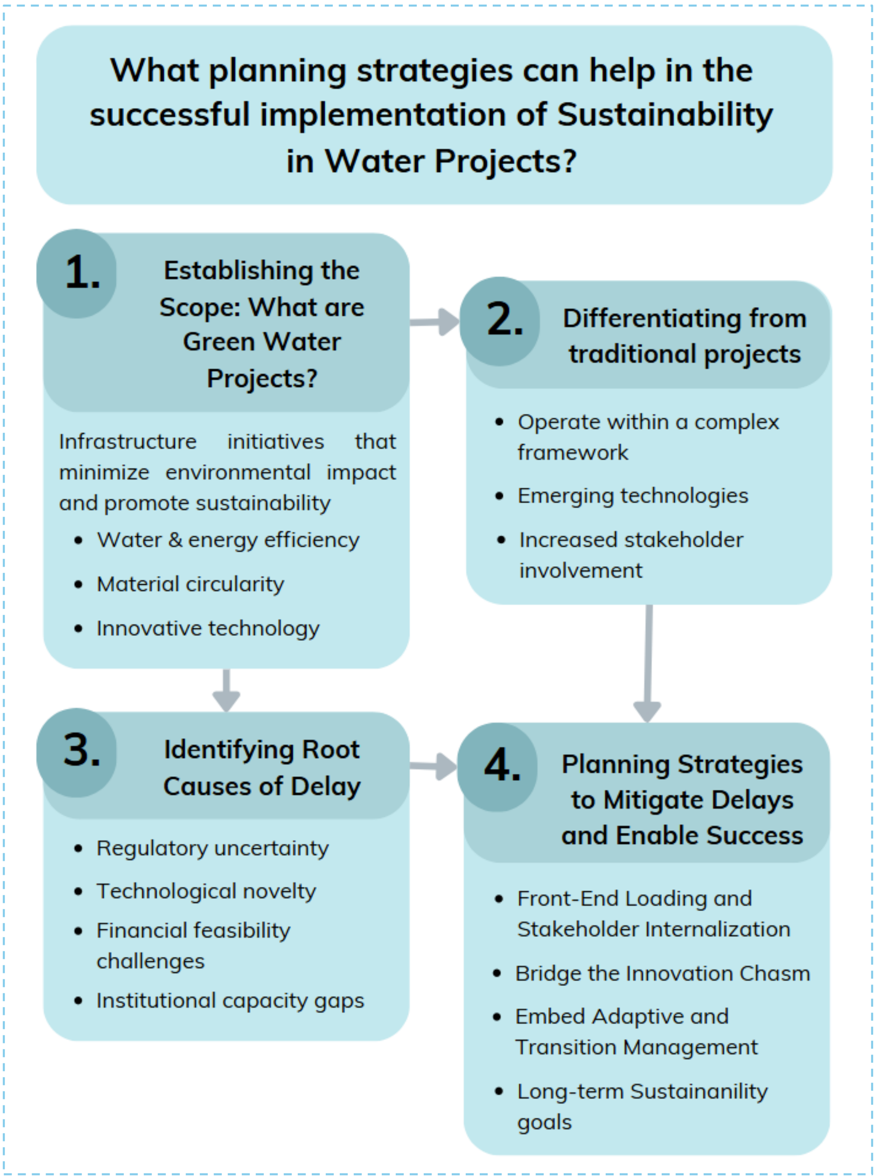
Executive Summary

The integration of sustainability into water infrastructure projects is no longer optional it is essential for delivering long-term environmental, social, and economic value. However, the implementation of sustainability in green water projects introduces a unique set of complexities that can contribute to significant delays and operational inefficiencies. These challenges include regulatory complexity, innovation adoption barriers, financial limitations, and institutional inertia. Despite the growing emphasis on sustainability in infrastructure, the specific impact of these factors on project timelines remains underexplored in existing literature.



This thesis investigates how sustainability-related complexities affect the timely execution of green water projects and identifies targeted planning strategies to mitigate those impacts. The central research question driving this study is: *What planning* *strategies can help in the successful implementation of Sustainability in Water Projects?* To answer this, the following sub-questions are explored:

1. What are Green Water Projects?
2. How do they differ from traditional projects?
3. What differentiating green factors could result in delays in Green Water Projects?
4. How can these delays be mitigated?

A qualitative multi-phase research approach was adopted to answer these questions, consisting of four key stages: exploratory interviews, literature review, semi-structured expert interviews, and expert feedback workshop with industry stakeholders at Bilfinger Engineering and Consultancy. The exploratory interviews scoped the landscape and helped define "green water projects" in practical terms. The literature review established the conceptual framework, while the semi-structured interviews provided in-depth insights into sustainability-related project delays. The final expert validation tested the practical applicability of the proposed strategies.

The research draws on real-world experiences, including cases involving hydrogen infrastructure, algae-based protein production, and sustainable fuel development, to contextualize the analysis.

The study identifies four core planning solutions tied to the delay drivers:

- Regulatory Uncertainty: Mitigated through early stakeholder alignment and adaptive frameworks like *Front-End Loading (FEL)* and the *Transition Management Framework*.
- Technological Novelty: Addressed via iterative testing and feedback using tools such as the *Innovation Chasm Strategy* and *Adaptive Management*.
- Financial Feasibility: Enhanced by reducing risk perception through *Risk Scoring Matrices*, *Process Thinking*, and *Outcome-Based Financing* approaches.
- Institutional Capacity: Strengthened through *Organizational Learning*, *Bow Tie Risk Models*, and *Multilevel Transition Management*, which foster resilience and governance alignment.

Building on these findings the study introduces a comprehensive roadmap structured around four interlinked pillars consisting of early stakeholder engagement, bridging the innovation adoption gap, adaptive project management, and institutional alignment with long-term sustainability goals. These pillars are operationalized through a layered approach across strategic, tactical, and operational levels, reflecting the complex, dynamic, and socio-technical nature of sustainability implementation. This multi-level structure enables flexible and adaptive planning that accommodates evolving regulatory, technological, and financial conditions, thereby supporting resilience in project delivery.

A key insight of this research is the redefinition of the traditional Iron Triangle of project management. By incorporating sustainability as a core dimension alongside cost, time, quality, and scope, the study proposes a new paradigm for project planning that aligns with contemporary environmental and social requirements. This reconceptualization allows project teams to evaluate trade-offs more holistically and design solutions that do not sacrifice long-term goals for short-term efficiency. Although the strategies have been tailored to green water projects, they are designed for adaptability and can be applied more broadly to green projects.

Ultimately, the findings serve as a practical guide for project managers and policy stakeholders seeking to overcome sustainability-induced delays. The research contributes to both academic understanding and industry practice by offering an actionable, multi-level planning framework that supports the successful implementation of sustainable infrastructure. By embedding adaptive and transition management principles alongside enhanced governance synchronization, the proposed strategies enable proactive management of uncertainty and institutional alignment, which are essential for scaling sustainable innovations in complex infrastructure projects.

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1. INTRODUCTION

1.1 Background

Infrastructure development is a cornerstone of economic growth, environmental resilience, and societal well-being. Despite significant global investments in large-scale projects aimed at enhancing resilience and sustainability, the success of these efforts remains inconsistent. A striking illustration of this challenge is presented by Flyvbjerg (2011), who found that more than 90% of infrastructure projects are delivered late and over budget. This persistent pattern reflects systemic inefficiencies and underscores the limitations of current project management practices.

Traditional approaches to infrastructure delivery often fail to address the complex, uncertain, and multifunctional nature of contemporary projects. This is especially evident in sectors such as water infrastructure, where long-term resilience and adaptability are critical. Yet, many mega-projects continue to fall short of fulfilling genuine societal needs due to flawed appraisal frameworks and limited expertise (Dimitriou & Field, 2019). These gaps in strategic decision-making and knowledge integration not only compromise project outcomes but can also exacerbate the very economic and environmental issues such projects are intended to solve.

Lazurko and Pinter (2022) further emphasize that a lack of holistic, forward-looking strategies prevents infrastructure investments from achieving their intended impact. Without embracing sustainability principles and leveraging emerging technologies, projects risk becoming inefficient, misaligned, or even counterproductive.

Within this complex landscape, Bilfinger Engineering & Consultancy operates as a prominent player in the process industry, offering services across a broad range of sectors including food, pharmaceuticals, chemicals, energy, manufacturing, and oil & gas. They provide advices at strategic, tactical and operational level (Loorbach & Van Raak, 2006) across these sectors. The company's vision is to become the number one partner for enhancing both efficiency and sustainability. It pursues a dual strategy of enhancing internal performance through operational excellence and strengthening its external role as a full-service solution partner (Bilfinger, n.d.). This dual approach positions Bilfinger to contribute meaningfully to the growing demand for more resilient and effective infrastructure project delivery.

1.2 Delays in Green Projects

Bilfinger has encountered significant challenges in executing sustainability-focused projects, with several initiatives being halted either before or after the Final Investment Decision (FID). These interruptions highlight the broader complexities of managing green infrastructure developments in evolving market and regulatory environments. While this research does not treat the pre-FID and post-FID phases as separate areas of study, referencing them helps structure the analysis and improve understanding of when and how sustainability-related delays tend to arise across the project lifecycle.

Before Final Investment Decision (FID):

Delta-Rhine Corridor (Pipelines)
The Delta-Rhine Corridor (DRC), a crucial pipeline infrastructure project connecting Rotterdam with industrial areas in the Netherlands and Germany, faced significant delays before FID due to complex permitting processes, regulatory bottlenecks, nitrogen restrictions, staff shortages, and rising project costs. These challenges created uncertainty, impeding progress toward climate targets (Port of Rotterdam Authority, 2024).

Tata Steel – H2 Pricing Complexity
The transition to hydrogen-based steel production for Tata Steel Nederland encountered delays due to uncertainties around the pricing of green hydrogen. These issues arose from underestimations of production expenses and a lack of subsidies, creating financial barriers that affected Bilfinger's involvement in the project (Dieterle, 2025).

Zenith EOS – Liquid Hydrogen Project
Bilfinger faced a halt in the Zenith EOS liquid hydrogen project in British Columbia due to unmanageable production costs and infrastructure risks as a result of innovation. The project struggled with a lack of firm offtake agreements and market uncertainty, reflecting broader limitations in the hydrogen energy sector (Barnard, 2025).

Phycom – Protein from Algae
The Phycom protein from algae project was delayed before FID due to challenges in scaling production, securing infrastructure, and ensuring market demand. These difficulties in the food sector highlighted the complexity of navigating sustainability projects that require both technological innovation and long-term investments (Phycom, n.d.).

After Final Investment Decision (FID):

Plastic Recycling – Umincorp
In the plastic recycling sector, Bilfinger encountered delays after FID, with seven companies, including Umincorp, going bankrupt. Umincorp faced challenges due to low market prices for fossil-based plastics, which undermined its business model despite operational successes. This situation reflects broader issues faced by Bilfinger in sustaining projects post-FID, where external market forces, inadequate regulatory support, and economic factors disrupt even well-planned sustainability ventures (Change.inc, 2024).

Shell – Compressed Hydrogen

Bilfinger also faced challenges with the Shell Compressed Hydrogen project in Rotterdam after FID. Delays occurred due to regulatory changes and market conditions, particularly the Dutch government's introduction of a "corrective factor," which reduced financial incentives for hydrogen in the fossil fuel industry. This significantly undermined the economic feasibility of Shell's 1 billion euro Holland Hydrogen I project, which now risks never becoming operational (NL Times, 2025).

Shell Red to Green – Sustainable Aviation Fuel
Bilfinger faced a halt in construction for the Sustainable Aviation Fuel project at Shell Energy and Chemicals Park Rotterdam before FID. Shell cited the need to reassess project delivery strategies to ensure future competitiveness amid current market conditions (Shell, 2024).

These examples illustrate the broad range of issues Bilfinger faces with sustainability projects, driven by regulatory, market, and financial challenges both before and after the Final Investment Decision.

1.3 Project Success and Delays

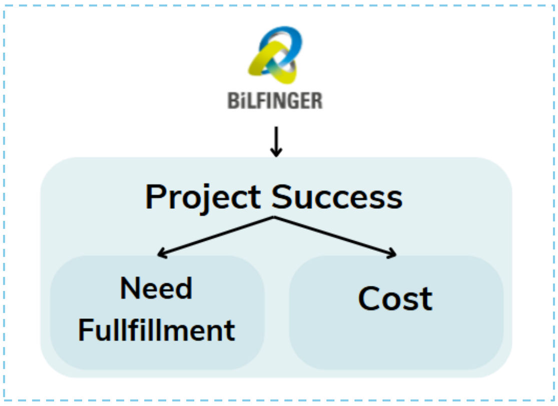


Figure 1 Project Success

Project success remains a fundamental objective across all infrastructure initiatives, particularly in environmentally focused developments where outcomes have far-reaching social and ecological consequences. As outlined by Bilfinger Engineering & Consultancy, project success hinges on two primary criteria: the fulfilment of needs (fitness for purpose) and cost-effectiveness, which includes both financial and environmental dimensions (see Figure 1). In environmental projects, where ecological consequences may outweigh direct monetary concerns, the urgency of timely delivery becomes even more important. For businesses, achieving project success under these parameters not only supports compliance and reputation but also enhances long-term value creation and competitive advantage.

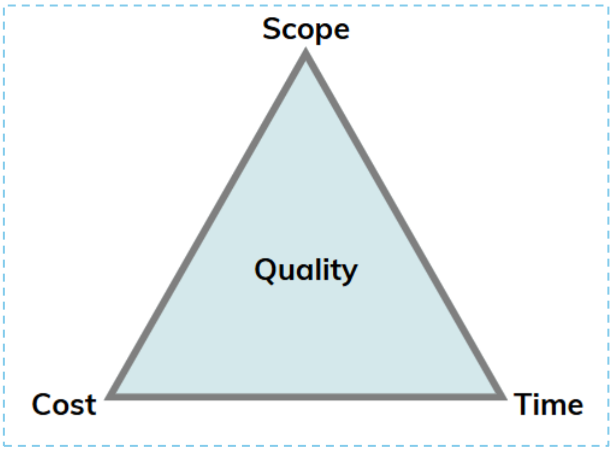
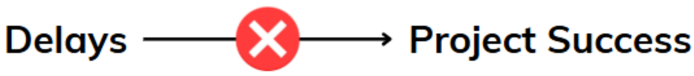


Figure 2 Iron Triangle (Atkinson, 1999)

The significance of time in determining project success is long established. The traditional 'iron triangle' comprising time, cost, and scope (see Figure 2) remains a widely accepted framework for evaluating project performance (Jha & Iyer, 2007; Atkinson, 1999). Within this framework, adherence to schedule is not merely a procedural goal but a key determinant of overall effectiveness. Unlike scope which is often fluid, subject to change, and difficult to quantify delays are more measurable and quantifiable, making them a clearer indicator of performance and easier to analyse when assessing project success. Delays disrupt schedule compliance, which in turn undermines functional efficiency, escalates costs through opportunity losses and environmental burdens, and ultimately hinders the achievement of project objectives. Thus, failure to meet time targets compromises both the intent and outcome of the project. Moreover, delayed project success often translates into delayed sustainability benefits or, in some cases, reduced sustainability altogether. This further reinforces the importance of timely delivery in environmentally focused developments. Therefore, investigating delays becomes essential not only for improving project efficiency but also for maximizing long-term ecological and societal impacts.



The issue of persistent delays is not limited to isolated cases. Park (2021) highlights that 77% of public infrastructure projects continue to miss schedule targets, despite decades of advancements in project management methodologies. This ongoing trend not only delays the fulfilment of critical societal and environmental needs but also reduces the operational efficiency and value of the project. Delays, therefore, are more than setbacks they actively erode project success.

Moreover, as Omoush (2020) emphasizes, the same critical success factors (CSFs) that underpin project performance are also closely linked to the causes of delays when not adequately managed. The research shows that project-related factors are among the most significant contributors to both successful and delayed outcomes. This dual role underscores the interconnected nature of project success and delay. Therefore delays are not merely symptoms of poor performance, but active barriers that must be addressed through strategic attention to CSFs.

In summary, while cost, quality, and time have traditionally guided the assessment of project performance, increasing environmental responsibilities and urgency demand that greater emphasis be placed on minimizing delays. Delays not only lead to increased costs and late delivery but also hinder need fulfilment and reduce the overall impact and sustainability of projects. Therefore, addressing the root causes of delays is critical to achieving comprehensive project success.

1.4 Challenges of Sustainability

Sustainability has emerged as a core principle shaping today's infrastructure practices, reflecting the ability of urban environments and infrastructure networks to maintain economic growth, social inclusion, and ecological balance over time. It is no longer a supplementary consideration but a core requirement in addressing global challenges. Sustainable infrastructure plays a vital role in achieving long-term social, environmental, and economic benefits, contributing directly to international targets such as the United Nations Sustainable Development Goals (SDGs), and complying with regulatory frameworks like those of the European Union (Kustova et al., 2024). As the construction industry faces mounting pressure to reduce its environmental impact, the shift toward sustainability is not optional sustainable projects are the future. Henceforth, all projects will have to be sustainable.

In contrast, traditional projects those implemented without explicit attention to long-term sustainability and circularity goals have been the norm until recent years. These projects often overlook the integrated requirements of 2030 and 2050 sustainability targets. As the sector transitions away from this traditional approach, sustainable projects demand more than just durable structures; they require adaptable planning systems, inclusive access to public goods, and consideration of long-term resilience (Andersson & Andersson, 2019).

Durability, which refers to the long-term physical resilience of capital goods such as buildings and infrastructure, contributes to sustainability but does not encompass its full scope. True sustainability introduces further complexities. It necessitates the integration of resilience, adaptability, and environmental consciousness into decision-making frameworks (Larrea-Gallegos et al., 2022). This transition calls for a departure from deterministic models toward probabilistic and adaptive approaches that embrace uncertainty and complexity (Peter & Swilling, 2014). The evolving interplay of self-organization, feedback loops, and socio-technical change demands an integrative mindset grounded in complexity theory.

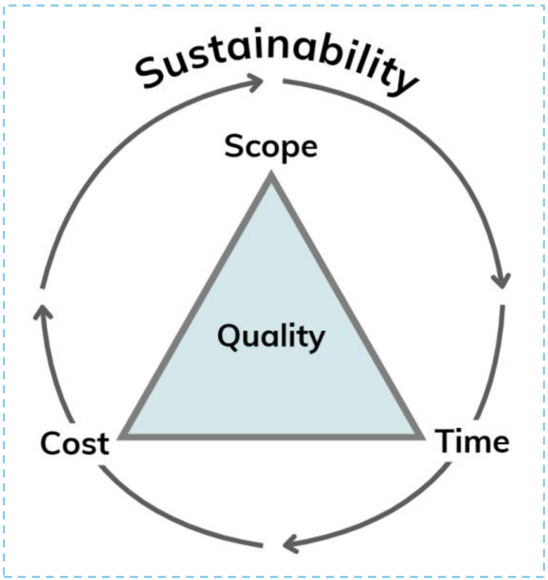


Figure 3 Iron Triangle + Sustainability

However, the pursuit of sustainability is often seen to lead to delayed project success but is still not addressed in the Iron Triangle by Atkinson (1999). Stable and inclusive growth depends on long-term investments, regulatory stability, and infrastructure development that may not yield immediate results but are essential for future resilience (Andersson & Andersson, 2019). This complexity extends to project execution, where management teams must navigate challenges such as limited training, high upfront costs, and unfamiliarity with green technologies (Ayarkwa et al., 2022). Moreover, aligning traditional project goals with evolving sustainability objectives increases the difficulty of managing stakeholders, mitigating risks, and allocating resources (Shokouhi & Bachari, 2024). Therefore, the integration of sustainability in infrastructure development demands strategic planning, supported by critical success factors and performance indicators to ensure successful outcomes.

1.5 Importance of Green Water Projects

Water is a central element in the pursuit of sustainability, intersecting ecological, social, and economic systems and playing a vital role in nearly all sustainability initiatives. As emphasized by Pahl-Wostl et al. (2013), water should not be treated merely as a sector-specific concern but recognized as a global change agent. Long-term, research-to-action water projects can serve as powerful vehicles for broader sustainability transformations by integrating interdisciplinary knowledge, governance strategies, and innovative methodologies at scale.

Within the sustainability sector, water-related initiatives offer strategic leverage for generating significant impact. Integrated water resource management and effective project execution are essential for ensuring that these initiatives fulfill their potential (Stoyanova et al., 2022). Successful water projects not only improve infrastructure but also contribute to ecosystem preservation, climate resilience, and risk mitigation particularly in addressing issues such as flooding. Their importance is further magnified by the need for stakeholder collaboration, transparency, and adherence to sustainable practices throughout the project lifecycle.

Water projects play a crucial role in sustainable development, given the extensive use of water across both industrial and domestic sectors. Nearly every industry relies on water at some stage of its production process whether directly in manufacturing, indirectly through cooling and cleaning, or in waste disposal and recycling. The connection to water is often not limited to production alone but extends to the treatment and responsible management of industrial by-products.

Considering the diversity and complexity of water projects ranging from sewage treatment and stormwater management to industrial water use and purification systems it is difficult to deep dive into a single specific type of project. However, due to their vital role and wide application, focusing on green water projects provides an ideal scope to enhance the overall impact of this research.

Bilfinger Engineering and Consultancy actively contributes to these efforts through its involvement in green water projects that span diverse applications. These include maintaining fresh water quality for fermentation and algae processes, supplying fresh water for hydrogen (H_2) production, recycling water for biobased and water-intensive operations, and developing treatment plants to address emerging contaminants like PFA, hormones, and micro/nano plastics. The company also meets critical cooling water needs in sectors such as energy power plants, electrolysers, chemicals, and steel production, aligning its operations with broader sustainability objectives.

In practice, green water projects are deeply embedded across three interconnected levels each involving distinct responsibilities and decision-making bodies. These levels include national entities such as Rijkswaterstaat, regional authorities like water boards, and local actors such as municipalities. Understanding the nature of sustainability-related challenges at each of these levels is essential for effective project planning and execution. Bilfinger is particularly interested in gaining clarity on the issues encountered across these three domains to strengthen its role as a consultant and implementer of sustainable water solutions.

While water projects are integral to sustainable development, managing them poses unique and substantial challenges. The complexity of sustainable projects often surpasses that of conventional infrastructure efforts, particularly due to the integration of novel, green technologies. As Hwang and Leong (2013) observe, green construction projects are more likely to experience delays than traditional ones, largely due to the limited familiarity with advanced technologies. These technologies require specialized knowledge and technical expertise, which can introduce inefficiencies and extend project timelines (J.C. Edison, 2015). Sustainability measures, though essential, often lead to unforeseen complications, making project management even more demanding.

Understanding these obstacles is crucial for improving the effectiveness of green infrastructure development. Sustainable construction, as noted by Kibert (2005), seeks to comprehensively address ecological, social, and economic concerns within communities. In this study, green water projects refer specifically to sustainable water initiatives that leverage environmentally friendly technologies, promote efficient resource management, and implement innovative solutions to improve water conservation, purification, and distribution.

This research aims to explore the sustainability-related challenges that contribute to delays in green water projects and propose mitigation strategies to address them. By doing so, it not only enhances the efficiency of water-focused sustainability initiatives but also offers insights applicable to broader green infrastructure development. Given the shared sustainability principles across various green projects, the findings and strategies developed through this research may serve as valuable inputs for improving project outcomes across the sustainability sector at large.

1.6 Research Gap

As the global focus on sustainable development intensifies, infrastructure projects are increasingly expected to integrate ecological responsibility, social inclusion, and long-term economic resilience. However, despite growing emphasis, sustainability remains a relatively new and evolving dimension within mainstream project management, particularly in large-scale infrastructure development. Traditional project delivery models, often shaped by deterministic planning and short-term priorities, struggle to accommodate the complexity, adaptability, and systemic integration required by sustainable infrastructure (Peter & Swilling, 2014).

Previous research has extensively examined general causes of project delays, often through the lens of the ‘iron triangle’ of time, cost, and quality (Jha & Iyer, 2007; Atkinson, 1999). Yet, the integration of sustainability introduces new variables such as regulatory compliance, environmental targets, and interdisciplinary coordination that are not fully captured by conventional frameworks. These sustainability-driven factors can fundamentally alter project trajectories, adding layers of complexity and uncertainty that traditional approaches are not well equipped to manage (Larrea-Gallegos et al., 2022).

While studies have identified how critical success factors (CSFs) influence project outcomes and delays (Omoush, 2020), there remains limited empirical research that determines the impact of sustainability-related challenges on project delays particularly within the subset of green projects. This is a critical oversight, as green projects are not only more likely to experience delays (Hwang & Leong, 2013), but also require advanced technical knowledge and innovative methods, which can extend timelines and reduce efficiency if not properly managed (J.C. Edison, 2015).

Within this already under-researched domain, green water projects present a particularly compelling focus. Water is a strategic and cross-cutting element of sustainability, intersecting environmental, social, and economic systems (Pahl-Wostl et al., 2013). However, the specific challenges associated with green water initiatives such as meeting regulatory standards, ensuring resource availability, and deploying unfamiliar technologies can lead to significant delays. These delays have wide-reaching implications, not only inflating costs and reducing project efficiency, but also delaying critical solutions to global issues like water scarcity, pollution, and climate adaptation (Stoyanova et al., 2022).

Given that over 90% of infrastructure projects are already delivered late and over budget (Flyvbjerg, 2011), understanding the unique delay drivers in green water projects is both urgent and essential. Despite their growing importance, there is a clear gap in the literature concerning how sustainability-specific challenges contribute to project delays and how targeted project management strategies can mitigate them. Addressing this gap is crucial for improving the efficiency, reliability, and impact of green water projects, and by extension, for advancing the broader goals of sustainable infrastructure development.

1.7 Problem Statement

Sustainability is still a relatively new concept in project management, and its impact on project timelines remains unclear. While green water projects aim to enhance environmental and social outcomes, their implementation may introduce challenges that affect project efficiency. The extent to which sustainability-related factors contribute to delays in the process of planning and execution of these projects has not been thoroughly investigated. This study seeks to explore these challenges and develop strategies to mitigate potential delays, ensuring that sustainability goals can be achieved without compromising project timelines.

1.8 Research Objective

To identify the sustainability-related challenges contributing to delays in Green Water Projects, and develop effective mitigation strategies to enhance project efficiency.

1.9 Research Questions

In this study, green water projects refer to sustainable water initiatives that utilize environmentally friendly technologies, efficient resource management, and innovative solutions to improve water conservation, purification, and distribution. More broadly, green projects refer to sustainability initiatives that address the ecological, social, and economic concerns of society.

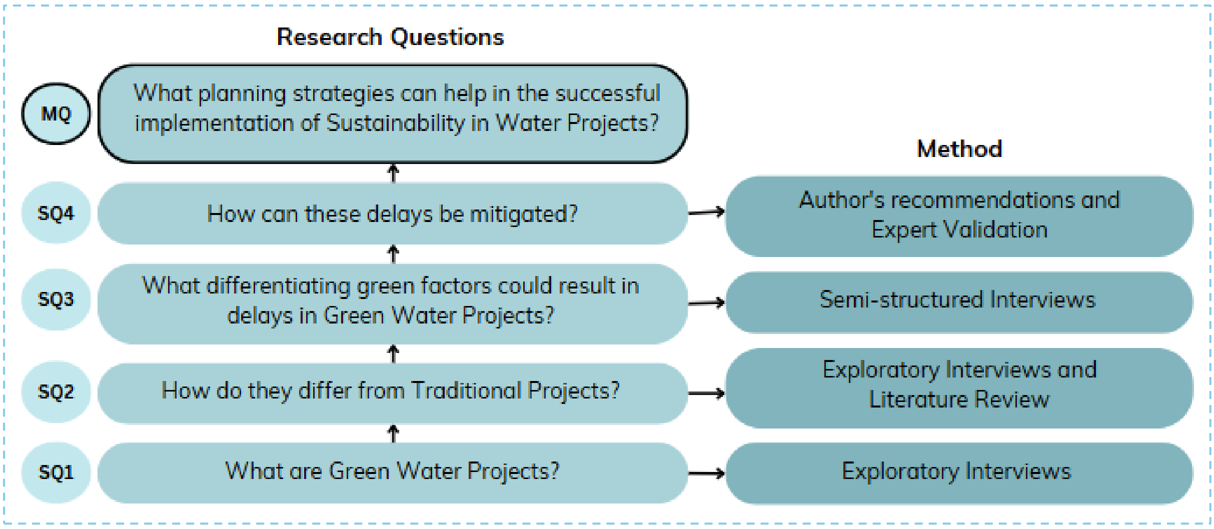


Figure 4 Research Questions and Method

Main Research Question:

What planning strategies can help in the successful implementation of Sustainability in Water Projects?

Research Sub-Questions:

1. What are Green Water Projects?
   - Define and categorize Green Water Projects to establish a clear scope.
2. How do they differ from traditional projects?
   - Establish why Green Water Projects require a different approach compared to traditional water infrastructure projects.
3. What differentiating green factors could result in delays in Green Water Projects?
   - Identify the root causes of project delays in sustainable water initiatives.
4. How can these delays be mitigated?
   - Develop practical solutions to reduce delays and improve efficiency.

1.10 Relevance

This research aims to develop practical guidelines and strategies to mitigate sustainability-related delays in green water projects. The findings will support project managers in improving efficiency while maintaining sustainability goals.

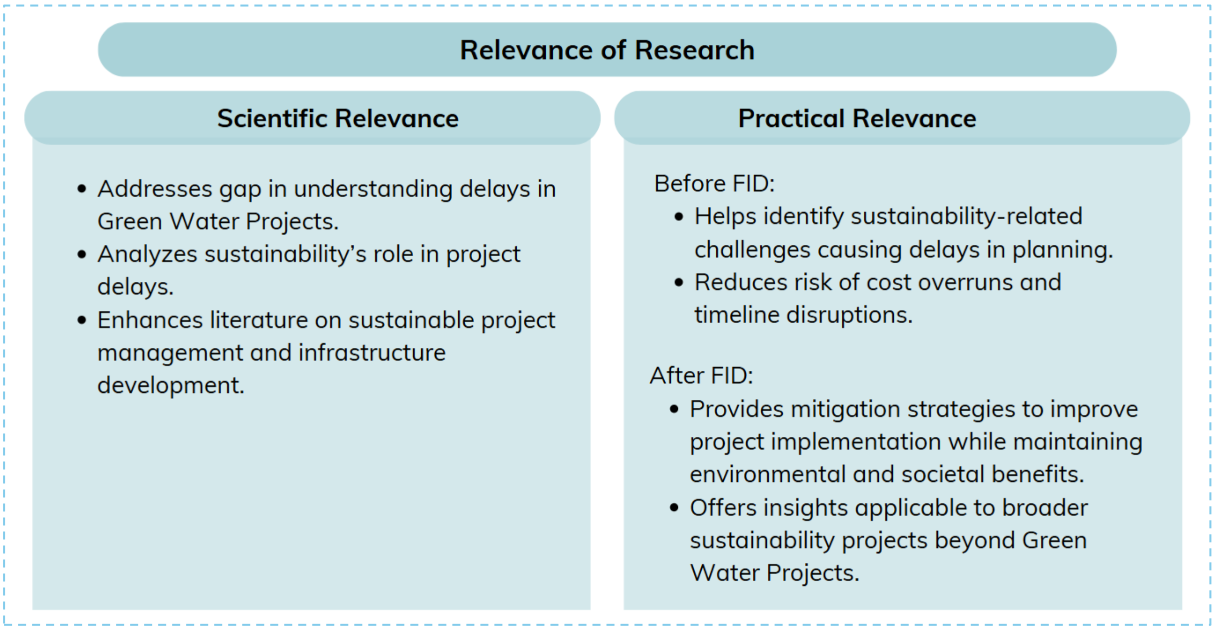


Figure 5 Relevance of Research

Scientific Relevance:

This research contributes to the field of project management by addressing a gap in understanding delays specific to Green Water Projects. By analysing the role of sustainability in project delays, this study adds to existing literature on sustainable project management and infrastructure development.

Practical Relevance:

Before FID:

The findings will assist project managers and policymakers in identifying sustainability-related challenges that may contribute to delays during the planning phase of Green Water Projects. Early recognition of these factors can support more informed decision-making before the Final Investment Decision, reducing the risk of cost overruns and timeline disruptions.

After FID:

By offering actionable mitigation strategies, the study will help improve the efficiency of Green Water Project implementation after the Final Investment Decision. Addressing sustainability-driven delays during execution will support the timely delivery of project outcomes, ensuring that environmental and societal benefits are not compromised.

Furthermore, the insights gained can be applied to a broader range of sustainability projects, making the study valuable beyond the scope of Green Water Projects.

2. Research Method

2.1 Research Approach

This study employs a qualitative approach that integrates multiple data collection techniques to ensure a comprehensive understanding of delays in green water projects. The methodology consists of four key phases: exploratory interviews, a literature review, semi-structured interviews, and expert validation. Each phase plays a critical role in identifying causes of delays and formulating effective mitigation strategies.

Figure 6 Connection between the different phases

2.2 Exploratory Interviews: Scoping the Research Landscape

The first phase of data collection involved brief, exploratory interviews with Aquatech and Aqua Nederland engineers and project managers. The aim was to determine whether sustainability concerns contribute to project delays and to uncover initial themes related to these delays in green water infrastructure projects, as compared to traditional ones.

These interviews were intentionally unstructured and open-ended, guided only by a few broad topics to maintain flexibility. As Harvey (2025) explains, exploratory interviews are designed to surface emerging ideas, reveal early hypotheses, and shape the trajectory of further research. Responses were carefully noted, and summaries were validated by the interviewees to ensure accuracy and shared understanding.

A thematic analysis (Clarke & Braun, 2017) was applied to this early qualitative data to identify recurrent patterns across interviews. The analysis was conducted using Microsoft Excel (Bree and Gallagher, 2016) and a small sample size (9 participants) was deemed appropriate for this preliminary stage, where the goal was to gain a foundational understanding of key barriers and define what constitutes a "green water project" in practice.

This involved transcribing interview notes into Excel, organizing the data by individual comments or quotes in separate rows. Each comment was then coded with initial labels reflecting key ideas, using Excel's color-coding feature to visually group similar codes. The data was sorted and filtered by these color-coded themes to bring together related points, which were further refined through several rounds of review in separate worksheets. This iterative process helped consolidate and synthesize the data, ultimately generating key themes and sub-themes relevant to the study.

Significance & Role in Research Design:

- This phase served as a scoping exercise establishing a foundational understanding of what qualifies as a Green Water Project and whether sustainability contributes to project delays in practice. This allowed for the contextual refinement of Sub-questions 1 and 2.
- Findings helped inform the structure of the literature review, ensuring thematic alignment between practice and theory.
- Insights from this phase were also used to develop the question guide for the subsequent, more rigorous semi-structured interviews.

2.3 Literature Review: Theoretical Framing of Themes

Following the exploratory interviews, an in-depth literature review was conducted to examine how green water projects differ from traditional infrastructure projects and how these differences may contribute to project delays. This phase served to ground the emergent themes from initial fieldwork in existing academic discourse and industry knowledge.

Relevant academic articles were selected based on the themes identified in the exploratory interviews. The review focused on key areas such as project management challenges, sustainability related constraints, regulatory influences, the integration of innovative technologies in green water projects.

The literature was analysed to trace how these factors influence project delivery timelines. Particular attention was paid to the interplay between sustainability goals and delays.

Significance & Role in Research Design:

- This phase provides the theoretical framework for understanding the distinct characteristics of green water projects.

- It acts as a validating bridge between practice and theory by confirming (or contesting) insights from the exploratory interviews.
- It directly addresses Sub-question 2 by offering a comparative analysis of green vs. traditional project execution models.
- The outcomes of this phase informed the development of the semi-structured interview guide, ensuring alignment with both empirical themes and academic perspectives.

2.4 Semi-Structured Interviews: Deepening the Study

Building upon the themes identified during the exploratory phase and the literature review, the third phase employed semi-structured interviews to gain richer insights into the causes of project delays in green water projects.

These interviews followed a more structured protocol, with a pre-defined but flexible set of open-ended questions (Ruslin et al., 2022). Questions were derived directly from the exploratory phase findings and supported by theoretical concepts from the literature. 8 interviews were conducted comprising of clients, contractors, and innovation experts at Bilfinger Engineering and Consultancy. They were selected for their hands-on experience in project execution.

Each interview lasted longer and allowed participants time to reflect on specific projects. Similar to the first phase, a thematic analysis (Clarke & Braun, 2017) was used to interpret the data in excel (Bree and Gallagher, 2016). Audio recordings captured both verbal and non-verbal cues, and interviews were conducted until data saturation was reached, which means when no substantially new information emerged.

Similar to the Exploratory interview analysis the interview transcripts and notes were entered into Microsoft Excel, with each comment or relevant data point placed in individual cells. The data was then coded inductively, assigning labels to cells reflecting emerging themes, which were color-coded for easy grouping. Using Excel's sorting and filtering functions, similar codes were organized into thematic clusters across multiple worksheets. This iterative process allowed the researchers to refine the themes and identify patterns until data saturation was reached, ensuring a thorough and rigorous analysis.

Significance & Role in Research Design:

- This phase directly addresses Sub-question 3 by offering deep, role-specific insights into project delays.
- It provides a comparative, triangulated perspective by including diverse stakeholders.

- The structured nature of this phase allows for rigorous theme validation and the exploration of connections between sustainability goals and project performance.

Since the study consists of two phases of interviews it is important to know the difference between the two interview phases as indicated in Figure 7:

	Exploratory Interviews	Semi-Structured Interviews
Purpose	Identifying initial themes, scoping	Deep dive into causes of delays
Format	Unstructured, Informal	Pre-defined guide but flexible
Participants	Engineers and Project Managers at Aquatech & Aqua Nederlands	Bilfinger Clients, Contractors and Innovation experts
Sample size	9	8 (until saturation)
Analysis	Thematic	Thematic
Role in Research	Informs Literature Review + Semi-Structure Interview Guide	Main empirical data

Figure 7 Exploratory vs Semi-structured Interviews

2.5 Expert Validation: Testing Practical Relevance

As the final phase of the research process, an expert validation session was conducted in a workshop format, in modified Delphi method (Okoli & Pawlowski, 2004) with four senior professionals from Bilfinger Engineering and Consultancy. This step is designed to critically assess the research findings and proposed mitigation strategies for project delays in green water infrastructure.

During the session, a synthesis of the thematic findings and proposed solutions were presented to participants. Experts were encouraged to provide feedback, question assumptions, and offer suggestions for practical improvement (see Appendix C). This dialogical format supports collaborative learning and strengthens the applicability of the research outcomes.

According to Ahmed (2024), incorporating practitioner feedback helps reduce researcher bias and enhances the reliability and generalisability of qualitative findings. Expert validation ensures that the final recommendations are both contextually grounded and operationally feasible.

Significance & Role in Research Design:

- This phase functions as a quality control mechanism, ensuring that the proposed solutions align with real-world project conditions.
- It strengthens the credibility and transferability of the research by integrating multiple stakeholder perspectives.

- It validates Sub-question 4 by evaluating the practical relevance and viability of the suggested delay mitigation strategies.
- This step concludes the iterative research cycle and prepares the ground for final conclusions and recommendations.

3. EXPLORATORY INTERVIEWS

To establish a foundational understanding of Green Water Projects and their practical implications, this study conducted nine exploratory interviews (see Appendix A) with professionals involved in water-related sustainability initiatives. The interviews aimed to address Sub-question 1 (*What are Green Water Projects?*) and Sub-question 2 (*How do they differ from traditional projects?*) by gathering real-world insights into how sustainability impacts project execution. Participants ranged from Research Managers to Project Engineers, working across sectors such as water purification, sustainable mechanical systems, and construction. Thematic analysis of these interviews uncovered common patterns, key differences, and recurring challenges in implementing green initiatives within water infrastructure.

3.1 Findings of Exploratory Interviews

Sustainability causes delays. Most participants (7 out of 9) stated that sustainability introduces project delays. As a few participants described, *"Sustainability does cause extra delays" (Interviews 2, 3, 4, 7, 8)*. Another noted, *"Sustainability causes extra delays currently as it is still a new concept" (Interview 4)*. Further, one interviewee emphasized, *"Sustainability projects usually do not go as expected due to lack of knowledge and experience" (Interview 3)*. Regarding regulatory complexity, one respondent stated, *"Regulations and the approval process about sustainability are too complex, making them clearer can help speed up the process" (Interview 2)*. These comments illustrate how uncertainty and innovation in sustainability contribute to extended project durations. Two participants reported no significant delays, citing pre-existing sustainable designs or efficient processes, with one stating, *"No, sustainability does not cause delays as products have to meet certain criteria and requirements related to sustainability goals and if these are met then the government approvals are easier and faster to get" (Interview 6)*.

What are Green Water Projects?

Across interviews, participants consistently associate green water projects with sustainability-focused goals. These goals define the relevance of such projects and help distinguish them from traditional water infrastructure projects. Key sustainability objectives mentioned include:

- Environmental impact reduction
- Circular practices
- Resource efficiency
- Minimizing harmful outputs

Interpretation:
Green Water Projects are sustainable water-related initiatives aiming to reduce environmental harm, improve efficiency, and promote circular and renewable practices. Green Water Projects encompass purification, reuse, efficiency improvements, and sustainable material use. They include engineering, chemical, and technological disciplines.

Examples of Green Water Projects mentioned:

- PFAS removal technologies
- Closed-loop water cooling systems
- Advanced wastewater treatment (wastewater and brine water)
- Energy-efficient mechanical components for water projects
- Plastic reduction through water purification solutions
- Polymer recycling for water networks

These examples show that Green Water Projects involve resource efficiency, circular economy principles, energy reduction, contaminant removal, and water reuse, contrasting with traditional projects that mainly prioritize basic water supply or wastewater disposal without broader ecological goals.

Key Similarities

The exploratory interviews revealed several key similarities across Green Water Projects. Most projects face delays due to the integration of sustainability, with participants agreeing that incorporating sustainable practices increases complexity and causes delays. Common drivers of these delays include regulatory hurdles, lack of sustainability expertise, and higher initial costs, which make project initiation and funding more difficult.

A recurring issue was the knowledge and awareness gap, with limited experience in new sustainable technologies among clients, engineers, and governmental approval bodies. As one participant remarked, *"Lack of knowledge about sustainability" (Interview 1)*. Another said, *"There is a big gap between knowledge of sustainability and construction process" (Interview 8)*. Additionally, *"Clients willingness to take risk is very low but they want sustainability resulting in added challenges" (Interview 8)*.

Complex and unclear regulatory frameworks were frequently cited as bottlenecks, while policy gaps and bureaucratic processes also emerged as major obstacles. As one participant noted, *"Policies vary from region to region resulting in further complexity" (Interview 1)*. Another stated, *"Due to bureaucracy the complexity of sustainability is more difficult to process for the companies" (Interview 4)*. Despite these challenges, innovative technologies such as adaptive flow pumps, biodegradable chemicals, and PFAS filters are common across projects, with water reuse and resource efficiency identified as key goals. However, the high degree of innovation often introduces uncertainty, leading to trial-and-error phases that further prolong project delivery, described as *"More trial and error and there is no defined fixed correct result" (Interview 8)*.

Key differences

The exploratory interviews revealed several key differences among Green Water Projects. The type of green innovation varied, with some companies focusing on treatment solutions and others on technology upgrades. Experience levels also differed, as some companies had mature sustainable processes, while others were still adapting.

Regional variation played a significant role, with companies operating across multiple regions, especially in Europe compared to other areas, facing greater complexity due to differing regulations. Company readiness influenced delays, with certain firms which had pre-existing sustainable product lines, experiencing fewer delays than those newly adopting sustainability measures.

The type of sustainability efforts also mattered. Projects emphasizing material reuse, such as circular construction, generally faced longer delays than those focused on efficiency improvements like energy-saving pumps. One participant explained, *"Reusing materials takes a lot of time as the materials should be dismantled and then transported to the new project venue" (Interview 7)*. Public perception and risk appetite further affected timelines, with some projects delayed due to low public awareness or client hesitancy toward new sustainable technologies. Additionally, perceptions of sustainability differed as for some companies, it served as a competitive advantage, while for others it remained a burden requiring external support.

3.2 Thematic Analysis

Following Clarke and Braun's (2017) thematic analysis method, the interview data (see Appendix A) was coded and organized into recurring themes. While qualitative analysis software such as NVivo or Atlas.ti can assist in managing large datasets, Excel was chosen for its accessibility and the small size of the dataset, allowing for a hands-on and deeply engaged analytical process. Bree and Gallagher (2016) indicates a detailed method of how thematic analysis can be conducted in excel (see Appendix A). This involved transcribing interview notes into Excel, organizing the data by individual comments or quotes in separate rows. Each comment was then coded with initial labels reflecting key ideas, using Excel's color-coding feature to visually group similar codes. The data was sorted and filtered by these color-coded themes to bring together related points, which were further refined through several rounds of review in separate worksheets. This iterative process helped consolidate and synthesize the data, ultimately generating key themes and sub-themes relevant to the study. Detailed thematic analysis is mentioned in Appendix A.

Key themes identified across the exploratory interviews that make green water projects special are summarized in Table 1:

Theme	Description	Mentioned In
Regulatory Complexity	Sustainability projects face complex, unclear, and region-specific regulations and unclear approval processes causing delays.	7 interviews
Lack of Knowledge and Experiance	Lack of sustainability expertise and knowledge gaps among engineers and contractors and at company and client levels, affecting planning and execution.	6 interviews
High Initial Costs	Higher initial investment needs, complicating financing and stakeholder buy-in compared to traditional projects.	6 interviews
Technological Innovation and Risk	Green water projects often involve untested technologies, leading to unpredictability and extended timelines due to trial-and-error processes.	5 interviews
Material Circularity Challenges	Reusing and recycling materials introduces additional time-consuming steps like dismantling, testing and adapting used resources.	4 interviews
Government Support/Subsidies	Insufficient subsidies or support policies increase financial and scheduling risks and prolong project execution.	4 interviews
Stakeholder Coordination Issues	Misalignment between contractors, clients and regulatory bodies causes halts in project execution. Client's low risk tolerance and public opposition also contribute to delays.	3 interviews

Table 1 Thematic Analysis of Exploratory Interviews

Following the thematic analysis of the exploratory interviews, it is essential to contextualize the subject of investigation 'Green Water Projects'. Understanding what constitutes a Green Water Project is a critical step in framing the discussion, as it sets the boundaries for subsequent analysis and ensures clarity in evaluating the challenges and potential solutions. By defining and categorizing these projects, a clearer picture emerges of their scope, objectives, and distinguishing features, which, in turn, provides a solid foundation for assessing their implementation in real-world contexts. This can be achieved by addressing the first sub-question.

SQ1 What are Green Water Projects?

Green Water Projects are infrastructure initiatives that aim to reduce environmental impact through the implementation of sustainable practices. These projects emphasize water and energy efficiency, promote material circularity, and often incorporate new or experimental technologies. They are characterized by their alignment with environmental sustainability goals and may include features such as PFAS removal systems, zero-liquid discharge processes, and the use of biodegradable materials. While not limited to a single type, Green Water Projects can vary significantly depending on regional regulations, levels of innovation, and specific project objectives, establishing a broad but clearly sustainability-focused scope.

So how do they differ from traditional projects?

To further contextualize the findings from the exploratory interviews and thematic analysis, Table 2 presents a comparative summary highlighting how green water projects differ from traditional water projects. While both aim to address water-related challenges, green projects introduce new layers of complexity, innovation, and stakeholder involvement at different levels due to their sustainability focus. The table is derived from data gathered during the exploratory interviews keeping traditional projects as the benchmark and consolidates key insights across seven dimensions—time, cost, regulations, expertise, materials and methods, stakeholder engagement and risk, revealing fundamental contrasts between sustainable and conventional approaches to water project development and execution.

Differences	Green Water Projects	Traditional Projects	Supporting Quotes (exploratory interviews)
Time	Often delayed due to complexity, lack of expertise, and innovative processes.	Faster and more predictable due to standardized methods and simpler workflows.	"Sustainability does result in delays." "The circularity process is longer and time consuming."
Cost	Higher initial investment due to new materials, tech, and compliance with sustainability criteria.	Lower upfront costs using established, cheaper resources and techniques.	"Green water projects often have higher initial costs..." "More money, initial investment is extremely high."
Regulations	Evolving, region-dependent, and unclear, increasing complexity and delays.	Well established and easier to navigate.	"Absence of clear regulatory frameworks." "Policies are different for every region..."
Expertise	Requires specific knowledge and skills in sustainable practices and emerging technologies.	Requires general, widely available technical expertise.	"Technology to be used is relatively new and expertise is low." "Gap between knowledge of sustainability and construction process."
Materials & Methods	Emphasis on circularity, reusability, and innovation in equipment and processes, often requiring dismantling, transport, and adaptation.	Use of standardized materials and proven processes.	"Reusing materials takes a lot of time..." "Highly innovative... creates extra complexity."
Stakeholder Engagement	Requires more public and stakeholder awareness, involvement, and education to overcome resistance and build consensus.	Less stakeholder engagement required due to familiarity and trust in traditional methods.	"Public perception and stakeholder engagement becomes difficult." "Clients want sustainability but are risk averse."
Risk	High uncertainty due to trial-and-error approaches and lack of validated outcomes	Tried and tested techniques with predictable results	"More trial and error and there is no defined fixed correct result." "Projects do not go as expected due to lack of knowledge."

Table 2 Green Water Projects vs Traditional Projects – Exploratory Interviews

To deepen understanding of the barriers to green water project implementation, a preliminary round of scoping interviews was conducted. These early conversations informed the identification of key themes and guided the selection of relevant academic literature. The following literature review is thus structured around these emerging themes, offering a theoretical lens through which the main empirical study, the semi-structured interviews is later conducted and analysed.

4. Literature Review

The following literature review explores key themes identified through exploratory interviews (see table 1), providing a broader academic context to the barriers faced in Green Water Projects. By examining existing studies, the review seeks to validate and deepen the understanding of challenges such as knowledge gaps, high initial costs, technological risks, material circularity, government support, and stakeholder coordination. Each theme is analysed through relevant research work to highlight how these issues have been addressed in previous research, thereby grounding the interview findings within the wider body of literature and emphasizing the complexity of overcoming these barriers to advance sustainable water project practices.

Regulatory Complexity

Research highlights the challenge posed by complex, region-dependent, and evolving regulatory frameworks for green water projects. Wiek and Larson (2012) explain that sustainability compliance varies widely by geographic and historic contexts, making governance highly region-specific. Rodriguez-Nikl and Brown (2011) emphasize the growing and evolving state of green building codes, describing sustainability regulations as “imperfect and incomplete,” forcing reliance on individual professional judgment rather than standardized guidance.

Lo et al. (2020) specifically address the regulatory challenges in water projects, showing that green projects face evolving, unclear regulations causing complexity and delays, whereas traditional projects benefit from established regulatory pathways. They also note a shift from traditional command-and-control regulations toward market- and information-based approaches, adding further ambiguity and regional variation. Additionally, Lo et al. highlight the absence of formalized institutional structures in participatory governance models common in green projects, increasing complexity compared to the more established governance of traditional projects. This aligns with findings from Dahal (2024), who stresses the growing intricacy of environmental regulatory governance and the necessity of long-term research to manage evolving dynamics.

Building on these challenges, Bakke and Johansen (2025) propose front-end loading (FEL) as a key mitigation strategy to reduce delays caused by regulatory uncertainty. FEL engages clients, regulators, and stakeholders early in the project through workshops and collaborative planning, fostering shared understanding and anticipatory problem-solving.

To contextualize regulatory complexity within broader governance structures, Van Der Brugge and Van Raak (2007) situate regulatory actors within a transition management model, describing them as tactical-level agents translating strategic sustainability visions into enforceable standards and incentive structures. Recognizing this role helps align project proposals with evolving regulatory trends while contributing to long-term transition goals.

Finally, Koppenjan et al. (2010) stress the necessity of adaptive management across operational, regulatory, and financial domains such as updated maintenance procedures, revised effluent standards, and flexible procurement contracts to foster institutional transitions. These transitions require multilevel coordination, feedback loops, and cross-sector collaboration to effectively manage the regulatory complexity in green water projects.

Expertise and Knowledge Requirements

Green water projects demand specialized, multidisciplinary expertise that contrasts with the broader technical knowledge typical in traditional projects. Gedamu et al. (2025) highlight the need for expertise in climate-resilient infrastructure and sustainable land management to counter challenges such as climate variability and water source degradation.

AlHaddid et al. (2024) expand this perspective by identifying multiple knowledge domains like sociocultural, economic, political, environmental, and technological, that shape sustainability attitudes and practices. They advocate for educational programs and awareness campaigns tailored to local socio-cultural and religious contexts, underscoring the necessity of context-sensitive expertise for green projects.

Jacobs et al. (2010) support these findings by highlighting widespread knowledge gaps among professionals involved in water infrastructure delivery, including designers, contractors, clients, and regulators. Opoku et al. (2019) further discuss resistance from experienced engineers to adopting new sustainable concepts, which complicates client persuasion and the broader adoption of green practices.

Building on these challenges, Matinaro and Liu (2015) emphasize organizational barriers beyond technology such as leadership skills, communication, and workplace culture that hinder innovation adoption in project-based industries. They highlight the importance of organizational learning and innovative leadership to overcome resistance to change, which is especially relevant for managing sustainability-driven complexities in green water projects. Their reference to Moore's "chasm" in technology adoption (the gap between early enthusiasm and mainstream acceptance) offers a valuable framework for understanding the diffusion challenges of sustainability innovations and suggests that strategic efforts are required to bridge this gap effectively.

Together, these studies support interview findings that green water projects require a more diverse and gradual knowledge base than traditional projects, where general technical skills often lead to inappropriate technology use and system unreliability.

Materials and Methods

Dahal (2024) distinguishes green water projects by their emphasis on material circularity, reuse, and innovation in equipment and processes. These projects require dismantling, transport, and adaptation to local conditions, demanding a dynamic and participatory approach.

Dahal highlights the importance of maintaining well-managed reserves of tools and fittings, employing skilled technicians, and adopting adaptive operation and maintenance practices, all reflecting the innovative and flexible nature of green projects. In contrast, traditional projects typically rely on standardized materials and proven but rigid processes, lacking the same degree of adaptability and sustainability orientation.

Bogataj and Grubbström (2011) provide a model for reverse logistics, illustrating how material circularity introduces delays due to transport, handling, labor, and dependency on available recoverable items. These factors exemplify the operational challenges faced in green water infrastructure projects.

Building on this, Koppenjan et al. (2010) reinforce the need for operational flexibility by highlighting how institutional change must span operational procedures, regulatory practices, and financial structures. This cross-sector interdependence necessitates robust adaptive management to successfully implement innovative methods in green water projects.

Stakeholder Engagement

Langsdale and Cardwell (2022) demonstrate that green water projects require more extensive public and stakeholder involvement than traditional projects. Novel approaches often face resistance, necessitating inclusive, agile engagement processes. Effective stakeholder engagement demands overcoming power imbalances, valuing diverse local knowledge, and rapidly addressing misinformation to build trust and shared understanding. In contrast, traditional projects benefit from established familiarity and trust, reducing the intensity of stakeholder engagement required.

Megdal et al. (2017) emphasize that institutional and political contexts critically influence water policy implementation. A document from Medal's report governance failures in Mexico linked to decentralization without sufficient local resource allocation. Sigalla et al. (2021) reveal how stakeholder platforms in Tanzania often exclude private and civil society actors, skewing water governance and limiting effectiveness.

These studies reinforce the need for tailored, context-aware engagement strategies to overcome coordination challenges in green water projects. Matinaro and Liu (2015) further stress the critical role of cooperative communication and organizational culture in overcoming resistance, suggesting that fostering these within stakeholder groups is essential for smooth project implementation.

Risk and Uncertainty

Dahal (2024b) discusses multifaceted risk factors like technical, socio-environmental, financial, and institutional that must be considered in sustainability assessments of water projects. Risk scores assigned based on the likelihood of failure highlight greater variability and uncertainty in green projects due to the use of complex and innovative sustainability indicators. In contrast, traditional projects, which rely on standardized methods, tend to exhibit more predictable outcomes and lower uncertainty. Dahal's findings affirm that green water projects inherently carry higher risk and complexity, requiring advanced tools and refined risk management strategies.

Ahmed et al. (2023) note that public water utilities' risk aversion, driven by responsibilities over public health and the long lifecycles of infrastructure, further impedes the adoption of innovative green technologies. De Ruijter and Guldenmund (2016) propose the Bow Tie Risk Assessment model to visualize and manage threats that may lead to cascading failures. By mapping central risks alongside their causes and consequences, organizations can install preventive barriers such as regulatory protocols and mitigating controls like contingency funds or modular designs, thereby increasing implementation certainty.

Koppenjan et al. (2010) also emphasize adaptive management practices that can navigate the interdependencies among water, energy, materials, and community trust, reinforcing the need for resilience-oriented risk management in sustainable transitions.

Government Support and Subsidies

Heyl et al. (2022) emphasize that the effectiveness of subsidy programs depends on bureaucratic capacity, expert knowledge, and robust data systems. Poorly targeted subsidies increase financial and scheduling risks, undermining the sustainability of water projects.

Zolfagharinia et al. (2023), while focusing on green product development, provide insights relevant to water infrastructure, showing how subsidies influence market dynamics, consumer awareness, and the overall success of green strategies. These findings reinforce the importance of well-designed and context-specific support mechanisms for green water projects.

Cost Barriers

Green water projects generally require higher upfront investments than traditional projects, complicating financing and stakeholder buy-in. Ekins and Zenghelis (2021) observe elevated capital costs associated with sustainable water infrastructures.

Dwaikat and Ali (2016) report that green buildings incur a cost premium ranging from -0.4% to 21% compared to conventional structures, despite long-term benefits. Kang et al. (2013) attribute part of these higher initial costs to the more extensive preproject planning required for green construction.

Windapo and Machaka (2018) highlight that clients and contractors often prefer conventional methods due to cost concerns, even when sustainability advantages are clear.

Time and Schedule Performance

Hwang et al. (2014) find that green building projects take approximately 8% longer to complete than conventional ones, primarily due to extended design and planning phases. Their survey shows that 43% of green projects experience schedule overruns, averaging 4.8% longer than planned.

Hwang and Leong (2013) report that green projects are twice as likely to be delayed, attributed to the increased complexity from integrated design and construction phases. Consultant experience significantly influences schedule performance, reflecting the longer durations and intricacies inherent in green water projects.

Matinaro and Liu (2015) further highlight leadership and communication as critical to overcoming delays caused by innovation adoption gaps, emphasizing the importance of proactive management in bridging implementation challenges.

Literature Review Table:

Author(s)	**Year**	**Focus Area**	**Key Findings**	**Relevance to Green Water Projects**
Wiek & Larson	2012	Regulatory Complexity	Sustainability compliance is region- and history-dependent, making governance highly specific.	Highlights regional variability in regulatory frameworks.
Rodriguez-Nikl & Brown	2011	Regulatory Complexity	Sustainability regulations are evolving and incomplete; professionals rely on individual judgment.	Illustrates the lack of standardized regulatory guidance in green projects.
Lo et al.	2020	Regulatory Complexity	Unclear, evolving regulations and lack	Underscores regulatory

			of institutional structure delay green projects.	ambiguity and structural limitations compared to traditional projects.
Dahal	2024	Regulatory Complexity	Environmental regulations are increasingly complex and demand long-term governance research.	Supports the need for sustained regulatory management in green projects.
Bakke & Johansen	2025	Regulatory Complexity	Front-End Loading (FEL) reduces delays by early stakeholder engagement and shared problem-solving.	Provides a mitigation strategy for managing regulatory uncertainty.
Van Der Brugge & Van Raak	2007	Regulatory Complexity	Regulatory actors act as tactical agents within transition management frameworks.	Offers a model to align green projects with evolving regulatory visions.
Koppenjan et al.	2010	Regulatory & Operational Flexibility	Emphasize adaptive management across operational, regulatory, and financial domains.	Advocates for cross-sector coordination to handle complexity in green projects.
Gedamu et al.	2025	Expertise Requirements	Specialized knowledge in climate-resilient infrastructure and land management is essential.	Stresses the need for multidisciplinary expertise in green projects.

AlHaddid et al.	2024	Expertise Requirements	Emphasize sociocultural, political, and technological knowledge and context-sensitive education.	Promotes localized awareness and specialized knowledge for sustainability success.
Jacobs et al.	2010	Expertise Requirements	Professionals lack knowledge across water infrastructure sectors.	Identifies gaps in project delivery competence.
Opoku et al.	2019	Expertise Requirements	Experienced engineers resist adopting sustainable concepts, complicating client persuasion.	Highlights cultural resistance to green practices in engineering communities.
Matinaro & Liu	2015	Expertise, Schedule, & Stakeholder Engagement	Leadership, communication, and organizational learning are critical; innovation faces adoption barriers.	Cross-cutting insights into delays, resistance, and engagement challenges.
Dahal	2024	Materials and Methods	Emphasizes material circularity and adaptability, requiring skilled technicians and flexible practices.	Differentiates operational needs between green and traditional projects.
Bogataj & Grubbström	2011	Materials and Methods	Reverse logistics introduce operational delays due to recovery and transport of reusable items.	Demonstrates logistical and timing challenges in sustainable material use.
Langsdale & Cardwell	2022	Stakeholder Engagement	Public and stakeholder engagement must	Advocates for inclusive and adaptive

			overcome resistance and misinformation to build trust.	engagement strategies.
Megdal et al.	2017	Stakeholder Engagement	Institutional/political settings affect water policy implementation.	Shows how political context influences success in green water governance.
Sigalla et al.	2021	Stakeholder Engagement	Exclusion of private and civil society actors weakens stakeholder platforms.	Highlights gaps in participatory governance models.
Dahal	2024b	Risk and Uncertainty	Green projects have more variable risk profiles due to innovative sustainability indicators.	Argues for advanced tools to manage elevated uncertainties.
Ahmed et al.	2023	Risk and Uncertainty	Risk aversion in public utilities delays adoption of innovative green technologies.	Explains institutional conservatism as a barrier to green technology adoption.
De Ruijter & Guldenmund	2016	Risk and Uncertainty	Bow Tie model helps visualize risk causes and mitigation pathways.	Suggests structured approaches to manage cascading project risks.
Heyl et al.	2022	Government Support/Subsidies	Bureaucratic and knowledge limitations reduce subsidy effectiveness.	Underscores the need for institutional capacity to

				implement financial support.
Zolfagharinia et al.	2023	Government Support/Subsidies	Subsidies shape market dynamics and green strategy success.	Indicates broader policy impacts of well-targeted support systems.
Ekins & Zenghelis	2021	Cost Barriers	Green infrastructure has high upfront costs.	Affirms financial challenges in initiating green water projects.
Dwaikat & Ali	2016	Cost Barriers	Green buildings cost -0.4% to 21% more despite long-term benefits.	Quantifies the cost premium of sustainable construction.
Kang et al.	2013	Cost Barriers	Extensive pre-project planning raises costs.	Links financial barriers to additional green design requirements.
Windapo & Machaka	2018	Cost Barriers	Clients/contractors prefer conventional methods due to cost concerns.	Reflects hesitation to invest in green projects despite long-term benefits.
Hwang et al.	2014	Time & Schedule Performance	Green buildings take 8% longer; 43% face delays of 4.8% due to design and planning.	Highlights significant schedule risks in green project timelines.
Hwang & Leong	2013	Time & Schedule Performance	Green projects are twice as likely to be delayed due to complexity.	Emphasizes impact of integration and consultant experience on schedules.

Table 3 Literature Review

Building on the insights summarized in the literature review, it becomes clear that Green Water Projects face a unique set of challenges across regulatory, technical, financial, and social domains. These challenges not only distinguish them from traditional water infrastructure efforts but also underscore the need for new frameworks, skill sets, and stakeholder dynamics. The following section explores these differences, shedding light on how Green Water Projects diverge from conventional practices and why they demand fundamentally different approaches.

SQ2 How do they differ from Traditional Projects?

Green Water Projects differ from traditional water infrastructure projects in several ways that necessitate a distinct approach. Unlike traditional projects that rely on standardized methods, established regulations, and widely available expertise, Green Water Projects are characterized by their focus on sustainability, innovation, and circularity. This leads to higher initial costs, longer timelines, and increased complexity due to evolving and region-specific regulations, the use of novel materials, and the need for specialized knowledge in emerging technologies. Additionally, these projects involve greater stakeholder engagement to address public perception and build consensus around unfamiliar and experimental practices.

The inherent uncertainty and risk in Green Water Projects, often coming from trial-and-error implementation and lack of validated outcomes, contrasts sharply with the predictability and reliability of traditional approaches. As a result, Green Water Projects require a more adaptive, informed, and collaborative project management strategy that accommodates innovation, regulatory variation, and the demands of sustainable development goals.

With a clearer understanding of how Green Water Projects diverge from traditional infrastructure models, both in theory and practice it becomes increasingly important to ground these insights in the experiences of those directly involved in their execution with clients from varied management levels as indicated in Chapter 1 . While the literature review offered a solid conceptual framework, it also highlighted areas where theoretical knowledge alone is insufficient to fully explain the complexity of real-world project delays.

To address this gap and deepen the analysis, the next phase of this research turns to semi-structured interviews. These interviews aimed to capture the perspectives of practitioners actively working on Green Water Projects, providing role-specific insights that connect high-level theory with on-the-ground realities. The following chapter outlines this third phase of the research, giving deeper insights to identifying the green factors that could result in delays.

5. Semi-structured Interviews

To further examine the factors contributing to delays in sustainable water projects, a series of semi-structured interviews were conducted with professionals across multiple roles at Bilfinger Engineering and Consultancy. These included project managers, technical specialists, regulatory advisors, researchers, and innovation experts. The interviews followed a predefined question guide while allowing for elaboration and contextual insight, thereby balancing structure with flexibility (see Appendix B). Using thematic analysis (Clarke & Braun, 2017), key patterns were identified across the eight interviews, capturing both converging experiences and role-specific perspectives.

Similar to the procedure used for the exploratory interviews Microsoft excel was used for the thematic analysis. While qualitative analysis software such as NVivo or Atlas.ti can assist in managing large datasets, Excel was chosen for its accessibility and for allowing a hands-on analytical process. Bree and Gallagher (2016) indicates a detailed method of how thematic analysis can be conducted in excel (see Appendix B). This involved transcribing interview notes into Excel, organizing the data by individual comments or quotes in separate rows. Each comment was then coded with initial labels reflecting key ideas, using Excel's color-coding feature to visually group similar codes. The data was sorted and filtered by these color-coded themes to bring together related points, which were further refined through several rounds of review in separate worksheets. This iterative process helped consolidate and synthesize the data, ultimately generating key themes and sub-themes relevant to the study. Detailed thematic analysis is mentioned in Appendix B.

A prominent similarity among the interviews was the identification of regulatory complexity as a major barrier to timely execution. Participants consistently referred to challenges in aligning with dynamic and often region-specific environmental regulations, particularly those concerning nitrogen limits, PFAS treatment, and compliance with the European Water Framework Directive (KRW). These issues were cited not only as technical challenges but also as procedural bottlenecks that delay permitting and prolong decision-making. Similarly, technological uncertainty emerged as a core theme. The introduction of novel technologies such as algae-based treatment systems, zero-liquid discharge processes, and hydrogen-based infrastructure were frequently associated with extended piloting phases, unpredictable process behaviour, and the need for trial-and-error implementation. Interviewees emphasized that while these innovations are essential for achieving sustainability goals, they inherently increase project risk and timeline variability.

Financial and market-related concerns were also cited across multiple interviews. Sustainability-focused water initiatives often suffer from weak short-term return-on-investment visibility, making them less attractive to clients who prioritize economic certainty. This hesitation, as highlighted by both client- and contractor-side interviewees, delays project approvals and procurement. Another recurring theme was institutional inertia and stakeholder misalignment. Projects involving public-private collaboration or municipal clients were particularly susceptible to fragmented responsibilities, slow decision-making, and inadequate early-stage engagement. Several professionals pointed to outdated asset management practices and unclear ownership of sustainability objectives as key delay-inducing factors.

While these overarching themes were broadly shared, distinct perspectives emerged based on professional orientation. Contractors and innovation experts emphasized the technical risks tied to sustainable design, material sourcing, and modular scalability. For instance, the implementation of unfamiliar systems demanded multiple iterations and field adjustments, resulting in timeline extensions. In contrast, client-facing and regulatory roles emphasized internal coordination challenges and the difficulty of aligning institutional strategies with the operational requirements of sustainability. Some interviewees noted that industrial clients often lack sufficient water expertise, leading to misinformed expectations and insufficient planning buffers. Others cited difficulty in securing subsidies due to unclear policy interpretations or gaps in cross-departmental communication.

None of the participants explicitly distinguished between delays occurring before the Final Investment Decision (FID) and those arising after it. This absence of differentiation suggests that, from the perspective of the interviewees, the timing of the delay relative to the FID is not seen as a significant factor in understanding project delays. Consequently, for the purposes of this research, it is not considered meaningful to treat pre-FID and post-FID delays as separate analytical categories. This remains true despite the practical reality that delays occurring before and after the FID often lead to substantially different outcomes and implications due to the varied investment in time, materials and personnel as indicated by Bilfinger in Chapter 1.

Based on the semi-structured interviews several key sustainability-related factors were identified as contributors to delays in Green Water Projects. These factors emerge from the unique characteristics of sustainable water initiatives and distinguish green projects from traditional ones (see Table 4).

Factor	Challenge	Semi-structured Interview Insights
1. Regulatory Complexity	Changing compliance frameworks (Tightening standards and permit challenges)	EU Water Framework Directive compliance - about 60% water bodies non-compliance causing permit risks • Interview 5: Discussed how shifting legal definitions around PFAS impact engineering scope. • Interview 8: Noted difficulty in keeping up with evolving EU regulations. • Interview 7: Mentioned inconsistencies between permitting authorities. • Interview 6: Highlighted delays due to inter-jurisdictional review processes.
2. Technological Uncertainty	Piloting & testing new systems (Innovative technologies with limited track record)	Advanced oxidation for micro-pollutants, PFAS treatment, future-proof system designs • Interview 5: Described risks with scaling up water treatment innovations. • Interview 8: Talked about extended lead times for validating untested treatment methods. • Interview 6: Cited issues when integrating academic tech into industrial systems. • Interview 3: Noted how unproven digital monitoring tools delayed certification.
3. Water Resource Risk	Availability & permit constraints (Scarcity increases pollutant concentration)	Impact on emission limits and treatment efficacy • Interview 6: Raised challenges with obtaining extraction permits for pilot sites. • Interview 8: Emphasized tension between innovation and environmental licenses. • Interview 4: Discussed seasonal unpredictability affecting algae inputs.
4. Financial Barriers	High costs, unclear ROI (Higher costs for advanced treatment and infrastructure)	Cost doubling for oxidation steps; increased taxes impacting public support • Interview 5: Said sustainability adds “cost layers” without immediate return. • Interview 8: Cited high capital expenditure as a deterrent for stakeholders. • Interview 6: Noted misalignment between grant timelines and project delivery. • Interview 1: Interviewee expressed hesitation in investing in new green solutions without reliable ROI data.

Factor	Challenge	Semi-structured Interview Insights
5. Stakeholder Engagement	Lack of early awareness & coordination (Underestimation of water's critical role)	Delayed recognition of water risks in project business cases, esp. hydrogen projects • Interview 8: Discussed the gap between R&D and contractor communication. • Interview 7: Highlighted how late-stage buy-in leads to implementation resistance. • Interview 3: Observed that community expectations can shift project direction unexpectedly. • Interview 1: Indicated client-side misalignment on sustainability targets.
6. Institutional Capacity Gaps	Weak asset/admin systems (Insufficient organizational resources and administrative systems to manage sustainability requirements)	Weak asset and administrative systems delaying decision-making and regulatory compliance, causing slowdowns • Interview 7: Raised issue of undertrained facility operators for new technologies. • Interview 6: Pointed out lack of tools to track sustainability metrics. • Interview 3: Mentioned gaps in internal standards that delay adaptive management.
7. Lifecycle & Adaptability	Long project timelines facing change (Regulation changes during long project duration)	Need for adaptable designs; tension with long payback times • Interview 6: Cited difficulty in planning when tech and policy evolve mid-project. • Interview 8: Talked about adjusting for lifecycle thinking, especially in algae and hydrogen projects. • Interview 4: Shared experience of pivoting mid-project to meet new climate guidelines. • Interview 1: Mentioned technology quickly becoming outdated before implementation.

Table 4 Factors causing delays

1. Regulatory Complexity and Compliance Challenges

Interviewees consistently emphasized that evolving and increasingly stringent environmental regulations pose significant challenges for Green Water Projects. Notably, directives such as the European Union's Water Framework Directive require extensive documentation, continuous monitoring, and frequent adaptation throughout project execution. These regulatory complexities often lead to delays, especially when projects must respond to new or changing permit requirements related to pollutant discharge limits and emerging contaminants like PFAS.

For example, Interviewee 8 highlighted the difficulty in accurately identifying wastewater composition, stating, “often it’s very difficult to know what is exactly in your wastewater... you have to know what’s in the water and its impact.” Interviewee 7 described how water boards struggle to keep up with evolving standards such as the KRW (Water Framework Directive), which demands extensive internal alignment and the development of new compliance standards. Furthermore, Interview 6 highlighted instances where projects were halted due to nitrogen permit delays, leading to funding withdrawal and the need for re-application. Overall, these insights indicate that regulatory changes compel project teams to repeatedly revise compliance documentation, which significantly slows down project timelines and contributes to delays in Green Water Projects.

2. Technological Uncertainty and Innovation Risks

Green Water Projects frequently incorporate novel or experimental technologies, such as advanced oxidation processes, PFAS removal systems, and zero-liquid discharge technologies, which often lack fully proven operational histories. Interviewees emphasized that project teams and technology providers must develop systems capable of withstanding future regulatory tightening and managing unknown operational variables, thereby increasing overall project complexity and risk. Moreover, integrating these innovative technologies with existing infrastructure or creating tailor-made solutions further extends design and implementation timelines.

Interviewee 5 described piloting a chemical-free cooling treatment, noting client uncertainty regarding its performance. Interview 8 elaborated that treatment steps involving oxidation for micro-pollutants can double costs and require novel equipment, while also highlighting that processes like PFAS removal or zero-liquid discharge are relatively new and involve lengthy pilot and demonstration phases. These insights illustrate that the adoption of unproven technologies inherently introduces iterative trial-and-error cycles—including piloting, demonstration, and debugging—which contribute to prolonged project durations in sustainable water initiatives.

3. Water Availability and Quality Variability

Several interviewees highlighted how water scarcity and fluctuations in water quality significantly affect Green Water Projects by amplifying the complexity of emissions control and treatment processes. Declining water availability often results in increased pollutant concentrations, which complicates treatment efforts and raises operational costs. These environmental constraints necessitate adaptive project planning, including additional risk assessments and mitigation strategies, which can contribute to project delays.

Interviewee 8 emphasized the critical role of water availability, noting that "First cut off is industry… if water's not there they cannot run the company." Similarly, the interviewee from Interviewee 2 pointed out that water scarcity exacerbates emissions impacts and complicates the permitting process. These insights suggest that environmental factors such as drought conditions or restrictions on water withdrawal permits can interrupt or delay project progress, particularly during construction and operational phases. Thus, variability in water availability and quality represents a key challenge that can lead to significant delays in the implementation of sustainable water infrastructure projects.

4. Financial Constraints and Cost Uncertainties

The introduction of advanced treatment technologies, such as micro-pollutant oxidation processes, significantly increases operational expenses, often doubling treatment costs. These elevated costs impact project budgets and operational expenditures, leading to potential delays caused by funding challenges or the need for renegotiations with financial stakeholders. Additionally, tax increases introduced to fund advanced water treatment infrastructure because the money has to come from somewhere, may affect public acceptance and political support, which in turn can impact project timelines.

Financial and business-case challenges were highlighted by multiple interviewees. For example, Interviewee 1 discussed client resistance to leasing sustainable equipment compared to purchasing, where policy and budget hurdles led to project delays. Interviewee 5, emphasized that treatment upgrades could double costs, adversely impacting payback periods and causing postponements. Additionally, Interviewee 8 pointed out that payback periods of 2–3 years for traditional projects often conflict with the long-term nature of sustainability investments (5-10 years), complicating funding decisions. These insights collectively indicate that high capital and operational expenditures coupled with uncertain returns on investment contribute to slowed investment decisions and stalled early project phases in Green Water Projects.

5. Stakeholder Engagement and Awareness Gaps

The interviews highlighted a recurring issue where companies often underestimate the critical importance of water resource availability and quality, leading to delayed recognition of regulatory and operational challenges. For instance, projects such as hydrogen plants are heavily dependent on reliable water supply, yet decision-makers frequently overlook these water-related risks during early business case development. This oversight results in unforeseen project hold-ups and delays when water-related issues arise unexpectedly during project execution, such as delayed permit approvals or construction slowdowns.

This theme was strongly reflected in the interview data. Interviewee 8 noted, "Companies neglect water too much… they don't include that risk in early stage," pointing to the low prioritization of water risks in project planning. Similarly, Interviewee 7 emphasized that traditional mindsets and resistance to adopting program-based collaborative approaches impede early stakeholder alignment. These findings suggest that inadequate integration of water sustainability considerations and insufficient stakeholder engagement in the early phases of project planning contribute significantly to delays in Green Water Projects.

6. Institutional Capacity and Internal Processes

Several interviewees identified institutional capacity limitations and internal organizational processes as significant contributors to delays in Green Water Projects. Insufficient asset management and poor coordination within project organizations were highlighted as key barriers. Interviewee 7 noted that water boards often lack comprehensive and accurate asset data, which hampers project preparation and leads to delays. Additionally, Interview 6 emphasized that the complexity of subsidy frameworks, coupled with strict compliance requirements, further exacerbates administrative bottlenecks.

These internal challenges create fragmented decision-making and impede timely procurement and execution. Consequently, inadequate institutional capacity and cumbersome internal processes undermine effective project planning and coordination, resulting in postponed project milestones and extended timelines. Addressing these organizational weaknesses is therefore critical to improving the efficiency and success of sustainable water infrastructure initiatives.

7. Dynamic and Lengthy Project Life Cycles

Green Water Projects generally have extended lifespans compared to rapidly evolving industries such as IT. This prolonged duration necessitates that projects remain flexible and adaptable to changing regulatory frameworks throughout their lifecycle, which can lead to delays caused by redesigns, retrofitting, or reassessments. Interviewees underscored the importance of creating robust, future-proof designs capable of withstanding evolving standards and requirements to ensure long-term project viability.

This challenge was emphasized in Interview 6 where the interviewee stated that projects “must be designed to endure evolving regulations—make sure they are robust for the future.” Likewise, Interviewee 8 highlighted that permits and regulatory outcomes often change during project execution, which can disrupt ongoing construction activities. Additionally, the long payback periods typical of water infrastructure projects ranging from five to ten years creates tension between the need for upfront investments and achieving long-term sustainability goals, especially since water projects often face lower pricing pressures due to the generally low cost of water. These factors collectively illustrate how the dynamic nature and extended timelines of Green Water Projects increase their susceptibility to delays driven by regulatory shifts and environmental uncertainties.

Similarities in the Semi-structured Interviews:

Across the eight interviews conducted, several consistent themes emerged that reveal common challenges in executing green water projects. Most notably, regulatory complexity was universally acknowledged as a major source of delay. Interviewees 6, 7 and 8 highlighted how evolving environmental regulations and permitting procedures—particularly concerning discharge limits, nitrogen, PFAS, and Water Framework Directive (KRW) compliance often outpace the speed of project development. Another commonality was the technological uncertainty tied to the experimental nature of many green water innovations. Interviewee 5 and 8 emphasized how implementing novel, often untested technologies demands extended piloting phases and introduces risk that delays execution. Additionally, almost all participants noted the issue of financial and business-case challenges, with Interviewees 2, 5 and 8 pointing out that sustainability investments frequently suffer from weak short-term returns, causing hesitations from clients and funders. Lastly, several interviewees mentioned stakeholder misalignment and organizational inertia especially Interviewees 8 and 9 citing insufficient early engagement and slow institutional change as barriers to timely project initiation.

Differences in the Semi-structured Interviews:

Despite the shared insights, there were notable differences shaped by each interviewee's professional role and focus area. For instance, contractors and innovation experts like Interviewees 5 and 8 emphasized technical delays due to material selection, process performance uncertainty, and the iterative nature of piloting new systems. In contrast, clients and regulatory-facing roles such as Interviewees 6 and 7 highlighted delays stemming from internal coordination, policy misalignment, and difficulties navigating complex subsidy frameworks. Another point of divergence lies in perceived ownership of delays. While some like Interviewee 2 and 8 suggested that industrial clients underestimate water-related risks and thus under-prepare, others such as Interviewee 7 observed that even public institutions struggle with capacity, citing outdated asset management systems. Moreover, views on mitigation also varied. Interviewee 5 and 6 leaned toward structural changes in procurement and leasing models, while Interviewee 2 and 7 emphasized long-term, adaptive planning and data-driven asset management. These differences underscore how the nature and framing of delays can shift depending on whether one is designing, managing, approving, or regulating a green water project.

Drawing on the insights obtained from the semi-structured interviews, we can now address the third sub-question, which aims to identify the key factors that may contribute to delays in green water projects.

SQ3 What differentiating green factors could result in delays in Green Water Projects?

Delays in Green Water Projects are primarily driven by four interrelated factors that distinguish them from conventional water infrastructure: **regulatory uncertainty**, **technological novelty**, **financial feasibility challenges**, and **institutional capacity gaps**. These projects often operate under evolving environmental regulations, such as those targeting micro-pollutants or PFAS, which require iterative permitting and compliance updates. The use of unproven or pilot-stage technologies extends design and validation timelines, while higher capital and operational costs complicate business cases and funding flows particularly in a sector with typically low water pricing and long payback periods. Additionally, fragmented institutional responsibilities and limited internal capacity hinder cross-sector alignment and project coordination. While seven thematic delays were identified overall, these four domains were selected for their systemic and recurring influence across cases, making them the most critical for understanding the unique delay patterns in sustainability-oriented water infrastructure.

Understanding the differentiating factors that cause delays in Green Water Projects highlights the need for strategic responses tailored to their unique sustainability-oriented challenges. While the interplay of regulatory, technological, financial, and institutional barriers introduces additional '*Green Complexity*' compared to conventional projects, it also opens up opportunities for proactive solutions. As such, the following chapter shifts focus from diagnosis to mitigation concept exploring how project stakeholders can navigate these challenges more effectively. Drawing from interview and literature insights, sub-question 4 examines concrete strategies that help reduce delays, foster resilience in project planning, and accelerate the implementation of sustainable water infrastructure.

6. Concept Solutions to Mitigate Delays

Green Water Projects are crucial in realizing environmental sustainability goals in the water sector. However, their implementation is often hindered by complex challenges spanning regulatory, technological, financial, and institutional domains. This chapter proposes solutions addressing each of these domains through systemic planning, stakeholder integration, and adaptive governance. Drawing from both empirical data and relevant theoretical perspectives, the following sections outline targeted strategies to overcome delay-inducing obstacles in each area (see Table 5).

Challenge	Proposed Solution	Key Methods/Tools
Regulatory Uncertainty	Align early with stakeholders & evolving policy frameworks	- Front-End Loading (FEL) - Transition Management Framework
Technological Novelty	Bridge innovation gaps through testing & feedback-rich adaptation	- Innovation Chasm Strategy - Adaptive Management
Financial Feasibility	Reduce risk perception via transparency & alignment with long-term sustainability goals	- Risk Scoring Matrix - Process Thinking & Outcome-Based Financing
Institutional Capacity	Build resilience & adaptability through culture, leadership, and systemic governance	- Organizational Learning - Bow Tie Risk Model - Multilevel Transition Management

Table 5 Proposed solutions

Based on the interviews conducted, it is evident that the four key factors—**regulatory uncertainty**, **technological novelty**, **financial feasibility challenges**, and **institutional capacity and resilience** issues do not occur in isolation but rather interact simultaneously and systemically throughout the lifecycle of Green Water Projects. Interviewees consistently highlighted that delays rarely stem from a single cause; instead, they arise from the compound effect of overlapping challenges. For instance, one project manager in the interviews explained how unclear regulatory standards (regulatory uncertainty) complicated the adoption of an innovative water treatment technology (technological novelty), which in turn made it difficult to secure financing (financial feasibility). Simultaneously, the lack of institutional readiness and technical expertise (institutional capacity) further slowed implementation. This dynamic reflects the interconnected tensions described in the Iron Triangle (Atkinson, 1999) in Chapter 1, where scope, time, and cost trade-offs often compound one another. This confirms that these factors form an interconnected web rather than a linear sequence, reinforcing the need for integrated planning strategies that address these challenges holistically and in parallel.

6.1 Addressing Regulatory Uncertainty

Front-End Loading and Early Stakeholder Integration

Regulatory uncertainty emerged as a dominant cause of delays in Green Water Projects, largely due to the lack of alignment between innovative project proposals and existing legal frameworks. A critical mitigation strategy is front-end loading (FEL) as suggested by Bakke & Johansen (2025), which involves engaging clients, regulatory bodies and other key stakeholders in the earliest phases of project development. Through workshops, design reviews, and collaborative scenario planning, stakeholders can co-develop a shared understanding of potential roadblocks and develop anticipatory responses.

A risk-scoring framework can be applied at this stage, wherein all regulatory assumptions such as discharge limits or licensing timelines are scored based on their likelihood and impact. This transparent assessment allows the team to plan for contingencies and avoid mid-project redesigns due to unanticipated regulatory shifts.

Transition Management Framework

To place individual regulatory challenges within a broader governance context, the transition management model offers a structured lens (Van Der Brugge & Van Raak, 2007). Regulatory actors operate predominantly at the tactical level, translating strategic sustainability visions into enforceable standards and incentive structures. By understanding this role, project leaders can better align proposals with near-term regulatory trends while still contributing to long-term transition goals.

The transition management levels are:

- Strategic: Global and national sustainability goals
- Tactical: Regulatory and policy development
- Operational: Project implementation and compliance

Management Spheres

Sphere	Focus	Problem Scope	Time Scale
Strategic	Culture	Societal System	Long-term (30 years)
Tactical	Structures	Regime	Mid-term (5-15 years)
Operational	Practices	Project	Short-term (0-5 years)

Table 6 Management spheres (Loorbach & Van Raak, 2006)

A well-coordinated dialogue across these levels enables regulatory agility while preserving environmental integrity.

6.2 Navigating Technological Novelty

Bridging the Innovation Chasm

The rapid development of sustainable water technologies often outpaces the readiness of adopters and institutions to integrate them. As described by Moore's concept of the "chasm", there exists a gap between early technological innovation and mainstream market adoption. Many utilities and water service companies, already operating within optimized and regulated frameworks, find it difficult to adopt unfamiliar, high-risk technologies even when these offer long-term sustainability benefits.

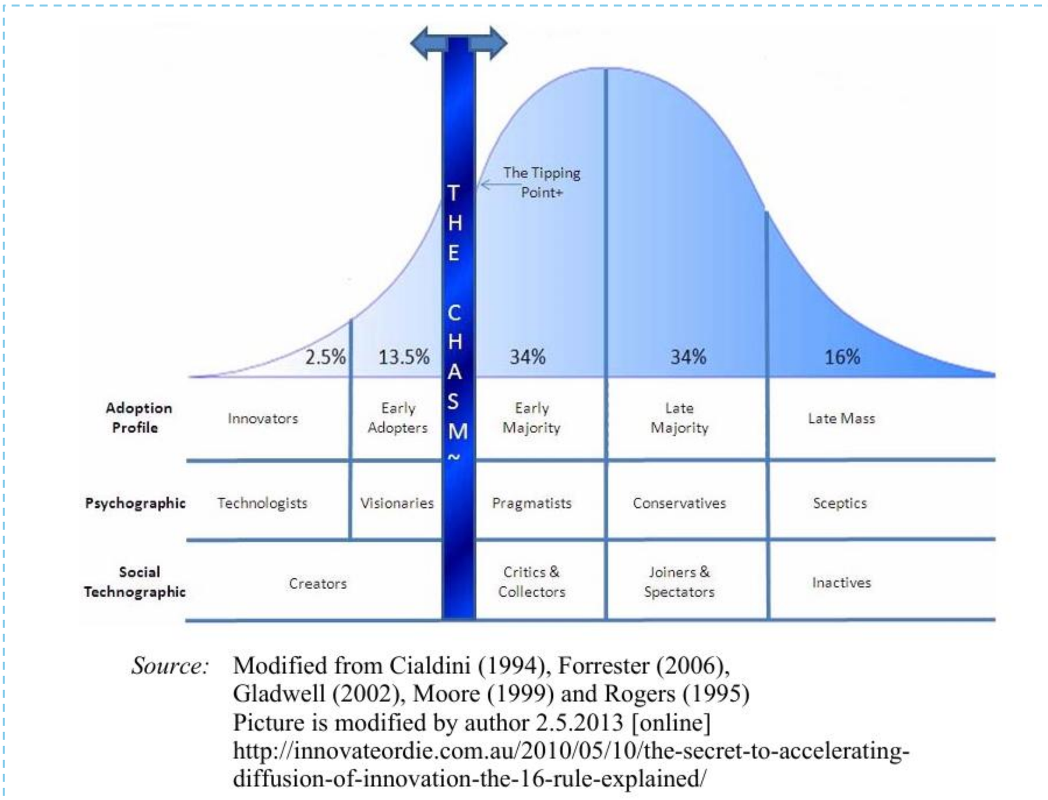


Figure 8 Innovation chasm (Marinaro and Liu, 2015)

The work of Matinaro and Liu (2015) reinforces that the barrier is not simply technical, but also organizational and cultural. Leadership competencies, communication, and openness to change are essential for bridging this adoption gap. For successful implementation, Green Water Projects must embed organizational learning practices, promote pilot testing, and use demonstration projects to validate new technologies in real-world contexts.

Adaptive Management for Socio-Technical Complexity

Given the interdependencies between water technology, infrastructure, and societal needs, projects must shift from a predict-and-control paradigm to a prepare-and-commit approach. This is the core of adaptive management (Koppenjan et al., 2010), a strategy that allows for flexible responses to emerging data and stakeholder feedback. Especially with novel technologies, where unforeseen issues can arise during scale-up, an iterative, feedback-rich management process ensures sustained progress despite initial uncertainty.

6.3 Overcoming Financial Feasibility Challenges

Internalizing Uncertainty Through Risk-Scoring and Stakeholder Co-Evaluation

One of the primary reasons financial institutions hesitate to fund Green Water Projects is the high level of perceived risk, especially when novel technologies or unclear regulations are involved. To address this, project developers can adopt a structured risk evaluation system during the planning phase, co-created with financiers, technology vendors, and regulators. Each assumption such as expected capital cost or technology maturity is evaluated using a quantitative risk matrix, assigning scores for likelihood and consequence.

This process improves financial decision-making and allows investors to better understand where public guarantees, flexible contracts, or phased investments might reduce exposure. Moreover, group-based assumption analysis enhances transparency, fostering mutual trust and increasing the likelihood of cross-sector collaboration.

Process Thinking and the Dual Role of Projects

Sustainable water infrastructure should not be treated as isolated investments but as parts of a broader transition process (Van Der Brugge & Van Raak, 2007). Understanding projects as both financial ventures and components of systemic change opens up new funding pathways, including impact investing, green bonds, and outcome-based financing. It also underscores the importance of aligning financial planning with long-term transition goals and operational resilience.

6.4 Enhancing Institutional Capacity and Resilience

Organizational Change and Capacity Building

Institutional inertia remains one of the most challenging aspects of sustainability-oriented innovation. Many Green Water Projects face delays not because of external constraints but due to limited internal capacity to manage complexity and innovation. As noted by Matinaro and Liu (2015), organizational culture, leadership, and communication flow are critical enablers of innovation diffusion.

Institutions should adopt continuous learning mechanisms such as communities of practice, cross-functional task forces, and innovation sandboxes to normalize experimentation and reduce fear of failure. Empowering staff at all levels to engage with sustainability objectives not only improves capacity but also builds internal legitimacy for innovation.

Adaptive and Transition-Oriented Governance

The dual requirement for transition management (system-wide strategic alignment) by Van Der Brugge & Van Raak (2007) and adaptive management (operational flexibility) by Koppenjan et al., (2010) suggests that institutional change must happen at multiple levels. For example, transitioning to a new PFAS treatment technology may necessitate concurrent shifts in:

- Operational procedures (new maintenance regimes),
- Regulatory practices (updated effluent limits),
- Financial structures (flexible procurement contracts).

Because these domains are interdependent, transition in one system evokes transition in another. A robust institutional response must therefore incorporate cross-sector coordination, feedback loops, and multilevel governance.

Risk Management via the Bow Tie Method

To operationalize this resilience, the Bow Tie Risk Assessment model (De Ruijter & Guldenmund, 2016) (see Figure 9) can be used by institutions to visualize and manage threats that could trigger cascading failures. By mapping central risk events and their causes and consequences, organizations are better prepared to install both preventive barriers (e.g., regulatory engagement protocols) and mitigating controls (e.g., contingency funds, modular design features). When institutional capacity is structured to recognize and respond to systemic risk, projects gain a higher level of implementation certainty.

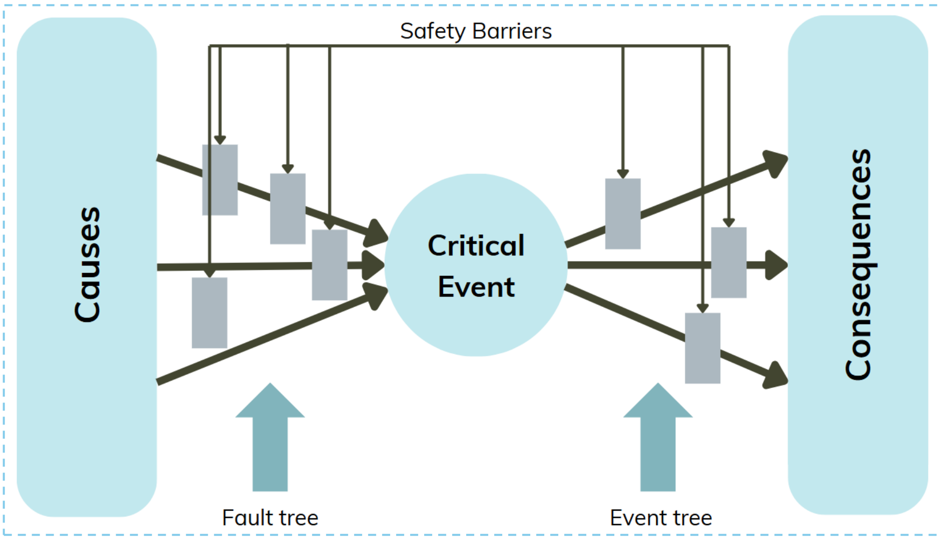


Figure 9 Bow Tie Risk Assessment Method (De Ruijter & Guldenmund, 2016)

6.5 Interconnection of the Proposed Solutions

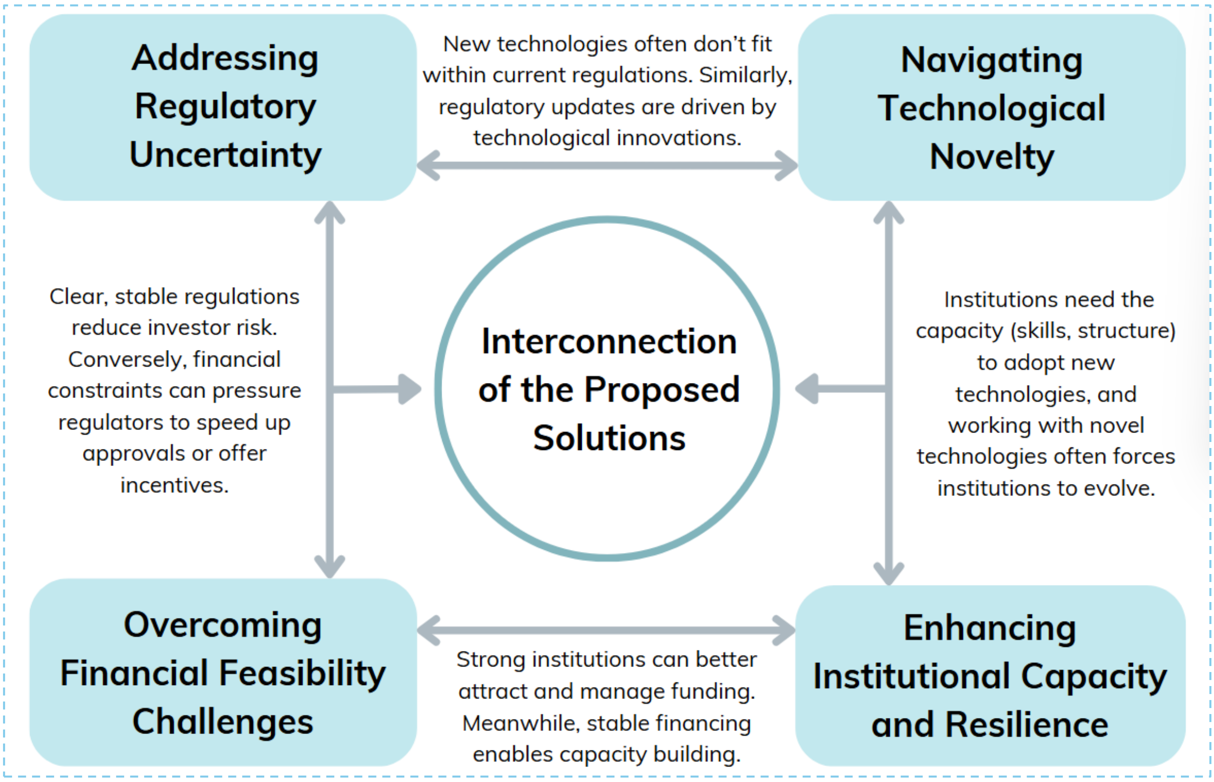


Figure 10 Interconnections of Proposed Solutions

The proposed concept solutions to address regulatory uncertainty, technological novelty, financial feasibility, and institutional capacity are deeply interconnected and must be managed as part of a cohesive system rather than as isolated interventions (see Figure 10). Each solution influences the others, sometimes positively reinforcing progress, and at other times creating unintended tensions or delays if not aligned properly.

For example, early stakeholder engagement through Front-End Loading (Bakke & Johansen, 2025) enhances regulatory clarity, which in turn reduces perceived financial risk and builds institutional readiness. However, if regulatory engagement occurs without input from technical experts or financial stakeholders, it may lead to overly rigid frameworks that stifle technological innovation or complicate investment planning. Similarly, adopting adaptive management to handle novel technologies can increase institutional flexibility, but without sufficient capacity-building, staff may resist iterative processes or lack the skills to execute them effectively.

These interdependencies highlight the need for integrated coordination mechanisms. A transition-oriented perspective, as supported by the *Roadmap for Accelerating Sustainability Transitions*, calls for deliberate alignment across strategic, tactical, and operational levels. Misalignment such as piloting a novel technology without concurrent regulatory flexibility or institutional readiness can result in incomplete implementation and decrease stakeholder confidence.

To avoid such misalignments, project teams should institutionalize cross-sectoral planning forums and shared risk-scoring frameworks, enabling joint assumption testing and scenario development. These tools not only synchronize expectations but also promote mutual understanding across domains. The best outcomes emerge when solutions reinforce each other across the four pillars: **adaptive governance** ensures regulatory and institutional responsiveness; **innovation bridging** smooths the path from pilot to scale; **risk-aware financing** underpins long-term viability; and **capacity building** ensures institutions can learn, adapt, and lead transformative change.

Ultimately, a systems-thinking approach, embedded within governance processes, is essential to coordinate these solutions dynamically. This ensures that as sustainability transitions accelerate, the enabling structures evolve thus, maintaining momentum while minimizing friction.

7. Concept Roadmap for Accelerating Green Projects

Building upon the systemic challenges and strategic responses discussed above, this section aims to consolidate those findings into a forward-looking, policy and practice-oriented roadmap. The purpose of this roadmap (see Figure 12) is to support a coordinated acceleration of sustainability transitions within the water sector, specifically in relation to Green Water Projects. The roadmap is designed to provide structure for actors across different scales from international policymakers to on-the-ground project implementers and is framed across four core pillars: **governance**, **innovation adoption**, **financing**, and **institutional capacity**. Each pillar outlines actionable directions across strategic, tactical, and operational levels as per the requirement of Bilfinger Engineering and Consultancy. The goal is to move from fragmented, reactionary responses to a more aligned, anticipatory, and adaptive mode of transition management (Van Der Brugge & Van Raak, 2007) (see Figure 11).

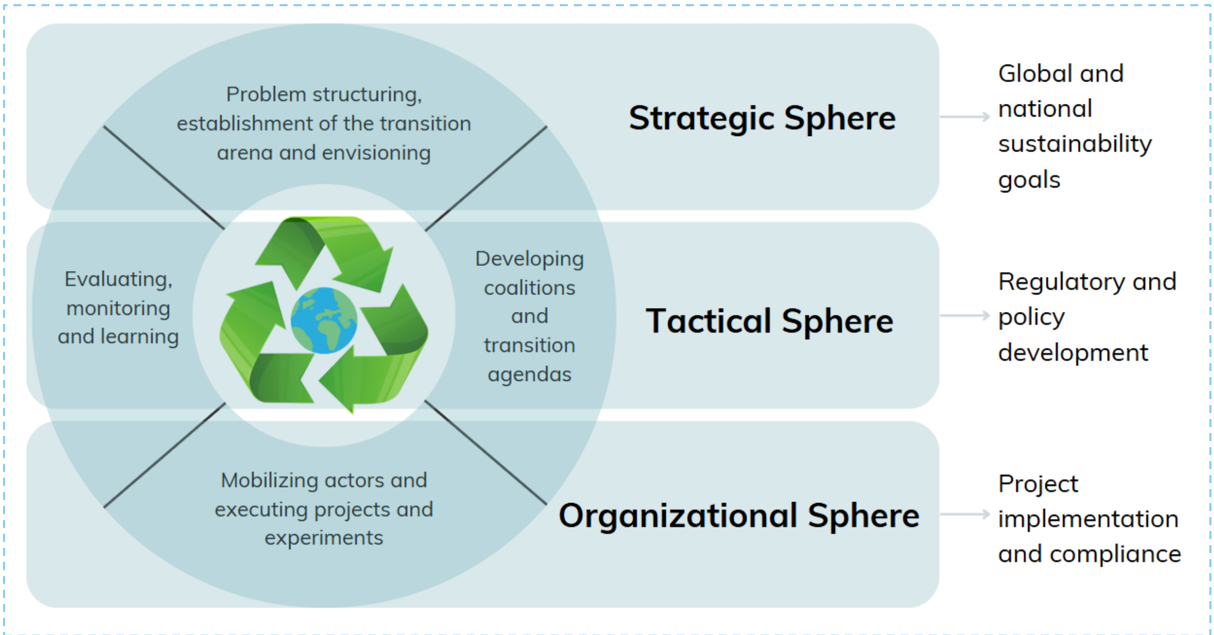


Figure 11 Transition Management Spheres (Van Der Brugge & Van Raak, 2007)

	Pillar I Adaptive & Coherent Governance	Pillar II Bridging the Innovation Chasm	Pillar III Sustainable & Risk-Aware Financing	Pillar IV Institutional Capacity & Learning
Strategic	• Embed long-term, flexible goals in national/supranational policies; ensure adaptability to change.	• Invest in awareness-focused national/regional programs; mandate innovation; shift to performance-based compliance.	• Reframe value assessment; expand access to green/climate-aligned finance; reward aligned risk-taking.	• Embed learning in policy mandates; mandate evaluations; develop professionals in systems thinking and transitions.
Tactical	• Create integrated planning frameworks with early stakeholder involvement; use regulatory sandboxes.	• Institutionalize demonstration projects with feedback mechanisms; build cross-disciplinary collaboration platforms.	• Use assumption mapping for shared risk responsibility; evaluate likelihood/impact collaboratively.	• Foster inter-org and cross-sector knowledge-sharing networks; use task forces and transfer programs to reduce duplication.
Organizational	• Apply front-end loading; engage stakeholders early; use common risk evaluation frameworks.	• Establish innovation units/task forces; use modular design for scalability and flexibility.	• Use adaptive financing tied to milestones; apply bow-tie risk analysis for proactive/reactive control mapping.	• Shift to prepare-and-commit management; use adaptive practices to handle interdependent system changes.

Figure 12 Roadmap for Accelerating Green Projects

7.1 Pillar I: Adaptive and Coherent Governance

The first and most foundational pillar focuses on improving governance mechanisms to reduce uncertainty and foster a shared trajectory across different actors. As highlighted earlier, the current fragmentation of regulatory processes and lack of early coordination between stakeholders often result in substantial delays.

An adaptive (Koppenjan et al., 2010) and coherent governance structure must begin with strategic-level vision setting. This includes embedding long-term, flexible sustainability goals within national and supranational water policies. These goals must be designed with enough adaptability to withstand technological evolution and regulatory reconfigurations, particularly in response to pressing socio-technical uncertainties.

At the tactical level, this vision translates into integrated planning frameworks that bring together environmental regulators, technology developers, and local authorities early in the project lifecycle. Tools from transition management theory (Van Der Brugge & Van Raak, 2007) can be especially valuable here, framing governance as a layered process involving strategic, tactical, and operational alignment. Regulatory sandboxes controlled environments for testing innovative solutions can allow for temporary relaxation or adaptation of existing standards without compromising safety or compliance.

On the operational level, the concept of front-end loading (Bakke & Johansen, 2025) becomes essential. Rather than engaging stakeholders only once a project design is finalized, regulators, community representatives, and technology vendors should be included in the early planning phase. This allows for shared understanding of constraints and assumptions. Additionally, the use of a common risk evaluation framework, such as a scoring system that maps project assumptions and their potential impacts, provides a systematic way to anticipate regulatory roadblocks before they escalate.

7.2 Pillar II: Bridging the Innovation Chasm

The second pillar focuses on addressing a critical gap in the sustainability transition process: the “chasm” between innovative solutions and their large-scale adoption. As discussed through the lens of Matinaro and Liu (2015) and Moore’s chasm metaphor, many promising technologies remain trapped in pilot phases, unable to cross over into mainstream infrastructure deployment. This gap is especially pronounced in Green Water Projects, where experimental methods like PFAS removal or zero-liquid discharge challenge traditional procurement models and regulatory frameworks.

At the strategic level, bridging this chasm requires deliberate investment in national or regional programs that focus on awareness and not just development. Public-private partnerships must be oriented not only toward creating technologies but enabling their adoption at scale. This can be supported through innovation mandates, preferential procurement policies, and the establishment of performance-based, rather than prescriptive, compliance metrics.

At the tactical level, demonstration projects should be institutionalized as formal instruments for learning and evaluation. These projects should include feedback mechanisms and transparency requirements that allow other actors to benefit from the trial-and-error of early adopters. In parallel, collaboration between disciplines particularly engineering, policy, and implementation fields must be facilitated through structured forums and knowledge-sharing platforms.

At the operational level, utility companies and project developers need support in internalizing innovation. This might include the creation of dedicated innovation units or cross-functional task forces capable of handling both the technical and organizational dimensions of new technologies. Additionally, embedding modular design principles allows for flexibility and scalability, accommodating innovation without requiring full system overhauls.

7.3 Pillar III: Sustainable and Risk-Aware Financing

The third pillar addresses the financial dimension of transition delays. Green Water Projects, by nature, involve higher up-front costs and uncertain long-term benefits. This creates friction between project developers and financiers, especially when funding frameworks prioritize short-term return over long-term sustainability. Moreover, rigid financial planning models are not suited for projects where uncertainty is not a bug but a feature embedded within socio-technical systems.

At the strategical level, governments and funding institutions must reframe how they assess value in water infrastructure. This includes expanding access to green bonds and climate-aligned finance, while tying capital allocation to long-term performance and adaptability rather than static technical specifications. It also means introducing policy that reward risk-taking when it is well-managed and aligned with sustainability goals.

At the tactical level, risk management must become a shared responsibility. This is where the assumption mapping and scoring frameworks introduced earlier can be particularly useful. In a collaborative setting, stakeholders jointly identify the key assumptions embedded in project design such as expected regulatory shifts, cost trajectories, or technology advancement and evaluate their likelihood and impact. This group process enables a shared understanding of where risks lie and who holds responsibility for them.

On an operational level, projects can benefit from adaptive financing models, where funding is released in segments on reaching pre-agreed milestones. The bow-tie risk analysis method (De Ruijter & Guldenmund, 2016) is also a valuable tool here, helping project teams visually map the causes and consequences of potential disruptions, as well as identify proactive and reactive controls. This not only makes financing more resilient but also makes it easier to align technical milestones with stakeholder expectations.

7.4 Pillar IV: Institutional Capacity and Learning

Finally, even the most coherent policies and well-financed projects will fall short without institutional cultures that support learning, flexibility, and innovation. Sustainability transitions require not just technological upgrades, but also adaptive management practices (Koppenjan et al., 2010) capable of navigating the interdependencies between water, energy, materials, and community trust.

At the strategic level, institutional learning must be embedded within national policy mandates. This can include requirements for regular post-project evaluations, as well as professional development programs focused on systems thinking, scenario planning, and sustainability transitions. The cyclical nature of transition management from strategic foresight to tactical alignment and operational execution must become an institutional norm, rather than an exception.

At the tactical level, knowledge-sharing networks must be fostered between organizations and across sectors. These might take the form of professional communities, temporary transfer programs, or interdepartmental task forces. The goal is to reduce duplication of effort and ensure that lessons from both successful and failed projects are disseminated and utilized.

At the operational level, the management culture of water projects must shift from predict-and-control to prepare-and-commit. This involves acknowledging that sustainable infrastructure operates within complex systems, where changes in one domain (e.g., energy regulation) ripple into others (e.g., water treatment choices). This interdependency makes adaptive project management essential, requiring dynamic resourcing, continuous feedback, and responsive governance structures.

This roadmap provides a multi-level approach to overcoming the challenges associated with sustainability implementation in the water sector as per the requirement of Bilfinger Engineering and Consultancy. It addresses regulatory complexity, innovation spreading, financial barriers, and institutional inertia through four interlinked pillars. Each pillar highlights actions across strategic, tactical, and operational levels as indicated in Table 6 (Chapter 6), reflecting the layered and dynamic nature of real-world implementation. Together, these pillars offer a coherent, adaptive, and future-oriented strategy one that moves beyond fragmented innovation to systemic transformation. With this information, we can now address sub-question 4, which explores how delays in green water projects can be mitigated.

SQ4 How can these delays be mitigated?

Delays in the implementation of sustainable water projects can be mitigated through a set of interrelated, practical strategies. These solutions must recognize the complex, socio-technical nature of sustainability transitions and adopt a layered approach that operates across governance levels strategic, tactical, and operational. Drawing on the frameworks and insights developed in previous chapters, the mitigation of delays centres around four integrated strategies: strengthening early stakeholder engagement, bridging the innovation adoption gap, embedding adaptive project management, and aligning institutional incentives with long-term sustainability goals.

1. Internalize Stakeholders Early Through Front-End Loading and Risk-Based Planning

Delays often stem from misaligned expectations, late-stage objections, or unforeseen stakeholder concerns. These can be substantially reduced by applying front-end loading methodologies that bring external stakeholders such as clients, regulators, local communities, and environmental agencies into the project during the conceptual and planning stages. Early inclusion ensures mutual understanding of objectives, limitations, and regulatory expectations, thereby reducing the likelihood of downstream disruptions.

Practically, this includes conducting joint assumption-mapping workshops, where stakeholders collectively identify project assumptions and assess their implications using a risk-scoring system. This proactive risk planning enables the team to foresee potential obstacles and assign mitigation strategies or fallback options before execution begins. Such engagement also builds trust, increases transparency, and ensures shared ownership of outcomes.

2. Bridge the Innovation Chasm Through Structured Pathways

One of the core challenges is the chasm between emerging sustainability innovations and their mainstream adoption. To mitigate delays caused by resistance or uncertainty toward novel approaches, governments and funding bodies must proactively design structured awareness programs that incentivize experimentation while reducing adoption risks. This includes formalizing the use of pilot projects with built-in evaluation cycles, and creating clear regulatory pathways for integrating non-standard technologies.

At a strategic level, governments can foster innovation ecosystems by establishing performance-based procurement systems and innovation quotas in public tenders. At the tactical level, partnerships between regulators, and research institutions can accelerate validation and certification processes. At the operational level, project developers can adopt modular design principles that allow for incremental integration of new technologies without jeopardizing the overall project timeline.

3. Practice Adaptive and Transition-Aware Project Management

Traditional project management, based on linear planning and rigid execution, is not suited for the dynamic and interconnected nature of sustainable infrastructure. To counter this, project teams must shift toward adaptive project management models that emphasize learning, feedback, and flexibility. This is particularly vital in socio-technical systems, where changes in one part of the system (e.g., regulation or energy availability) ripple through other domains.

Embedding transition management frameworks helps structure decision-making across strategic (vision-setting), tactical (goal alignment), and operational (execution) levels. Tools such as bow-tie risk analysis enable visual identification of potential threats and safeguards, fostering both proactive prevention and reactive contingency planning. Furthermore, transitioning from a predict-and-control to a prepare-and-commit mindset empowers teams to respond to change rather than resist it, improving both speed and resilience.

4. Align Institutional Structures with Long-Term Sustainability Objectives

Institutional barriers such as independent responsibilities, rigid financing structures, and fragmented regulations often slow down the realization of sustainability projects. These delays can be mitigated by aligning institutional mandates and performance metrics with broader sustainability goals. This includes revising evaluation criteria used by financing institutions to include long-term environmental and social value, rather than short-term financial return alone.

At the strategic level, governments can introduce adaptive policy frameworks that allow temporary regulatory exceptions or accelerated permitting for projects with high sustainability potential. At the tactical level, interdepartmental task forces can help accelerate coordination of cross-sectoral efforts. At the operational level, building internal capacity through training, scenario planning, and simulation exercises prepares institutions to handle evolving sustainability demands with greater agility.

8. EXPERT FEEDBACK

This study employed a modified Delphi method (Okoli & Pawlowski, 2004) to validate the proposed concept solutions and gather expert insights. Initially, the research findings and proposed mitigation strategies were presented to a panel of four experts from Bilfinger Engineering and Consultancy, who had not been involved in the thesis prior to this session. Experts independently rated each solution for its relevance and effectiveness across three levels—strategic, tactical, and operational using a structured questionnaire (see Appendix C) on a scale from 1 to 10. This quantitative assessment was followed by a workshop-style group discussion (see agenda in Appendix C), where the solutions were reviewed in detail and experts provided qualitative feedback, suggestions, and clarifications.

While this approach did not involve multiple anonymous iterative rounds characteristic of the Delphi method, it combined individual expert judgment with collaborative discussion, enabling a practical and efficient validation of the findings.

During the workshop, experts discussed each recommendation across the four pillars of the study—Adaptive and Coherent Governance, Bridging the Innovation Chasm, Sustainable and Risk-Aware Financing, and Institutional Capacity and Learning at the three transition spheres. The aggregated rating scores and key problems and solutions for each pillar and level are presented in the following table (see Table 7).

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Level	Governance	Innovation Adoption	Financing	Institutional Capacity
Strategic	Problem: Inflexible regulations hinder sustainable progress. Solution: Embed long-term, adaptable goals in regulation frameworks. **Rating: 4.5**	Problem: The innovation gap delays scaling of sustainable solutions. Solution: Invest in awareness programs, mandate innovation, and shift to performance based compliance or incentive (eg. subsidies). **Rating: 6.25**	Problem: Sustainable projects face misaligned risk-reward structures. Solution: Reframe value, expand green finance, reward aligned risk-taking. **Rating: 7**	Problem: Institutions lack transition and systems thinking. Solution: Mandate governmental policy learning, evaluations, and develop systems-thinking professionals. **Rating: 5.25**
Tactical	Problem: Fragmented planning limits effectiveness. Solution: Use integrated frameworks, early stakeholder involvement, and regulatory sandboxes. **Rating: 7**	Problem: Innovation lacks feedback and collaboration between different parties. Solution: Institutionalize demonstration projects; create cross-disciplinary company platforms. **Rating: 8**	Problem: Risk responsibilities are unclear. Solution: Use assumption mapping and shared risk evaluation and ownership. **Rating: 7.5**	Problem: Redundant or disconnected institutional efforts. Solution: Create cross-sector networks, task forces, and knowledge-sharing programs. **Rating: 7.75**
Operational	Problem: Delayed input (eg. permits) and rigid plans block adaptability. Solution: Apply front-end loading, early stakeholder engagement, common risk assessment frameworks. **Rating: 6.75**	Problem: Rigid, projects fail to scale flexibly. Solution: Create innovation units; use modular, adaptable design to bridge the innovation gap. **Rating: 8.5**	Problem: Inflexible, reactive funding undermines resilience. Solution: Use adaptive milestone-based financing; apply bow-tie risk analysis. **Rating: 7.25**	Problem: Teams struggle with dynamic system changes. Solution: Adopt prepare-and commit management; use adaptive practices for complex problems. **Rating: 7**

Table 7 Expert Ratings on Proposed Solutions Across Levels and Pillars

Governance

At the strategic level, embedding long-term and adaptable regulatory goals received a relatively low rating of (4.5), reflecting concerns about the rigidity of current regulatory frameworks and doubt about the feasibility of flexible regulation in practice. However, at tactical (7) and operational (6.75) levels, integrated planning frameworks and front-end loading approaches were viewed more favourably, suggesting that experts see practical value in early stakeholder involvement and risk assessment mechanisms.

Innovation Adoption

Solutions addressing the innovation gap scored progressively higher, with the operational level receiving the highest rating (8.5) for modular design and innovation units, reflecting confidence in these practical, scalable strategies. Tactical level strategies like demonstration projects and collaboration platforms were also well received (8). However, strategic investments in awareness programs and mandates scored moderately (6.25), indicating some uncertainty regarding high-level policy-driven innovation incentives.

Financing

The financial feasibility solutions consistently scored above average, with the highest rating (7.5) at the tactical level for shared risk evaluation and assumption mapping. Adaptive milestone-based financing and bow-tie risk analysis at the operational level (7.25) also received positive feedback. The strategic recommendation to reframe value assessment and expand green finance was rated moderately (7), highlighting the experts concern around large-scale systemic change.

Institutional Capacity

Institutional capacity solutions received moderate ratings across all levels, ranging from (5.25) at the strategic level to (7.75) at the tactical level. Experts acknowledged the need for cross-sector knowledge sharing and adaptive governance but expressed concerns about organizational inertia and the practical challenges of implementing systemic cultural change due to competitive environment. The operational focus on prepare-and-commit management practices scored a solid (7), indicating support for adaptive management techniques.

8.1 Expert Comments and Insights

Need for Practical Examples

Experts consistently expressed unfamiliarity with some of the conceptual frameworks and requested examples demonstrating the application of these strategies in sustainable projects. This highlights a limitation of the current research and identifies a clear direction for future studies involving empirical validation.

Project Decomposition and Capacity

One expert emphasized the importance of decomposing projects into functional modules, each with its own "proof of concept" assessment. This approach can help address issues where insecurity or lack of clarity leads to delayed governmental decisions often causing a sudden, simultaneous rollout of multiple projects, which in turn creates realization of capacity bottlenecks.

Knowledge Sharing Programs and Competitive Barriers

One expert proposed that knowledge sharing is a critical solution to disconnect in institutional efforts in sustainable infrastructure. However, they emphasized that in practice, companies are often unwilling to share insights due to competitive pressures. This contradiction reveals a major barrier and emphasizes the need for strategies that incentivize collaboration without compromising commercial advantage.

Focus on Impact

Questions were raised by one expert about the specific impact of delays on environmental goals and how mitigation strategies directly address these outcomes.

Clarity and Terminology

There was a common suggestion for clearer explanations of key concepts and terminology. However, this feedback may partially reflect the limited time everyone had to fully read and discuss the thesis due to their demanding schedules.

Across the expert panel, there was an appreciation for the structured approach of proposing solutions at the strategic, tactical, and operational levels. While there was general alignment in support of the solutions, the scores and comments revealed differences in perception. Three experts consistently gave higher scores at the operational and tactical levels, particularly valuing practical tools like modular project design, adaptive frameworks, and innovation platforms, possibly indicating doubts about high-level feasibility to change. All experts recognized the merit in distinguishing solutions by level, and the average scores suggest the strongest consensus around tactical-level interventions.

Overall, while individual views varied, the collective input affirmed the direction of the proposed framework confirming the relevance of the proposed solutions and offered valuable insights for refinement. Future research should focus on empirical testing of the roadmap in live projects and developing practical implementation guides to support sustainable water infrastructure development.

9. Discussion

This chapter synthesizes insights from the exploratory interviews, literature review, and semi-structured interviews to address the research objectives and highlight how the empirical data bridges gaps identified in existing knowledge. It further introduces the Iron Triangle with Sustainability as a conceptual framework to understand the unique complexities of Green Water Projects and their implications for cost and time.

9.1 Bridging Gaps Between Literature and Empirical Findings

The literature review provided a foundational understanding of traditional causes of delays in infrastructure projects, particularly emphasizing the Iron Triangle constraints of cost, time, and quality. However, existing literature was found to inadequately capture the distinctive challenges faced by sustainable water projects, notably those related to evolving environmental regulations, technological innovation, and institutional capacity. While prior studies acknowledged regulatory and financial factors, they largely overlooked the dynamic and complex nature of sustainability-specific issues such as PFAS treatment, micro-pollutant control, and zero-liquid discharge technologies.

Exploratory interviews with practitioners at Bilfinger revealed practical insights into how these factors contribute in project environments. For instance, the interviews highlighted that traditional frameworks do not sufficiently address the iterative trial-and-error cycles inherent to novel technology adoption or the multi-layered stakeholder misalignments stemming from public-private collaborations. This practical perspective surfaced critical elements such as the underestimation of water risks in early project phases and the limited organizational capacity to manage evolving compliance demands.

The semi-structured interviews further deepened understanding by identifying seven thematic delay factors specific to sustainable water initiatives, grouped broadly into regulatory complexity, technological uncertainty, financial constraints, stakeholder engagement gaps, institutional capacity limitations, and project lifecycle dynamics. These themes expose a “Green Complexity” that surpasses challenges typically described in conventional infrastructure literature. Notably, interview data emphasized that delays are not confined to discrete project stages but extend throughout the lifecycle due to shifting regulations and long-term operational uncertainties. Interestingly, no significant difference was found between delays occurring before and after the Final Investment Decision (FID), even though it was initially expected given that the consequences and financial implications of delays in these phases vary significantly.

Thus, the empirical findings fill significant gaps left by prior research by explicitly characterizing the sustainability-oriented barriers that extend project timelines and complicate cost management. The combined insights confirm that sustainable water projects demand tailored analytical frameworks and management strategies beyond traditional project delay models.

9.2 Integrating Sustainability into the Iron Triangle

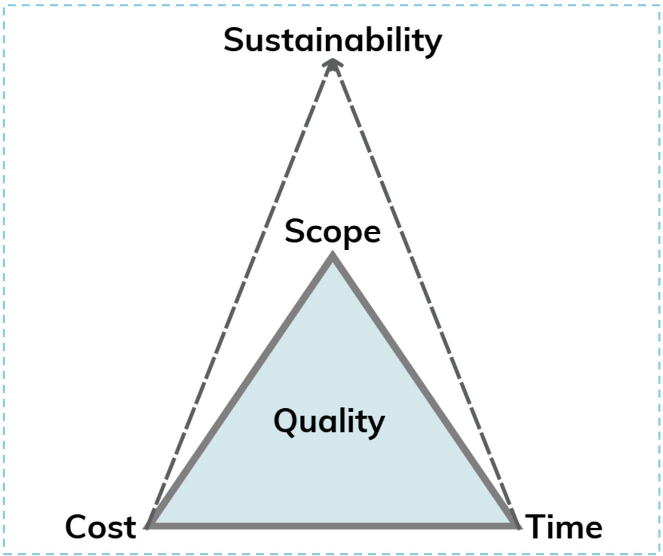

Figure 13 Iron Triangle with Sustainability

The Iron Triangle of project management traditionally comprising cost, time, and quality serves as a foundational model for assessing project performance. However, the findings from both literature and interviews demonstrate that this model is insufficient to capture the additional dimension of sustainability, especially for Green Water Projects.

Including sustainability as a fourth dimension is critical because it introduces new complexities and trade-offs not adequately addressed by cost, time, and quality alone. Regulatory compliance with environmental standards such as the European Water Framework Directive requires continuous adaptation, which affects project scope and scheduling. Innovative treatment technologies, while essential for sustainability, inherently carry higher risks and uncertainty, impacting timelines and budget predictability. Furthermore, sustainability goals often extend project lifespans and require adaptive designs to accommodate future regulatory changes, thus complicating traditional project constraints.

This expanded Iron Triangle with Sustainability reflects the inherent tension between achieving ecological and social objectives and managing conventional project parameters. It helps explain why Green Water Projects experience unique delay patterns as inclusion of sustainability demands more robust planning, iterative validation, and institutional collaboration, all of which can increase both cost and duration.

9.3 Cost and Time Implications on Sustainability Complexity

The semi-structured interviews consistently revealed that the integration of sustainability elements directly influences cost and time dimensions. Novel treatment processes such as PFAS removal, algae-based systems, and zero-liquid discharge often require extended piloting and demonstration phases, resulting in trial-and-error cycles that prolong project delivery. These technologies tend to double operational and capital costs compared to traditional systems, exacerbating financial constraints and slowing investment decisions.

Moreover, regulatory uncertainty and frequent changes necessitate ongoing compliance efforts and permit renegotiations, which further delay project milestones. Institutional capacity deficits and stakeholder misalignment contribute additional procedural bottlenecks, reinforcing timeline extensions.

The combination of these factors means that introducing sustainability into water infrastructure projects generally increases complexity, which, in turn, inflates both project costs and durations. These increases challenge traditional project planning paradigms that prioritize short-term economic returns and predictable schedules.

10. CONCLUSION

We often overlook the complexity arising due to sustainability, which in turn hinders project success. This research helps us understand this complexity and provides us with planning strategies to overcome such complexities. These strategies may also apply to other types of project complexities however, they have been specifically designed to address those emerging from sustainability factors. Experts validated the relevance of these multi-level solutions, particularly appreciating practical tools and adaptive planning at tactical and operational levels, which highlights the importance of the proposed roadmap.

The roadmap developed in this report provides a multi-level approach to overcoming challenges associated with sustainability implementation in the water sector, as per the requirement of Bilfinger Engineering and Consultancy. It addresses regulatory complexity, innovation spreading, financial barriers, and institutional inertia through four interlinked pillars each highlighting actions across strategic, tactical, and operational levels. This layered and dynamic structure reflects the real-world implementation environment and supports a coherent, adaptive, and future-oriented strategy moving beyond fragmented innovation to systemic transformation. Experts noted the importance of decomposing projects into modular components with "proof of concept" assessments to better manage delays and capacity constraints caused by simultaneous project rollouts following late governmental decisions.

Delays in the implementation of sustainable water projects can be mitigated through four integrated and interrelated strategies: strengthening early stakeholder engagement, bridging the innovation adoption gap, embedding adaptive project management, and aligning institutional incentives with long-term sustainability goals. These strategies recognize the socio-technical nature of sustainability implementation and emphasize the importance of early stakeholder inclusion, structured innovation pathways, adaptive and transition-aware project management, and institutional alignment with sustainability objectives.

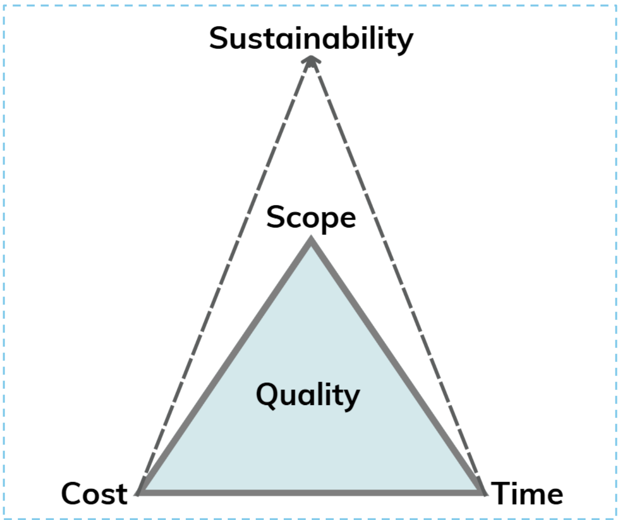

Figure 13 with Sustainability

Ultimately, the Iron Triangle of project management, mentioned in the introduction of this thesis can be redesigned to include the element of sustainability alongside cost, time, quality, and scope (see Figure 13). While this research has been conducted for green water projects, the planning strategies are designed in such a way that they can be applied to the broader spectrum of green projects in general.

To bring the findings of this research into focus, it is essential to reflect on the core objective that guided this study. The diagram on the following page presents the central insight that emerged from the analysis and directly addresses the main research question.

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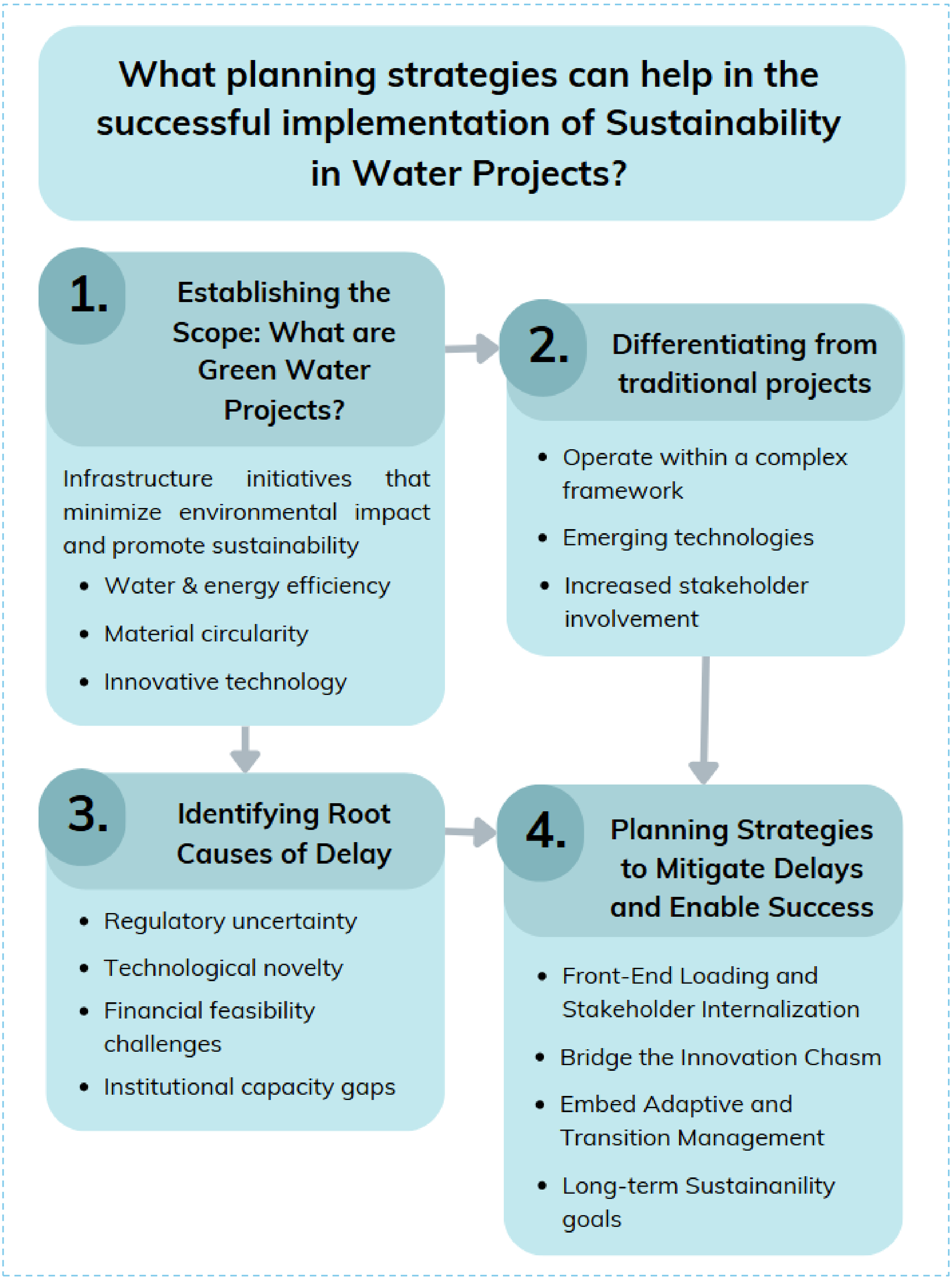

Figure 14 Research Overview

MQ

What planning strategies can help in the successful implementation of Sustainability in Water Projects?

The successful implementation of sustainability in water projects requires integrated, forward-thinking planning strategies that account for both the technical and systemic complexities unique to these initiatives. Synthesizing the findings from all four sub-questions, this research identifies a set of planning strategies that respond to the scope, differentiating characteristics, barriers, and practical solutions associated with Green Water Projects.

1. Establishing the Scope: Understanding Green Water Projects

Green Water Projects are infrastructure initiatives designed to minimize environmental impact and promote sustainability through practices such as energy efficiency, water reuse, material circularity, and the adoption of emerging technologies (e.g., PFAS removal, zero-liquid discharge systems, and biodegradable components). These projects are inherently aligned with broader environmental goals and require innovation beyond the conventional water management. Their scope is therefore characterized not only by technical specifications but also by regulatory, ecological, and social imperatives.

2. Differentiating from Traditional Projects

Unlike traditional water infrastructure projects, Green Water Projects operate within a more complex framework. They face evolving regulatory landscapes, rely on emerging or unstandardized technologies, and require broader stakeholder involvement due to their sustainability-driven nature. These factors lead to increased technical, institutional, and financial uncertainty. Consequently, traditional linear and rigid planning models are insufficient. Green Water Projects demand more adaptive, cross-disciplinary, and participatory approaches to planning, design, and execution.

3. Identifying Root Causes of Delay

Through thematic analysis of interviews and literature, four primary domains were identified as contributing to delays in Green Water Projects: regulatory uncertainty, technological novelty, financial feasibility, and institutional misalignment. While seven themes emerged overall, these four categories were chosen due to their consistent and interconnected influence across project stages. Regulatory bottlenecks delay permitting and approval; untested technologies require extended validation periods; long payback times challenge funding mechanisms; and segregated governance hinder coordinated action. These sustainability-specific barriers intensify the complexity of project delivery, distinguishing Green Water Projects from conventional models.

4. Planning Strategies to Mitigate Delays and Enable Success

To address these delays and support the successful implementation of Green Water Projects, a set of interrelated planning strategies are proposed:

- Front-End Loading and Stakeholder Internalization: Engage stakeholders including regulators, communities, and suppliers at the earliest stages. Using structured tools like assumption mapping and risk scoring, potential conflicts and uncertainties can be identified early, thereby reducing resistance and redesigns.
- Bridge the Innovation Chasm: Apply targeted strategies to facilitate the transition of sustainable technologies from niche to mainstream. This includes pilot projects, performance-based procurement, and innovation-enabling regulatory pathways that reduce adoption risk and accelerate learning.
- Embed Adaptive and Transition Management: Integrate cyclical and multi-level transition management frameworks into project planning. Adopt adaptive project management principles such as "prepare and commit" rather than "predict and control," allowing for resilience in the face of evolving technical or policy conditions.
- Align Institutions Through Governance Synchronization: Reconfigure planning frameworks to better reflect the socio-technical nature of Green Water Projects. This involves strategic-level policy flexibility, tactical coordination between agencies, and operational capacity-building for project teams. The use of tools like bow-tie risk analysis and modular project design further enhances adaptability and efficiency.

In conclusion, planning for sustainable water projects must move beyond conventional models to embrace complexity, uncertainty, and innovation. The successful implementation of sustainability in water infrastructure requires planning strategies that are systems-oriented, risk-aware, and stakeholder-inclusive. By operationalizing these strategies across strategic, tactical, and operational levels, the water sector can overcome implementation barriers and accelerate the transition toward more resilient, equitable, and environmentally sound infrastructure systems.

The planning strategies, solutions, and roadmap developed in this study while grounded to the context of Green Water Projects offer valuable insights applicable to a wider spectrum of sustainability initiatives. The systemic challenges identified, such as regulatory uncertainty, technological novelty, financial feasibility, and institutional misalignment, are not exclusive to the water sector. Other sustainability projects across sectors, particularly those involving emerging technologies and interdependent infrastructures, often encounter similar barriers that require adaptive, participatory, and risk-aware planning approaches.

By emphasizing early stakeholder engagement, flexible governance structures, innovation enablement, and institutional learning, the findings of this study provide a transferable framework for navigating complex socio-technical transitions. The integration of tools like front-end loading, assumption mapping, transition management frameworks, and modular design principles can support diverse projects in managing uncertainty and aligning multi-actor efforts. As such, the insights gained from the Green Water Project context serve as a channel for broader sustainability transitions, making this research relevant and instructive for advancing resilient and future-ready infrastructure systems beyond the water sector.

11. Limitations and Recommendations for Further Research

While this research offers a structured and multi-level roadmap for addressing sustainability-related challenges in green water projects, certain limitations must be acknowledged. Firstly, the study remains conceptual in nature even though it has been validated by experts, drawing on existing frameworks, theoretical models, and strategic planning tools without empirical validation through case studies or pilot project implementation. Experts highlighted the importance of real-world application and emphasized that actual project environments may reveal variations and challenges not fully captured by the conceptual framework. As a result, while the planning strategies are designed to be practical and adaptable, their effectiveness in real-world settings remains to be tested.

Secondly, the research has been developed with a specific focus on water sector projects under the guidance of Bilfinger Engineering and Consultancy. Although care has been taken to generalize the strategies to broader green project contexts, sector-specific variables and regional governance dynamics may influence the applicability and outcomes of these recommendations.

Thirdly, stakeholder perspectives particularly those of local communities, regulatory authorities, and project financiers have been incorporated through a literature-based lens rather than direct engagement. This limits the depth of insight into the socio-political factors that may either facilitate or obstruct the implementation of sustainability-driven planning strategies.

Fourthly, a limitation identified through expert feedback concerns the tension between the need for knowledge sharing to bridge institutional gaps and the competitive pressures that inhibit open collaboration among organizations. This contradiction was not deeply explored in the current research but represents a significant barrier to effective implementation of sustainable infrastructure projects. Future studies should investigate mechanisms to incentivize inter-organizational learning without compromising commercial advantages.

Given these limitations, several directions for future research are recommended. Empirical studies involving real-time application of the proposed roadmap across different types of sustainable infrastructure projects would provide valuable validation and refinement of the strategies. Comparative research across sectors (e.g., energy, transportation, waste management) could further reveal how contextual factors shape implementation outcomes. Additionally, more research into institutional dynamics and stakeholder behaviour including resistance to innovation and mechanisms of trust-building would deepen our understanding of the socio-technical complexities highlighted in this thesis.

Finally, integrating simulation-based modelling or decision-support tools in BIM could strengthen the operational utility of the proposed strategies, enabling project managers and policymakers to visualize trade-offs and outcomes before implementation. These extensions would not only validate the current framework but also support its evolution into a robust planning tool for navigating sustainability implementation in complex projects.

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Appendix A

Exploratory Interview 1

Position: Research Manager
Company type/product: PFAS sensor (Water purity sensor for water purification projects)

- Sustainability results in delays.
- Policies vary from region to region resulting in further complexity.
- Sustainability comes with a cost and subsidy is not given every time.
- Innovation comes with a cost as the technology to be used is relatively new and expertise is low.
- Lack of knowledge about sustainability.
- Lack of knowledge about the consumers and their demands. Consumers are change averse.
- The issue about delays can be solved if government can help support the companies to fasten the process currently.

Exploratory Interview 2

Position: Manager of Product Development
Company type/product: Water treatment and Cooling chemicals

- Sustainability does cause extra delays.
- An example of sustainability project is Closed Circuit and CCHW (Closed Cooling Hot Water)
- Absence of clear regulatory frameworks.
- Lack of data to have the required outcomes.
- Products are often projected as green but are not entirely green.
- Measures taken to increase the sustainability of their projects are reduced water wastage by 90% and, using biodegradable and bio produced.
- The issue about delays can be solved if the data and important information about solving issues about sustainability can be shared openly.
- Regulations and the approval process about sustainability are too complex, making them clearer can help speed up the process.
- Subsidies can help reducing the impact on cost thus helping the company to focus on schedule and delays.

Exploratory Interview 3

Position: Sales and Engineering Manager
Company type/product: Water Treatment

- Yes, sustainability does result in delays.
- Examples of sustainability water projects are waste water treatment, brine water treatment and drinking water treatment.

- Sustainability projects usually do not go as expected due to lack of knowledge and experience.
- Complying to all the rules is difficult as there are too many rules and restrictions.
- The delays can be avoided if the rules are being read carefully.

Exploratory Interview 4

Position: Product Manager – Water Treatment

Company type/product: Water Treatment

- Sustainability causes extra delays currently as it is still a new concept.
- Delays are only temporary and in the coming years after a bit more awareness and knowledge this delay will not be prominent.
- Due to bureaucracy the complexity of sustainability is more difficult to process for the companies.
- Example of sustainability product for water treatment are the use of FerSol where no harmful product is used instead Ferrateb(VI) is used which dissolves in iron and is safe to use. Hot wash is reduced to make the process more energy efficient and sustainable. This results in less chemical and energy usage.
- Challenges faced in Netherlands are that only drinking water (pure water) is available and permissible which increases costs as compared to process water. Companies have to work only with either drinking water which is expensive or waste water which is impure.
- Examples are Polymer recycling and Cleaning Diary industry pipes.

Exploratory Interview 5

Position: Director

Company type/product: Water Purification

- Improving the sustainability by creating a product that reduces the use of plastic bottles.
- The product is sturdy and long lasting resulting is lesser replacement.
- Green water projects often have higher initial costs and financing challenges. This results in higher costs of the products and public perception and stakeholder engagement becomes difficult.
- Projects usually face delays due to technical challenges in integrating sustainable solutions and public opposition or lack of awareness
- Delays can be avoided by improving project planning and risk assessment methods.

Exploratory Interview 6

Position: Manager

Company type/product: Flow drivers for pump

- No, sustainability does not cause delays as products have to meet certain criteria and requirements related to sustainability goals and if these are met then the government approvals are easier and faster to get.
- The flow driver is a sustainable product as it adapts to the flow of water and avoids causing any energy wastage. It has a long life and the maintenance required is low. Flow drivers control the speed so that the extra energy is not wasted thus saving energy.
- This was an already existing product which was later made sustainable by making the speed of the drivers flexible. Therefore it did not face much challenges with respect to sustainability.

Exploratory Interview 7

Position: Project Manager

Company type/product: Mechanical components for Water cleaning Plant

- Yes, sustainability does cause delays.
- More planning is required because of sustainability
- The company supplies mechanical components that automates the system making the system more efficient than manual control as the key at every point is now adaptive.
- They ask all the pump suppliers the efficiency of each pump and put it in a code. Some pumps do not have valves. This also needs to be coded for better efficiency. The company then designs a circuit for optimum flow of the water and high efficiency of the water cleaning plant.
- Additionally the company supports sustainability by reusing their material and their electric equipment which often results in a lot of delays.
- Reusing materials takes a lot of time as the materials should be dismantled and then transported to the new project venue.

Exploratory Interview 8

Position: Construction Engineer

Company type/product: Mechanical components for Water cleaning Plant

- Sustainability causes delays.
- The circularity process is longer and time consuming.
- Materials and expertise available are less. Machines are not enough.
- There is a big gap between knowledge of sustainability and construction process.
- Highly innovative, every sustainability project is innovative and creates extra complexity.
- More trial and error and there is not defined fixed correct result.
- More money, initial investment is extremely high. Traditional projects are cheaper and more reliable.

- Difficult to implement new measured (for example geo concrete) as it is not reliable and clients and government do not approve. Government only approves reliable projects and are risk averse.
- Communication and knowledge sharing is currently not adequate enough for smooth progression of the projects.
- Clients willingness to take risk is very low but they want sustainability resulting in added challenges.
- Sustainable materials are not always safe for use creating more complexity. For example not all concrete are accepted for drinking water.
- Equipments are new and innovative and expertise to use these equipment is very low.
- There are hardly any traditional projects now a days. The world is shifting towards sustainable construction but we still follow the steps of traditional projects and not sustainable projects.
- Traditional projects are easier, cheaper and more predictable.

Exploratory Interview 9

Position: Engineer

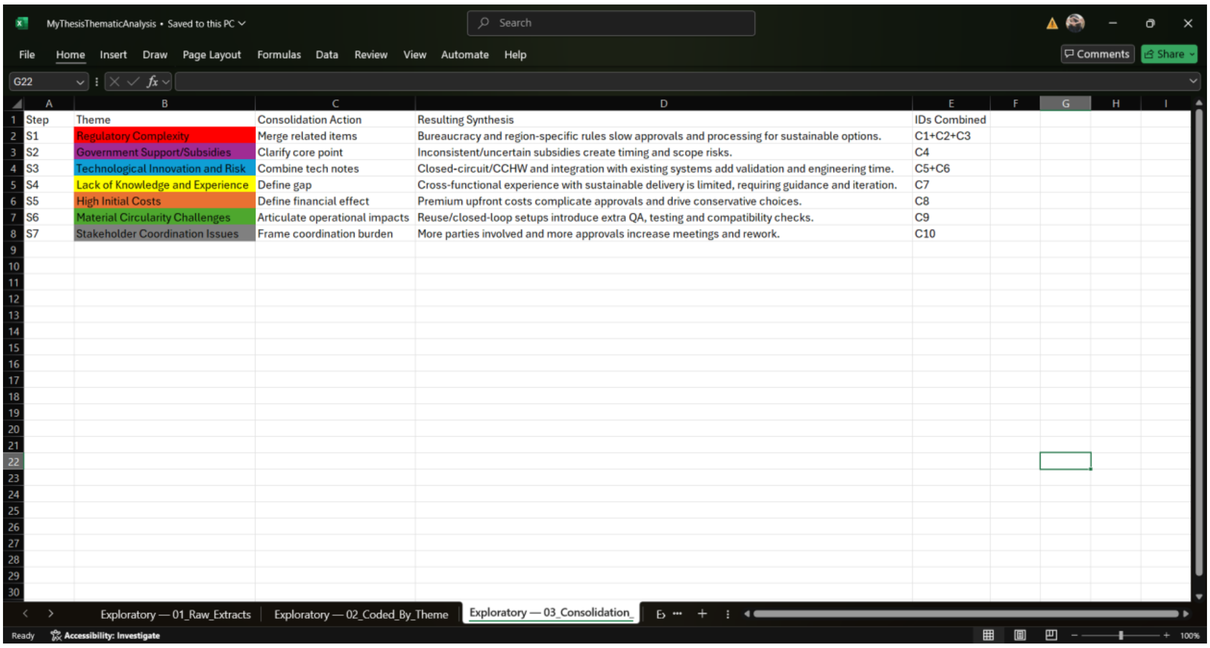
Company type/product: Water treatment

- No, sustainability does not cause delays.
- The company contributes to sustainability by doing water treatment and helping in water reuse. It supplies several equipments that help in the water filtration process.
- The products are delivered on time.
- Delays if caused due to sustainability are probably in the construction process and not in the product delivery.

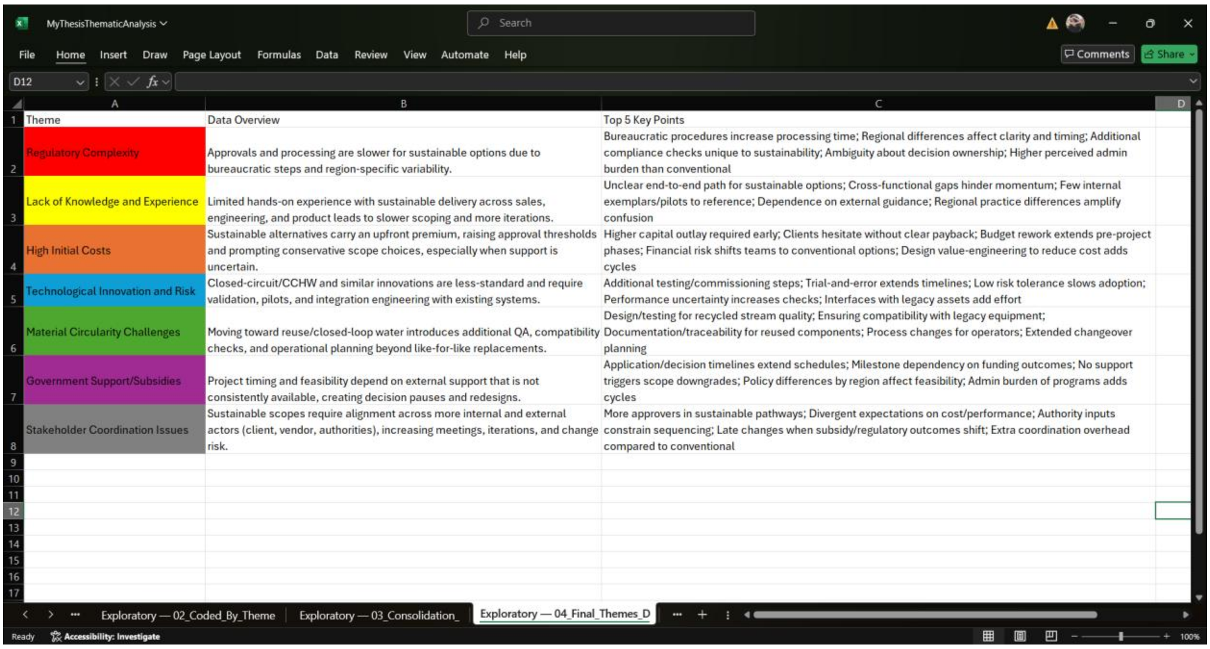
Thematic analysis of Exploratory interviews in Excel:

ID	ParticipantTag	SourceNote	PreliminaryTheme
R1	E1	Sustainability does result in delays.	Regulatory Complexity
R2	E2	It depends on the region.	Regulatory Complexity
R3	E3	Sustainability comes with a cost and subsidy is not given every single time.	Government Support/Subsidies
R4	E4	Examples of sustainability projects include Closed Circuit and CCHW (Closed Cooling Hot Water).	Technological Innovation and Risk
R5	E5	Due to bureaucracy the complexity of sustainability is more difficult to process for the companies.	Regulatory Complexity
R6	E6	Company works in water treatment context (integration with existing systems implied).	Technological Innovation and Risk
R7	E7	Teams need guidance to navigate sustainable pathways across sales/engineering/product.	Lack of Knowledge and Experience
R8	E8	Higher upfront spend expected for sustainable options versus conventional.	High Initial Costs
R9	E9	Reconfiguration for reuse/closed-loop water adds testing and quality checks.	Material Circularity Challenges
R10	E1	Multiple internal and external parties must align on sustainable scopes.	Stakeholder Coordination Issues

ID	Theme	Code/Short Label	Evidence Extract	ParticipantTag
C1	Regulatory Complexity	Bureaucratic processing delays	Due to bureaucracy the complexity of sustainability is more difficult to process for the companies.	E5
C2	Regulatory Complexity	Regional variability	It depends on the region.	E2
C3	Regulatory Complexity	Sustainability pathways slower	Sustainability does result in delays.	E1
C4	Government Support/Subsidies	Subsidies inconsistent	Subsidy is not given every single time.	E3
C5	Technological Innovation and Risk	Non-standard setups (Closed Circuit/CCHW)	Examples include Closed Circuit and CCHW.	E4
C6	Technological Innovation and Risk	Integration effort with existing assets	Water treatment context implies extra integration effort.	E6
C7	Lack of Knowledge and Experience	Cross-functional know-how gaps	Teams need guidance to navigate sustainable pathways across sales/engineering/product.	E7
C8	High Initial Costs	Upfront cost premium	Higher upfront spend expected for sustainable options versus conventional.	E8
C9	Material Circularity Challenges	Closed-loop/circular QA burden	Reconfiguration for reuse/closed-loop water adds testing and quality checks.	E9
C10	Stakeholder Coordination Issues	Multi-actor alignment	Multiple internal and external parties must align on sustainable scopes.	E1



Step	Theme	Consolidation Action	Resulting Synthesis	IDs Combined
S1	Regulatory Complexity	Merge related items	Bureaucracy and region-specific rules slow approvals and processing for sustainable options.	C1+C2+C3
S2	Government Support/Subsidies	Clarify core point	Inconsistent/uncertain subsidies create timing and scope risks.	C4
S3	Technological Innovation and Risk	Combine tech notes	Closed-circuit/CCHW and integration with existing systems add validation and engineering time.	C5+C6
S4	Lack of Knowledge and Experience	Define gap	Cross-functional experience with sustainable delivery is limited, requiring guidance and iteration.	C7
S5	High Initial Costs	Define financial effect	Premium upfront costs complicate approvals and drive conservative choices.	C8
S6	Material Circularity Challenges	Articulate operational impacts	Reuse/closed-loop setups introduce extra QA, testing and compatibility checks.	C9
S7	Stakeholder Coordination Issues	Frame coordination burden	More parties involved and more approvals increase meetings and rework.	C10



Theme	Data Overview	Top 5 Key Points
Regulatory Complexity	Approvals and processing are slower for sustainable options due to bureaucratic steps and region-specific variability.	Bureaucratic procedures increase processing time; Regional differences affect clarity and timing; Additional compliance checks unique to sustainability; Ambiguity about decision ownership; Higher perceived admin burden than conventional
Lack of Knowledge and Experience	Limited hands-on experience with sustainable delivery across sales, engineering, and product leads to slower scoping and more iterations.	Unclear end-to-end path for sustainable options; Cross-functional gaps hinder momentum; Few internal exemplars/pilots to reference; Dependence on external guidance; Regional practice differences amplify confusion
High Initial Costs	Sustainable alternatives carry an upfront premium, raising approval thresholds and prompting conservative scope choices, especially when support is uncertain.	Higher capital outlay required early; Clients hesitate without clear payback; Budget rework extends pre-project phases; Financial risk shifts teams to conventional options; Design value-engineering to reduce cost adds cycles
Technological Innovation and Risk	Closed-circuit/CCHW and similar innovations are less-standard and require validation, pilots, and integration engineering with existing systems.	Additional testing/commissioning steps; Trial-and-error extends timelines; Low risk tolerance slows adoption; Performance uncertainty increases checks; Interfaces with legacy assets add effort
Material Circularity Challenges	Moving toward reuse/closed-loop water introduces additional QA, compatibility checks, and operational planning beyond like-for-like replacements.	Design/testing for recycled stream quality; Ensuring compatibility with legacy equipment; Documentation/traceability for reused components; Process changes for operators; Extended changeover planning
Government Support/Subsidies	Project timing and feasibility depend on external support that is not consistently available, creating decision pauses and redesigns.	Application/decision timelines extend schedules; Milestone dependency on funding outcomes; No support triggers scope downgrades; Policy differences by region affect feasibility; Admin burden of programs adds cycles
Stakeholder Coordination Issues	Sustainable scopes require alignment across more internal and external actors (client, vendor, authorities), increasing meetings, iterations, and change risk.	More approvers in sustainable pathways; Divergent expectations on cost/performance; Authority inputs constrain sequencing; Late changes when subsidy/regulatory outcomes shift; Extra coordination overhead compared to conventional

Appendix B

Questions for the industry professionals:-

Q1: What type of water projects are you involved with?

Q2: Are there sustainable drivers in those projects? Which ones?

Q3: Do your projects run on schedule from start to finish?

Q4: What are the aspects connected to those delays, before and after FID?

Q5: Do you have any personal experience with this aspect?

Q6: What went well and what could improve?

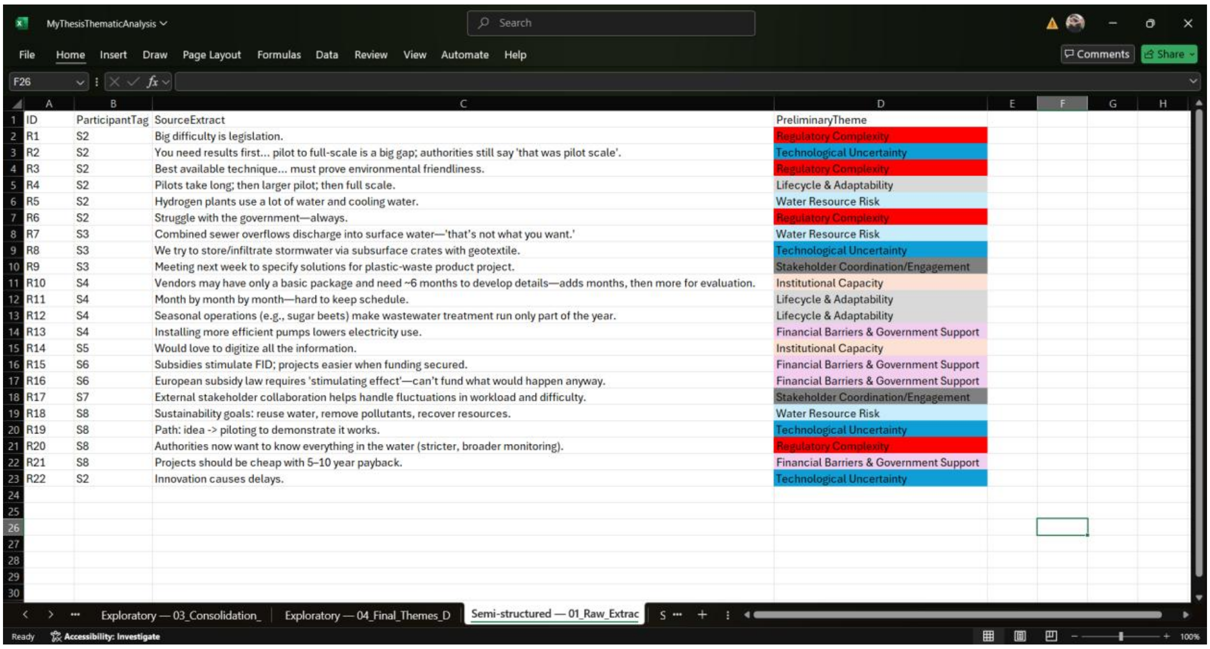
Q7: What was the cause of the issue? Are there more?

Q7: Do you have a generic advice?

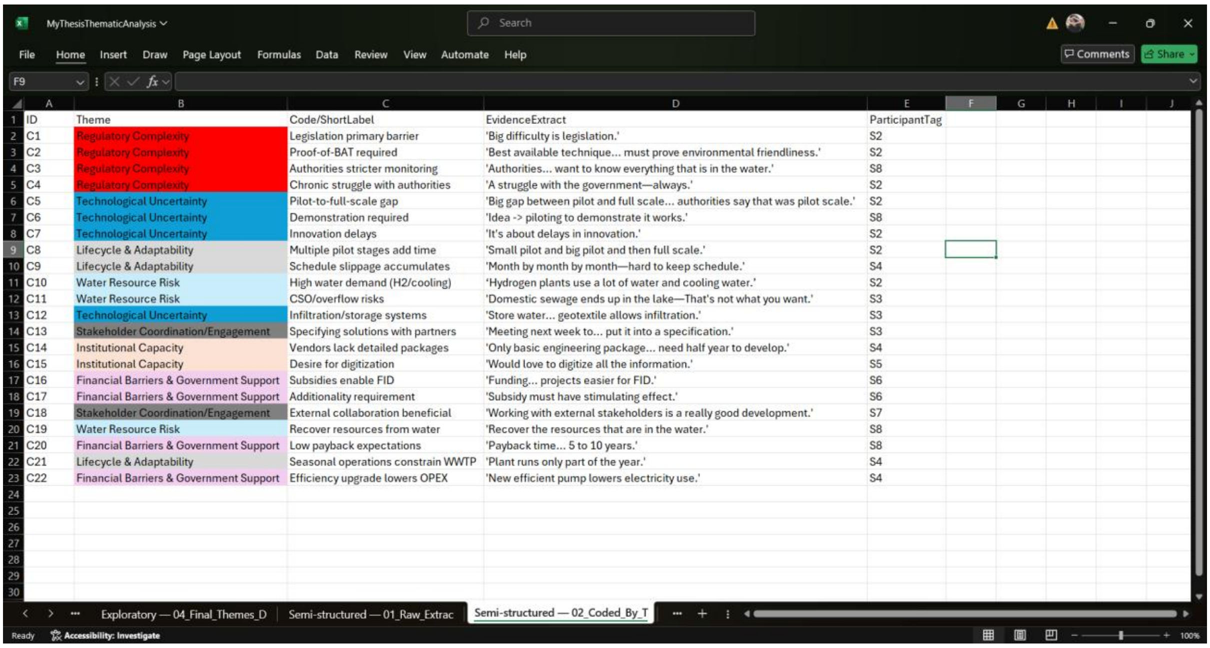
Guiding questions after Q7
Please tell your experience with:

- Regulatory complexity experienced by green water projects
- Does Bilfinger need more expertise and knowledge about green water projects?
- In your experience how is material circularity navigated.
- Is the current stakeholder engagement adequate for green water projects? If not why?
- How are risks and uncertainties managed for green water projects?
- Shed light on government support and subsidies for green water projects in your experience. Do they help avoid delays?
- In your experience do green water projects face cost barriers? If yes please explain.
- What effects the schedule performance of green water projects?

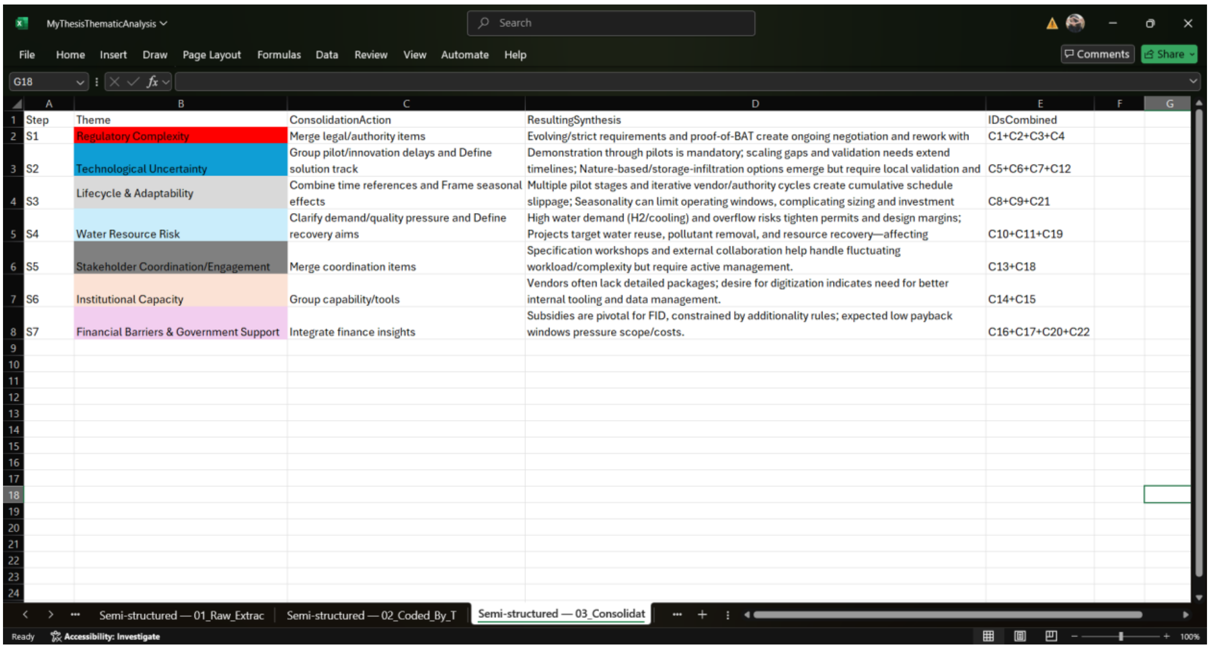
Thematic analysis of Semi-structured interviews in Excel:



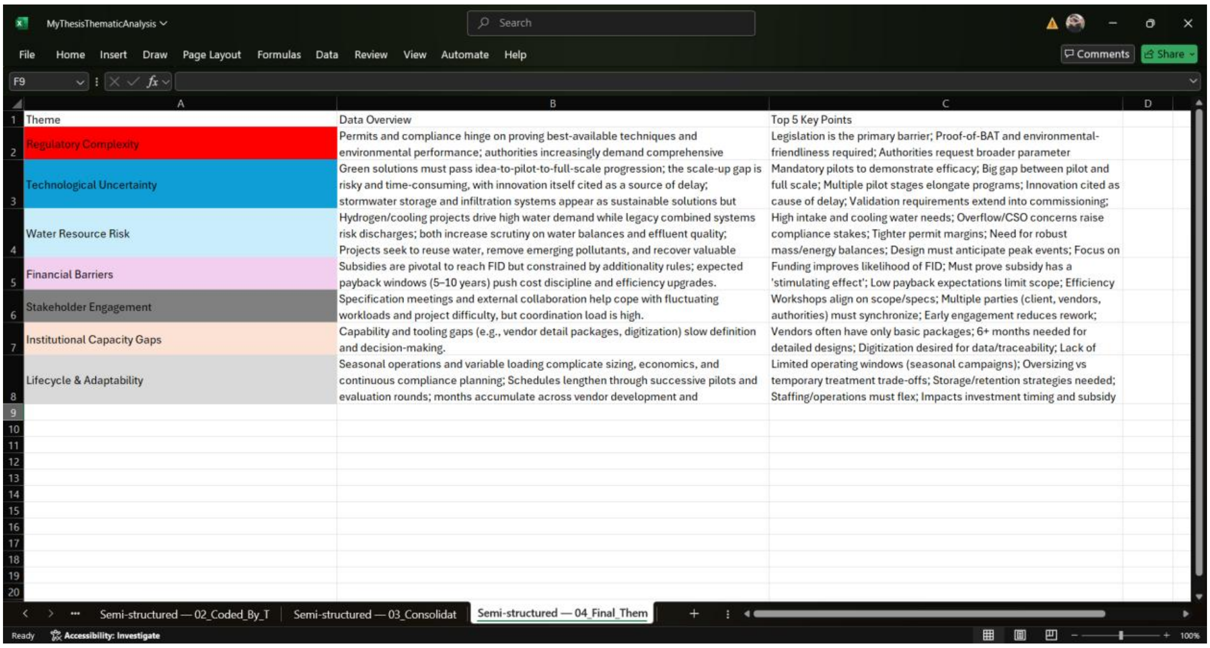
ID	ParticipantTag	SourceExtract	PreliminaryTheme
R1	S2	Big difficulty is legislation.	Regulatory Complexity
R2	S2	You need results first... pilot to full-scale is a big gap; authorities still say 'that was pilot scale'.	Technological Uncertainty
R3	S2	Best available technique... must prove environmental friendliness.	Regulatory Complexity
R4	S2	Pilots take long; then larger pilot; then full scale.	Lifecycle & Adaptability
R5	S2	Hydrogen plants use a lot of water and cooling water.	Water Resource Risk
R6	S2	Struggle with the government—always.	Regulatory Complexity
R7	S3	Combined sewer overflows discharge into surface water—'that's not what you want.'	Water Resource Risk
R8	S3	We try to store/infiltrate stormwater via subsurface crates with geotextile.	Technological Uncertainty
R9	S3	Meeting next week to specify solutions for plastic-waste product project.	Stakeholder Coordination/Engagement
R10	S4	Vendors may have only a basic package and need ~6 months to develop details—adds months, then more for evaluation.	Institutional Capacity
R11	S4	Month by month by month—hard to keep schedule.	Lifecycle & Adaptability
R12	S4	Seasonal operations (e.g., sugar beets) make wastewater treatment run only part of the year.	Lifecycle & Adaptability
R13	S4	Installing more efficient pumps lowers electricity use.	Financial Barriers & Government Support
R14	S5	Would love to digitize all the information.	Institutional Capacity
R15	S6	Subsidies stimulate FID; projects easier when funding secured.	Financial Barriers & Government Support
R16	S6	European subsidy law requires 'stimulating effect'—can't fund what would happen anyway.	Financial Barriers & Government Support
R17	S7	External stakeholder collaboration helps handle fluctuations in workload and difficulty.	Stakeholder Coordination/Engagement
R18	S8	Sustainability goals: reuse water, remove pollutants, recover resources.	Water Resource Risk
R19	S8	Path: idea -> piloting to demonstrate it works.	Technological Uncertainty
R20	S8	Authorities now want to know everything in the water (stricter, broader monitoring).	Regulatory Complexity
R21	S8	Projects should be cheap with 5–10 year payback.	Financial Barriers & Government Support
R22	S2	Innovation causes delays.	Technological Uncertainty



ID	Theme	Code/ShortLabel	EvidenceExtract	ParticipantTag
C1	Regulatory Complexity	Legislation primary barrier	'Big difficulty is legislation.'	S2
C2	Regulatory Complexity	Proof-of-BAT required	'Best available technique... must prove environmental friendliness.'	S2
C3	Regulatory Complexity	Authorities stricter monitoring	'Authorities... want to know everything that is in the water.'	S8
C4	Regulatory Complexity	Chronic struggle with authorities	'A struggle with the government—always.'	S2
C5	Technological Uncertainty	Pilot-to-full-scale gap	'Big gap between pilot and full scale... authorities say that was pilot scale.'	S2
C6	Technological Uncertainty	Demonstration required	'Idea -> piloting to demonstrate it works.'	S8
C7	Technological Uncertainty	Innovation delays	'It's about delays in innovation.'	S2
C8	Lifecycle & Adaptability	Multiple pilot stages add time	'Small pilot and big pilot and then full scale.'	S2
C9	Lifecycle & Adaptability	Schedule slippage accumulates	'Month by month by month—hard to keep schedule.'	S4
C10	Water Resource Risk	High water demand (H2/cooling)	'Hydrogen plants use a lot of water and cooling water.'	S2
C11	Water Resource Risk	CSO/overflow risks	'Domestic sewage ends up in the lake—That's not what you want.'	S3
C12	Technological Uncertainty	Infiltration/storage systems	'Store water... geotextile allows infiltration.'	S3
C13	Stakeholder Coordination/Engagement	Specifying solutions with partners	'Meeting next week to... put it into a specification.'	S3
C14	Institutional Capacity	Vendors lack detailed packages	'Only basic engineering package... need half year to develop.'	S4
C15	Institutional Capacity	Desire for digitization	'Would love to digitize all the information.'	S5
C16	Financial Barriers & Government Support	Subsidies enable FID	'Funding... projects easier for FID.'	S6
C17	Financial Barriers & Government Support	Additionality requirement	'Subsidy must have stimulating effect.'	S6
C18	Stakeholder Coordination/Engagement	External collaboration beneficial	'Working with external stakeholders is a really good development.'	S7
C19	Water Resource Risk	Recover resources from water	'Recover the resources that are in the water.'	S8
C20	Financial Barriers & Government Support	Low payback expectations	'Payback time... 5 to 10 years.'	S8
C21	Lifecycle & Adaptability	Seasonal operations constrain WWTP	'Plant runs only part of the year.'	S4
C22	Financial Barriers & Government Support	Efficiency upgrade lowers OPEX	'New efficient pump lowers electricity use.'	S4



Step	Theme	ConsolidationAction	ResultingSynthesis	IDsCombined
S1	Regulatory Complexity	Merge legal/authority items	Evolving/strict requirements and proof-of-BAT create ongoing negotiation and rework with	C1+C2+C3+C4
S2	Technological Uncertainty	Group pilot/innovation delays and Define solution track	Demonstration through pilots is mandatory; scaling gaps and validation needs extend timelines; Nature-based/storage-infiltration options emerge but require local validation and	C5+C6+C7+C12
S3	Lifecycle & Adaptability	Combine time references and Frame seasonal effects	Multiple pilot stages and iterative vendor/authority cycles create cumulative schedule slippage; Seasonality can limit operating windows, complicating sizing and investment	C8+C9+C21
S4	Water Resource Risk	Clarify demand/quality pressure and Define recovery aims	High water demand (H2/cooling) and overflow risks tighten permits and design margins; Projects target water reuse, pollutant removal, and resource recovery—affecting	C10+C11+C19
S5	Stakeholder Coordination/Engagement	Merge coordination items	Specification workshops and external collaboration help handle fluctuating workload/complexity but require active management.	C13+C18
S6	Institutional Capacity	Group capability/tools	Vendors often lack detailed packages; desire for digitization indicates need for better internal tooling and data management.	C14+C15
S7	Financial Barriers & Government Support	Integrate finance insights	Subsidies are pivotal for FID, constrained by additionality rules; expected low payback windows pressure scope/costs.	C16+C17+C20+C22



Theme	Data Overview	Top 5 Key Points
Regulatory Complexity	Permits and compliance hinge on proving best-available techniques and environmental performance; authorities increasingly demand comprehensive	Legislation is the primary barrier; Proof-of-BAT and environmental-friendliness required; Authorities request broader parameter
Technological Uncertainty	Green solutions must pass idea-to-pilot-to-full-scale progression; the scale-up gap is risky and time-consuming, with innovation itself cited as a source of delay; stormwater storage and infiltration systems appear as sustainable solutions but	Mandatory pilots to demonstrate efficacy; Big gap between pilot and full scale; Multiple pilot stages elongate programs; Innovation cited as cause of delay; Validation requirements extend into commissioning;
Water Resource Risk	Hydrogen/cooling projects drive high water demand while legacy combined systems risk discharges; both increase scrutiny on water balances and effluent quality; Projects seek to reuse water, remove emerging pollutants, and recover valuable	High intake and cooling water needs; Overflow/CSO concerns raise compliance stakes; Tighter permit margins; Need for robust mass/energy balances; Design must anticipate peak events; Focus on
Financial Barriers	Subsidies are pivotal to reach FID but constrained by additionality rules; expected payback windows (5–10 years) push cost discipline and efficiency upgrades.	Funding improves likelihood of FID; Must prove subsidy has a 'stimulating effect'; Low payback expectations limit scope; Efficiency
Stakeholder Engagement	Specification meetings and external collaboration help cope with fluctuating workloads and project difficulty, but coordination load is high.	Workshops align on scope/specs; Multiple parties (client, vendors, authorities) must synchronize; Early engagement reduces rework;
Institutional Capacity Gaps	Capability and tooling gaps (e.g., vendor detail packages, digitization) slow definition and decision-making.	Vendors often have only basic packages; 6+ months needed for detailed designs; Digitization desired for data/traceability; Lack of
Lifecycle & Adaptability	Seasonal operations and variable loading complicate sizing, economics, and continuous compliance planning; Schedules lengthen through successive pilots and evaluation rounds; months accumulate across vendor development and	Limited operating windows (seasonal campaigns); Oversizing vs temporary treatment trade-offs; Storage/retention strategies needed; Staffing/operations must flex; Impacts investment timing and subsidy

Appendix C

Agenda

Master Thesis Expert Review Workshop: ***July 7th, 2025***

Subject: Delays in water projects related to sustainability aspects

Description	Start time	End time
☐ Arrival & Gathering	14:45	15:00
☐ **Welcome & Start (Safety flag)**	**15:00**	**15:03**
☐ Introduction and goal of the workshop, Introduction of the participants with their expectations	15:03	15:10
☐ Presentation: Master Thesis Introduction Literature study, interviews, findings, proposed strategies	15:10	15:25
☐ Per participant: Fill out the feedback form per advised mitigation aspect on 3 levels: Strategic / Tactical / Operational. In what level contributes each advise to improvement?	15:25	15:45
☐ Evaluation of this used individual expert review approach	15:45	15:50
☐ ***Break***	**15:50**	**16:00**
☐ Plenary workshop about the advised improvement aspects that contribute to less delays. Collect, sort and prioritize positive and negative aspects.	16:00	16:30
☐ Transfer the best valued aspects into next step actions	16:30	16:45
☐ Workshop Evaluation and what will be done with the results	16:45	17:00
☐ ***Closure***		**17:00**

Agenda Rev 0; 02-07-2025

Expert Validation Questionnaire

Navigating Delays in Green Water Projects: Identifying Sustainability-Related Challenges and Mitigation Strategies

Organization: Bilfinger Engineering & Consultancy
Researcher: Arya Lotliker
Date: 07-07-2025

Participant Information:

- Role at Bilfinger: ______________________________________
- Years of Experience: _________

Instructions:

Each row in the table presents a challenge and a corresponding solution proposed in this research, grouped into strategic, tactical, and operational levels.
Please rate the effectiveness of each solution provided in the table in addressing its challenge on a scale of 1 (not effective) to 10 (highly effective).

Q: Do you have any additional comments or suggestions regarding the proposed solutions or the report overall?

____

____

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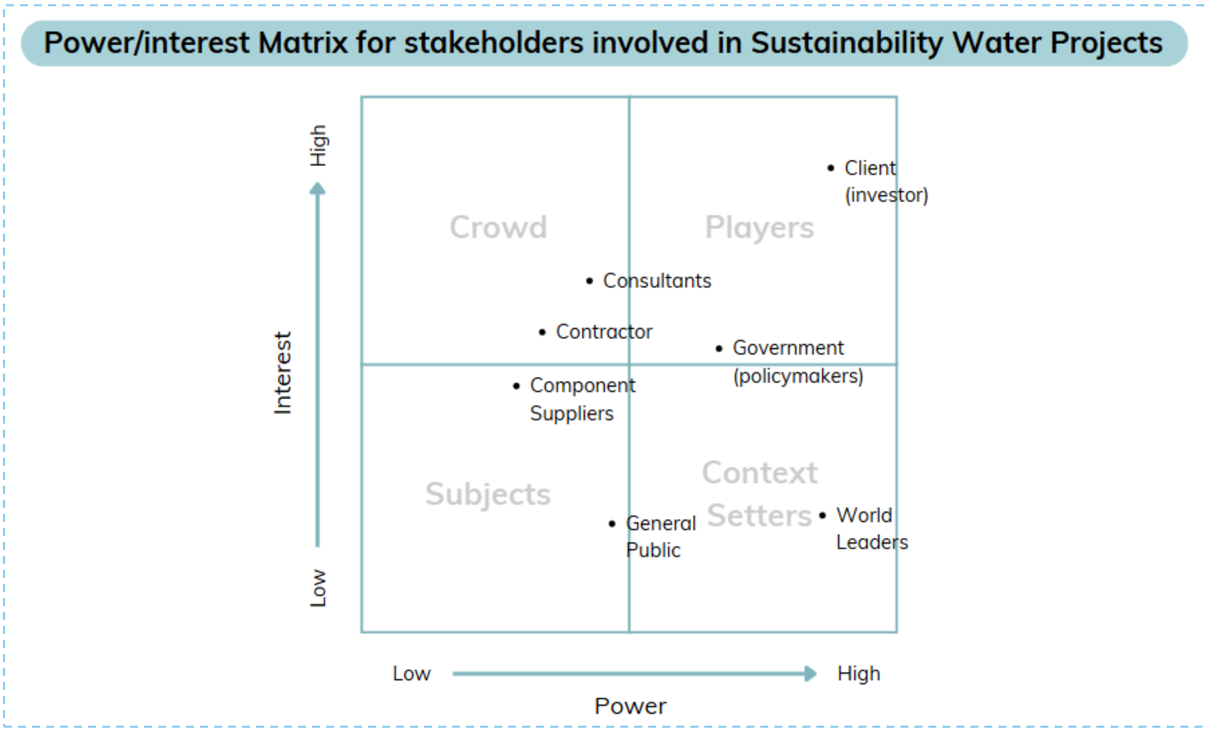
____

____

Rate the Mitigation Strategies (1–10):

Level	Governance	Innovation Adoption	Financing	Institutional Capacity
Strategic	Problem: Inflexible policies hinder sustainable progress. Solution: Embed long-term, adaptable goals in policy frameworks. Rating: ___	Problem: The innovation chasm delays scaling of sustainable solutions. Solution: Invest in awareness programs, mandate innovation, and shift to performance-based compliance. Rating: ___	Problem: Sustainable projects face misaligned risk-reward structures. Solution: Reframe value, expand green finance, reward aligned risk-taking. Rating: ___	Problem: Institutions lack transition and systems thinking. Solution: Mandate policy learning, evaluations, and develop systems-thinking professionals. Rating: ___
Tactical	Problem: Fragmented planning limits effectiveness. Solution: Use integrated frameworks, early stakeholder involvement, and regulatory sandboxes. Rating: ___	Problem: Innovation lacks feedback and collaboration. Solution: Institutionalize demonstration projects; create cross-disciplinary platforms. Rating: ___	Problem: Risk responsibilities are unclear. Solution: Use assumption mapping and shared risk evaluation. Rating: ___	Problem: Redundant or disconnected institutional efforts. Solution: Create cross-sector networks, task forces, and knowledge-sharing programs. Rating: ___
Operational	Problem: Delayed input and rigid plans block adaptability. Solution: Apply front-end loading, early stakeholder engagement, common risk assessment frameworks. Rating: ___	Problem: Rigid, projects fail to scale flexibly. Solution: Create innovation units; use modular, adaptable design to bridge the innovation chasm. Rating: ___	Problem: Inflexible, reactive funding undermines resilience. Solution: Use adaptive milestone-based financing; apply bow-tie risk analysis. Rating: ___	Problem: Teams struggle with dynamic system changes. Solution: Adopt prepare-and-commit management; use adaptive practices for complexity. Rating: ___

Appendix D



Using the power-interest grid for stakeholder analysis allows for managing a broad range of stakeholders while keeping the process focused and actionable by emphasizing power and interest dimensions (Ackermann & Eden, 2010).