A Key Skills Framework to Manage Uncertainty in Large Infrastructure Projects

CME Master Thesis

Reshma Khanam

TU Delft

DURA VERMEER

The world we have created is a product of our thinking; It cannot be changed without changing our thinking.

Albert Einstein

A Key Skills Framework to Manage Uncertainty in Large Infrastructure Projects The case of the 2GW Landstation

by

Reshma Khanam
5765056

In partial fulfilment of the requirements for the degree of
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Graduation Committee

Chair	**Prof. Dr. PWC. (Paul) Chan** Faculty of Architecture and the Built Environment Technische Universiteit Delft
First Supervisor	**Dr. E.J. (Erik-Jan) Houwing** Faculty of Civil Engineering and Geosciences Technische Universiteit Delft
Secondary Supervisor	**Dr. J. (Johan) Ninan** Faculty of Civil Engineering and Geosciences Technische Universiteit Delft
Company Supervisor	**Y. (Youri) Pieters** MSc, MBA Technical Manager Dura Vermeer Infra Landelijke Projecten BV
Graduation Company	**Dura Vermeer Infra Landelijke Projecten BV**

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As I look back on this incredible journey, I cannot help but acknowledge how difficult it was to choose academics after years of working. Leaving behind a good independent life was a constant battle between my mind and my heart. But deep down, there was always a part of me that craved growth, and when COVID hit, it gave me the space to think about my dreams. The thrill of finally pursuing those dreams gave me the strength to start over. I had to begin by unlearning everything I thought I knew, approaching this journey with a deep hunger for learning. The path to my Master's was like a roller coaster, especially during the early planning phase. My mind was filled with complexities and there was a pressure to make the right choice for my future. The biggest challenge was finding a university and country where I could grow both academically and personally. After extensive research, I knew that TU Delft was the place where I wanted to explore. In fact, TU Delft lived up to its academic hype, even pushing me to question my abilities at times. But with each challenge, I grew more confident. I am grateful for this chapter of my life and will always cherish it.

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Reshma Khanam,
Delft, the Netherlands,
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Executive Summary

Megaprojects are inherently characterized by high levels of uncertainty due to their large scale, complexity, and unique one-time delivery nature. Throughout the project life cycle (PLC), multiple internal and external stakeholders have conflicting demands that fuel uncertainty. The complexity of these projects is also believed to be growing, which poses great challenges to the management of these projects.

Construction practitioners often have varying perceptions of uncertainty within large construction projects. Even within the same project or organization, individuals may view project uncertainties differently. Currently, in practice, there has been more focus on risk, and uncertainty is almost neglected. One of the main reasons for the failure of large infrastructure projects is the underestimation of uncertainty. Therefore, effective uncertainty management is the key to the successful delivery of these projects. Addressing this pervasive uncertainty requires a variety of strategies and key competencies among project members. Identifying and managing uncertainties is expected to improve the success of the Landstation project, and this research explored how project members can be equipped with the critical skills needed to achieve this. This led to the main research question as follows:

How can the project members of a large infrastructure project like the 2GW Landstation develop their key skills to manage uncertainties?

This research contributed to the management of science of project management within large infrastructure projects. The objective of the project was to identify the different sources of uncertainties, the implications of different perceived uncertainties for the project performance of large construction projects, and the implications for the management of uncertainty within these projects. The research further explored strategies to manage project uncertainties to determine whether perceived uncertainties influenced project performance through these strategies. Strategies are actions that practitioners use to address project uncertainties, with the aim of reducing or controlling them.

The research was carried out in collaboration with Dura Vermeer, a prominent Dutch construction company, after their successful bid to design and implement innovative '2GW Landstation project'in the Netherlands. As this initiative introduces a novel concept on a national scale, it inherently carries numerous unforeseen uncertainties that could present significant challenges and potentially lead to project delays. The lack of extensive experience with such innovative projects highlighted the need for research on the specific competencies required to effectively manage these uncertainties.

Methodology

Research can be seen as descriptive, explanatory, and exploratory and uses an inductive approach based on qualitative data. Internal validation has not been performed. External validation was done with literature and an expert meeting. The methodology involved several key steps. First, a literature study was conducted to define the relevant concepts. Building upon a conceptual framework of elements that play a role in the management of uncertainties, an empirical study was then performed to supplement this framework with practical experience. The empirical study involved fifteen interviews with Dura Vermeer and other partner organizations in the Landstation project, process, and technical

management. These were followed by a brainstorming session with two project experts. This served the purpose of putting the interview findings in perspective and providing an additional view on the concept of uncertainty in the Landstation project.

Literature

A literature study was conducted for three reasons: (1) to see what is known about uncertainty and how this research would integrate within current knowledge; (2) to see how this research could describe uncertainty in a meaningful way; and (3) to see what is known about managing project uncertainty and how this research could confirm or reject these existing theories. From the literature, it was found that uncertainty is an unavoidable element of project management. It is a lack of available knowledge or competence in something. Its probability of occurrence and potential outcome are usually unquantifiable and immeasurable. The literature also highlighted that the current project management methodology contains only techniques for managing risks in the project. The presence of uncertainty complicates project management because the available knowledge and skills are often insufficient to address it. As a result, decisions are made without all relevant information, which can lead to overruns in cost and time. The literature further showed that uncertainty management consists of different core elements: identification, classification, and the act of dealing with uncertainties. Dealing with uncertainty requires innovative solutions; thus organizations should balance exploitation (using existing knowledge) and exploration (seeking new knowledge).

Results

The interviews determined that in the Landstation project, the participation of multiple stakeholders from various organizations, each with unique perceptions, contributes significantly to the emergence of uncertainties. The interviews revealed that uncertainties are not deliberately addressed at present. However, from the examples and context provided, it can be inferred that aspects of uncertainty management are applied subconsciously. This means that they are often not used to specifically address uncertainties, but instead to tackle risks. The empirical study also aimed to understand the barriers that hinder the adoption of an effective approach to uncertainty management and why the drivers were not sufficient to motivate the project members.

The proposed framework, depicted in Figure 1, serves as a guiding tool for facilitating Dura Vermeer's transition from its current state of uncertainty management to the desired state through structured and achievable steps. This framework consists of 4A's, such as *Address, Accomplish, Adapt/Adjust and Acquire*, as four strategies that provide a structured progression from top to bottom, aimed at developing key skills for managing uncertainty. Specific goals were established to achieve the desired state of uncertainty management, with relevant measures assigned to each strategy accordingly. Each strategy reinforces the overall approach to uncertainty management, ultimately leading to the development of essential skills needed. By creating this framework, the research successfully achieves its main objective: Developing a key skill framework to support the project team of a large infrastructure project such as the 2GW Landstation to manage uncertainty. The proposed framework is grounded in the literature recommendations and supported by empirical research findings. This ensures that the measures presented are both realistic and feasible for organizations to implement. However, since validation has not yet been completed, this remains a key recommendation for current and future Landstation projects.

Recommendations for Dura Vermeer

1. *Increase awareness of Uncertainty*

It has been observed that while Dura Vermeer has a robust risk management system, the team lacks awareness of managing uncertainties specifically. It is recommended to ensure that the team understands what uncertainty is, how it differs from risk, and why it needs to be handled differently.

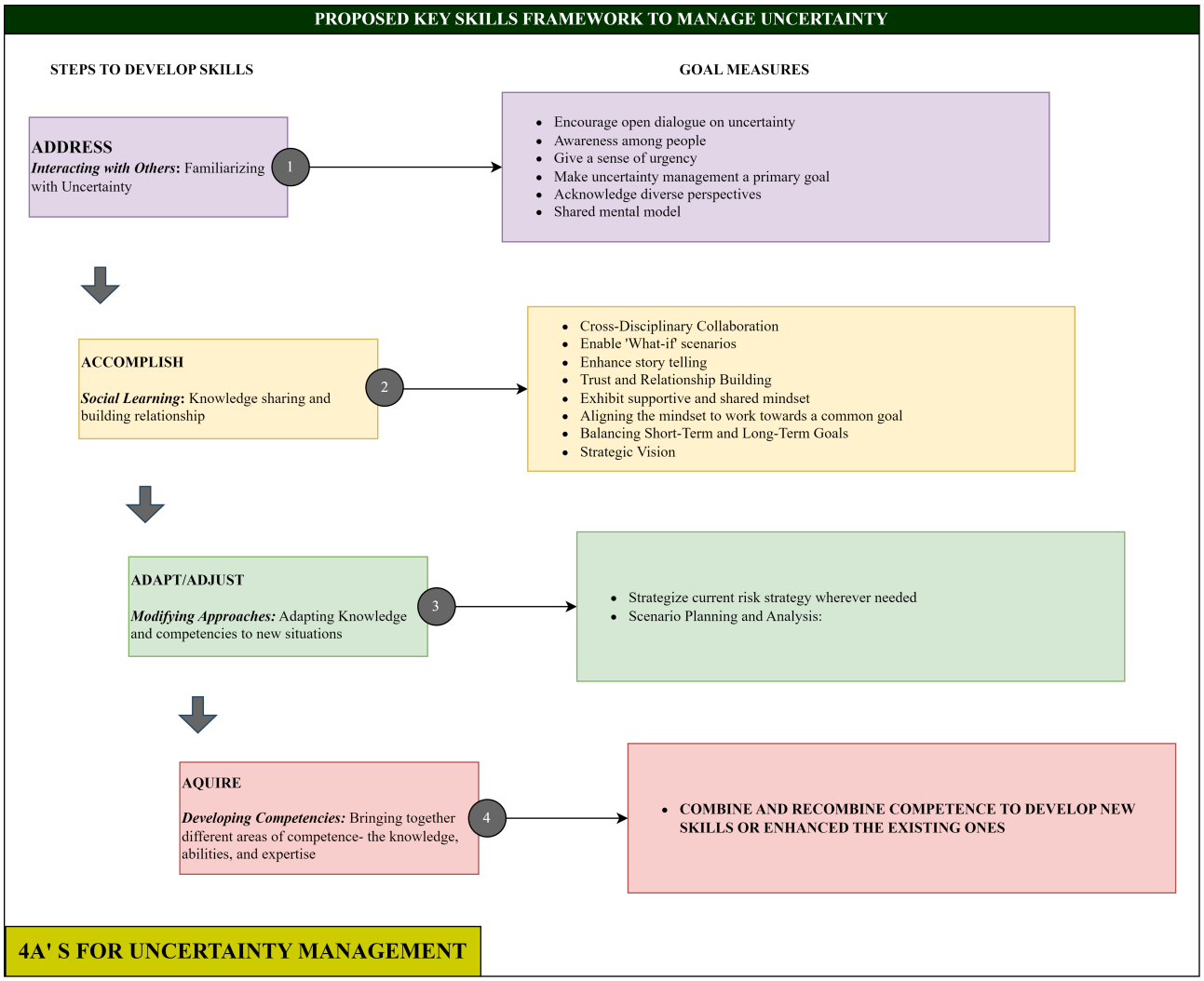

Figure 1: Proposed 4A's key skills framework for uncertainty management

2. *Incorporate Uncertainty into Risk Management*

Although uncertainties and risks are distinct, it is recommended to integrate uncertainty management into the existing risk management framework to make it a standard practice. This starts with introducing the concept of uncertainty and ensuring that everyone has a shared understanding. By doing so, the team can approach uncertainty with the same level of seriousness as risk, treating it as a routine part of their work rather than an additional task.

3. *Extend ways of working*

Dura Vermeer's methods of working should be expanded to include uncertainty management practices. The empirical study revealed that many components of uncertainty management are already being applied subconsciously in practice. These should be formalized and made common knowledge for all employees, ensuring consistency across the organization. In addition, a flexible approach should be implemented to respond to changing project environments.

4. *Appoint an Uncertainty Manager*

To effectively manage uncertainties, it is recommended that Dura Vermeer appoint an "Uncertainty Manager" to raise awareness and ensure uncertainties are addressed throughout the project life cycle. This role will help the team approach uncertainties distinctly from risks, ensuring that they are managed proactively rather than overlooked.

5. *Implement 4A's framework*

The proposed framework (Address, Accomplish, Adapt/Adjust, Acquire) should be implemented to provide a structured approach to uncertainty management. Although Dura Vermeer has traditionally focused on technical solutions, further advancements are possible. Putting emphasis on trustful collaboration strategies will help overcome human barriers to uncertainty management. This framework supports a necessary shift toward a more comprehensive focus on uncertainties. At the project level, it will provide a platform for collaboration, knowledge sharing, and skill development, helping to shift the team's mindset from being solely risk-focused to actively considering uncertainties.

6. *Develop a Lessons Learned Database*

The next step involves collecting data to better understand the uncertainty and improve the team's approach. It is recommended that Dura Vermeer create a comprehensive database to document lessons learned from past projects, specifically focused on managing uncertainties. This database should include both positive and negative outcomes, categorize uncertainties by type, and provide context for each uncertainty. It should also link the strategies used to manage uncertainties with relevant technical and soft skills. By capturing diverse stakeholder perspectives and regularly updating the database, Dura Vermeer can improve its ability to predict and address uncertainties in future projects. Facilitated workshops to collect lessons learned provide a structure that helps the team to analyze the uncertainty better.

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List of Abbreviations

BIM	Building Information Modelling
GW	Gigawatt
HVDC	High Voltage Direct Current
OPM	Opportunity Management
PMI	Project Management Institute
PM	Project Management
PLC	Project Life Cycle
QCA	Qualitative Content Analysis
RM	Risk Management
RMP	Risk Management Plan
SM	Stakeholder Management
TOE	Technical, Organizatinal, and Environmental
UM	Uncertainty Management
Unk unk	Unknown unknown

Chapter 1

Introduction

This chapter starts with background information about the research topic in Section 1.1. Subsequently, Section 1.2 describes the research context, while Section 1.3 articulates the problem statement. Section 1.4, explains the research objective. Later, the theoretical relevance of this research is explained in Section 1.5.

1.1 Background

The tech is easy, people are hard

Complex projects, often known as megaprojects, are designed to ambitiously change society (Flyvbjerg (2014)). A megaproject is a large-scale infrastructure project that costs an investment of over $1 billion dollars, long lead time, is typically delivered by private companies on behalf of a government; involves multiple public and private stakeholders, is transformational, and impacts millions of people (Koppenjan (2005), Flyvbjerg (2017)). Mega-projects are united by their extreme complexity (both in technical and human terms) and by a long record of poor delivery. The proportion of megaproject delivery failures has been put as high as 66% (Merrow et. al (2024)). Mega infrastructure projects are not merely a larger version of smaller projects; their scale, complexity, and impact set them apart. As a result, they demand professionals with in-depth multi-skills and project leaders who are reflective practitioners, equipped with deep expertise in the relevant domain to solve the diverse challenges (Flyvbjerg (2017)).

The primary factors contributing to the sub-par performance of megaprojects are the underestimation of inherent complexity and uncertainty (Denicol et.al (2020), Ahiaga-Dagbui et al. (2017)), biased forecasting, insufficient information regarding cost and benefit, and poor stakeholder management are considered the main cause of poor megaproject performance (Ashkanani et.al (2022)). This research is motivated by the widespread recognition among researchers that stakeholders are an major source of uncertainty in projects (Hillson et.al (1997)). Due to the dynamic complexity and uncertainty of the connections between megaprojects and the stakeholder community, stakeholder satisfaction has been a concern. Therefore, effective project management requires identifying and understanding these sources of uncertainty to develop appropriate strategies. Stakeholder-related uncertainty involves identifying relevant stakeholders and understanding their perceptions, significantly influencing project performance (Ward and Chapman (2008)). In megaprojects, achieving success requires balancing the "iron law" of exceeding budget, time, and quality constraints, while ensuring stakeholder satisfaction remains paramount (Flyvbjerg (2017)).

Some of the key challenges leading to schedule and budget overruns in megaprojects, compared to other projects, stem from several factors. These include the increased risks associated with complex interfaces and extended planning timelines, the involvement of many stakeholders with conflicting interests, the likelihood of significant changes in project scope over time and the potential to present misleading information to the public about the costs, benefits, and risks involved (Flyvbjerg (2017)). Therefore, to effectively manage and improve project performance, megaprojects need to go beyond risk management to uncertainty management to handle 'unforeseen events' or 'unknown unknowns' (unk unks) (Davies et.al (2016)), Atkinson et.al (2006)). Risks are events, circumstances, situations, or conditions that might occur with a specific probability and have a potential negative impact on meeting predefined project objectives. Risks are the so-called "known unknowns" and can be separated from uncertainty if they are measurable, calculable, and predictable for the course of the project (Lechler, Edington and Gao (2012)). In comparison to uncertainty in project management: Uncertainty can be defined as all unknown or unexpected project situations with a potential significant impact on the project. Uncertainties are unknown, not foreseeable, and are not predictable with the set of tools and instruments for the course of the project. In other words, the so-called 'unknown unknowns' (unk unks) or 'black swans' (Perminova et.al (2008)).

Uncertainty is often said to have its root cause in the lack of available information, available knowledge, or competence (Johansen (2015)). It is crucial to identify which professionals can bridge the gap between known unknowns and unknown unknowns. For instance, even though project managers allocate resources to manage identified risks, such as purchasing insurance or set aside contingency funds, unexpected events can still occur. These unforeseen events can result in additional costs that

were not anticipated, leading to higher overall project expenses (Krystallis et.al (2022)). According to (Ramasesh et.al (2014)), it is thus necessary to recognize and reduce unk unks by bringing them to the realm of known unknowns, as shown in Figure 1.1.

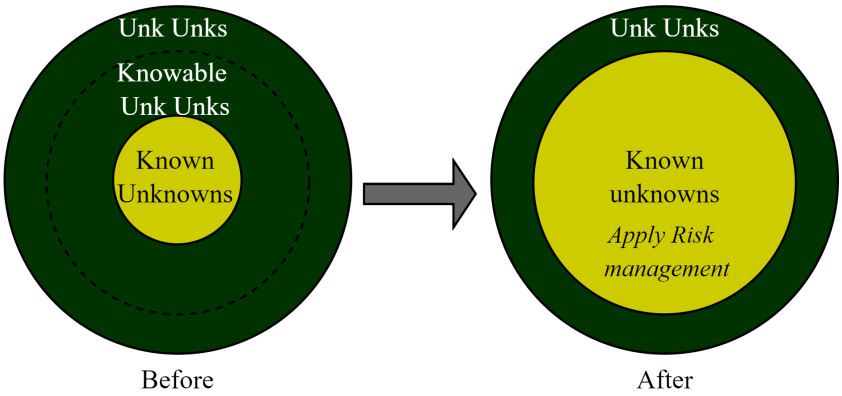


Figure 1.1: From Unknown Unknowns to Known Unknowns, Ramasesh et.al (2014)

Although practitioners often use the terms "risk" and "uncertainty" interchangeably, it is important to distinguish between the two (Johansen et.al (2019)). Recently, there has been a growing interest in uncertainty management, as it has become increasingly clear that traditional risk management techniques are inadequate to handle uncertainties that are difficult to quantify and require a new mindset. Studies have largely focused on risk perception and management, yet there is still a gap in understanding how uncertainty is perceived and managed in megaprojects (Daniel et.al (2018)). However, despite these developments, there has been little exploration of whether project members in large infrastructure projects need new skills to manage uncertainty, or whether they can rely on the skills used in risk management. And there we see the problem: If new skills are necessary, it remains unclear which specific skills are required to effectively recognize and reduce uncertainty.

1.2 Research Context

Dura Vermeer, A Dutch construction company

This study involves an investigation into the Dutch construction company in the Netherlands, especially focusing on their role as contractors striving to manage a large and complex infrastructure project. Dura Vermeer builds and manages a large number of infrastructure projects such as bridge restoration, dike reinforcement, dams, and pumping stations, expansion of high-voltage substations, and 2GW Landstation projects, etc. (DuraVermeer (2023)). This research will explore an ongoing project where Dura Vermeer secured the contract for civil work on the 2GW Landstation project. Given the complexity of the project, Dura Vermeer, as the main civil contractor, has to work closely with various subcontractors to design and execute the project successfully. With multiple stakeholders involved, Dura Vermeer understands that the project progress is heavily based on stakeholder interests, behavior, and contractual obligations that have direct consequences on project progress, such as their interest being positively or negatively affected by the project progress (Johansen et.al (2019)). All stakeholders are experts in their respective roles and most, including Dura Vermeers project team, have a technical mindset that focuses primarily on risk, which contributes to the uncertainty surrounding the design, objectives, and stakeholder relationships. However, the project also requires a management mindset to drive the project forward. Dura Vermeer recognizes that large infrastructure projects must go beyond risk management to also address uncertainty management. However, there is a lack of the skills needed to effectively manage uncertainty. Uncertainty management is not yet ingrained in the regular workflow of Dura Vermeer or the processes of other partner organizations. It is currently perceived as an additional task for a select few within the organization but should evolve

into a norm for the entire organization of Dura Vermeer.

1.3 Problem Statement

With the increasing complexity of projects, there is a growing awareness of the need for effective uncertainty management. Construction organizations like Dura Vermeer can no longer rely solely on traditional risk management practices to deliver successful projects. Although the urgency for change is acknowledged, the organization faces challenges in moving beyond a traditional technical mindset, improving maturity levels among project managers, and integrating new processes into daily practices. This transition impacts certainty in decision making, design, objectives, and fundamental relationships between project stakeholders. Therefore, to manage uncertainty and make it a regular practice, the organization must focus on raising awareness of uncertainty management and encourage the development of critical skills to deal with unpredictability.

Most studies highlight the need to rethink project risk management, suggesting that current practices could contribute to problems rather than solve them (Winch (2015)). This critique points out that there is often an excessive focus on risks, while neglecting the broader concept of uncertainties. Many projects do not clearly distinguish between risk and uncertainty, often conflating the two, which leads to uncertainty being treated like risk or completely ignored (Hillson (2019)). Furthermore, the management of unknown unknowns remains unclear (Lechler et al. (2012)).

Standardized project management processes contain the aspect of risk management with a strong focus on identifying, assessing, and mitigating known risks. However, none of these project management standards deals with the aspect of uncertainty (Project Management Institute (2013)). Traditional risk management techniques often fail when dealing with the unknowns that arise in such environments. As projects become more complex, the number and impact of uncertainties increase, leading to potential disruptions that may not be fully anticipated or controlled by existing risk management strategies. However, the literature has not yet clearly outlined the specific competencies required for professionals to effectively manage these uncertainties in unpredictable project environments. In addition, there is a lack of research on how to facilitate the necessary shift in mindset from risk management to uncertainty management. Therefore, this is the research gap that this study aims to investigate.

1.4 Research Objective

This study aims to address the existing need for uncertainty management by developing key skills tailored to specific uncertainties. These skills will help keep uncertainties at an acceptable level or translate them into known unknowns, allowing risk strategies to be applied. This will be achieved by examining the Landstation project of Dura Vermeer The objective of this research is twofold:

1. Identify the measures to develop the framework
2. Develop a conceptual framework that provides insights into how key skills can be developed that help the project team of Dura Vermeer better equipped in managing uncertainty for better project outcomes in the Landstation project.

1.5 Research Relevance

1.5.1 Theoretical Relevance

In terms of scientific and theoretical relevance, this research introduces a complexity-driven approach to uncertainty management, offering an opportunity to broaden understanding of the sources of uncertainty in large infrastructure projects. By shifting the focus to include not only complexity-related risks but also uncertainty, the research suggests viewing uncertainty through dual perspectives to gain new insights and enhance the uncertainty management process. This dual approach is feasible only when the lack of knowledge and skills is thoroughly analyzed in terms of complexity dimensions (Mitchell et.al (1997)). The research also emphasizes that uncertainty should be taken equally into account as risk, as any source of threat could also present opportunities (Hillson (2019), Johansen (2015), Olsson (2007)). It highlights that uncertainty is distinct from risk, emphasizing that risk management should not be used as an umbrella term for uncertainty management(Hillson (2003)). This highlights the theoretical understanding that uncertainty extends beyond what traditional risk strategies can address, emphasizing the need for additional approaches to effectively manage it. In addition, in infrastructure projects, the participation of multiple actors adds complexity to uncertainty, as their conflicting interests and goals can exacerbate it. Therefore, it is crucial to understand the knowledge and skills required to align these varying perspectives on uncertainty to manage it effectively.

Chapter 2

Research Design

This chapter presents the research approach, beginning with defining the research scope in Section 2.1. In Section 2.2, the formulation of the primary research question and associated subquestions is discussed. The methodology employed in this research is described in Section 2.3. A review of relevant literature is provided in Section 2.4. The empirical study, which includes semi-structured interviews, is covered in Section 2.5. Section 2.6 details the methods used for data analysis. Section 2.7 introduces the interview coding framework utilized in the study. Ethical considerations are addressed in Section 2.8, and Section 2.9 gives a concise overview of the research structure.

2.1 Research Scope

To complete the research assignment within the given time frame, it is crucial to clearly define the research boundaries and establish its scope. This study is conducted in collaboration with Dura Vermeer, an independent construction company based in the Netherlands. Research focuses on uncertainty management, a concept often used interchangeably with risk management in complex projects. This interchangeability can lead to conflicting perceptions and, consequently, poor project performance. By distinguishing between these concepts and specifically addressing uncertainty management, the research aims to improve project outcomes by providing clarity and more effective management strategies.

Uncertainties arise due to lack of knowledge (Johansen (2015)). An observation from the literature is the recurring emphasis on the difference between uncertainties and risks. These terms are often used interchangeably as if the same, but that is not the case (Koleczko (2012)). In the early literature, risks and uncertainties are considered two different types of uncertainty Knight et.al (1921). The explanation of the two terms in the recent literature is still based on this definition. The general consensus seems to be that risks have a probability of occurrence and uncertainties are usually unquantifiable and immeasurable (Daniel et.al (2018), Hillson (2019)).

In this thesis, risk is considered a subset of uncertainty. Both concepts are taken into account and shall not be used interchangeably. In projects, some uncertainties can significantly influence their success, either positively or negatively. Positive uncertainties present opportunities, while negative uncertainties, or threats, present risks. Although there are many formal techniques for managing project risks, all start by identifying these risks, essentially converting them into known unknowns. Traditionally, uncertainty management in the project context has been closely associated with risk management. However, it is important to distinguish between the two. The following presents the definition of uncertainty, as interpreted from the literature study;

Uncertainty is a lack of understanding which may grow to be a risk or an opportunity as more information becomes available. Risk is therefore a subset of uncertainty (Hillson (2003)) and is quantifiable as a result of knowledge and past experiences. For uncertainty, both the probability of occurrence and the potential impact cannot be quantified (Daniel et.al (2018)).

The main contribution of this thesis is the development of skills to manage uncertainty and to establish a common understanding among the project team to effectively deal with unknown unknowns (unkunks) as shown in Figure 2.1.

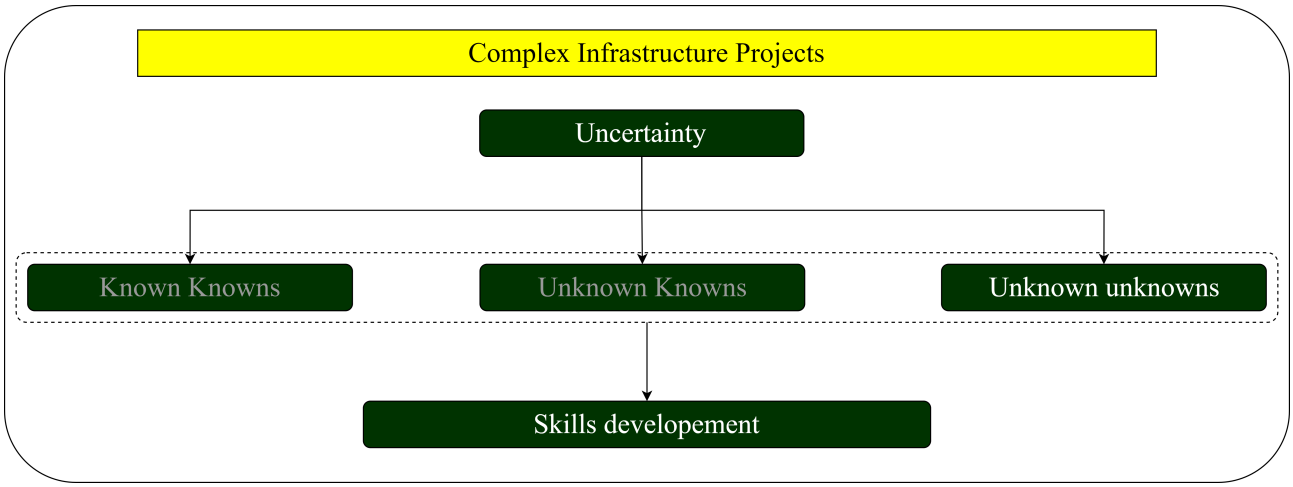


Figure 2.1: Research Scope

2.2 Research Questions

2.2.1 Main Research Question

How can the project members of a large infrastructure project like the 2GW Landstation develop their key skills to manage uncertainties?

2.2.2 Sub-Research Question

- **SQ1-What is the current state-of-art in large infrastructure projects?**

  This sub-question aims to explore the various concepts, classifications, and methods discussed in the literature to better understand how uncertainty and its management are perceived and applied. In addition, it seeks to examine why knowledge and skills are critical for effective uncertainty management in large infrastructure projects. By gaining clarity on these concepts, the goal is to study the relationship between uncertainty management and the necessary knowledge and skills, highlighting how these competencies are essential to navigate and mitigate the complexities of uncertainty.

- **SQ2-What is the current state of uncertainty and its management practices in a large infrastructure project, like the Landstation, and how do the project teams handle them?**

  This sub-question aims to review the process of uncertainty management in practice, drawing on practitioners' experiences. This involves examining how they perceive uncertainty in projects and the current approaches they use to manage it. In addition, the barriers and drivers that influence the effective implementation of uncertainty management, particularly about knowledge and skills, are explored. Finally, the goal is to identify potential ways to improve the implementation of uncertainty management in practice.

- **SQ3- What measures are identified from practice to develop the framework?**

  This sub-research question seeks to identify the specific actions, strategies, or methods that have been observed or derived from real-world experiences and practices. The objective is to understand which practical measures can be incorporated into the development of a framework designed to improve the management of uncertainties. The focus is on gathering information from actual practice to ensure that the framework is grounded in reality and can be implemented effectively.

- **SQ4- How can a framework be developed to assist the development of key skills for managing uncertainties?**

  This sub-research question aims to explore the process of creating a structured approach or framework that can guide the development of essential skills needed to effectively manage uncertainties in a project or organization. It focuses on identifying the key components, steps, and methodologies that should be included in such a framework to ensure that individuals and teams can acquire the necessary competencies to handle unpredictable and complex situations. The question seeks to understand not just what skills are needed, but also how they can be systematically developed and integrated into an organization's practices to improve their ability to manage uncertainty.

2.3 Research Methodology

This section outlines the methodology used in the research to achieve its objectives and address all research questions as stated in Section 2.2. The research is primarily divided into three main parts, as

shown in Figure 2.2. Combining the research results of all three parts, an answer can be formulated to the main research question of this research.

1. Literature study part: This section defines the key concepts of the research by examining existing literature to demonstrate the relationships between these concepts and their interdependence within the context of infrastructure projects. (addressing sub-question 1).
2. Empirical Study Section: This part of the research involves investigating the uncertainty management process in practice through semi-structured interviews with Dura Vermeer managers and other stakeholders from partner organizations. The goal is to understand their different perceptions of uncertainty and uncertainty management, as well as to identify barriers and drivers for implementing effective uncertainty management in projects. Additionally, the study aims to pinpoint the types of uncertainties that may arise, where they are likely to occur, and how to improve the process of identifying and managing these uncertainties (addressing sub-question 2). Following this, an expert discussion session will be conducted to explicitly articulate the identified gaps. These discussions are expected to provide more clarity and improve the overall results of the study.
3. Development part: Developing a framework that provides a structured way for developing skills to manage uncertainty in the 2GW Landstation project. The framework connects the project members to exchange and understand their existing knowledge and skills through social learning and adaptability.

The research strategy is summarized in Figure 2.2:

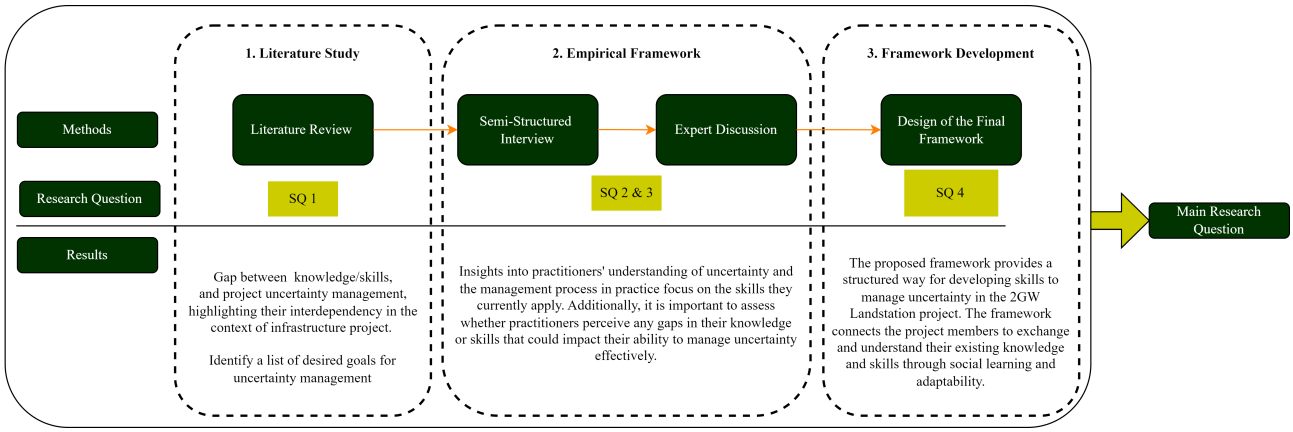


Figure 2.2: Research Strategy

2.4 Literature Study

This part aims to gain a comprehensive understanding of uncertainty management, stakeholder perceptions, and their relationship. This is achieved after a clear definition of all relevant concepts. This part helps in answering the first sub-question using a literature review: First, it is essential to establish a comprehensive understanding of the concept of uncertainty. Given the considerable amount of existing research on this subject, it was determined that a review of the literature is the most appropriate method to establish a conceptual framework. The literature review is of significance in this thesis for several reasons. It will offer methodological insights Bolderston (2008) on uncertainty, provide additional context to the issue, and facilitate a deeper understanding of the structure of the subject.

A wide range of papers were reviewed for the literature related to sub-question 1. Data for this part of the research were gathered from existing sources, including research articles, published books, previous thesis projects, and lecture slides, all accessed through Scopus and the TU Delft Repository. The objective was to construct a conceptual framework that would serve as the basis for the empirical

study. However, the extensive literature on uncertainty initially posed challenges in defining the scope, thus demarcating the thesis outline was crucial, as shown in Figure 2.7. The literature review began by exploring the intricacies of uncertainties and their relationship with risk, as well as methods of identification and management. Keywords and phrases utilized during this initial phase included:

- Infrastructure Projects
- Complexity
- Uncertainty
- Risk
- Uncertainty management
- Knowledge
- Skills

2.5 Empirical Study- Semi-Structured Interviews

Data collection involved conducting semi-structured interviews with expert personnel selected from various departments within the organization, as well as from partner organizations. The interviews were conducted according to the guidelines and ethical obligations of human subjects research. The primary goal of the interviews is to gain insight into the current views of practitioners on uncertainty management and to identify existing skills gaps in effective uncertainty management. The interviews also seek to identify barriers and drivers for implementing effective uncertainty management in projects. A total of 15 interviews were conducted. Table 2.1 mentions the descriptions of the interviewees. All interviews were scheduled for one hour, three were conducted remotely using Microsoft Teams, and the rest face-to-face. An interview guide composed of 20 questions was prepared to fulfill the purpose of the interviews. The guide is described in Appendix A. The interviews were recorded using Microsoft Teams for remote sessions or conducted face-to-face, transcribed into text, and then analyzed using the qualitative content analysis (QCA) approach. It is a method used to systematically describe the meaning of the qualitative data collected by allocating successive parts of the qualitative material to categories of a coding frame (Schreier et.al (2019)).

2.5.1 Interviewees Selection and Background Information

The purpose of the interviews was to gain insight into the current views of practitioners on uncertainty management and to identify the existing skills gaps to effectively manage uncertainty. In addition, the interviews were designed to explore how these perceptions can be better understood by developing key skills that facilitate more effective uncertainty management. This understanding will help pinpoint the essential skills needed to manage uncertainties successfully and is crucial for answering sub-questions 2 and 3. The targeted practitioners included Project Manager, Project Control Manager, Project leads, Contract Manager, Design Manager, and Risk Manager. More information on the interviewees can be found in Table 2.1. The reason for interviewing Control Managers is to understand how they handle various aspects of project management that intersect with process management. Process management deals with managing complex interactions between stakeholders in a dynamic environment, where actors with different characteristics and project objectives enter and leave the process (Edelenbos and Klijn (2009)). The process involves numerous uncertainties due to its dynamic nature and the diversity of actors involved (De Bruijn, Ten Heuvelhof et al. (2010)). This variability presents opportunities to understand the perceptions of other parties, making it crucial to consider the perspectives of Project Control Managers. In addition, the role of Risk Manager encompasses evaluating and monitoring identified risks within a project by continuously updating the risk register. The Risk Manager, in

collaboration with the Project Manager and other key participants, is also tasked with identifying new risks. Therefore, their views on opportunity management are equally significant.

An invitation was extended to 15 practitioners at Dura Vermeer and its partner organizations. Of these, 14 accepted the invitation, resulting in a response rate of 93 33%. Among the 14 interviewees, there were 4 project managers, 4 project leaders, 1 project control manager, 2 risk managers, 1 purchasing manager, 1 grip manager, 1 design manager, 1 contract manager, and 1 manager of work preparation. The participants have different backgrounds: Civil, structural, mechanical, electrical, business development and architecture. All participants (P=14) have at least 5 to 10 years of experience with infrastructure projects. The distribution of the interviewees according to their role and background is seen in Figure 2.3.

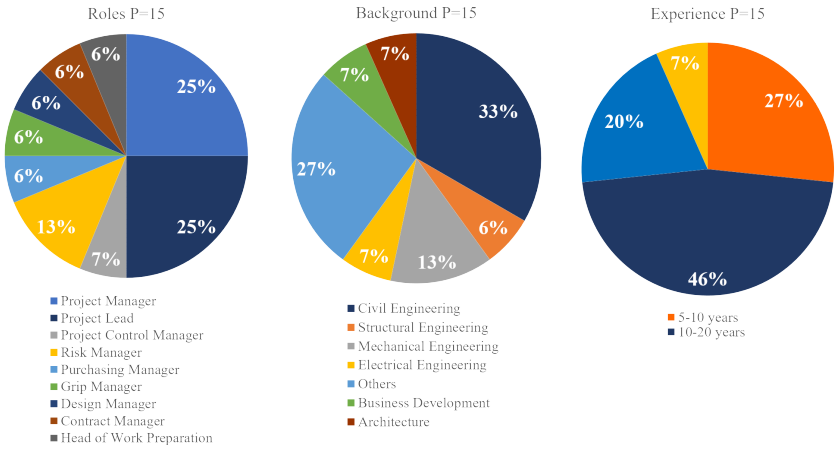


Figure 2.3: Division of Roles, Background and Experience

ID	Experience	Current Project
PM1	Working as a project manager	2GW Landstation
PM2	Working as a project control manager	2GW Landstation
PM3	Working as a civil and infrastructure project lead	2GW Landstation
PM4	working as a purchasing manager	2GW Landstation
PM5	working as a grip manager	2GW Landstation
PM6	working as a Contract manager	2GW Landstation
PM7	working as a head of work preparator	2GW Landstation
PM8	working as a project manager	2GW Landstation
PM9	working as a project lead	2GW Landstation
PM10	working as a project manager	2GW Landstation
PM11	working as a project lead	2GW Landstation
PM12	working as a project lead	2GW Landstation
PM13	working as a technical expert	2GW Landstation
PM14	working as a risk manager	others

Table 2.1: Interviewee description

2.5.2 Interview Guide

The interviews conducted within this graduation project were semi-structured, aiming to find out what the exact problem is and where the exact problem lies. Semi-structured interviews include an interview guide with several predetermined questions, but the interviewer is free to use probing questions to dig deeper into the interview responses (McGrath et.al (2019)). Therefore, an interview guide with 20 questions was created to help guide the discussion during the interview and also to ensure that all interviews produce comparable results for later analysis. The interview guide was formulated so that it is focused on understanding the Landstation project from various involved parties, as it is a

novel concept and the first of its kind. Therefore, the main focus of the interviews was to identify key skills and areas of improvement. The interview guide is found in Appendix A: Interview Protocol and Guide.

The interview guide starts with four background questions (Questions 1-4) followed by 20 mainly open-ended questions (Questions 5-20) to encourage full answers instead of a simple *yes or no.*. The purpose of the first four questions is to collect background information from the engineers interviewed. Also, to understand how they overview the project from their and their organization's perspective. It was a good flow to see that each interviewer had a different way of interpreting the project for the analysis of the result.

In this graduation project, it is crucial to understand the positions, backgrounds, and working experiences of engineers within the company for a later analysis of the results. This information is important because it reveals their organizational affiliation, their connection to the main contractor and the client, and their tenure with the company. This helps gauge their seniority and level of involvement in the project. Furthermore, it is fascinating to observe how experience significantly impacts the management of complex projects, even when some project managers do not have a university degree. Also, before starting the interview, it is a good idea to first introduce some easy questions to smooth the transition to the interview topic, as well as to make the interviewee comfortable (McGrath et.al (2019)) especially if the interview guide was not shared with the interviewees in advance.

2.6 Interview Coding Frame

Data collected from the interviews were analyzed according to the Qualitative Content Analysis (QCA) approach with ATLAS. ti software. QCA is ideal for interpreting rich verbal data gathered from interviews, as it systematically describes qualitative material by creating a coding frame(Friese (2019)).

During the preparation phase, the 14 interviews were transcribed and inserted into the ATLAS.ti environment. Then familiarization with the data was achieved by reading through the transcripts and highlighting the key and relevant information related to each question. These highlighted segments are called quotations in ATLAS.ti. In this way, 527 quotations were created. The codes were then assigned to these quotations. The goal of coding is to describe the data so that at a later stage one can retrieve data segments by subjects or topics to group them (Friese (2019)). The creation of the codes is done data-driven using a subsumption strategy (William B (2017)). This strategy implies examining one quotation after the other, following these steps:

1. Reading the quotations and summarizing them into concepts or ideas.
2. Checking, for every quotation, if a code covering its concept/idea has already been generated.
3. If so, subsuming the concept/idea under the corresponding code. If not, a new code is created to cover it.
4. Continue reading until all relevant concepts/ideas are encountered.

A total of 39 codes were developed in this study and are shown in the Appendix D. The creation of code groups, which organize collections of codes, was concept-driven. This approach relies on existing research, prior knowledge, theoretical frameworks, or the interview guide (Schreier et.al (2019)).

To effectively manage multiple codes, the relevant codes are combined and named one code group, ensuring that the overall framework remains clear. The grouping of multiple codes under one umbrella makes sense when they address the same theme. This method ensures that the different aspects

of the same theme are not lost. For example, during the interviews, participants discussed the definition of stakeholders and, from their perspective, identified key stakeholders based on this definition. Therefore, quotations addressing the stakeholder definition and the identification of key stakeholders were initially coded separately but later combined into a single code group named "stakeholder." This method ensures that different aspects of the same theme are organized together, providing a coherent and streamlined coding structure.

In this case, the interview guide shaped the code groups, resulting in 10 distinct categories. The Landstation project, uncertainty, phases, stakeholder, stakeholder perceptions, barriers, drivers, knowledge, and skills. By integrating results from both the data-driven and concept-driven approaches, a comprehensive coding framework was constructed, revealing key insights. The findings of this analysis are detailed in Chapter 5.

The whole process of analyzing the data collected from the interviews is summarized in Figure 2.4.

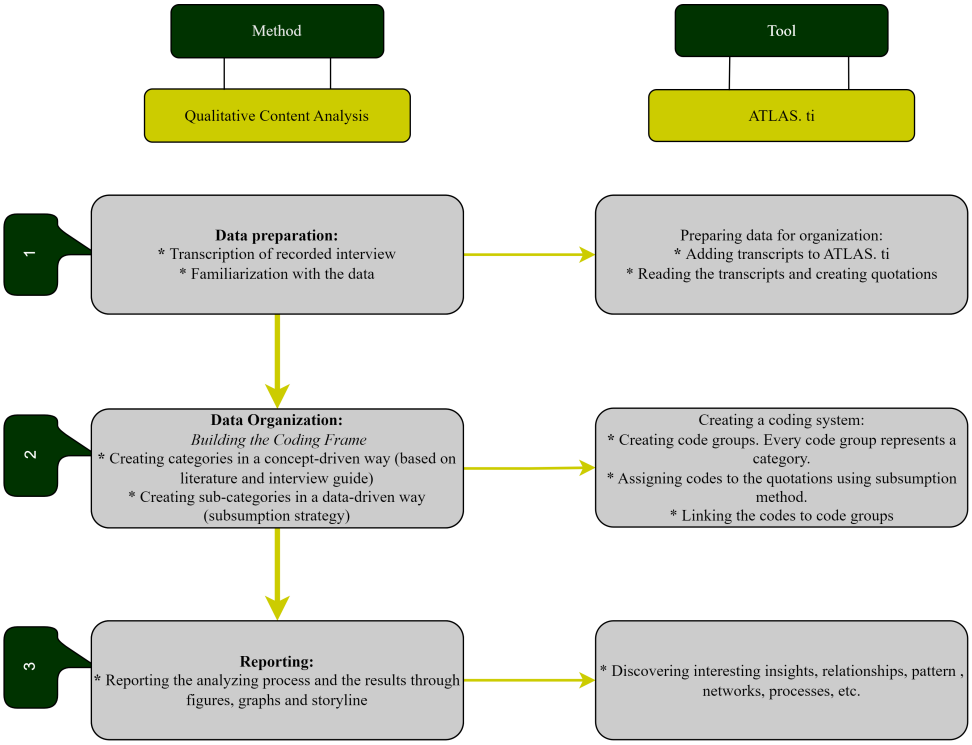


Figure 2.4: Analyzing interviews data

All codes and the code groups including these codes are presented in Appendix D: Quotations, Codes, and Code Groups in ATLAS.ti. Figure 2.5 illustrates the coding frame.

The code groups are arranged in such a way that they create a story that is directly related and is illustrated at the same level as seen in Figure 2.5. For instance, the definitions and understanding of the terms, and at the beginning of the project phase I, the design phase, the uncertainties are high and must be included in the initial phase to create a contingency plan. In addition, the involvement of multiple stakeholders creates opportunities and threats for the project due to different perceptions. Now, it is important to have effective dialogue and engagement with stakeholders. Subsequently, improvement of the skill development is based on certain drivers that will incentivize the Managers to effectively identify and manage the stakeholders. The discussion of all these aspects is done systematically according to those relationships. First, the results of the interview analysis are descriptively presented before being discussed for the findings in the literature.

Content analysis is considered a descriptive approach to qualitative data analysis and is suitable when a relatively low level of interpretation is required (Vaismoradi, Turunen and Bondas (2013)). This approach is suitable in this research for analyzing the data generated from the interviews for many

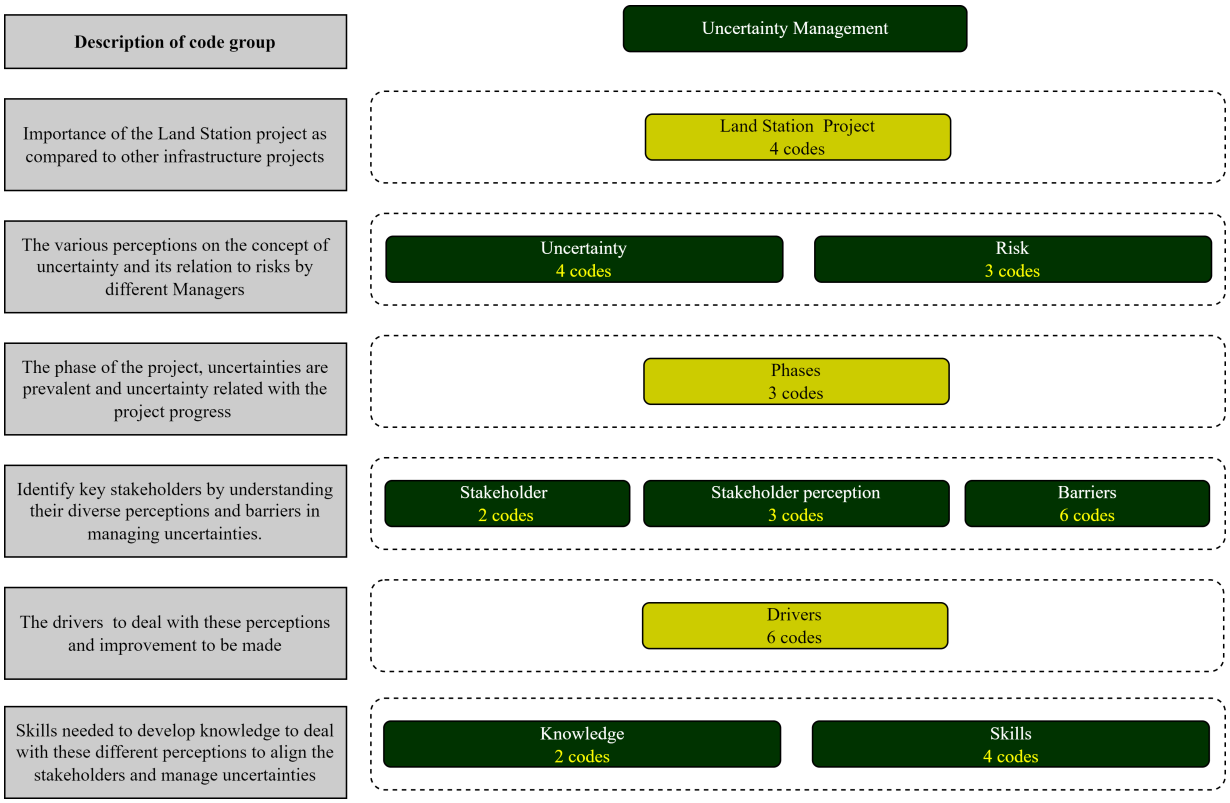


Figure 2.5: Interviews analysis- Coding frame

reasons. First, it aims to reduce the data (Friese (2019)). The 14 interviews produced a large volume of data. Since not all of this information is relevant to the second and third research questions, it is necessary to condense the data and eliminate irrelevant parts. Furthermore, the goal was to organize the data systematically according to the interview questions without conducting a detailed analysis or in-depth interpretation of the results. Another reason for using QCA is its flexibility, as it allows for a combination of data-driven and concept-driven categories within a single coding frame (Flick (2013)). This approach ensures that the coding frame provides a valid description of the data relevant to the research material. QCA involves three main steps: preparation of the interview data for analysis, organization of the data, and reporting the results (Vaismoradi et al. (2013)). The coding frame is constructed using the ATLAS.ti qualitative data analysis software tool ATLAS.ti. This tool is chosen because its design aligns with the QCA process, as it focuses on coding, which is central to building the coding frame (Friese (2019)).

Finally, the findings of the interview analysis were discussed, which involves the examination of theoretical findings in the literature. The theoretical background of the research served as a lens through which the collected data was analyzed, helping situate the results within the existing theory. Consequently, the findings of the literature review were used to discuss the interview results with practitioners. This approach provided a better understanding of the perspectives of practitioners on the concept of uncertainty management and identified gaps between theory and practice. These gaps were considered in the later stages of the research when developing the final framework.

Expert's Discussion

The main objective of the expert discussion is to understand how uncertainties in the Landstation projects, in general, are looked upon and managed. This is achieved in a discussion setting, where participants are invited to brainstorm about the uncertainties associated with the Land Station project. A brainstorming session is organized because the dynamic and interactive character of such a setting stimulates creative thinking among participants through collaborative discussion, which will produce more ideas about types of uncertainty (Pavelin, Pundir and Cham (2014)).

After the interviews, key findings were used to identify gaps, which were then presented to a two-person expert panel consisting of a project manager and a Dura Vermeer team member. Given the limited time available, the session focused on six specific gaps, as shown in Figure 2.6, with two hours allocated to thoroughly discuss each. This session aimed to spark discussion around these gaps, provide a broader context for the findings, and possibly enhance the results. The panel members were asked to share their insights not only from a project-level perspective but also from a broader viewpoint, considering both uncertainty management and involved stakeholders. The preliminary findings supporting these gap statements were shared with experts before the discussion, allowing them to react and contribute meaningfully during the discussion.

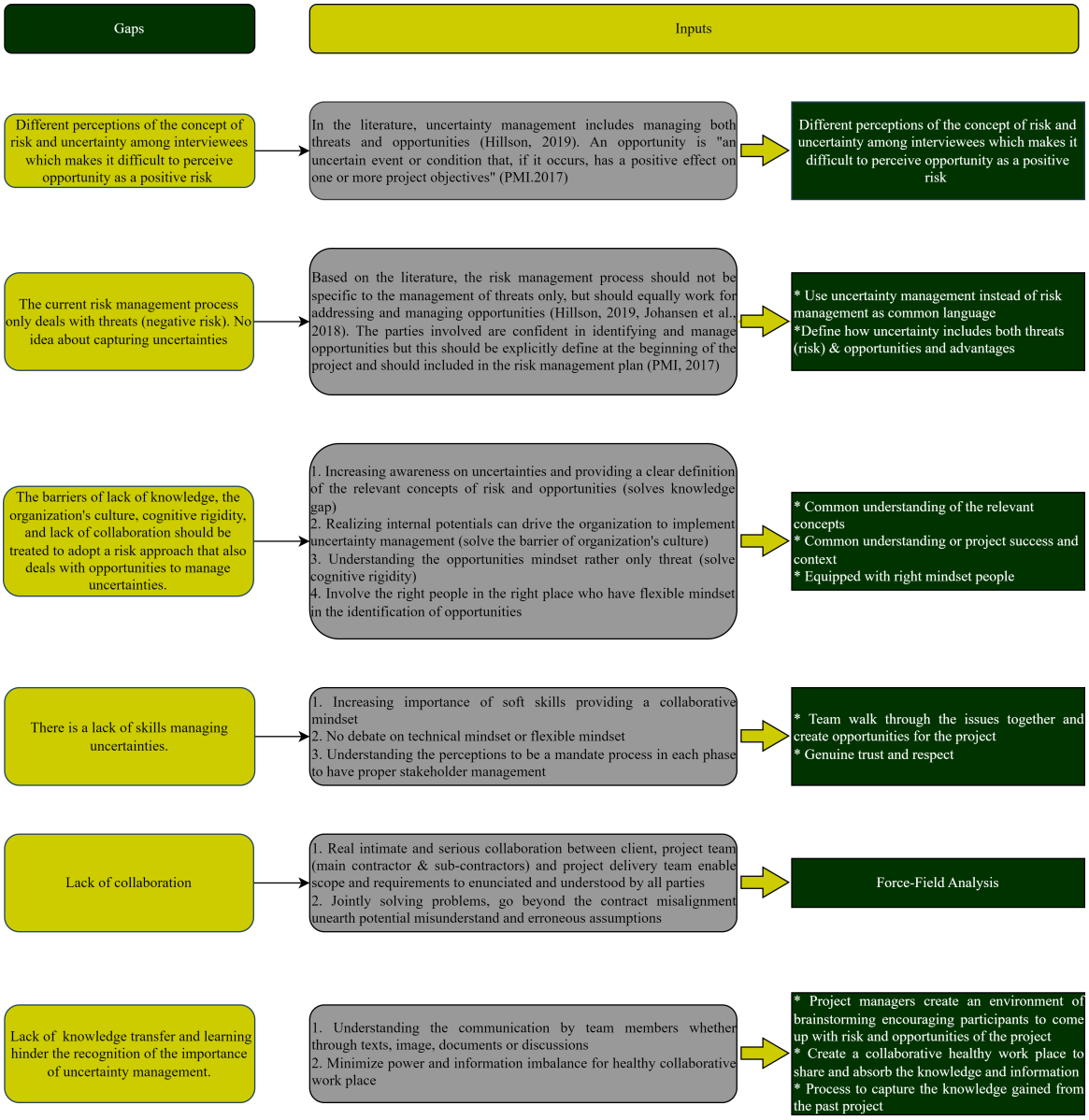


Figure 2.6: Identified Gaps

2.7 Ethical considerations

During research, an important aspect to consider is the issue related to confidentiality and ethics. The interviews were conducted in accordance with the guidelines and ethical obligations for research involving human subjects. Harrop (1982) confidentiality involves "the task of the interviewer to obtain information, often of a highly personal and private nature, from a respondent who is a stranger and may be reluctant to answer questions. Harrop (1982) also emphasizes the importance of build-

ing a strong relationship between the researcher and the interviewees, stating that "the interviewer must communicate trust, reassurance and likability to the respondent to maintain their interest and motivation in the interview." This can be nurtured by adopting ethical behavior.

Permission is required at the start of the interview to record the conversation to develop an environment of trust and to avoid errors in reproducing the data for later analysis based on memory. The data collected from each organization is kept confidential and is not shared with third parties. All confidential data is destroyed after the completion of this report.

2.8 Research Outline

The outline in Figure 2.7 presents an overview of the different chapters of the research report.

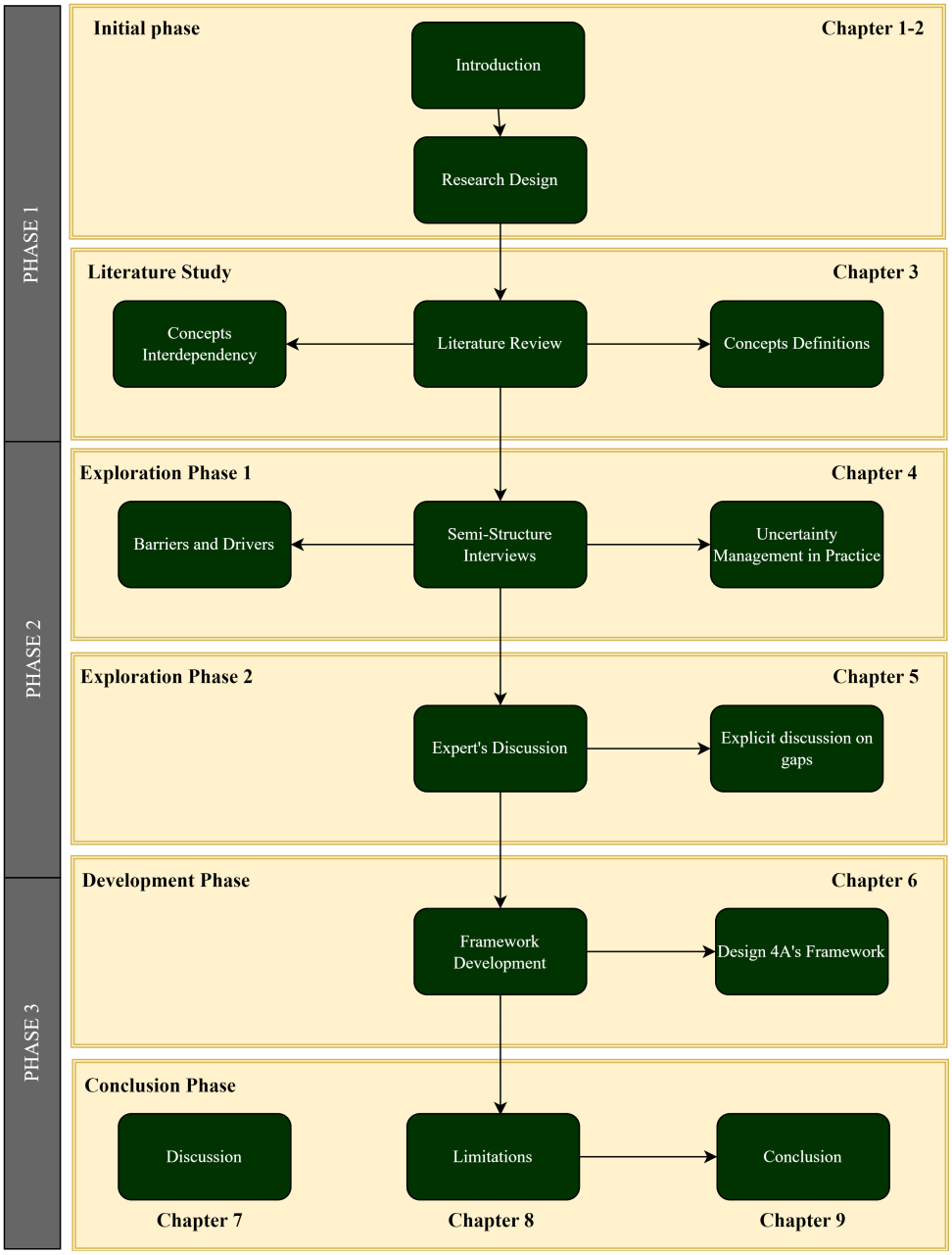


Figure 2.7: Research Outline

Chapter 3

The 2GW Landstation Project

This chapter aims to provide a comprehensive understanding of the Landstation project by focusing on several key aspects. First, it explores the background of the Landstation project to establish a contextual foundation. It then examines the internal organizational structure of Dura Vermeer, focusing on the roles and contributions of the various parties involved in the project. This analysis includes a breakdown of how responsibilities and tasks are distributed throughout the organization, providing insight into the management and execution of such a large-scale project.

In addition, the chapter seeks to understand the current strategies of Dura Vermeer to manage uncertainty within the project. This involves analyzing how the organization identifies, assesses, and mitigates uncertainties that could impact the project outcomes.

The information presented in this chapter is drawn from a variety of internal sources, including documents and presentations. These resources are used to construct a detailed narrative that serves as the basis for subsequent interviews, ensuring that the interviews are informed by a thorough understanding of the project and organizational dynamics.

3.1 Case Selected

The 2GW Landstation project presents an ideal case study for understanding uncertainty management due to its scale, complexity, and the involvement of multiple stakeholders with diverse interests. As a large infrastructure project, it inherently involves numerous uncertainties, ranging from technical challenges and regulatory changes to stakeholder coordination and environmental considerations.

The ambitious goals of the project and cutting-edge technology further add layers of uncertainty, making it a rich environment for studying how these uncertainties are identified, assessed, and managed.

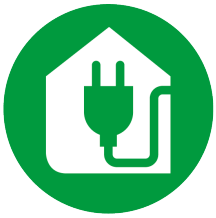
3.2 Introduction to the 2GW Landstation Project

To deliver green energy to the land, there are designated wind energy areas as shown in Figure 3.1.

Figure 3.1: Designated wind areas

The offshore 2GW Landstation project is an energy infrastructure initiative spearheaded by the Dutch Ministry of Economic Affairs and Climate Policy, aligning with the aim of the Paris Climate Agreement to achieve an 80-95% reduction in CO2 emissions by 2050. The European Union acknowledged the rising demand for energy and net-zero challenges, and the answer to this challenge is the European Powerhouse North Sea. This leads the government to define the ambitious offshore energy goals, and those are: 60 GW of offshore wind capacities by 2030 and 300 GW by 2050. As an offshore transmission system operator, TenneT came up with a solution with the 2 gigawatt (GW) Program. By 2050, TenneT aims to bring 70 GW of electricity from offshore sources to land, which will require the construction of approximately 35 Landstations. Most of this electricity will be integrated into the grid through these installations, while a smaller portion will be converted to hydrogen at dedicated hydrogen factories. To achieve this, TenneT has selected Dura Vermeer, BAM Infra Netherlands, and

Visser and Smit Bouw for the civil engineering works involved in constructing the Landstations for the 2GW projects across the Netherlands. TenneT will build at least 14 high-voltage direct current (HVDC) offshore grid connection systems with a transmission capacity of 2 GW each in the Dutch and German North Sea by 2031. Once implemented, they will have the following benefits:



(a) Supply green wind energy up to 35 million households

(b) Deliver a capacity of 28 GW

(c) Deliver a capacity of 28 GW

Project Details

The Landstation station project is located at the Borssele location. According to the new 2GW standard, the generated power from offshore wind farms is brought to land via an HVDC connection. The Landstation forms the link between offshore wind farms and the high-voltage grid. In the Landstation, the direct current is converted to alternating current, and the voltage of 525kV is transformed to 380kV, which makes it suitable for the Dutch high-voltage grid, as shown in Figure 3.3.

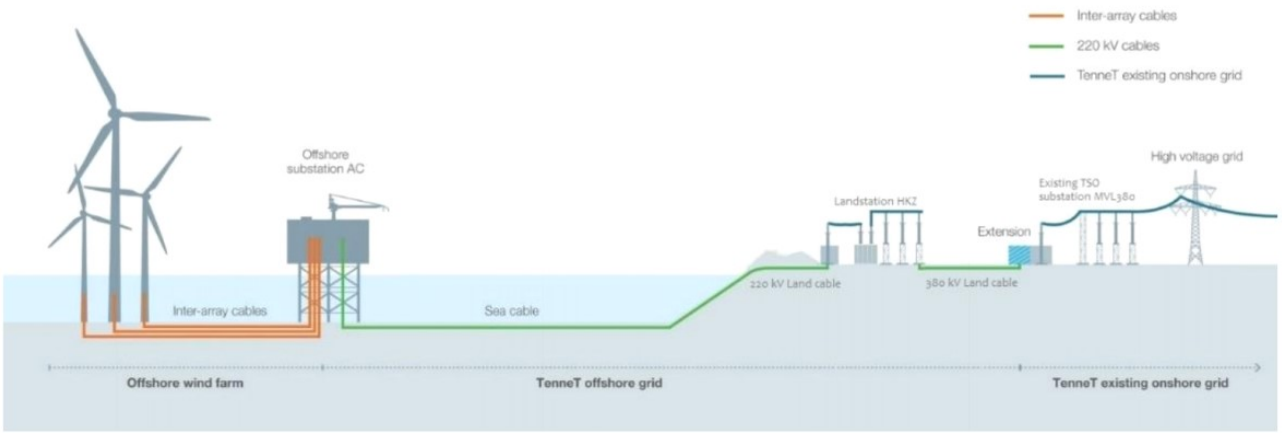


Figure 3.3: Line diagram-Landstation

Dura Vermeer, BAM Infra Netherlands, Visser, and Smit Bouw will realize the civil construction work, building-related installations, and site development. At least eight land stations will be completed by 2030. The civil building of the Landstation is shown in Figure 3.4. This building has 9 different components as shown in the Appendix B.

Dura Vermeer has been awarded the framework agreement for the Offshore Grid - 2GW Land Stations project by TenneT. Under this three-year framework agreement, Dura Vermeer, in collaboration with WSP Engineering, De Kok Staalbouw, and Spie Industries, will develop the Landstation for the IJmuiden Ver Alpha project at the Borssele location. Furthermore, Dura Vermeer has been selected for the construction of additional TenneT Landstations, pending final approval and licensing from the government. Dura Vermeer is responsible for the civil works, buildings, and building-related installations for this Landstation (DuraVermeer (2023)).

Dura Vermeer is a local Dutch construction company that has existed since 1855 with a yearly turnover of 1.8 billion euros. There are more than 3,000 employees. They are into residential construction, non-residential construction, infrastructure, and technology. The core activities include the design, development and realization of construction and infrastructure projects, including management and

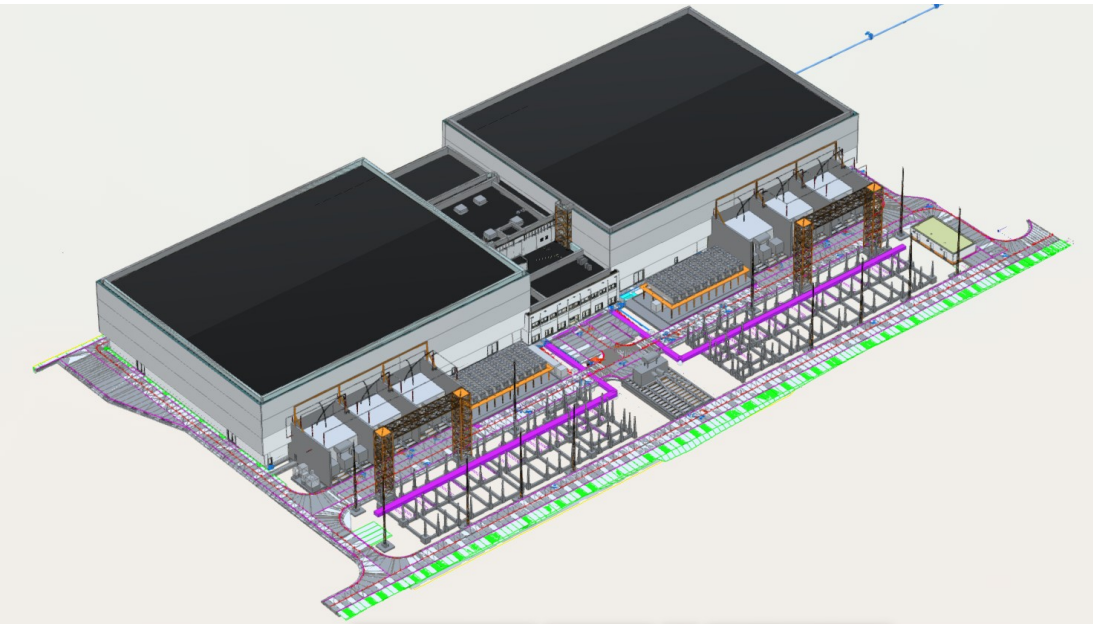


Figure 3.4: 2GW Landstation civil building

maintenance, renovation, and transformation. The 2GW Landstation project falls under their infra-nation projects, less than 100 million euros. Dura Vermeer's Landelijke Projecten department deals with large multidisciplinary projects between 10-100 million euros and has 330 employees. The organization has five divisions as shown in Figure 3.5, which manage various infrastructure projects such as the restoration of bridges, dike reinforcement, dams and pumping stations, and the expansion of high-voltage substations (DuraVermeer (2023)). The 2GW Landstation project also falls into this department.

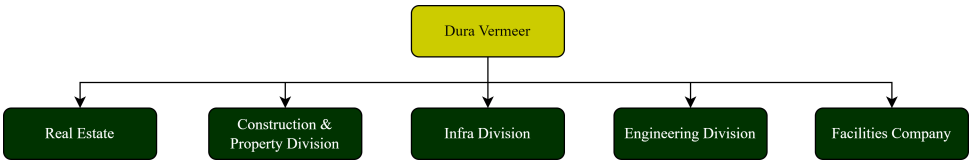


Figure 3.5: Dura Vermeer Divisions, (DuraVermeer (2023))

The following projects are part of the 2GW program:

Party Responsible	Project	Location	Year of Commissioning
Dura Vermeer	IJmuiden Ver Alpha	Borssele	2029
BAM	IJmuiden Ver Beta	Amaliahaven (Maasvlakte)	2028
BAM	IJmuiden Ver Gamma	Amaliahaven (Maasvlakte)	2029
Dura Vermeer	Nederwiek 1	New Station (Borssele)	2030
BAM	Nederwiek 2	Amaliahaven (Maasvlakte)	2030
Dura Vermeer	Nederwiek 3	Amaliahaven (Maasvlakte)	Around 2030
Dura Vermeer	Doordewind 1	Eemshaven Old Ship	Around 2030
Dura Vermeer	Doordewind 2	New Station (Eemshaven)	Around 2030

Table 3.1: Project Timelines

Phases of the project

Figure 3.6 illustrates that the Landstation project has four phases. The first phase is the preliminary design phase, where the basic design is developed as a precursor for the detailed design phase, during which the client will simultaneously take approvals for various permits. The next phase is the detailed design phase, where procurement is carried out in parallel by both the main and subcontractors in

coordination with suppliers. This is followed by the execution design phase, where the detailed civil design is completed, leading to the final execution phase. In addition, site facilities are managed as a parallel activity during the design and execution phases, including the construction of temporary buildings, roads, and other necessary infrastructure.

The project is currently in the detailed design phase, which requires complex and continuous collaboration among all partners. Unfortunately, the project is experiencing delays because the design completion milestone has already passed, causing a delay in the execution design phase. Despite the incomplete design, the execution phase has already begun, creating challenges for the entire team and complicating the project's overall progress.

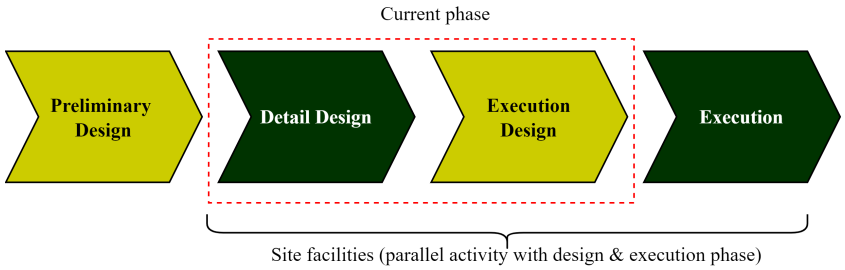


Figure 3.6: Phases of the Landstation project

Stakeholders and their roles

In current project management theory, stakeholders are typically classified as primary or secondary (Rolstadås et.al (2019)). This classification is based on their varying levels of influence over the project. Primary stakeholders are those who can directly affect project decisions and include both internal and external parties. The primary internal stakeholders encompass the project owner and the project organization. However, secondary stakeholders might occasionally exert direct influence on the project, but generally their impact tends to be more indirect. There are three major groups of primary stakeholders:

- The project owner
- The project organization carrying out the project
- External persons or organizations.

Given the scale, complexity, and sensitivity of the project, many excellent design, construction, and consulting firms were invited and worked together in a collaborative environment to build this project. Dura Vermeer is the main civil contractor for the Landstation project, along with Hitachi Energy, who is responsible for technical design and equipment installation. Table 3.2 lists the main participants of the Landstation project organization who will realize the Landstation for the IJmuiden Ver Alpha project in Borssele.

Stakeholder (Companies)	Explanation
TenneT	Client
Dura Vermeer	Main civil contractor responsible for design and execution
Hitachi Energy	Main technical contractor responsible for technical design and installation
Spie	Sub-contractor responsible for building-related services (HVAC, lighting)
De Kok Staalbouw	Sub-contractor responsible for steel design and procurement
Prysmian Group	Main contractor responsible for delivering and offshore installation of the cables
NRG	Main contractor responsible for the onshore installation of the cables (delivered by Prysmian)
WSP Engineering	Sub-contractor responsible for design as consultants

Table 3.2: Main Participants in the Landstation Project

The stakeholders collaborate with the Dura Vermeer project team as partners, acting as a single cohesive unit. Although each stakeholder is responsible for their respective components of the project, they operate collectively towards the project's goals, as detailed in Section 3.2. These stakeholders are vital to the success of the Landstation Project, as each has a distinct and significant role to contribute to the progress of every phase of the project.

The Dura Vermeer project team is responsible for both the design and execution of the Landstation project, as well as overseeing key aspects such as project management, contract management, and technical management. The team is heavily involved in digitization efforts, including the use of 4D models to test for unsafe situations, conducting virtual safety walks, performing interface and clash checks using Augmented Reality, and advancing BIM (Building Information Modeling) practices. They are also piloting projects for 5D development, which integrates cost and time management. In addition, the Dura Vermeer team plays a crucial role in coordinating between the client, TenneT, Hitachi Energy, and other subcontractors. They ensure that the client is kept informed of all ongoing and emerging risks and that the project team aligns with the overall goals and timeline of the project by effectively managing the flow of information and tasks between all parties involved. The project team is structured into three main verticals, each led by a key manager. At the top, the Project Manager oversees the entire 2GW Landstation project, ensuring overall coordination and alignment with project goals. Supporting the Project Manager are two crucial verticals: one led by the Project Management Manager, who is responsible for project control, contracts, risk management, process management, and other critical administrative functions, and the other led by the Technical Manager, who oversees all technical aspects, including systems engineering, safety, and technical disciplines such as civil infrastructure and buildings. Each of these verticals includes specialized roles and discipline leaders who manage specific areas, ensuring that all project components are executed efficiently and meet the required standards.

3.3 Project challenges

As mentioned in the previous section, the Landstation project is currently in both the design and execution phases, with the project team juggling multiple tasks to stay on track with the project milestones. Table 3.3 outlines several uncertainties that are present and require immediate attention.

Uncertainty factors	**Source(s)**
Project scope, schedule, timeline, and cost	Project management
Design maturity and quality	Design
Complete technical understanding and feasibility	Technical
Lack of design information to complete the design	Design
Collaboration among different stakeholders	Stakeholder
Clients are more focused on strategic and contextual risks	Stakeholder
Contract misalignment on milestones	Contract
Lack of experience and experts in the team	Resource availability
Permits, appeals and regulations	Political
Clarity on roles and responsibilities of different stakeholders	Relationships

Table 3.3: Uncertainty factors of the Landstation project

Currently, Dura Vermeer has an established risk management system; however, this system is not entirely sufficient to address all the uncertainty factors listed in Table 3.3. Therefore, effective uncertainty management is crucial to the success of the Landstation project. The lessons learned from this project can be applied to future Landstation projects, helping to standardize processes. As highlighted in the literature review, analyzing the potential outcomes of each uncertainty is vital. This analysis allows risk management strategies to address certain uncertainties, while others can be explored further until uncontrollable situations become manageable.

This situation presents a valuable opportunity to collaborate with the project team (Dura Vermeer and its partners) to gain a deeper understanding of the current challenges and viewpoints and to develop a framework for addressing them. The resulting framework could also be advantageous for other upcoming Landstation projects, as outlined in Chapter 6.

Chapter 4

Literature Study

This chapter lays down the theoretical base for the study, primarily through literature reviews, addressing two key aspects. Initially, it delves into the uncertainty management theory to pinpoint necessary elements for crafting a conceptual framework. Subsequently, it reviews existing literature to discern the ideal state of organizational uncertainty management. Comprehending certain concepts was crucial for grasping the nature of uncertainty. Therefore, the characteristics of infrastructure are detailed in Section 4.1. Following this, Section 4.2 delves into the concepts of uncertainty and risk, elucidating related terms like uncertainty, risk, and opportunity. The connection between infrastructure projects and requisite knowledge and skills is discussed in Section 4.4. The conceptual framework proposed in the study is presented in Section 4.5. Lastly, conclusions are summarized in Section 4.6. The research question tackled in this section is as follows:

SQ1- What is the current state of art in large infrastructure projects?

4.1 Complex Infrastructure Projects

In this section, we explore Complex Infrastructure Projects, focusing on their distinct characteristics and challenges. First, we briefly discuss and examine the nature of infrastructure projects. We then address project complexity, breaking it down into two key areas: the drivers of complexity, which include factors like technical requirements, stakeholder involvement, and regulatory constraints; and the impacts of complexity, which often lead to increased risks, delays, and uncertainties. Finally, we highlight the relationship between complexity and uncertainty, emphasizing the importance of managing these elements for successful project outcomes.

4.1.1 Infrastructure Projects

This research focuses on infrastructure projects, so it is important to begin by defining what infrastructure is. According to Masrom et.al (2015), the infrastructure is the basic physical system of a business, region, or nation. This includes, as illustrated in Figure 4.1: transportation (such as roads, bridges, railways, airports), water systems (including water supply, coastal restoration, sewage and drainage systems, dams), communication networks (telephone and Internet), and energy infrastructure (power grids, power stations, gas pipelines, wind turbines). Investments in these systems are typically costly, but form the basis for economic growth and prosperity (Flyvbjerg (2017)). Over the past decade, there has been a significant increase in the frequency and scale of infrastructure projects. However, many large projects have performed poorly in terms of environmental impact, economic viability, and public support, despite their critical importance. Failures in such megaprojects can lead to the collapse of companies or even governments(Flyvbjerg (2014)). Therefore, it is crucial to improve the performance of infrastructure projects in all aspects, with project risk management a key area of focus.

Figure 4.1: Infrastructures projects

Infrastructure projects are usually classified as complex construction projects characterized by technical, organizational, and environmental complexity (Bosch-Rekveldt, Jongkind, Mooi, Bakker and Verbraeck (2011)). Organizational complexity arises in particular from the need to manage relationships between a large number of actors with multiple interests and objectives (Flyvbjerg (2017)). Consequently, optimizing these projects is a highly complicated process (Abdel-Kader et.al (2022)).

Infrastructure projects are typically commissioned by the government and executed by private companies with the help of multiple contractors to develop and manage the public utilities infrastructure. These mega projects often attract significant public attention due to their substantial impacts on communities, the environment, and local and national government budgets. They play a crucial role in

the economy of a country, as they significantly influence the environment and social life of the areas where they are located (Flyvbjerg (2014).

Large infrastructure projects typically span a long period, often exceeding 10 years from initiation to delivery, making infrastructure projects highly challenging and difficult to succeed (Johansen et.al (2019)). Due to the complexity and constantly changing demands and expectations of clients throughout the project, there is a high level of uncertainty that must be managed through effective project management practices. (Johansen et.al (2019)). These projects are carried out in environments with high uncertainty, ambiguity, and complexity, often under very tight deadlines and budgets (Dunovi et.al (2014)). The complexity of projects has been widely studied in the literature due to its impact on project goals and failure in terms of costs and time overruns, as well as quality issues (Dunovi et.al (2014), Thome et al. (2016). Therefore, it is crucial to study and understand project complexity, which will be explored in detail in the next section.

4.1.2 Project Complexity

The following two quotes highlight the realization of complexity and its importance.

The first one is the statement of the great physicist Stephen Hawking in his Millennium interview in January 2000, which became a widely cited prophecy.

I think the next century will be the century of complexity"

The second one by Steven Strogatz from Sync stated that:

"Every decade or so, a grandiose theory comes along, bearing similar aspirations and often brandishing an ominous-sounding C-name. In the 1960s it was cybernetics. In the '70s it was catastrophe theory. Then came chaos theory in the '80s and complexity theory in the '90s".

The inherent complexity of a project often indicates how much hidden uncertainty exists within it. The level of project complexity is determined by two main factors:

1. the number of project elements;
2. the number and nature of interactions between elements

A large project involves numerous elements, such as various tasks, deliverables, subcontractor inputs, clients expectations and managing a large team. However, this is just one aspect of complexity. The real challenge arises when these elements interact with each other and have significant dependencies. In such cases, a change in one part of the system can have major or unpredictable effects on other parts of the project (Salehi et.al (2022)).

Complexity is a challenging concept in project management that offers many challenges in achieving project objectives (Salehi et.al (2022)). The lack of consensus on the clear definition of project complexity is one of the problems in understanding the concept (Bosch-Rekveldt et al. (2011)). As a result, numerous researchers have proposed different definitions for project complexity (Salehi et.al (2022)). Since there has been a lack of consensus and difficulty in dening complexity, some authors have focused on identifying the factors that contribute to or increase project complexity. Thus, to better understand project complexity, this section aims to first look at the various interpretations of this concept in the literature and then at the drivers of complexity in projects (causes) and the impact that it can have on the project (consequences), as presented in Figure 4.2:

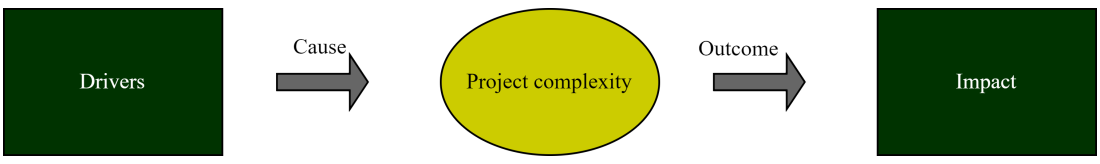


Figure 4.2: Cause-effect relationship of project complexity

The complexity of infrastructure project evaluations focuses on three key aspects: the variety of different elements involved in heterogeneity, uniqueness, and context (Gerrits and Verweij (2018)). 1. Heterogeneity refers to the fact that infrastructure projects involve many different actors, each with their perspectives, values, interests, and goals, which often conflict with one another (Machiels et al. (2023)). This actor heterogeneity is a significant yet often overlooked aspect of project complexity (Bosch-Rekveldt et al. (2011), Zheng et.al (2016)). 2. The second aspect is the uniqueness of each project. Every project is distinct due to specific configurations of physical elements such as cables and pipelines, as well as social and institutional structures such as laws and regulations. This uniqueness limits what can be planned and often means that there is little prior experience with similar projects to guide decisions. 3. The third aspect is context. Infrastructure projects are not isolated; they interact with their surroundings and are influenced by changes in the environment, such as changing ground conditions or changing stakeholder preferences (Gerrits and Verweij (2018). Because contexts are dynamic and often unpredictable, projects cannot fully avoid these influences. The context has a massive impact on the development of projects (Vidal et.al (2008)).

Definition of complexity

Baccarini (1996), as one of the first theorists of project complexity, believes that "project complexity be defined as 'consisting of many varied interrelated parts' and can be operationalized in terms of differentiation and interdependency". In 1999 Edmonds (1999) proposed that complexity is that property of a model, which makes it difficult to formulate its overall behavior. Later on Vidal et.al (2008) defined project complexity as "the property of a project, which makes it difficult to understand, foresee, and keep under control its overall behavior".

When it comes to conceptualizing complexity, Baccarini's work is regarded as the initial attempt within the field of project management. According to Baccarini (1996), complexity can be divided into two main categories: technological complexity and organizational complexity. Technological complexity refers to the number of distinct tasks within a project and their interdependencies, while organizational complexity refers to the large number of organizational units or departments involved and their interactions. Building on this, M Williams et.al (1999) merged the technical and organizational aspects into what he called structural complexity and introduced an additional dimension of complexity, uncertainty goals, and methods, as illustrated in Figure 4.3.

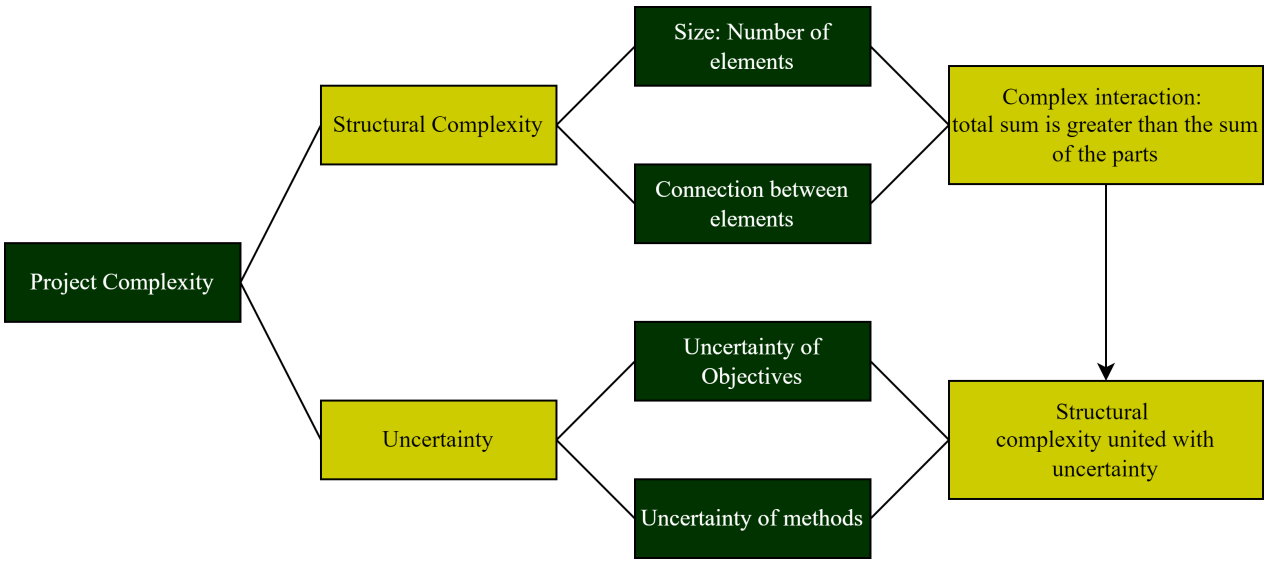


Figure 4.3: Dimensions of Project complexity, (Williams (2017))

The framework developed by Williams was later expanded by (Geraldi, Maylor and Williams (2011)), who introduced additional dimensions such as pace, dynamic, and socio-political complexity. The pace dimension addresses the time pressure driven by the criticality and urgency of scheduled goals.

The dynamic dimension refers to the changes that occur within the project elements, such as goals, specifications, stakeholders, and environmental factors. The socio-political dimension encompasses the emotional aspects related to the behavioral attitudes of stakeholders and the political aspects tied to the project's significance (Geraldi et al. (2011)). More recently, Maylor et.al (2017) further refined these frameworks by merging uncertainty and dynamic dimensions into a single category called emergent complexity and by incorporating the pace dimension into structural complexity.

Researchers continue to introduce new dimensions to project complexity in an effort to enhance the understanding of the concept of complexity. This ongoing exploration highlights that there is no universally accepted definition of project complexity, primarily due to its inherently subjective nature. It is crucial to explore the subjective perspective of project complexity, as perceptions of complexity can vary significantly among individuals (Maylor et.al (2017)). This variation in perception is influenced by various factors, including the experiences and cultural background of the person or project team, the specific context of the project, the availability of resources, stakeholder considerations, the perceived impact of complexity, and numerous other objective and subjective elements (Flyvbjerg (2017)). The following section will discuss the drivers of project complexity.

Drivers of project complexity

Given the lack of consensus on a precise definition of complexity, some researchers have shifted their focus toward identifying the drivers of complexity, as shown in Figure 4.4, or in other words, the factors that contribute to project complexity (Vidal et.al (2008), Bosch-Rekveldt et al. (2011), Geraldi et.al (2007)). The drivers are project size, project variety, project interdependencies within the system, and project-context dependence.

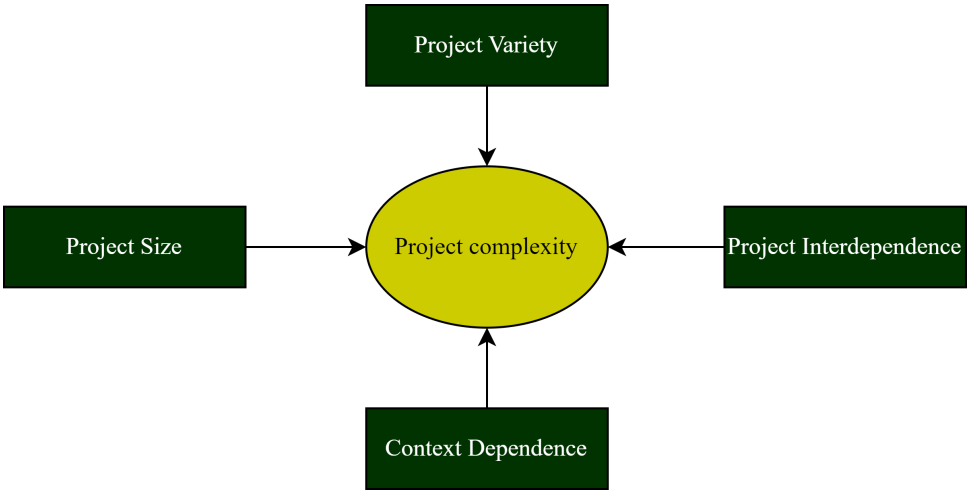


Figure 4.4: Drivers of Project Complexity, (de Nadae et.al (2019))

- Project size- is closely related to the number of elements within the project and is a key factor in determining project complexity. Recent studies suggest that an organizational system must reach a certain minimum size to be considered complex (Corbett et.al (2002)).
- Project Variety- is defined as the diversity of individual elements within the project system and diversity is closely related to the number of emergent properties and is essential for complexity (Corbett et.al (2002)).
- Project interdependence- refers to the relationships between individual elements within the project system, each element affects and is influenced by the others. This aspect is closely related to the functional side of project complexity, focusing on the interactions needed to execute the project (Baccarini (1996)).
- Project-context dependence- refers to the environment in which a project takes place. The practices and context of one project cannot be directly applied to other projects with different

institutional and cultural settings. These differences must be considered in project management and leadership processes (Atkinson et.al (2006)).

Similarly, Remington et.al (2016) identified various drivers of project complexity, including technology, goals, time, stakeholders, management processes, interfaces, interdependencies, and work practices. Additionally, the concept of uncertainty plays a significant role in project complexity. There are two perspectives on the relationship between uncertainty and complexity. Some researchers argue that uncertainty is not a driver but a consequence of complexity (Vidal et.al (2008), Floricel et.al (2016)). Others believe that uncertainty is an inherent part of complexity and contributes to it (Bosch-Rekveldt et al. (2011), Geraldi et.al (2007), M Williams et.al (1999)). The relationship between project complexity and uncertainty will be further explored in Section 4.1.3.

Impact of project complexity

As discussed previously, there is a lack of consensus on the exact definition of project complexity. To gain a better understanding, researchers have explored the factors that contribute to complexity in projects. But why is it important for Project Managers to grasp this concept? Primarily, because complexity is recognized as a characteristic that can potentially affect project outcomes, often negatively (Butler et.al (2020)), and thus leads to a higher likelihood of unknowns. Project complexity affects the management of projects and is thus considered very important in the project management process (Erol, Dikmen, Atasoy and Birgonul (2020)). For instance, it influences project planning and control, and it can have a significant impact on project outcomes such as cost, time, and quality (Denicol et.al (2020)). However, the influence of complexity is not always negative. Positive influences are considered opportunities that result from the complex project environment and negative influences are considered threats that result from the difficulty to control the project. Thus, dealing with the complexity of a project requires the Project Manager and his team to mitigate or reduce the negative impacts of complexity, and to seize and capitalize on the opportunities that emerge from it throughout the project life cycle (Butler et.al (2020)). Managing the complexity of projects is considered to be one of the factors of success in modern project management. In conclusion, the definition of complexity is perceived in different ways among researchers. Many elements in a project can induce or increase the degree of complexity. If not properly managed, this complexity can negatively impact the project. To fully grasp the concept of project complexity, it is essential to define the specific type of complexity discussed in detail. As a result, many researchers have developed categorizations and classifications of project complexity, creating various frameworks that highlight different factors of complexity.

4.1.3 Complexity and Uncertainty

Daniel and Daniel (2018) conducted a comparative analysis of the literature on uncertainty and complexity, revealing several similarities. Initially, the study indicated that the two concepts are often mistaken for each other, concluding that both are considered distinct entities (Daniel et.al (2018)). The general agreement is that uncertainty within a project is frequently linked to its perceived complexity (Daniel et.al (2018); Sommer et al. (2009);M Williams et.al (1999)). As Ward and Chapman (2003) note, the interdependencies of potentially influential factors on the project's course constitute a component of complexity (Ward and Chapman (2003)). While Atkinson et.al (2006) align with this perspective, considering complexity as a component of uncertainty, Geraldi et.al (2007) and Geraldi et al. (2011) propose the opposite viewpoint: uncertainty as a component of complexity. They argue that complexity increases due to the changing circumstances arising from uncertainties (Dunovi et.al (2014)). Furthermore, the literature presents a third viewpoint, suggesting that complexity and uncertainty are independent (Padalkar et.al (2016)).

Having highlighted the ambiguous relationship between complexity and uncertainty in the literature, it is pertinent to dive into the sources of complexity to understand their influence on the level of uncer-

tainty in this context. According to Project Management Institute (2013), the sources of complexity can be categorized into human behavior, system behavior, and ambiguity.

4.2 Risk and Uncertainty: A confusion of terms

Uncertainty and Risk lie along a spectrum, which includes certainty. Despite extensive research, uncertainty remains a challenging and elusive concept. Its inherent nature makes it difficult to define or predict clearly. In project management, the term "uncertainty" is often used vaguely or incorrectly, sometimes referring to different situations, which has led to multiple definitions. This varying interpretation has led to multiple definitions of uncertainty, highlighting the importance of consulting the literature for clarity. The discussion will first examine the various interpretations and perceptions of uncertainty. It will then explore the relationship between complexity and uncertainty, followed by an analysis of the distinction between risk and uncertainty.

The concept of uncertainty has different perceptions and interpretations in the literature, and here are some of its definitions.

- The most cited study presents uncertainty as "the difference between the amount of information required to perform a particular task, and the amount of information already possessed" by the individual (Galbraith (1973)).
- According to the British economist John Keynes, uncertainty is a state in which individual actors find it impossible to attribute a reasonably definite probability to the expected outcome of their choice. In other words, uncertainty for him is a situation when it is impossible to calculate the risk Linder et.al (2003).
- According to the American economist Frank Knight, uncertainty is either epistemic or aleatory. The former is described as an uncertainty that derives from a lack of knowledge and which could be foreseen given more knowledge. The latter is described as an uncertainty that cannot be foreseen and has to do with chance Perminova et.al (2008).
- In psychology, uncertainty is described as a state of mind characterized by a conscious lack of knowledge about the outcomes of an event Bar et. al (2009).

Based on the broader definitions of uncertainty mentioned above, it can be concluded that uncertainty refers to a situation where there is a lack of knowledge and difficulty in assigning a specific probability or predicting an outcome. Risk is essentially a measurable form of uncertainty (known unknowns) via probabilities, while uncertainty is viewed as an immeasurable risk (unknown unknowns). In simpler terms, uncertainty is classified as a risk when it can be measured and assigned a probability (Clegg et.al (2002)). Other structural challenges for practitioners exist at the system level and include complexity and interconnectivity. Understanding the characteristics and scope of these conditions is a crucial first step in developing broader analytical frameworks (Garvey et.al (1999)). Many people still confuse risk with uncertainty, which often leads to premature use of quantitative methods when a qualitative assessment would be more beneficial. This distinction is crucial because quantifying something can give the illusion of precision and validity, even when that level of accuracy is not justified (Garvey et.al (1999)).

Now lets put the concept of uncertainty in the context of projects. Perminova et.al (2008) define uncertainty as a context for risks, as events that have a negative impact on the projects outcomes, or opportunities, as events that have a beneficial impact on project performance. This definition indicates a dual nature of uncertainty in which it can have a negative or positive impact on the projects outcomes.

Figure 4.1 summarizes different traditional perspectives on the concepts of risk and uncertainty.

Risk	Uncertainty
Quantifiable	Unquantifiable
Outcomes are known	Outcomes unknown
Certainly a probability	No probabilistic determination
Controllable	Uncontrollable
May be taken or not	Circumstance must be faced
Predictable loss	Unpredictable damage

Table 4.1: Difference between uncertainty and risk, (Toma et al. (2012))

4.2.1 Uncertainty Types

There are many different ways to classify uncertainty types. For example, Daniel et.al (2018) advocates categorizing them based on their impact, into *foreseen uncertainty, unplanned uncertainty, and chaos*. Another approach is to categorize them based on their sources. Most scholars agree that uncertainty can arise from sources both *internal* and *external* to the project and suggested categories that reflect this concept (O'Hazir et.al (2020). In the context of general project management (Perminova et.al (2008) described the sources of uncertainty as technological, resource, competitive, supplier, consumer, and political uncertainty. Similarly, Ward and Chapman (2003) focused on uncertainties that have a large influence on project management such as design and logistics, objectives and priorities, as well as relationships between project parties. The current literature agrees that a project will typically display a mix of uncertainty types, but lacks any insight into the nature of this mix. Project uncertainty refers to the uncertainty surrounding the goals, defined by the project (Hillson (2019)).

Another source of uncertainty can lie within the organization and refer to its capability to provide or receive the service. Organizational uncertainty originates from outside the project boundaries, yet remains within the boundaries of the organization owning the project. It is related to strategic issues, such as the future direction of the organization, and structural issues such as organizational structure, functions of the different departments, business processes, and reporting (Ward and Chapman (2003)). Organizational uncertainty often originates from changes to the organizational structure or the introduction of new technology and therefore creates job-related uncertainty. The organization might lack the necessary information to complete a task, leading to uncertainty in the task. Uncertainty can also stem from project partners and their relationships, leading to relational uncertainty. This means that the behavior of those involved in the project can be unpredictable. Relational uncertainty goes beyond understanding who the relevant stakeholders are and their influence and interest in the project (Hillson (2019)).

According to Ward and Chapman (2003), it includes the quality and reliability of the work of the partners. It also includes the level of goal alignment, that is, the degree to which the parties objectives are aligned with each other and the overall project goals. This is particularly important when the dependency on project partners for project success is high. It includes trust in the partners' reliability to fulfill the promises and deliver in time to the agreed level of quality.

4.2.2 Nature of Uncertainty

The nature of uncertainty has been distinguished into two types: *Epistemic uncertainty* refers to uncertainty due to lack of knowledge about a phenomenon, therefore a characteristic of the human state of mind which may be reduced by more research, empirical efforts, and experience. The relevant range for assessing the degree of this uncertainty varies between perfect knowledge and total ignorance. *Variability uncertainty* refers to uncertainty due to inherent variability in the phenomenon such as cost, duration, or quality, which can behave in a chaotic manner making it impossible to fully predict outcomes. For instance, imagine that we are trying to predict how long a project will take or how much it will cost. Even if you plan everything carefully, some factors just vary naturally, such as the weather that affects construction or the way different team members work at different speeds. These

natural variations create uncertainty because they cannot be completely controlled or predicted. This is what we call variability uncertainty (Dewulf et.al (2018)).

Uncertainties due to variability

1. Behavioral Variability: This refers to the unpredictability in how people behave, such as when their actions dont match what they say, or when they act differently than usual or expected.
2. Societal Variability: This refers to the unpredictable and chaotic nature of social, economic, and cultural processes. These broad societal factors contribute significantly to uncertainty, as they can change in unexpected ways and impact the project.
3. Technological Surprise: This refers to unexpected new developments or breakthroughs in technology, as well as unforeseen consequences or side effects of existing technologies.

Assessing the nature of uncertainty helps determine how best to address specific uncertainties. For example, with epistemic uncertainty, additional research can enhance our knowledge, leading to better outcomes. However, with variability uncertainty, further research may not necessarily improve the quality of the results because the uncertainty is due to natural and unpredictable variations.

4.2.3 Uncertainty in project phase

Different types of uncertainty impact various phases of the PLC, and similarly, the level of uncertainty changes depending on the phase of the PLC (Atkinson et.al (2006)). Uncertainty has been highlighted as especially important in the earliest phase of the project. In principle, during the exploration phase of the PLC much of the uncertainty is removed by specifying some fundamental parameters, such as cost and project timeline, and by specifying resources and responsibilities. However, much of this uncertainty may remain unresolved until later project phases or even the end of the project (Ward and Chapman (2008)). Atkinson et.al (2006) identified common uncertainties management issues that arise during the different phases of the PLC. Their work indicates that in the early phases of a project, uncertainties are often related to difficulties in defining project goals and performance objectives. In contrast, later phases may experience uncertainties involving project partners, including contractual terms. However, no investigation has been performed on the specific types of uncertainty that occur during the various phases of change projects.

4.2.4 Drivers of uncertainty

The origins and drivers of uncertainty could be categorized into operational, strategic, and contextual risks (Johansen (2015)). The operational uncertainties related to project design and construction are managed by the project team. Uncertainties with strategic origins are business-level uncertainties handled by owners that are out of the control of a project manager. Uncertainties of contextual origin are conditions external to the project, which may have an impact on its process and results, such as war and events with global effects on the whole supply chain (Johansen et.al (2019)). To effectively manage uncertainties with different origins, project managers need a process supported by suitable tools and expert people.

4.3 Uncertainty in projects

Each project is a unique undertaking that requires something that has not been done before; the duration and cost are estimated through educated guesses based on comparable previous tasks. Unpredictability is inherent in any project. It is not something that we can eliminate by planning. Adequate planning can reduce unpredictability, but at some point we must stop planning and start managing the unpredictability. We must learn to live with unpredictability as a normal situation. If properly managed, it can provide opportunities to improve the benefit of the project during execution. Unpre-

dictability in projects is because any project can carry uncertainty. Uncertainty can be understood as a lack of knowledge (Johansen (2015)). As uncertainties may take different forms, there is a need for categorization. Many authors Kim et.al (2017), Johansen et.al (2014) distinguish between four categories of uncertainties:

- Known-knowns In this category, the uncertainty is fully predictable. It can be compared to the spin of the roulette wheel. All information about possible outcomes is fully known. The remaining three categories represent a lack of predictability.
- Known-unknowns In this category, uncertainties are identifiable and expected. It is known as the planners dilemma. As the planned event has not happened, the planner must guess possible outcomes. It is, of course, a guess based on a professional judgment from historical observations.
- Unknown knowns In this category, the available information is incomplete and/ or ambiguous. This is typically the case at decision gates and therefore influences the quality of the decisions to be made.
- Unknown unknowns In this category, uncertainty is unidentifiable and unexpected, called a black swan. If we make a decision associated with uncertainty, the decision may have more than one possible outcome or result (where one specific outcome is our plan or what we aim for when making the decision).

This classification stems from a 2002 speech by Donald Rumsfeld (Rumsfeld (2016), then US Secretary of Defense, where he said: *There are known knowns. There are things we know that we know. There are known unknowns. That is, there are things that we now know we dont know. But there are also unknown unknowns, that is, there are things we do not know we dont know.* ***(Rumsfeld, 2002)***

When deciding on conditions of uncertainty, there can be multiple possible outcomes or results. Among these, one outcome represents our planned or desired result. Figure 4.5 demonstrates this concept: when a decision is made to carry out an activity, uncertainty during the execution phase can impact the process, leading to various potential outcomes, some of which may be known and others unknown. This uncertainty can arise from three different sources:

- Caused by nature
- Caused by man
- Implied by deployed technology

Uncertainty caused by nature spans from rare and extreme events such as major earthquakes to more frequent occurrences such as adverse weather conditions. Uncertainty caused by human actions involves individual behaviors and decision-making processes within or between organizational units. Essentially, this type of uncertainty arises from the actions of the project's stakeholders, whose motivations, reasoning, and business interests might not be fully understood by the project management team. The uncertainty implied by the deployed technology recognizes the potential malfunction of equipment and systems. These issues can originate from design flaws, damage incurred during transport or storage prior to construction, construction errors, insufficient testing, or operational breakdowns. Essentially, technological uncertainties can often be traced back to human error.

4.3.1 Uncertainty Management

Grote et.al (2018) explores the concept of uncertainty in organizational settings and advocates for a broader approach to its management. In today's dynamic environment, organizational culture should adopt a more nuanced understanding of uncertainty that involves both reducing and embracing it. This comprehensive perspective allows for better support in managing uncertainty at both individual and

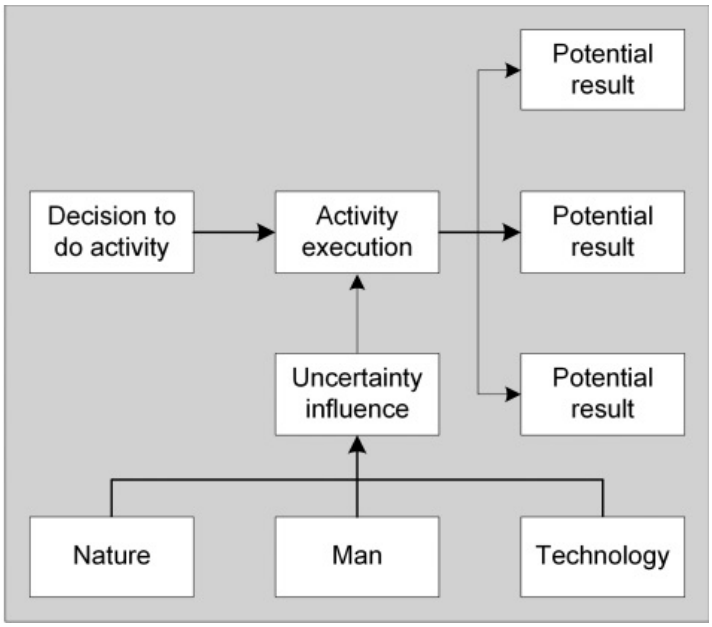


Figure 4.5: Influence of uncertainty on decision-making in a project, (Johansen et.al (2019))

organizational levels. Both internal and external uncertainties must be addressed by organizations, teams, and individuals. Internal uncertainties originate within the organization, including internal processes, culture, and interpersonal dynamics. In contrast, external uncertainties are factors outside the organization that can affect its operations and performance, such as market fluctuations, technological advancements, regulatory changes, and environmental events, which are typically beyond the organization's direct control.

Uncertainty is defined as a lack of knowledge and is related to thoughts (cognitions) and feelings (emotions) experienced in situations where more information is needed to make sound judgments and act effectively. This understanding of uncertainty is further examined through various theoretical frameworks at the individual, team and organizational levels, providing insights into how uncertainty is perceived and managed in different contexts (Grote et.al (2018)).

Individual uncertainty management

Individual uncertainty management involves how people handle situations with unknown outcomes, influenced by both cognitive and emotional factors. Kai-Ineman and Tversky (1979) demonstrates that people are more averse to uncertainty when dealing with gains than when dealing with losses. For instance, individuals prefer a certain smaller gain over an uncertain larger one but are more willing to accept an uncertain larger loss over a definite smaller loss. This reflects a tendency to be risk-averse in positive scenarios and risk-seeking in negative ones. Further exploring the role of emotions, Grote et.al (2018) identified the "pleasure paradox," in which positive moods of individuals persist longer when they remain uncertain about a positive event, suggesting that some forms of uncertainty can enhance emotional experiences.

Lerner et.al (2015) delve into how specific emotions, like fear and anger, influence perceptions of uncertainty. Fear leads to perceptions of low predictability and control, making individuals more cautious in uncertain situations. Conversely, anger generates a sense of high predictability and control, prompting a more decisive response to uncertainty. Moreover, personality traits also significantly influence how people manage uncertainty. For example, tolerance for ambiguity and uncertainty orientation determine an individual's level of comfort with uncertainty. The uncertainty identity theory of Hogg (2007) suggests that people identify with social groups to reduce uncertainty about how to feel, think, and behave. Similarly, the uncertainty management theory of fairness Lind et.al (2002) posits that perceived fairness helps people cope with uncertainty in social contexts. Key aspects of managing uncertainty include creativity, which involves embracing uncertainty to explore new

ideas, and feedback seeking, where individuals gather knowledge to reduce or, at times, increase uncertainty. Moreover, dealing with stress at work often involves managing complex tasks and uncertainties, where having more control can lead to better outcomes and reduce stress (Amabile et.al (2016)).

Uncertainty management in teams

Uncertainty management in teams involves complex dynamics, explored through specific frameworks and studies. Team self-regulation shifts the focus from individual goal setting to a collective effort, where the entire team sets goals and adapts to environmental changes, linking individual self-regulation with team-level processes (G Chen et.al (2006)). This cross-level interaction ensures that individual and team adjustments are aligned in the face of uncertainty. Team adaptation goes further by emphasizing the interaction between teams and their environment, highlighting how teams adjust their functioning during and after disturbances. This involves action phases, where teams implement plans and make necessary adjustments, and transition phases, where teams prepare for future tasks. Beyond immediate responses, adaptation includes long-term adjustments as teams develop routines and learn through daily interactions (D Dionysiou et.al (2013)). Leadership is a critical factor in managing team uncertainty. Traditional leadership, whether transformational or directive, aims to reduce uncertainty by providing clear guidance and purpose. The effectiveness of shared leadership in the management of complex tasks depends on how well a team can balance these evolving dynamics. Diversity in teams has been recognized for its potential to drive innovation by introducing varied knowledge and perspectives into decision-making (Anderson et.al (2014)). However, diversity can also bring about uncertainty, as it may lead to friction and conflicts due to differences in thinking and social categorization, like stereotyping. It has been observed that the presence of diversity can create uncertainty for team members regarding appropriate ways to think and act, which can either hinder or facilitate team performance depending on how it is managed (van Heerden et.al (2023)). According to Hogg (2007), uncertainty-identity theory, team members align themselves with their group as a way to reduce uncertainty. This identification with the group can influence behaviors such as performance monitoring, where individuals closely observe and assess their own and others' contributions to ensure the team's success. By doing so, they seek to maintain group cohesion and reduce any uncertainties related to their role or the team's overall performance Lastly, the concept of voice or speaking up within teams is closely tied to uncertainty management (Grote et.al (2018)). Speaking up is the discretionary communication of ideas or concerns aimed at improving organizational functioning (Morrison, 2011). While it can introduce uncertainty by challenging the status quo or suggesting changes, it is also essential to promote divergent thinking and innovation. The decision to speak up often involves weighing the costs and benefits, and the resulting uncertainty can discourage people from expressing their thoughts, particularly in high-pressure situations where the teams resources are already stretched (Grote et.al (2018)). However, fostering an environment of inclusive leadership and psychological safety can encourage this behavior, allowing teams to benefit from diverse viewpoints and adapt their strategies effectively (G Chen et.al (2006)).

Uncertainty management in organizations

Uncertainty management in organizations is framed by key theories such as contingency theory and organizational control theory. Contingency theory suggests that a rigid, structured approach works well in predictable environments, but in uncertain situations, organizations need to implement flexible designs that enable them to actively adapt to emerging uncertainties (Van de Ven et.al (2013)). Recent developments in contingency thinking suggest that many organizations need to employ mechanisms that both reduce and absorb external uncertainty simultaneously. Furthermore, organizational control theory deals with how managers ensure that employees' efforts are aligned with organizational goals amid uncertainty. Here, uncertainty is inherent in the manager-subordinate relationship, as employees may act in their interests unless guided by control mechanisms (Cardinal et.al (2017)). As uncertainty increases, especially in complex tasks, informal controls, such as frequent personal meetings, gain

importance over formal procedures.

When it comes to innovation, organizations must balance exploitation (using existing knowledge) and exploration (seeking new knowledge). This balance, known as ambidexterity, is crucial in uncertain environments (O'Connor et.al (2013)). Organizational change, by its nature, introduces uncertainty, leading to resistance if not managed properly. Providing people with opportunities to participate in the change process can alleviate this resistance by reducing uncertainty through participation (Grote et.al (2018)). Lastly, paradoxical thinking has emerged as an important concept, where organizations need to manage seemingly contradictory demands, such as being efficient yet adaptable (Schad et.al (2016)). This approach suggests that effective uncertainty management involves not only reducing uncertainty, but also embracing it to navigate the complexities of organizational life.

Johansen et.al (2014) suggested a nine-step uncertainty management process for identifying, analyzing, and following up project uncertainty as illustrated in Figure 4.6. This framework is a process that provides the project team a direction to achieve each milestone for overall uncertainty management.

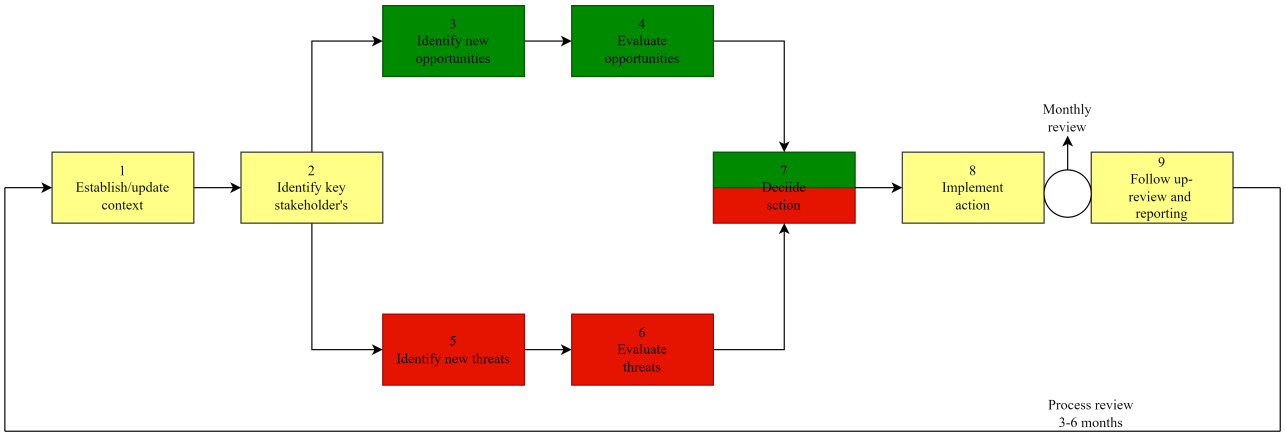


Figure 4.6: Nine step framework for uncertainty management (Johansen et.al (2014))

Steps 1 and 2 are for preparing the process, and Steps 3 to 7 are processes related to groups (workshops) to identify, analyze, and develop measures to exploit or control the uncertainty. The final steps of 8 to 9 are to follow up the uncertainty during the project life cycle. Typically, these steps are performed in a risk register with a matrix consisting of opportunities and risks with a follow-up function. These components are inseparable from uncertainty management practices because they are interdependent and may influence each other. Not knowing them makes the management process difficult or even impossible. This framework also highlighted that the process should be user-friendly and simple for project teams to implement and use in the daily management of the project. Adequate documentation is essential for effective uncertainty management because it facilitates knowledge sharing and provides a reference for future decision making. Collaboration and information exchange among project stakeholders also play a crucial role in the uncertainty management process. The human factor is an important part of uncertainty management (Johansen et.al (2014)).

This nine-step framework will form the foundation for developing the conceptual framework for this research. It provides key components for identifying, analyzing and managing uncertainty, offering valuable insights into uncertainty management. The literature also emphasizes that the successful implementation of these practices requires the involvement of the right people, those with the necessary competence, experience, and attitude. This will serve as the basis for the research.

4.4 Knowledge and Skills for project

Skill refers to the ability to perform a specific task or activity based on integrated knowledge derived from personal experience and mediated learning processes. These processes can include mentoring

from seasoned professionals, the use of technology, established procedures, and other facilitating tools. This approach encompasses both implicit (tacit) and formal (explicit) knowledge. Generic skills are also known as core, key, essential, basic, soft, and key competencies (Hunt et al. (2023)). Some skills can be acquired through observation and practice, while many others require deliberate mentorship. Therefore, individuals in key roles must focus on transferring their knowledge to team members. Developing conceptual skills involves integrating all forms of knowledge, from tacit to explicit, rational to emotional, and spiritual. Since generic skills integrate this comprehensive knowledge, they contribute directly to effective knowledge dynamics management.

Remington et.al (2016) managing complex projects demands a project manager with a distinct set of skills that differ from those required for simpler projects. The successful complex project manager must be able to transform complex areas of the project into elements that are easily understood and realized by the employees. This means that project managers must have the necessary management skills to succeed in the project. Fisher (2011) clarified that six essential skills are crucial for project managers to succeed. First, project managers must demonstrate cooperation, authenticity, and an understanding of the diverse behavioral traits of their team members. Second, effective leadership is a critical skill that enables managers to guide their teams successfully. Third, the ability to influence and motivate the team towards achieving organizational objectives is vital, reflecting the respect of a project manager for individual team members and the acceptance of their unique qualities. Additionally, project managers must be skilled in recognizing and resolving conflicts within the team. Finally, awareness of cultural differences between team members is essential to foster a collaborative and inclusive work environment. Project managers can use various approaches that incorporate social practices for managing project knowledge, including reflection, storytelling, and organizing trainings. Reflection involves engaging in intellectual and emotional activities to explore experiences, leading to new insights. Project managers can uncover new possibilities by reflecting on how they have acted in different situations (Algeo et.al (2016)).

Communities of practice provide a platform where project managers collaborate, fostering shared identities, and supporting social interactions. These communities facilitate knowledge exchange through shared activities and experiences. Storytelling, another key approach, is crucial for the exchange of knowledge. Through stories, essential technical knowledge is often transferred, highlighting the importance of social interaction in knowledge exchange (Algeo et.al (2016)).

4.4.1 Tacit and Explicit Knowledge

Knowledge is now widely recognized as a valuable organizational resource, leading to increased interest in the tacit dimension of knowledge over the past few decades. Unlike explicit knowledge, tacit knowledge is challenging to manage because it cannot be formally communicated and is often embedded within individuals. Despite being relatively unexplored, tacit knowledge has proven crucial for sustaining project performance and maintaining an organization's competitiveness. This has led to a heightened focus on tacit knowledge within the construction industry, where it is essential to achieve optimal value due to the inherent characteristics of the industry. The construction industry is considerably more fragmented than many other industries, and the services offered by these organizations are characterized by being highly tacit knowledge-intensive, with a wide range of partners involved, working as an interdisciplinary team in the execution of a project (Pathirage, Amaratunga and Haigh (2007)).

As a consequence of knowledge being recognized as a valuable organizational resource, organizations are increasingly focused on systematically managing it. Knowledge is generated from data and experience, which are processed into information. Unlike information, which is simply organized data, knowledge goes further by fully utilizing data and information while incorporating people's skills, expertise, ideas, intuition, dedication, and motivation It is necessary to view knowledge based on its final use or its context of use. This perspective highlights that knowledge is a component of a

task-performing system. It represents a state of the system that ensures the completion of the task and allows future repetition of the task (Pathirage et al. (2007)). Knowledge exchange is viewed as a social process based on past experiences, professional perspectives, and specific local conditions. Through interaction, this process systematically identifies, captures, and shares tacit knowledge, transforming it into explicit knowledge. This means that the knowledge people have in their minds is shared with others, making it easier for everyone in the project or organization to access and use. (Algeo et.al (2016)).

Tacit knowledge is derived from individual experiences and is expressed through actions such as evaluations, attitudes, points of view, commitment, and motivation. In contrast, explicit knowledge is codified and documented in organizational manuals, documents, and databases. Knowledge spans a spectrum ranging from tacit to explicit. Since tacit knowledge resides in humans and is deeply personal and often unconscious, it cannot be managed or taught like explicit knowledge. An organization's core competency goes beyond just having explicit knowledge, or "know-what" (theoretical information). It also requires tacit knowledge, or "know-how" (practical skills and experience), to effectively apply that theoretical information in real situations. Social interactions among organization members are crucial to creating new knowledge, as collaboration and communication help refine and generate insights. Information technology and other tools support and sustain these human interactions, acting as enablers rather than primary sources of knowledge. This highlights the importance of encouraging a collaborative culture in organizations to drive innovation and learning. Tacit knowledge is further classified into technical and cognitive dimensions. The technical dimension includes information and skills related to "know-how," while the cognitive dimension involves mental models, beliefs, and values (Pathirage et al. (2007)). Figure 4.7shows the bifurcation of knowledge for easy understanding.

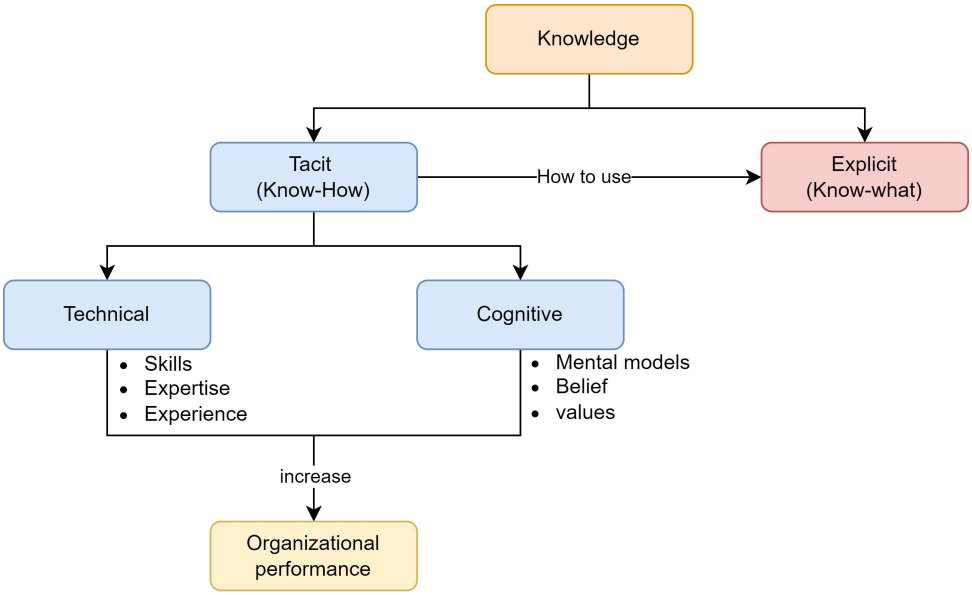


Figure 4.7: Classification of knowledge

Importance of Tacit Knowledge in Construction industry

The construction industry brings together multiple independent firms into a temporary, multidisciplinary organization to create investment goods such as buildings, roads, and bridges. and involves many professionals to complete a project. Construction companies frequently claim that "people are the greatest asset". People are an organization's most valuable asset, being its key resources, but they are also challenging to manage effectively. Managing people is one of the most challenging tasks for organizations that employ a very diverse workforce. This workforce includes individuals from various occupational cultures and backgrounds, such as unskilled laborers, skilled craftsmen, managers, and professionals. The diversity in roles and backgrounds makes it difficult to manage these individuals

effectively. Each group has different needs, motivations, and ways of working, and coordinating them to ensure organizational success is a complex task. Organizations expect people to come with different sets of knowledge and skills. In the construction industry, knowledge varies widely, but there is an increasing emphasis on tacit knowledge due to its labor-intensive nature. Professionals like engineers and architects cannot simply replicate past best practices because each construction project is unique and complex. They must use past experiences to find future solutions. Tacit knowledge, derived from shared practices and experiences, is crucial to project and organizational success. According to Wetherill (2003), knowledge in construction can be categorized into three types, as shown in Table 4.2.

Category	**Explanation**
Domain knowledge	The information available to all companies and is partly stored in electronic databases
Organizational knowledge	Company specific compromises knowledge about personal skills. project experiences of the employees
Project knowledge	Which includes both documented records of the project and the recorded and unrecorded memory of processes, problems, and solutions

Table 4.2: Classification of knowledge in Construction Domain, (Wetherill (2003))

Wetherill (2003) classification reflects the organizational hierarchy and as one transitions from domain knowledge to project knowledge, the focus on knowledge also moves from explicit to tacit nature. The tacit knowledge is developed through the individual or the project teams, while the explicit knowledge is created through processes, procedures, and routines that can be codified. Due to the lack of proper knowledge management, the transition of knowledge did not happen sufficiently and hence most of the time, the project faced challenges. A few of the reasons are explained below by (Beckett and Hyland (2011)).

1. A significant portion of construction knowledge naturally exists in the minds of individuals working in the domain.
2. The intent behind the decisions is often neither recorded nor documented.
3. Individuals with knowledge about the project often move on to other projects after the construction stage, resulting in their input not being captured.

Understanding the bipartite nature of knowledge is crucial because it affects how knowledge is managed, shared, and utilized within organizations. If the significance of both explicit and tacit knowledge isn't fully recognized, valuable insights and skills may be overlooked, leading to inefficiencies and missed opportunities for improvement and innovation.

4.5 Development Model for the Study

Uncertainty is managed by identifying what is not known in advance, analyzing potential consequences, and actively implementing measures to increase control over project development. The effective management of uncertainty in the PLC poses a perpetual challenge (Shabani et.al (2024)). Uncertainty management includes different components, such as human and organizational, processes and tools, and techniques (Johansen (2015), Shabani et.al (2024)). Familiarity with these components and the challenges they present is crucial for managers, engineers, and stakeholders (Agnar et.al (2019)). It equips them with the knowledge and skills necessary to effectively manage uncertainties and contribute to the success of the projects. Recognizing and understanding the different components of uncertainty management (Johansen (2015)) provides valuable insight into uncertainty management practices, helping project managers develop strategies to manage uncertainties in the different phases

of the project. In addition, this understanding helps identify both challenges and enablers for effective uncertainty management. These components are integral to uncertainty management practices because they are interdependent and can influence each other. Without this understanding, managing uncertainty becomes difficult or even impossible.

There are numerous models for uncertainty management (Ward and Chapman (2003), Atkinson et.al (2006), Shabani et.al (2024)). While the availability of these models is not a significant issue, there is a major concern about the lack of focus on the knowledge and skills required to identify and manage uncertainty effectively. Therefore, this section proposes a conceptual model for uncertainty management in infrastructure projects, combining the benefits of the models discussed previously 4.3.1 and considering organizational-specific aspects. Enhancing knowledge about uncertainty factors and management components is essential for developing the competencies needed to handle uncertainty successfully.

4.5.1 Proposed Conceptual Framework

Although the literature may provide some direction, it is ultimately the organizational environment that should determine a suitable management model that fits the purpose (Joseph Galli (2018)). Understanding the nature of uncertainty requires gathering more knowledge about the challenge at hand. Acquiring additional information increases the knowledge about the entire situation. This knowledge can either come from experience referred to as tacit knowledge, as explained in Section 4.4.1, or lessons learned from experience that include both negative and positive outcomes. These lessons might encompass the different and successful actions taken, along with how those methods can be implemented in the current scenario. The right combination of experience and knowledge is crucial in developing the skills needed to handle situations with uncertain outcomes. Knowledge sharing will ultimately enable project members to adapt to new challenges by combining their existing knowledge and skills with the insights they gain during knowledge-sharing sessions. This approach ensures that specific uncertainties are addressed using a combination of technical and management skills.

For this research, the proposed conceptual framework, as shown in Figure 4.8, primarily follows the phases of the nine-step framework described in Section 4.3.1 to outline key components for managing uncertainty. Successfully identifying and managing uncertainty requires an understanding of its sources, components, challenges, and enablers, which can be achieved through relevant experience or by sharing diverse knowledge among project members. This sharing and learning process builds the foundation for developing the competencies needed to manage uncertainty and make informed decisions to reduce its impact. Thus, this framework highlights the importance of knowledge and competence/skills as the foundational elements required for effective uncertainty management, as discussed in Section 4.5. It also helps convert some unknowns into known unknowns, allowing the application of risk strategies. The development of these relevant skills is a key recommendation of this study. Therefore, this research will develop a model that will be integrated into the process to help organizations cultivate the necessary skills to plan effective response strategies. This layered approach emphasizes that uncertainty cannot be managed in isolation; rather, it requires a well-rounded combination of both intellectual resources and practical abilities.

4.6 Conclusion

The purpose of chapter 4 was to answer the first sub-research question:

SQ1- What is the current state of art in large infrastructure projects?

It can be concluded that in the literature, different definitions of uncertainty can be found; however, for this research, uncertainty is defined as a lack of available knowledge or competence about something, and its probability of occurrence and potential outcome are usually unquantifiable and immeasur-

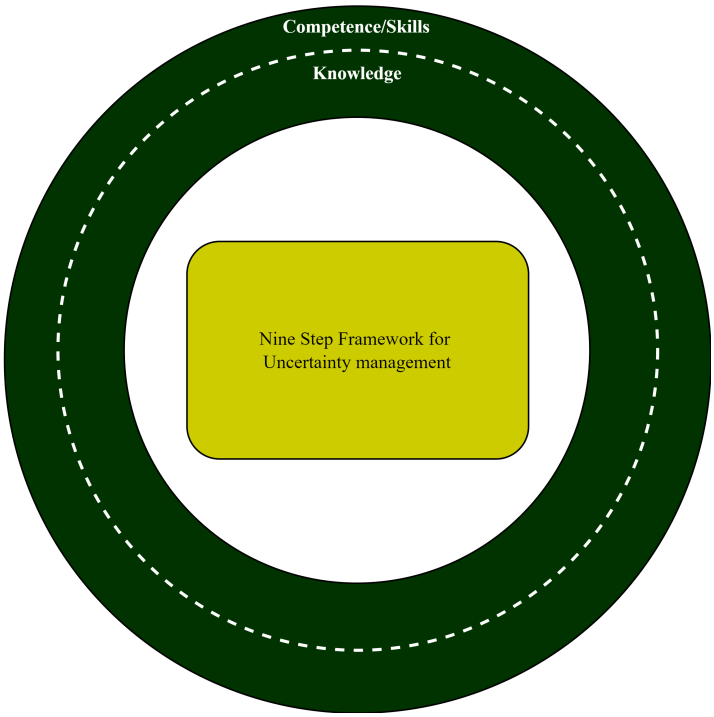


Figure 4.8: Conceptual uncertainty management framework

able. The term uncertainty expresses that the outcome cannot be fully predicted and that there may be alternative outcomes or variations. The consequences of the outcome are not included. Uncertainty can be both positive and negative. This knowledge can be cognitive, emotional, tacit, explicit, and actionable. It can potentially be exchanged through social interaction in a mutually beneficial and systematic manner to achieve a desirable outcome. Practitioners often use the terms "risk" and "uncertainty" interchangeably, but it is important to distinguish between them. Despite the growing need and availability of models specifically for uncertainty management, risk management strategies are still the go-to approach to dealing with uncertainty. However, conventional risk management techniques are inadequate in effectively managing uncertainties, especially related to human factors.

Uncertainty in the project can lead to various potential outcomes, and each potential result impacts the project, including cost, time, or both. As these uncertainties become more defined, they become what is known as known unknowns or risks, where the likelihood of occurrence and the potential impact can be quantified (Jaafari (2001)).In this context, the risk is understood as a subset of uncertainty (Hillson (2003)) that becomes measurable through the application of tacit knowledge (Nesan et.al (2005)). For uncertainty, both the probability of occurrence and the potential impact cannot be quantified (Daniel et.al (2018)). The literature study showed that the sources of uncertainty can be identified as internal or external (O'Hazir et.al (2020)). Internal uncertainties originate from within the organization or the project itself. They are often related to internal processes, team dynamics, and organizational structures. External uncertainties arise from factors outside the organization or the project. These uncertainties are often beyond the direct control of the project team. The classification of uncertainties serves a similar purpose, by focusing on their causes and/or consequences (Zheng et.al (2016)). More specifically, uncertainties are often classified based on their identifiability, potential impact, type and/or amount of available information, and their source. For uncertainties known before occurrence or that occur completely unexpectedly, the responsibility should be assigned to the party most suitable to manage it. As uncertainty develops over time, flexibility is required throughout a project to adapt to changing circumstances and be prepared to modify plans as new information and uncertainties arise. Facilitating team members is another crucial aspect, which includes providing support, resources, and guidance to help them effectively manage their assigned responsibilities.

The role of the project manager is crucial in complex projects, as they lead the team by example and

induce a healthy project culture of knowledge sharing, knowledge seeking, and skill development. Tacit knowledge, gained through experience, is crucial for making calculated decisions when future outcomes are unclear. Therefore, knowledge sharing is essential to motivate the team to better respond to challenges. Additionally, the literature highlights various types and sources of uncertainty, each requiring different key competencies and skills to help team members identify and manage the most critical uncertainties. The organization must develop these skills to build stakeholder trust and confidence in managing uncertainties. Skill development is a continuous learning process; As new information arises, team members must be willing to learn and formulate new solutions, such as scenario building, to address uncertainty.

The literature review reveals that uncertainty in large infrastructure projects is a multifaceted concept that requires a nuanced approach at the individual, team, and organizational levels. The way one looks at the uncertainty makes a difference. Dealing with uncertainty requires innovative solutions; thus organizations should balance exploitation (using existing knowledge) and exploration (seeking new knowledge). Embracing exploration involves being open to altering plans when necessary and acknowledging that uncertainty is an inherent aspect of project development. When identifying and analyzing uncertainty, it is often necessary to consult with a larger portion of the project team to accommodate varying abilities and experiences. A group of five to eight people with different professional backgrounds and experience is likely sufficient to address most of the operational uncertainties of the project (Johansen et.al (2019)). For example, team members experienced in the early phases of a project can pinpoint uncertainties relevant to that stage, while a seasoned contractor can highlight common uncertainties that tend to emerge during the construction and delivery phase. Proximity and relationships are additional factors that affect how we assess uncertainty. To effectively manage uncertainty, it is crucial to go beyond merely addressing apparent threats, opportunities, and their impacts. One must recognize the various underlying sources of uncertainty that shape our perception of it. This entails a thorough investigation of the root causes behind project uncertainty before attempting to manage it, free from biases regarding what is deemed desirable or undesirable.

Table 4.3 summarizes the goals identified in the literature and the exploratory discussion with a technical manager for each content-related aspect of change. These points act as desired goals for uncertainty management and were further discussed in the interview result chapter 5. Additionally, these points are further explored in the interview results to determine whether the interviewees recognize these goals and to identify the barriers that may prevent their achievement.

Goals	**Source(s)**
Understand the subjectivity of uncertainty	Daniel et.al (2018), Hillson (2019), Johansen et.al (2019)
Managing stakeholder perceptions of uncertainty for better relationship	Flyvbjerg (2017), Mok et.al (2015), Machiels et al. (2023)
Redesign process that incorporates uncertainty management	Johansen et.al (2019)
Value creation	Agnar et.al (2019)
Establish best practices in knowledge sharing ('know-what) to develop competence ('know-how') for the right mindset	Lechler et al. (2012), Alshammari et.al (2020)
Possess competencies essential for the uncertainty response	Flyvbjerg (2017), Hillson (2019)

Table 4.3: Desired goals identified from literature

Table 4.4 summarizes the strategies identified in the literature for managing uncertainty. These strategies will be discussed further and how they are used in the framework development outlined

in Chapter 6.

Strategies	**Effects**	**Effect Source(s)**
Perception-based management (Kool et.al (2017))	Awareness of different perceptions, Shared mental model, Proximity and relationships, Group cohesion and extremism, Define the concept	Johansen et.al (2014), Hogg (2007), Bosch-Rekveldt et al. (2011)
Interactive management (Hertogh.et.al (2008))	Brainstorming, Shared mental model, Learning, Lesson Learnt	Johansen (2015), Bosch-Rekveldt et al. (2011)
Adaptive management (Kool et.al (2017))	Self and group regulation, Team adaptation	Grote et.al (2018), Agnar et.al (2019)

Table 4.4: strategies for Uncertainty Management

Chapter 5

Result Exploration Phase 1: Interviews

This chapter presents the findings from the exploration phase, during which interviews were conducted with professionals. These interviews identified various perspectives on uncertainty among practitioners, as well as identified both enablers and core challenges for uncertainty management. These insights are crucial for shifting the project team's mindset from a risk-based approach to an uncertainty-focused approach, intending to improve project performance in large infrastructure projects like the Landstation project. The interview findings are discussed in Section 5.2.

5.1 Organizational context for Uncertainty Management

Investigations into Dura Vermeer's organizational context regarding uncertainty management practices were presented in Chapter 3. The interviews revealed that the project team recognized the idea of uncertainty management subconsciously but failed to manage it effectively. These central issues serve as barriers, offering insights into the current state of uncertainty management and identifying potential catalysts for change within the Dura Vermeer project team.

5.1.1 Core issues for Uncertainty Management

The following barriers were commonly pointed out in interviews.

- **Lack of awareness of Uncertainty Vs. Risk**
  One of the core barriers identified is the lack of awareness of the distinction between uncertainty and risk. Although organizations like Dura Vermeer often have solid risk management systems in place and apply them effectively within projects, they tend to address uncertainties through the same lens as risks. In doing so, uncertainties are often redefined or treated as risks, without a conscious acknowledgment of their true nature. Risk management typically deals with the knowns and unknowns, but the real uncertainties, those that cannot be fully anticipated, are overlooked. This leads to a misconception, as many believe that by addressing unforeseen risks, they are managing uncertainties when, in reality, they are not fully aware of the fundamental differences. This lack of distinction between uncertainty and risk represents a critical barrier to effective uncertainty management within the organization.

- **Risk-Oriented Mindset**
  The risk-oriented mindset of Dura Vermeer managers has been identified as a significant barrier, as highlighted in both the literature and interviews. The immediate reaction to any challenge is to view it as a risk, often associating it with cost, time, and quality concerns, without considering that the challenge might require a different strategy or approach. This mindset has been deeply ingrained in the practices of the construction industry for ages. As a result, when a project demands that uncertainty be managed differently, it becomes difficult for the team to step out of their comfort zones and address these situations effectively.

- **Differing expectations and Perspectives**
  In the Landstation project, the Dura Vermeer team faces significant challenges related to uncertainty, resulting from the differing expectations and perspectives of key stakeholders, including TenneT, Hitachi, WSP, and internal teams. Uncertainty management becomes particularly difficult when stakeholders, such as TenneT, demand detailed information and certainty in scenarios where unpredictability is inherent. This constant push for more information creates inefficiencies, as the Dura Vermeer team is forced to focus on delivering details, although no amount of data can eliminate the uncertainty involved in large-scale projects like this. The misalignment between contractors on timelines, expectations, and deliverables further exacerbates uncertainty. For example, Hitachis reluctance to provide timely design information due to contractual constraints has increased uncertainty in the Dura Vermeer design phase, resulting in repeated reworks and design adjustments. These delays introduce more uncertainty, as project execution is continuously affected by shifts in stakeholder inputs and deliverables. These differences create communication barriers, leading to gaps between "what gets said and what gets done", which contributes to an atmosphere of uncertainty. To address this, it is crucial to develop a method that facilitates mutual understanding between all parties, helps identify differences and potential problems, and provides solutions to effectively resolve these issues.

- **Lack of knowledge and competence**
  Another core issue at Dura Vermeer is the team's lack of knowledge and competence in man-

aging uncertainties. As highlighted in the interviews, the team often struggles to predict or address uncertainties effectively due to missing data and insufficient knowledge. Even when uncertainties are recognized, the team lacks the necessary skills to handle them in a structured way, leading to ongoing challenges. Develop essential competencies for managing unknowns. There is a shortage of specialists and operations-level employees needed to lead these unknown scenarios. Existing employees are often preoccupied with other tasks, causing them to overlook uncertain goals. From technical to management competence, a balance is needed to manage the unknowns and foster confidence in seeing uncertainty differently.

- **Lack of practical experience**
  Not all members of the project team have sufficient practical experience in managing uncertainties. Even those with relevant experience often struggle to effectively share their knowledge with others. Without this knowledge transfer, team members may not fully understand the specific requirements of uncertain situations. This gap in knowledge sharing reduces the motivation of the team to actively consider different outcomes. Even when they try to anticipate scenarios, they often feel uncertain about which skills or competencies to apply. Without clear guidance or shared expertise, team members are left guessing about the best course of action, which can result in applying the wrong approach or hesitating to act. Consequently, managing uncertainty becomes an added burden rather than a natural part of the project, hindering the teams ability to address it effectively.

- **Lack of Managerial Flexibility and Commitment**
  Although there is awareness at strategic levels, the project team often lacks clear directives from management to focus on uncertainty. Leaders may be uncertain about how to make decisions related to uncertainty, which results in a lack of responsibility toward addressing it. As a consequence, uncertainty is frequently overlooked

5.1.2 Enablers for Management of Uncertainty

The most favorable drivers identified to accelerate the management of uncertainty within the context of the Landstation project were:

- Long-Term Relationship Vision Among Partners: Dura Vermeer and its associate partners are working with a long-term mindset, looking ahead to build another 6-8 Landstations over the next decade or more. This forward-thinking approach encourages organizations to be better prepared for managing uncertainty. Embracing the "design-one, build-many" concept, the planning strengths of the team can be leveraged to effectively manage uncertainties, ensuring that they are well-equipped for future challenges.

  the whole project of Land stations gets completed by 2030. The project has a total of 8 Land Stations but Dura Vermeer makes 5. So, we are also associated with 5 and the last of these five will be completed by 2030".[PM13]

- Market Leadership and Long-Term Sustainability- The strategic goal of building a strong foundation for Dura Vermeers energy division and securing the companys future over the next 15 years drives the necessity for effective uncertainty management. Ensuring the success and continuity of the Landstation project is essential to achieving these long-term objectives.

  "I believe this is one of the best opportunities for Dura Vermeer to build a solid foundation for the energy division over the next 15 years. With this, we have a very good contract in place." [PM4]

- Exposure to gain knowledge and competence- This Landstation project has never been built before, hence being a part of this project will give a platform to all involved parties a plethora of exposure to gain new knowledge and competence, which will eventually make them market

players. This experience will ultimately position them as market players, strengthening their competitive edge in future projects.

"This is the first time it's being done worldwide, and the kilowatt program is not well-known globally, especially for offshore purposes." [PM11]

- A close-knit network among partners- drives effective uncertainty management by fostering strong communication, trust, and collaboration. This network encourages the sharing of resources and expertise, making it easier to address challenges as they arise. Additionally, with aligned goals and priorities, the partners can adapt quickly to new uncertainties. The close connections also make it easier to shift mindsets across the networkonce one team adopts effective uncertainty management practices, others are likely to follow, creating a snowball effect that enhances overall project resilience.

5.2 Interviews Findings

Lack of awareness between risk and uncertainty

The initial phase of interview questions aims to understand the views of the interviewees on the concept of uncertainty, which is crucial, as it reveals the common perceptions and practices within the organization. Table C.1 shows the different definitions of uncertainty discussed during the interview. It shows that most interviewees do not distinguish between uncertainty and risk, often using the terms interchangeably. Despite theoretical differences, both concepts are managed similarly in practice. Recognizing these shared perceptions helps in comprehending how uncertainty is viewed based on their roles are further interpreted in the discussion part.

From the interview, it was found that awareness about uncertainty is missing and that not everyone has a clear definition of uncertainty. The definition of uncertainty is inconsistent among interviewees.

"Uncertainty is a risk and an opportunity" [PM13]

"Uncertainty is identified by analyzing all received data, hence not every risk is in the uncertainty, but every uncertainty is a risk" [PM1]

Notably, 60% interviewees mentioned that they do not distinguish between uncertainty and risk in their work. Interviews with project managers revealed that even those who claim to differentiate between the two terms often do not in practice. This conclusion is drawn from the frequent interchangeable use of "risk" and "uncertainty," aligning with theories (Zheng et.al (2016), Koleczko (2012)). However, most of the interviewees indicated that within Dura Vermeer, uncertainties are treated as risks in practice. Consequently, they are not considered separate concepts and are not managed differently. Risks are seen as manageable through specific actions by 53% of interviewees, whereas uncertainties are viewed as unpredictable events that occur without warning. In this context, 57% specifically referred to these as unknown unknowns. Based on the interview results, the relationship between uncertainty and risk was difficult to pinpoint. When asked directly about the differences, most interviewees could explain their views. Throughout the interviews, it became evident that the discussions about uncertainties frequently circled back to risks. However, only a few participants agreed that uncertainty could not be managed with traditional risk management strategies.

"Risk and uncertainty are different. What we don't handle them separately". [PM4]

"Uncertainty refers to an event that cannot be predicted or foreseen, making it difficult to manage with standard risk management strategies". [PM11]

"Risk and uncertainty are recognized as different but are managed together without distinct strategies for each".[PM4]

Additionally, project managers appeared more relaxed when discussing uncertainty, believing that pondering about unknowns is a waste of time. In contrast, they were more proactive and engaged in discussing risks and risk management. This indicates that while risk is considered a subset of uncertainty, the approach to handling each differs significantly. It was also evident that risk is a subset of uncertainty, indicating that all risks are forms of uncertainty, but not all uncertainties qualify as risks. Within the group of interviewees, opportunities were mentioned a few times that referenced client satisfaction, value creation, and strategic partnerships. These concepts aim to encourage the pursuit of opportunities. This observation highlights a difference between interviewees in recognizing the positive aspects of uncertainty. Although some tend to see the potential benefits and opportunities that can arise from uncertainty (such as financial, long-term relationships, and innovation), others may not recognize these positive elements as readily.

"Like I said, uncertainty is like a coinone side is risk, and the other side is opportunity." PM13

"Thats for scheduling opportunities because you get more time. After all, secondary steel is not that important to them most of the time, and you get a financial opportunity because they pay you more for installing it later. Thats something thats a win-win for both the customer and us." [PM13]

As mentioned above, one conclusion from the interviews is that uncertainty management is not actively practiced within Dura Vermeer. Uncertainties are not classified at all. Currently, classification is only done for risks and is based on the level of risk. Retrospectively, classifications can be made based on financial impact or the degree of project success achieved. Depending on the risk category, priorities are set and communicated to project and technical managers. In the first part of the interviews, the interviewees were asked about the difference between uncertainty and risk and identified several characteristics of uncertainty that could be used effectively for classification purposes. Some comments from the interviewees were as follows:

If you don't manage your uncertainties well, they can become risks, mostly financial or schedule-relatedsometimes safety-related, but mostly financial. However, if you manage your uncertainties effectively, they don't become risks; instead, they become opportunities. By identifying them early and discussing them with the customer, you can gain more time in your schedule, create financial opportunities, and deliver a better product [PM13]

Multi stakeholder perspectives and expectations

The interviewees also highlighted that the Landstation project is considered complex due to the participation of multiple stakeholders with differing perceptions, driven by their different goals and interests. We identified a problem loop: As complexity increases, uncertainty becomes more likely. The interviewees stressed that uncertainties arising from differing stakeholder perceptions cannot be managed by traditional risk management strategies alone, but must be handled differently. This should involve stakeholder alignment to encourage better dialogue and reduce collaboration-related uncertainties. The ultimate goal is to manage or avoid these uncertainties to prevent misalignment, mismanaged expectations, miscommunication, and trust issues among the involved parties. Therefore, the next phase of the interview focused on the attitudes and expectations of the parties involved.

The interview focused on the stakeholders and was intended to uncover the reasons for their behavior. Although different stakeholders work toward the same goal, each stakeholder has different interests, leading to varying perspectives on the project goals.

"Because they have different interests and goals. For example, TenneT's goal is to finish the project on time, while for the next contractor, Hitachi, the goal is to build a high-quality land station that fits within the budget, even if it takes more time."[PM5]

The interview findings revealed that two key stakeholders, Hitachi, responsible for the technical design, had a significant impact during the design phase of the project. Hitachis flow of informa-

tion was unstable due to contractual milestone misalignment with the client, TenneT. Furthermore, Hitachi maintained a rigid contractual mindset, further complicating the situation. Compounding these issues, Hitachi frequently introduced new information and requested changes, leading to confusion among subcontractors and necessitating frequent design revisions. This cycle of rework created increased pressure, instability, and a high degree of uncertainty within the project.

"The completion of the land station, specifically the civil part, was originally planned for 2026. However, due to the lack of information from Hitachi, many design aspects remain uncertain, making it impossible to finish the design on time and proceed with construction. As a result, we see that this milestone is not achievable".[PM5]

Interviewee PM7 states that at the beginning, we were very ambitious about incorporating CSR (Corporate social responsibility) and sustainability measures, such as using green steel and ensuring the best ecological practices and human rights standards. There were high ambitions. However, these goals may not be achievable now due to pressure to meet deadlines. There's little time to consider these aspects, and if there's insufficient funding, there's less willingness to invest in greener solutions. The project timeline is tightening each day, so some considerations might revert to traditional building construction.

"In the beginning, they were very ambitious, focusing on CSR initiatives like sustainability measures, ensuring the use of green steel, the best ecological practices, and upholding human rights. There were very high ambitions in these areas. However, those ambitions may not be achievable now because they are prioritizing meeting deadlines. There isn't much time to consider these factors, and if they lack sufficient funds, they are less willing to invest in greener solutions, leading us back to traditional building methods."[PM7]

During the design phase of the Landstation project, most complications arise from the involvement of multiple stakeholders, both internal and external. For Dura Vermeer, the current issue lies with the internal project team's differing perceptions, creating uncertainty. For example, some internal stakeholders focus solely on profit and milestones, while the client prioritizes the overall completion of the project without aligning all parties to collaborate effectively.

"In the initial phase of the project there are a lot of uncertainties because a lot of parties are involved from a different organization like WSP, Spie, De Kok, etc" [PM9]

Furthermore, 60% of the interviewees pointed out that a strict contractual mindset destabilizes the information flow, leading to delays and inflexibility.

Therefore, the more stakeholders with different perspectives involved in the project, the higher the probability of uncertainty, as identified by 86.6% of the participants. In addition, this uncertainty impacts the stakeholders themselves. Thus, the involvement of multiple stakeholders with varying perceptions contributes to the complexity of the project. This complexity, in turn, further increases the uncertainty.

This includes the influenceability of uncertainty; for instance, creating a categorization based on low and high influenceability could be interesting when deciding on the approaches for specific uncertainties. For example, if the main contractor is resistant to sharing information due to contractual obligations, the influenceability is low. Due to the strict adherence of the contractor to the milestones set in the contract, it is difficult to complete the design. In this case, the team might need to develop an alternative response.

Another characteristic that came up was the quantifiability of uncertainty. If an uncertainty is quantifiable, the question arises: How precisely can it be measured? In other words, how uncertain is the uncertainty? For example, an interviewee mentioned that they got a design change to increase the floor thickness by 10 cm to accommodate the ducts as an optimized design change. However, the

request for this change came too late in the process. The uncertainties related to this change, such as the cost implications, the delay in design completion, and structural impacts, can be quantified. This quantifiable data then allows the project team to make an informed decision on whether to proceed with the change or not.

I think it's very important for these kinds of processes to allow engineers and design managers to clearly understand the impact of even small design changes on the overall design phase. For example, being able to see how changing the thickness of a floor by just a few centimeters affects the entire process.[PM11]

Also subjectivity, the interviewees pointed out that stakeholder perceptions are inherently subjective, varying greatly between individuals based on their experiences, biases, and interests. For example, an interviewee mentioned a scenario in which a contractor did not share crucial information needed for design because their focus was solely on meeting their milestones rather than considering the overall needs of the project. Understanding these subjective differences allows the project team to foresee uncertainties more clearly and discuss them with the client, enabling the development of more effective strategies to manage these perceptions.

Lack of knowledge and skill sets

This section described the pressing need for knowledge to distinguish between risk and uncertainty. Developing this understanding is essential for building relevant competencies to manage them differently. From the interviews, it became clear that Dura Vermeer has a well-established and solid risk management system, but does not explicitly address uncertainty. The project team has demonstrated competence in dealing with known and foreseeable risks, as they are adept at applying structured risk management practices. However, this expertise tends to focus primarily on managing risks that are well defined, while uncertainties that are more unpredictable and harder to foresee are often not distinguished clearly from risks.

One of the interviewees highlighted that the team needs to become more accurate and confident in applying risk strategies. This would allow them to convert some uncertain situations into more predictable ones and successfully implement risk management techniques. By streamlining the risk resolution process, the team can allocate more time and focus to effectively managing uncertainties.

"I think the team can do better in risk management. We need to focus on improving how we handle the risk management part because, for me, all uncertainties are actionable risks."[PM1]

Although the employees involved in the project possess strong technical skills, there is a clear need for interdisciplinary capabilities. Uncertainty can arise from various aspects of the project, whether due to technical challenges or the unpredictable behavior of stakeholders. Identifying the key skills required to manage these uncertainties and determining how to develop them is the focus of Section 5.3. The project concept is new and involves the use of complex cutting-edge technology, which requires a different approach to acquiring and refining the necessary knowledge and skills.

"Our project is unique in the high-voltage world because we have chosen an ultra-high voltage. Companies like Hitachi, Siemens, and others in the high-voltage industry must develop state-of-the-art equipment, including for this sea cable, to carry an ultra-high voltage of 525 kV. This type of cable has never been produced before. As a result, all tests are currently underway to verify if the cable system can withstand such high voltage." [PM9]

Furthermore, the novel aspect of the project introduces uncertainty about the understanding of the technical components. Despite having many partners involved who are interdependent, there is limited experience with some of the new technologies, resulting in a lack of knowledge. About 50% of the interviewees described uncertainty about the know-how of the processes. When enough new information arises, they must be willing to learn and then formulate new solutions. while 40% high-

lighted that excessive optimization efforts lead to unforeseen changes and additional costs. The lessons learned are also crucial in identifying uncertainties, as most of the interviewees agreed that the experience gained from these lessons benefits the project. Learning from events with unexpected and unfavorable outcomes helps reduce the likelihood of repeating such incidents.

Continuing the conversation, the final phase of the open-ended question focused on identifying the most critical success factors for the Landstation project and determining which improvements could improve performance. Almost 100% of the interviewees agreed that there is a lack of expertise and competencies needed to understand the people involved in the project and their perceptions. The discussion also explored the types of skills that were deemed necessary within the team to ensure satisfaction and reduce stress. The interviewees emphasized the importance of various soft skills, which are essential in an interdisciplinary project environment. Several quotations provided further clarity. These skills are essential for inducing personal connections, which benefit the project by creating a healthy work environment where employees can collaborate effectively and understand each other's perspectives and urgency. A total of 12 skills illustrated in the Appendix E. are dominated throughout the conversation and after a few points, the skills were repetitive. The top five skills are mentioned below:

1. Openness *"For me, listening is always very important. It's crucial to listen to the other party to understand their perspective".* [PM4] [PM5] [PM6] [PM9]
2. Communication- *"You must understand the client. So that's really when you talk about perspective, that you don't only consider your perspective, but especially consider the perspective of the client. So if you understand the decision-making of the client, that will help you get things done"* [PM6] [PM7] [PM8] [PM9]
3. Proactive

   "You have to be proactive" [PM12]

   "Its formalized in recognizing when there are too few people for certain types of jobs, which requires being proactive." [PM15]
4. Empathy

   "Knowing each other well helps a lot" [PM13]
5. Flexibility

   "I think one of the skills you need is" [PM11]

Some of the use cases of these skills mentioned were also discussed by the interviewees. The use cases mentioned by the interviewees are listed below.

- PM1- Helps you better understand the expectations of various parties in the current project, leading to more effective management.
- PM 2- Gives more peace of mind because you know you are busy with the right things. Peaceful dynamics of the project.
- PM 3- You can discuss concerns with each other based on knowledge but not on misjudgments.
- PM 4- Gives you an insight into the client's needs and interests.
- PM 5- A long-term commitment to each other.
- PM 6- Building trust, for example, if all the uncertainties are indicated in the pricing, you will make it very clear and thorough. This will also mitigate the main uncertainty or main risk of financial losses.

- PM 7- Define what's necessary and define the paths to establish the boundary conditions so that both parties can continue with the least mismatch later on.
- PM8- Less iteration to the design and the design will be complete within the timeline and the project can go to the next phase.

The skills mentioned above are soft skills that were rated as the most relevant between clients and contractors. Delving deeper into the interview data, the study observed the following how, when, and for whom the skills are relevant to support performance. Few quotes indicate the relevancy; below are the points to be considered. The arrows indicate the relevance of the soft skills to one another. Verbatim quotes from the interviewees are indicated in italics and placed between quote marks:

1. Team Members ↔ Team members

   The contribution of these skills will create trust and a sense of solidarity within the team. In addition, when team members can openly acknowledge and learn from their mistakes without feeling judged, they will feel heard and valued. "*happiness of the team*".

2. Project Manager → Team members

   Managers should be particularly responsible for "*encouraging them to think about how they can better develop themselves for the things they think they are not mastering*". Managers to involve them in the meeting because "*monkey sees monkey does is a very effective tool for learning* [PM3] and motivate them to share ideas so that *"project can benefit from their fresh ideas"*. Managers to understand how to communicate plans to their team members so that they *"feel more involved and heard"* [PM14], making them more productive by "*appreciation*. Manager to take time and *"recognize that people are getting stress"* [PM5].

3. Contractor → Partners from different organizations

   The interviewees explained that soft skills are needed to understand "*what the partner or sub-contractor means instead of what he says* and to *someone elses way of thinking and working and with their interests and problems*. By "*putting yourself on the chair of the user*" you will understand what problems he will be facing during operation. By "*open communication*" the need for particular information will be clear, and it will also be clear what is important to each other. By *transparent and open communication with someone from another discipline, creates trust*". It is about understanding each other and *being able to share ideas with the other person to support collaboration and integration between disciplines* and *o achieve a joint success*".

4. Client → Contractors

   Most of the interviewees mentioned that the owner and the contractor should be mutually open and "*realistic*". Also, the client should have equal "*contractual milestone* " for the contractors to maintain stability and "*create a culture of collaboration*" between all the contractors. This was mainly seen as the responsibility of the project managers from both ends. They should 'understand each other's interests' and know how to communicate and to be aware of how my counterpart perceives my comments and questions. A lack of */empathy* towards understanding what is feasible, reasonable, or possible for the other party often leads to "*unrealistic expectations*", which can cause changes in plans, budget overruns, and time delays. It was highlighted that, especially at the project's outset, empathy is essential " *to build mutual trust and understanding of each other's perspectives*" to ensure the project starts on the right foot. Therefore, empathy between the client and the contractor is vital even at the tender stage to grasp each other's "*requirements and risk responsibilities*".

One of the interviewees emphasized the need for the organization to cultivate a culture that encourages managers to go the extra mile to manage their teams, recognize and address employee stress, and

establish a process to train new joiners. For example, many new risk managers are left to navigate their roles without adequate guidance. The interviewee also pointed out the importance of educating team members about other disciplines. For example, those who work on projects related to electricity should have a basic understanding of how electricity is transported. People should have diverse perspectives to know everything and also understand how we can manage those people to assign them to projects where they can be effective. For instance, they can experience one role, such as installing a project, but on the next project, they can also do some architectural work instead of only working on concrete tasks. The interviewee explained that this culture of great learning starts at the organizational level and then drops down.

5.3 Measures for Uncertainty Management

This section presents results from interviews on practical measures of uncertainty management within organizations. Since the data was collected from experts on the Dura Vermeer team and its partners, these measures are both pragmatic and feasible for implementation. The discussions were guided by the theoretical framework derived from the literature, as shown in 4.3. Furthermore, the interviewees proposed additional goals to the existing ones, highlighted (bold) in the following Table 5.1. A discussion of the goals is given below. The underlying idea is that the associated uncertainties will be managed or reduced by achieving these goals. This will allow some uncertainties to evolve into risks, allowing the application of appropriate risk management strategies.

Goals	**Source(s)**
Ensure awareness of the subjective perspective of uncertainty & its distinction from risk	Daniel et.al (2018), Hillson (2019), PM2, PM4, PM6, PM13, PM11, PM13, PM15
Clear definition and accountability	PM1, PM4
Redesign process to better integrate uncertainty management with risk management	Johansen et.al (2019), PM6, PM9, PM13
Training and Learning	PM3, PM8
Managing stakeholder perceptions of uncertainty for better relationship	Flyvbjerg (2017), Mok et.al (2015), Machiels et al. (2023)
Establish best practices in knowledge sharing and monitor	Lechler et al. (2012), Alshammari et.al (2020), PM7, PM9
Possess competencies essential for the uncertainty response	Flyvbjerg (2017), Hillson (2019)
Understand stakeholder environment for information flow	PM13, PM2

Table 5.1: Desired goals for Uncertainty Management

5.3.1 Uncertainty Perception

Understand subjective perceptions of uncertainty

Organizations involve people to do the job. Each person may see, understand, and decide differently based on their unique perspectives. Therefore, it is crucial for those working toward a common goal to develop a shared understanding of the project situation to achieve a holistic view. Uncertainty is not always an objective reality; it is perceived differently depending on who you ask. Recognizing these subjective perspectives means acknowledging and exploring how different individuals view and react to uncertainty, shaped by their background, knowledge, and interests. Many interviewees emphasized the importance of understanding perception, highlighting communication as a key factor. Currently, there is a lack of a common understanding of uncertainty, often confused with risk.

Encourage Open Dialogue on Uncertainty- An environment where people from diverse backgrounds and organizations will come together to discuss their understanding of uncertainties. This process reveals various perspectives and helps build a shared understanding. It's important to encourage everyone to share their insights based on their personal and organizational experiences with uncertainties. Additionally, it helps to learn about the strategies their organizations use to handle uncertainties. This approach also induces a sense of belonging among participants.

"It's really important that we create a space where people from different backgrounds can openly discuss their views on uncertainties. This helps build a sense of belonging among the group." [PM5]

Acknowledge Diverse Perspectives- Recognize that different stakeholders may have varying interpretations of uncertainty. Emphasizing the importance of understanding these subjective perspectives ensures that all voices are heard and valued.

"We are humans and we don't to feel ignored. Teams are stagnant due to information lack" [PM10]

Give space to people aligning to a different perspective- The understanding shift from traditional risk management to uncertainty management takes little time, so the manager needs to foster this transitioning time and encourage people to take risks by experimenting with uncertainty.

mindset shift takes time. We need to give time to the team to get used to it. The team is multitasking, and asking to add something would demotivate them. [PM3]

Aware people to see uncertainty differently- Once everyone understands the need for a change in mindset and the importance of uncertainty, the next logical question would be how to implement it. One crucial step is to equip people with knowledge about uncertainty management. Organizations like Dura Vermeer have a fundamentally technical nature. Therefore, it is essential to impart knowledge about uncertainty management through training.

"If you consider the transition to circularity, its really about peoples behavior. The barriers arent technical, because technically, much of what we aim to do is already possible. Its the people who are holding things back at the moment." [PM6]

Give a sense of urgency- When uncertainty as a concept is continuously a part of the process or every meeting it creates a sense of urgency among people involved in the project. To tackle the uncertainties, knowledge is important, or else instead of managing it, it will be avoided and kept for the time it happens.

"I dont know if they focus on it. I dont think they ignore uncertainty, but theres not much you can do about it. The focus is mostly on risks because uncertainty, by nature, is unknown. Sometimes, it doesn't make sense to spend too much time on it." PM5

Keep uncertainty management as a primary goal- Currently, managing uncertainty often takes a backseat to other primary tasks, such as addressing unclear technical aspects of the project and managing interfaces. Due to contractual misalignment, design milestone timelines are often missed. However, given the complex dependencies, uncertainty management should evolve to become one of the primary objectives. It is essential to integrate uncertainty management strategies with other requirements so that it is not seen as an additional step but rather becomes 'the new normal' for working.

Exhibit a flexible and collaborative mindset- People with the right mindset are very crucial for large infrastructures like Landstation because of its evolving nature this 2GW is a new standard, thus it demands a flexible and open mindset to grab the knowledge and proactive in developing skills to understand the uncertainty and implement strategies. This goal encourages project teams to remain open to new ideas, adjust their thinking as new information emerges, and work together to interpret and navigate uncertainties.

But finding an engineer who can take an unstructured or flexible environment and bring structure to it is very, very rareand those are exactly the people you need for these kinds of projects. The positive side is that through this process, you identify engineers who can work effectively in both structured and unstructured settings, especially where customers and stakeholders are involved. Those engineers who can manage both can be trained to perform better [PM11]

Themes	Description	Source Interviewee(s)
Encourage open dialogue on uncertainty	The lead group should create a healthy environment to have a transparent discussion	PM5
Acknowledge diverse perspectives	The project leadership should actively recognize and value the different viewpoints and experiences that each stakeholder brings to the table	PM10
Give a sense of urgency	project success lies on how uncertainty is managed, thus it is important to make people realize its importance	PM5
Make uncertainty management a primary goal	Integrate circular principles into core tasks, giving them equal importance to other key requirements	PM5

Table 5.2: Measures for Goal 1

5.3.2 Redesign process

New standard and process- The process of restructuring and streamlining existing processes to learn to cope with uncertainty. This approach focuses on revising current procedures to make them more adaptable and responsive to unforeseen challenges. By simplifying and optimizing processes, the organization can better integrate learning and continuous improvement into its operations, ensuring that the team is equipped to effectively manage uncertainty throughout the project life cycle.

"In the initial phase of the project, there are a lot of uncertainties, but as the project progressesduring discussions, engineering, and procurement, those uncertainties are brought back to an acceptable level. The further you are in the process, the bandwidth of the uncertainties gets smaller. This is why the process of redesigning and streamlining existing workflows is so crucial; it helps to systematically reduce uncertainties as the project advances". [PM9]

"In a new situation, it's important to establish an efficient work process rather than reinventing it every year. Constantly changing processes is costly, exhausting, and ultimately burdensome for the whole team. Instead, refine your process to last for a few years before introducing new changes, allowing for a sustainable cycle of improvement".[PM6]

Better risk management- In the context of large infrastructure projects, better risk management also means integrating uncertainty management practices, ensuring that the organization is not only prepared for known risks but is also capable of adapting to unexpected challenges.

"In big projects, its not just about managing the risks we knowwe also need to be ready to adapt to the unexpected". [PM13]

Themes	Description	Source Interviewee(s)
New standard and process	To achieve efficiency, gain more knowledge on risk strategies	PM5, PM6
Better risk management	Flexibility allow the team to adjust strategies in response to new information	PM10

Table 5.3: Measures for Goal 2

5.3.3 Stakeholders' relationship

Managing relationships among a large number of actors involved with different interests and objectives

Infrastructure projects like Landstation projects involve many actors to complete the different parts of the project. The interdependencies are high, so it is important to manage stakeholders well to create a collaborative relationship.

Trust and Relationship Building- The importance of fostering trust among team members and stakeholders by promoting open and transparent communication. Trust is the foundation of effective collaboration, especially in environments where uncertainty is prevalent. By being open about challenges, progress, and changes, team members can build strong relationships, reducing misunderstandings and creating a supportive environment where everyone feels valued and informed. Transparency helps in mitigating fears and uncertainties. Relationship building needs the right mindset.

"It's when you realize that if you work together in a good way that you'll make it easier for everyone involved". [PM15]

Risk and Responsibility Sharing- Risk and responsibility sharing is a fundamental principle in managing complex projects, especially when multiple stakeholders are involved. This approach involves distributing both the potential risks and the associated responsibilities among all parties in a way that is equitable and aligned with their capacities and roles. By sharing risks, the project team ensures that no single entity bears the entire burden, which creates a sense of collective ownership and accountability.

"You know, sharing risks is key in big projects. When everyone takes on some responsibility, it brings people together. I remember on one project, we had contractors, suppliers, and our team all sharing risks. It changed the dynamic instead of blaming each other when things got tough, we all worked together to find solutions. It creates this sense of 'we're all in this together,' and that's when real teamwork happens." [PM11]

Aligning the mindset to work toward a common goal- In large-scale projects with multiple parties, each with their interests and priorities, aligning everyones mindset towards a common goal is essential for a cohesive way to look at the project goal. Different mindset creates unwanted delays and cost overruns.

"For example, you have the design manager, the design leads, and then the lead engineers. I believe the design lead should have the ability to know which decisions they can make independently. They need to evaluate the best approach to a problem and then check with me and the stakeholders to determine the best course of action, what's best for Dura Vermeer and the stakeholders." [PM6]

Exhibit supportive and shared mindset- There is a lack of awareness about uncertainty management. However, by interacting with others, the team can align complex relationships among diverse actors, bringing their interests and objectives into harmony to achieve the broader goal.

"OK, if I were in TenneT's shoes, I would focus on creating a common mindset among the contractors and establishing shared goals that we all want to achieve." [PM2]

Themes	Description	Source Interviewee(s)
Trust and Relationship Building	Ensuring that all parties are aligned and committed to the project's success	PM15
Risk and Responsibility Sharing	The project leadership should encourage a balanced distribution of risks and responsibilities among all stakeholders	PM11
Aligning the mindset to work towards a common goal	The project leadership should work towards creating a shared vision and aligning the goals of all	PM6
Exhibit supportive and shared mindset	The project environment should foster a culture where team members support each other	PM2

Table 5.4: Measures for Goal 3

5.3.4 Knowledge sharing

Establish best practices in knowledge sharing ('know-what)

Scenario planning and analysis- A strategy for team to strategize for multiple possible futures. It helps them discuss and anticipate challenges, shape strategies, and secure their future by considering different scenarios and potential outcomes.

'we think of multiple outcomes for each risk events" [PM5, [PM15]]

strategize current risk strategy wherever needed- With scenario planning risk strategy can be applied wherever is possible.

Enable sensemaking and story telling- Team can related to the story when they listen and carry the learning's for a long time. Story telling enables information transfer and build social relationship to have a better collaboration.

"if I have a new colleague, a junior project manager, or a junior site manager, invite them to the meetings with those stakeholders and tell the story and explain to them why you are doing it, and then yeah, you bring over the knowledge you have also to the to the stakeholder but also your new colleague". [PM9]

Lesson Learned- The lesson and insights gained through experience. Confidence from good understanding and past success is what we need to judge the potential significance of what we do not know.

"I feel lesson learning is a part of every day's learning" [PM1]

Themes	Description	Source Interviewee(s)
Strategize current risk strategy wherever needed	Evaluate and update risk management strategies as new information and situations arise	PM5, PM15
Scenario planning and analysis	The project team to engage in scenario planning for various potential future outcomes and their implications	PM5
Lesson Learnt	Learning to be captured well as a training format	PM1
Enable Sensemaking and storytelling	The project team should focus on creating a shared awareness and understanding by interpreting complex situations together	PM9

Table 5.5: Measures for Goal 4

5.3.5 Develop skills

Develop and improve skills as the uncertainty demands

The development of knowledge and skills is crucial, as it helps determine the causes and consequences of uncertainties. Continuous monitoring and review and development of contingency plans ensure proactive management.

Value addition- This added value ensures that the team is well-prepared for expected challenges and better equipped to handle unforeseen obstacles, resulting in more successful outcomes in uncertain environments. As a result, the team can surpass expectations, achieving superior results that enhance project satisfaction. Furthermore, effectively managing uncertainty for the client increases their satisfaction, which in turn fosters greater support and bolsters the team's reputation.

"Ultimately, its going to help. You gain peace of mind knowing that youre focused on the right tasks. This creates a more harmonious dynamic in projects, where discussions are informed by knowledge rather than misjudgments. In this way, it contributes to a more effective and collaborative environment." [PM5]

Emotional intelligence- After gaining knowledge and adapting existing competencies, the team feels more confident and capable of addressing previously challenging situations. This growth enables them to align attitudes and behaviors effectively, recognizing, understanding, and managing their emotions and those of others. As a result, decision-making, collaboration, and adaptability, and relationships are enhanced.

"That's what's happeningit's more of an emotional reaction from many people than an information-based decision." [PM2]

Themes	Description	Source Interviewee(s)
Value addition	Team is more capable of handling known and unknown uncertainties	PM5
Emotional intelligent	Drive understanding different attitude	PM2

Table 5.6: Measures for Goal 5

5.3.6 Value addition

Make decisions through value cases when the project is uncertain

When a project faces uncertainty, traditional decision-making methods focusing solely on financial metrics or business cases may fail. Instead, making decisions through value cases means considering a broader range of factors, such as long-term benefits, stakeholder impact, sustainability, and strategic alignment.

Balancing Short-Term and Long-Term Goals- It emphasizes the need to weigh immediate project needs against future objectives. For instance, a decision that offers quick financial gains might jeopardize the project's long-term sustainability or strategic goals. Conversely, overly focusing on long-term benefits could neglect pressing short-term issues. The challenge lies in finding a balance where decisions address current demands without compromising the project's future viability.

Intuitive Judgment and Accountability- Intuitive judgment is essential to make timely decisions when data are incomplete, while accountability ensures that these decisions are implemented effectively, adding value to the project by preventing delays or cost overruns.

"In my view, a project manager needs to be a visionary, you know, because they bring a lot of experience to the table. The decisions they make are crucial, and our motivation often depends on how those decisions pan outespecially when it comes to sustainability for our company." [PM12]

Themes	Description	Source Interviewee(s)
Strategic Vision	It will help the team work towards a common goal and give a clear direction for the future	PM12
Intuitive Judgment and Accountability	enable quick processing of multiple pieces of information with minimal cognitive effort	PM7

Table 5.7: Measures for Goal 6

5.3.7 Stakeholder environment

Understand stakeholder environment for information flow

Information Accessibility and Transparency- The availability, clarity, and openness of information within the stakeholder environment are crucial. This includes analyzing how accessible critical information is to various stakeholders, the transparency of information-sharing processes, and the impact of information bottlenecks or gaps on project outcomes.

Long term relationship- Honest, clear, accurate, and supportive communication is another essential part of building positive relationships and fostering trust. Due to long term relationships, people are getting used to ways of working, thus it will be easy to communicate and share.

"Build a good relationship. Be fair. Dont lie. Be transparent. But also, be clear when a request doesnt align with the requirements. Say, 'Im sorry, but I have to consider project costs and schedules. I cannot do it.' Be fair and transparent in that." [PM9]

Themes	Description	Source Interviewee(s)
Long term relationship	Project lead to ensure good relation to fast track the tasks	PM9
Information Accessibility and Transparency	Awareness to share information on-time	PM9

Table 5.8: Measures for Goal 7

5.4 Conclusion

The purpose of this chapter was to answer the 2 and 3 sub-research questions:

SQ2- What are the current state of uncertainty and its management practices in a large infrastructure project, like the Landstation, and how do the project teams handle them?

It can be concluded that there are different perceptions of uncertainty among the stakeholders. Currently, uncertainties are not considered a standalone concept in Dura Vermeer but are instead treated interchangeably with risk. As a result, uncertainty management is synonymous with risk management. This is due to the lack of a well-established foundation, necessary to implement uncertainty management in projects. It can be concluded that uncertainty management is not effectively implemented or is not implemented at all. The team focuses primarily on risk management rather than uncertainty management. Risks are often more apparent and urgent to address because they are associated with negative outcomes, such as cost overrun and potential loss to the Landstation project. Risks are seen as more tangible and predictable, while opportunities require an innovative approach to identify them.

The concept that uncertainty management should be treated with the same significance as risk management is not well understood. Project teams tend to rely on traditional risk management strategies to handle uncertainty, often considering contingency plans, such as setting aside a budget to manage uncertainty when it arises. However, uncertainty involves more than just setting aside a budget; it also requires allowing unexpected events to occur without directly impacting project outcomes negatively. Interestingly, the incorporation of contingencies as a method of dealing with uncertainty did not emerge in the literature study. Although including contingencies does serve a purpose, it may be considered more of a tool than a method. Therefore, it can be argued that relying solely on cost and planning contingencies would not suffice.

SQ3- What measures are identified from practice to develop the framework?

The barriers and drivers mentioned at the beginning of this chapter represent the current state of uncertainty management at Dura Vermeer. Barriers explain why there is no effective uncertainty management in place, while drivers are factors that could motivate Dura Vermeer to implement an uncertainty management process. Information on the desired state of uncertainty management has been drawn in part from the literature and in part from interviews. Five goals were identified from the literature: Understanding the subjective perspective of uncertainty; Redesigning the current process with proper uncertainty management; Managing relationships among diverse stakeholders having different backgrounds, interests, and objectives; Knowledge sharing and continuous improvement in skill development. All these points were directly or indirectly reflected in the interviewees' responses, however, two additional goals emerged. First, understand the stakeholder environment for information. It was highlighted that there is significant uncertainty around information sharing, which exacerbates uncertainty within the team. This leads to the second goal of understanding the importance of intuitive judgment and accountability. The Landstation project is not only technically complex, requiring accurate information for concrete decision-making, but it is also a new concept. This limits stakeholders' ability to make intuitive decisions or take accountability. Reluctance in accountability was also found to be due to fear of sharing wrong information. This suggests that there is also a lack of open and transparent discussion on fear and anxiety.

Different stakeholders operate in varying environments when dealing with the project, such as having a contractual mindset and obligations and demonstrating less understanding behavior toward other stakeholders who rely on the information. This issue was highlighted by most of the interviewees. Therefore, it is important to understand the stakeholders' environments and work processes; if managed effectively, the information flow will become more stable. In addition, they highlighted that

sharing experiences and learning is an important process in identifying uncertainties. However, experienced individuals often struggle to share their knowledge and tend to wait until uncertainties arise. Thus, the learning curve for developing and applying skills to manage specific uncertainties remains a key challenge. The interviewees also suggested that certain skills should be mandatory for the team, but there is confusion and uncertainty about which skills are needed and how they can be applied to create a win-win situation, rather than increasing uncertainty. One suggestion was that listening to past experiences allowed the team to identify the essential skills required to effectively manage uncertainty. In the current process, knowledge-sharing sessions and learned lessons are not performed optimally. Moreover, lessons are not effectively captured and there is no monitoring process in place. This results in a lack of key skill development to manage a specific uncertain situation.

To achieve these seven goals, the measures were derived from interviews and expert discussions. Overall, respondents found it challenging to clearly outline the steps for developing key skills, likely due to the ongoing nature of uncertainty that cannot yet be defined in a straightforward & black-and-white manner. The existing process also heavily focuses on risk management as a common organizational language, leading to an attitude of setting aside the impacts of uncertainty to be addressed later. As a result, key observations from all interviews were compiled and subsequently assigned to different stages of the proposed framework, which is described in the next chapter 6.

Chapter 6

Framework Development

This chapter explores the development of a framework designed to guide large infrastructure organizations, such as Dura Vermeer, in building key skills for managing uncertainties. The initial framework was derived from literature and then further refined through a series of expert interviews. The conceptual framework was presented during these interviews as a series of questions to validate and enhance its applicability. The insights gathered from these discussions culminated in the final uncertainty management framework. This chapter also highlights the skills developed from the framework and finally highlights the benefits of the framework.

The research question addressed is as follows:

SQ4- How can a framework be developed to assist the development of key skills for managing uncertainties?

The chapter begins by detailing the procedure used to develop the framework. Following this, the chapter presents the findings of the interviews that were conducted to understand the concept made. Finally, the chapter concludes with the introduction of the finalized key skill framework.

6.1 Framework Development

The concept behind the development of the framework is illustrated in Figure 6.1. The primary goal of the framework is to provide a structured pathway for team members to build the necessary competence to manage uncertainties, going beyond the limitations of traditional risk management practices. This framework addresses the specific challenges identified in the current state of the organization, particularly the team's risk-oriented mindset, the lack of awareness in differentiating between risks and uncertainties, and the differing perceptions among multiple stakeholders regarding uncertainties.

The framework is designed to bridge the gap between the existing barriers to uncertainty management and the desired state of effective and proactive management. This is achieved through a coordinated and structured approach, actively involving stakeholders. Although the theoretical framework outlines a nine-step process, from identifying uncertainties to following up, this framework emphasizes that successfully implementing each strategy goes beyond merely following the process. It requires developing specific skills and knowledge to carry out these strategies effectively. Therefore, the focus of this research is not only on the process itself, but also on the competencies needed to navigate each stage of uncertainty management. The aim is to highlight the importance of building the necessary skills and expertise to effectively manage uncertainties in a complex environment.

It fosters awareness, demonstrates the mutual benefits of a shared understanding of uncertainties to stakeholders, facilitate knowledge sharing, adapt to new challenges, and encourage the acquisition of new competencies. By guiding the development of these key skills, the framework empowers team members to manage uncertainty confidently, reducing their reliance on traditional risk management practices.

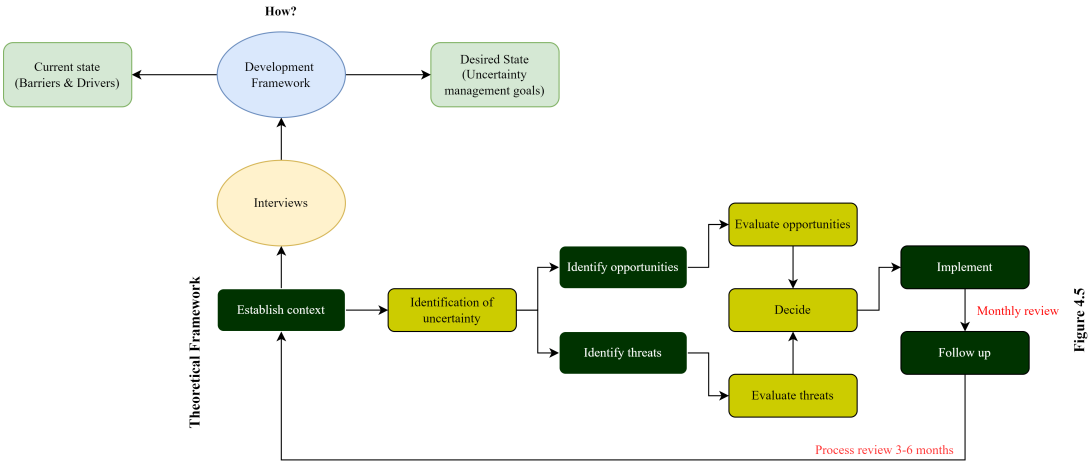


Figure 6.1: Concept of a development framework to guide the organization from current state to the desired state

6.1.1 Inputs of the framework

The framework proposed in this chapter is a synthesis of insights collected from the various steps conducted throughout this study. However, not every finding from each part of the research directly contributes to the framework. This is because many findings from earlier sections have already informed subsequent stages. For example, some conclusions drawn from the literature review were used to shape the interviews and workshop. Like in the interviews, insights from the interviews were used in the discussion. The current approach to managing uncertainty was studied through interviews and workshops. The gaps were then identified by comparing the interviews' findings with the theoretical findings in the literature.

In the traditional sense, professionals are expected to have strong technical abilities and follow set

procedures to manage risks. However, when it comes to managing uncertainty, it is not just about processes or technical knowledge; it is about how individuals and teams perceive and react to uncertainty.

Interviews have revealed that effective cooperation and collaboration are still lacking in the project management process. Thus, soft skills are extremely important to collaborate with stakeholders and understand the complex nature of large projects. It was also mentioned that the Land Station project needs actors who are equipped with both technical and soft skills. A telling example comes from De Kok, a subcontractor, who described a challenging situation: despite their factory pushing for steel production to start, they face delays due to missing information from TenneT and WSP, which is required from Hitachi. This lack of information creates uncertainty and complicates their ability to proceed, even as other stakeholders and TenneT pressure them to move forward if the project manager does not prioritize effective communication. This lack of foresight can negatively impact the dynamics and project support of the involved actor. Also, from the discussion, a few insights were deduced that uncertainties can be exploited, and this needs some right-minding professionals and it is an essential part of managing uncertainty. In addition, the expert discussion served as a pilot to prove that a) there is a lack of skills and expertise in the team to understand the system as a whole, b) providing a clear definition of uncertainty, and d) collaborating actors succeed in managing uncertainty.

6.1.2 Framework Design Procedure

The procedure for developing the framework is illustrated in Figure 6.2. So far, the study has completed the four initial strategies. The process began with an understanding of the context of the large infrastructure project and an extensive literature review, which led to the establishment of a theoretical guiding framework in Section 4.3.1. This framework included the key components necessary to develop the conceptual framework. Then, the goals for the desired state of uncertainty management were defined, as described in the theoretical framework (Table 5.1). Along with the goals, it was also important to list the strategies for uncertainty management, as described in Table 4.4. Building on these foundations, the study moved forward with empirical data collection through interviews. The analysis of these interviews revealed prominent themes that informed the identification of measures for uncertainty management, as discussed in Chapter 5. In this chapter, we will explore the two subsequent steps of the procedure, which are detailed below.

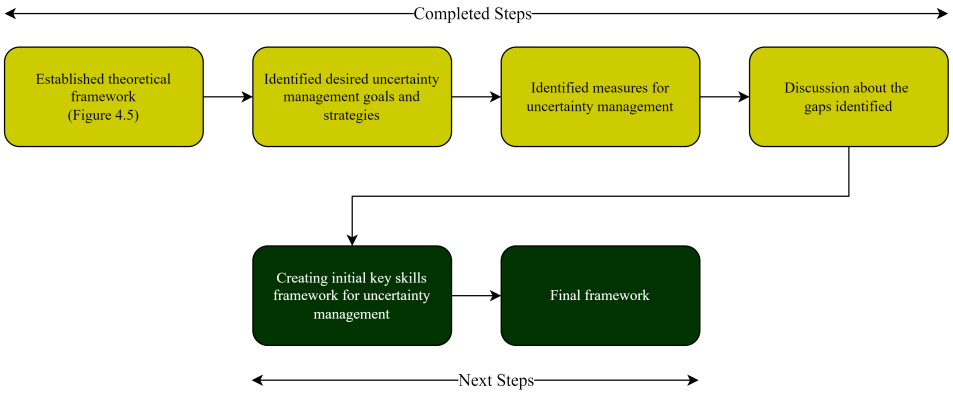


Figure 6.2: Procedure for framework development

6.1.3 Initial Framework

The literature review identified two critical components necessary to develop a framework. Effective management of uncertainty requires both the knowledge (tacit and procedural) of experienced individuals and the skills required to implement that knowledge. Consequently, the framework developed incorporates these elements into a conceptual framework, as shown in Figure 4.8. All the measures outlined for each goal (Table 5.2) were derived from literature and interviews to illustrate how the

Dura Vermeer project team can progress from the current state to the desired state of uncertainty management. The interviews acknowledged the lack of knowledge and skills needed to effectively manage uncertainties. Despite this, the interviews did highlight several key skills that the team should focus on developing, as detailed in the Appendix E. However, there was uncertainty about how to develop the skills required to address uncertainties from various sources.

6.2 Final Framework

Johansen et.al (2014) emphasized the importance of consulting a broader segment of the project team to leverage diverse skills and experiences when identifying and analyzing uncertainties. Building on this idea, this research has developed a conceptual framework aimed at guiding project teams in large infrastructure projects, such as Landstation, in cultivating the skills needed for effective uncertainty management.

This framework is derived from the strategies outlined in Table 4.4, which will be detailed in the next section. The strategies within the framework Address, Accomplish, Adapt/Adjust, and Acquire were chosen from various management approaches, as the literature suggests that a 'one-size-fits-all' method is insufficient for large, complex projects. The effects of these strategies were also drawn from both literature and interviews to improve the management of uncertainty and complexity, as illustrated in Table 6.3.

The arrangement of these strategies was carefully determined after an extensive literature review, where the authors did not provide a specific order for implementation. Therefore, the thesis applied the reasoning, informed by insights from the literature, to organize them in a way that is suitable for the intended purpose. However, one of the key findings from Kool et.al (2017) has highlighted that even before managing uncertainty, awareness of the concept of uncertainty should exist, as it is different from risk and requires a different management approach.

Figure 6.3 illustrates that each strategy within the proposed framework represents a different management approach. This creates a cascading effect in skill development or enhancement, where information flows sequentially to bridge the knowledge gap, progressing from awareness to learning, then to adaptation, and finally to development or improvement.

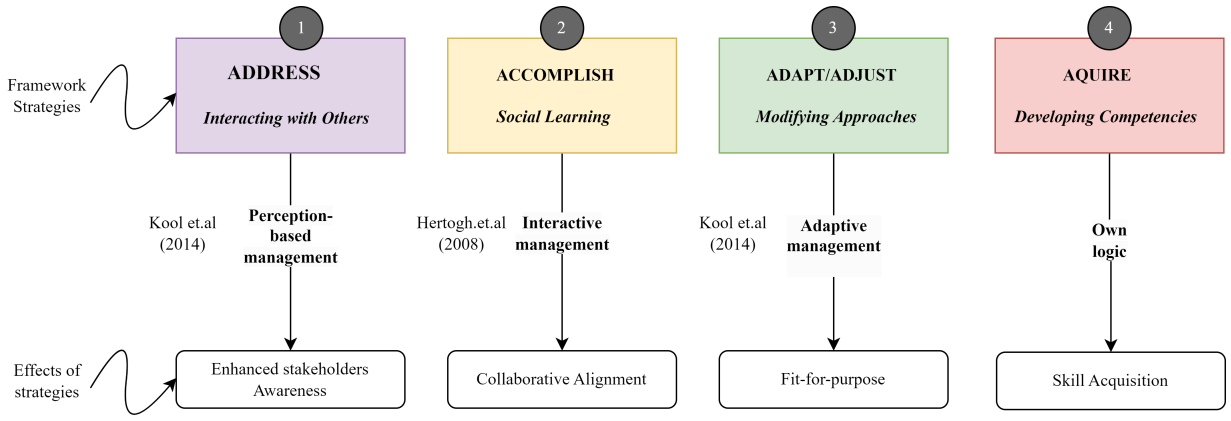


Figure 6.3: Framework strategies and their effects

The complete form of the framework is shown in Figure 6.4.

6.3 The 4A's Key Skills Framework

The proposed 4A's key skills framework assists the project team to shift from the risk mindset to a desired state of uncertainty management by following the four strategies addressing four A's, which

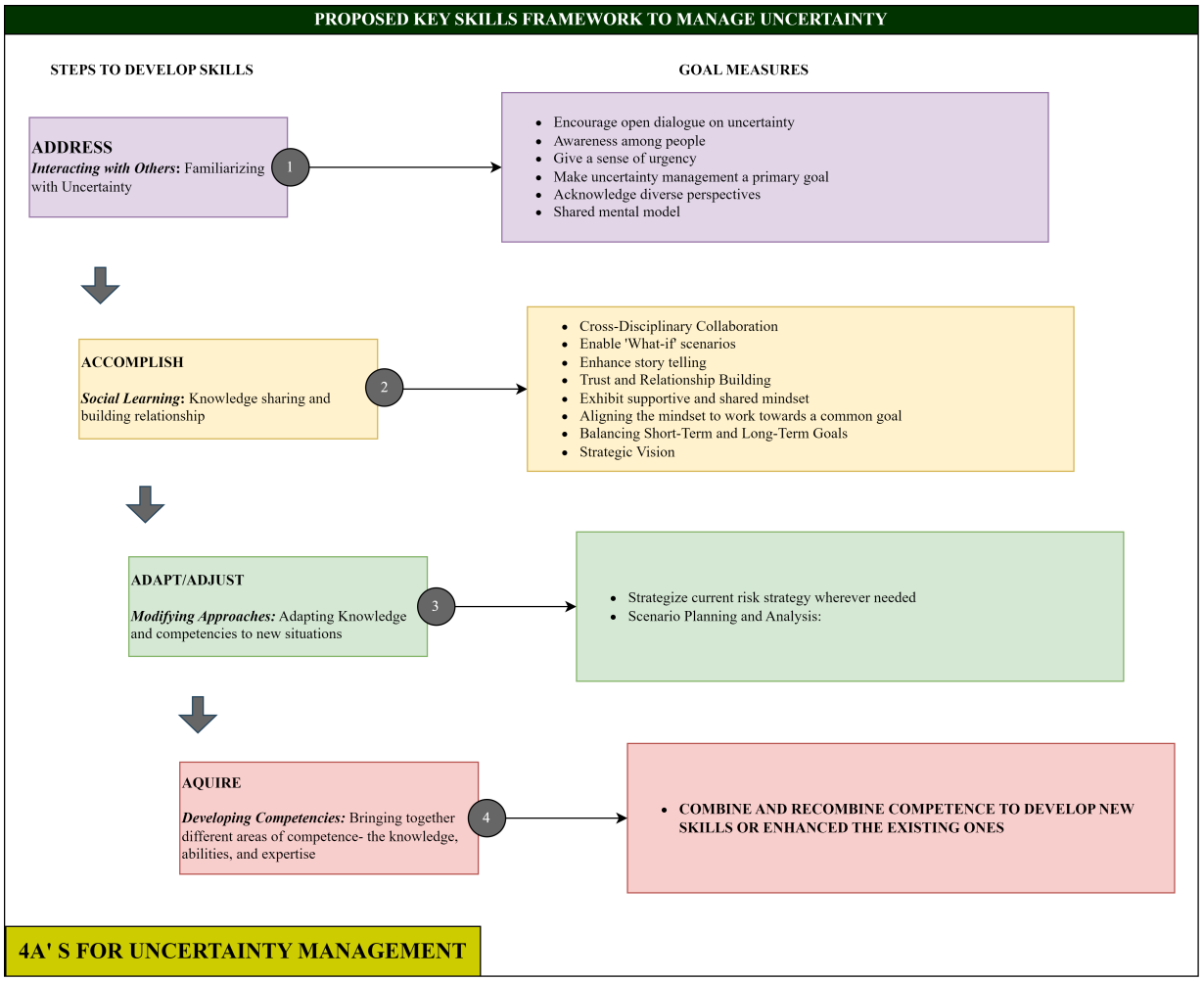


Figure 6.4: Proposed 4A's key skills framework for uncertainty management

is a rigorous tool to negotiate mind shift supported by literature and interviews. For a thorough understanding, this framework should be studied in conjunction with the detailed explanation of each measure provided in Section 5.3.

As the name suggests, the 4A's key skill framework is a tool that consists of four distinct yet interconnected stages: Address, Accomplish, Adapt/Adjust, and Acquire. Each strategy represents a critical step on the journey to mastering uncertainty management. This framework is comprehensive, based on insights gathered from both the literature and interviews, and follows a well-informed approach. The next crucial step is to validate its effectiveness through practical application.

The primary purpose of using this tool is to facilitate inclusive discussions, interactions, and social learning among project team members, not only from Dura Vermeer but also from partner organizations. By engaging all relevant stakeholders, the tool promotes a free flow of information to fill knowledge gaps and lays the foundation for the ultimate goal of acquiring the necessary skills to effectively manage uncertainties.

The following are the explanations for each strategy.

6.3.1 Address

Uncertainty perceptions are different for different players. Few see this as trouble, and others see this as a benefit as they can generate new information about the project. Perception-based management starts with awareness of different perceptions of uncertainty and an application of organizational learning, using a shared mental model. This concept underpins the first strategy, Address, in the 4A's framework. This initial strategy emphasizes engaging with others to gain a clear understanding

of these different perceptions. It is vital to note that uncertainty is a distinct concept from risk, even though the terms are often used interchangeably. Consequently, risk management usually takes precedence over uncertainty management.

Through these interactions, the goal is to shift the mindset of team members, helping them recognize that uncertainties can represent both risks and opportunities. The study has already highlighted that the focus tends to be on risks (threats), while potential opportunities are often overlooked. By broadening this understanding, the team can realize the positive impact that effective management of uncertainties can have, on one or more project objectives.

In this strategy, the project team will share their individual perspectives on the uncertainties involved in the project. Occasionally, a scenario may appear uncertain, but it can be resolved with resources that the involved individual may not be aware of. This strategy highlights the crucial role of transparent communication and teamwork among the team members and stakeholders. It promotes a collective awareness and mutual understanding by merging diverse viewpoints and interests. Through engaging in meaningful dialogue, the team can uncover various uncertainties that might otherwise go unnoticed. Therefore, this strategy is essential for developing a unified understanding of the upcoming challenges and to establish the foundation for a cohesive environment. Ultimately, the team will be able to achieve the measures depicted in Figure 6.5.

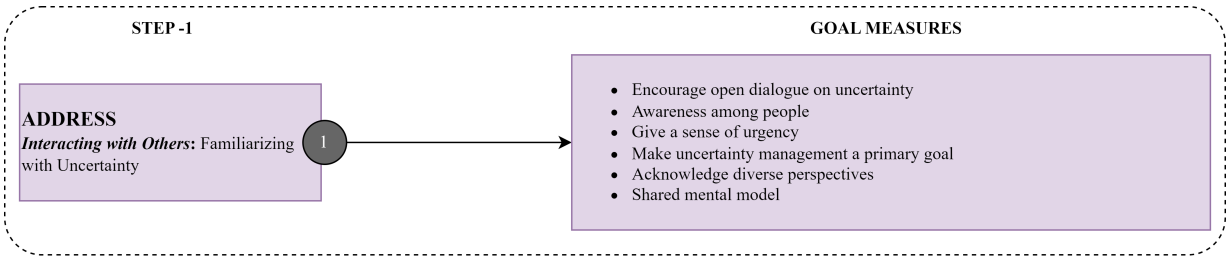


Figure 6.5: Proposed Framework-strategy 1

6.3.2 Accomplish

This is the second strategy in the 4A's framework, following the foundational address strategy, where the focus is on recognizing and discussing uncertainty. The Accomplish strategy is a crucial phase of the framework, as it centers on social learning and sense making, facilitating the what-if scenarios and the exchange of ideas and insights that lead to a more comprehensive understanding of the uncertainties at hand. This strategy is influenced by interactive management.

K Weick (2009) defined sense making as "the ongoing retrospective development of plausible images that rationalize what people are doing", meaning it is a continuous process in which individuals reflect on past experiences and actions, creating shared narratives or explanations that help make sense of their current practices and future predictions. Social learning is the process where individuals interact, sharing diverse perspectives and experiences to build a shared understanding and foundation for collective action. It plays a crucial role in raising awareness of personal barriers that hinder goal achievement and in recognizing the needs of others (Leclercq et.al (2023)).

Social learning facilitates the exchange of knowledge and participating in discussions about what has been learned serves as a built-in review process. Encouraging people to interact and share their insights helps them retain the information for a longer period. The focus on deepening the understanding of uncertainty is vital to building a more resilient and informed team. This strategy sets the stage for continuous learning, adaptability, and collective intelligence as the project progresses.

This shared understanding among the team members improves their ability to manage uncertainty more effectively. The empirical findings also highlighted that true collaboration, which is key to identifying unknowns, happens when there is a deeper, shared understanding of the project context. This understanding is achieved when team members not only share their experiences on both positive

and negative outcomes, but also actively listen and absorb the information that is exchanged. This binds the teams into a sink-or-swim-together attitude that promotes finding solutions to problems as they arise that are focused on a best-for-project outcome. It is in everyones interest to achieve a successful project outcome rather than an individual team-optimized outcome. Finally, this enables team members to share knowledge and learn from each other, achieving the measures outlined in Figure 6.6.

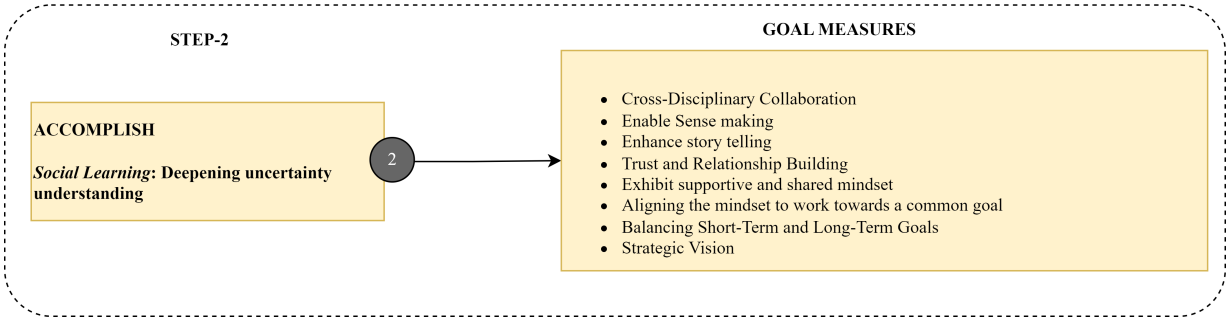


Figure 6.6: Proposed Framework-strategy 2

6.3.3 Adapt/Adjust

The Adapt strategy draws inspiration from adaptive management, also known as fit-for-purpose management, which recognizes the subjective nature of uncertainty and chooses the most suitable components to address it. This method provides an additional perspective, helping to identify various opportunities or threats. Leveraging the diversity within the team, it improves the project outcome by adopting the most appropriate approach. With this concept in mind, the Adapt/Adjust strategy was developed as the third strategy in the 4A's framework, focusing on modifying existing knowledge and skills to address new and changing circumstances. In this strategy, the team applies the new and deeper knowledge gained from the Accomplish strategy to refine and modify their strategies for managing uncertainty. As the team learns through social learning and collaboration, they may identify aspects of uncertainty that can now be reclassified as risks. This reclassification is crucial because it allows the team to shift from managing vague and uncertain situations to addressing more concrete risks with targeted strategies. This understanding enables the team to revisit and refine their existing risk management strategies, ensuring that they are aligned with the current state of the project. The team may need to adjust risk assessments, reallocate resources, or implement new mitigation measures to effectively manage these reclassified risks.

With a clearer understanding of the uncertainties and risks at play, the team engages in scenario planning to prepare for various possible future outcomes. By analyzing different scenarios, the team can anticipate potential challenges. The team will be able to better strategize against uncertainty by gaining new insights as shown in Figure 6.7.

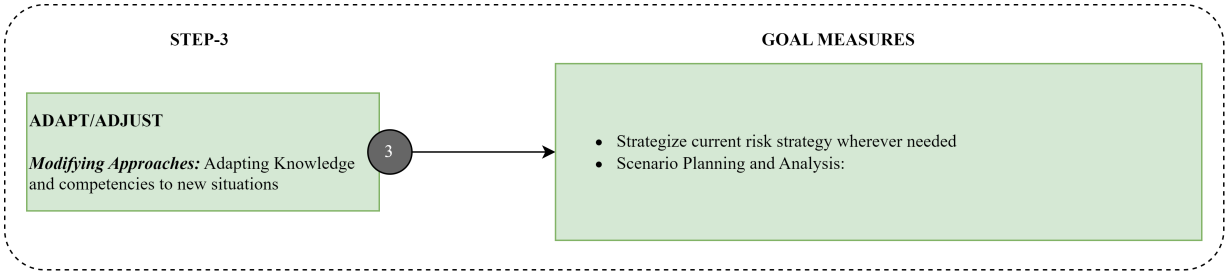


Figure 6.7: Proposed Framework-strategy 3

6.3.4 Acquire

The Acquire strategy is the final strategy in the 4A's framework, following the Adapt/Adjust strategy. This strategy focuses on consolidating and enhancing the competencies that the team has developed

throughout the previous stages. Here, the goal is to bring together various areas of competence, such as knowledge, abilities and expertise, to create a robust set of skills that equip the team to effectively manage uncertainty, as shown in Figure 6.8.

In this strategy, the team integrates the knowledge and experiences gained from earlier stages. This involves drawing on what has been learned by recognizing and discussing uncertainty, deepening understanding through social learning, and adapting approaches to new situations. The combination of these competencies is essential to develop new skills that are directly relevant to the management of uncertainty.

In addition, the team realizes that recombining existing competencies allows them to refine and strengthen their skill sets. This process may involve applying existing knowledge in new ways or blending different areas of expertise to address specific challenges. For example, the team might combine technical knowledge with improved communication skills to better manage stakeholder expectations under uncertain conditions.

As the uncertainties in the project continue to evolve, the team must develop new skills to address these challenges effectively. The Acquire strategy is where these new skills are cultivated, ensuring that the team is not just reacting to uncertainty, but proactively preparing for it.At the end of the process, the project team will gain better knowledge and ideas about the skills that are needed to emphasize.

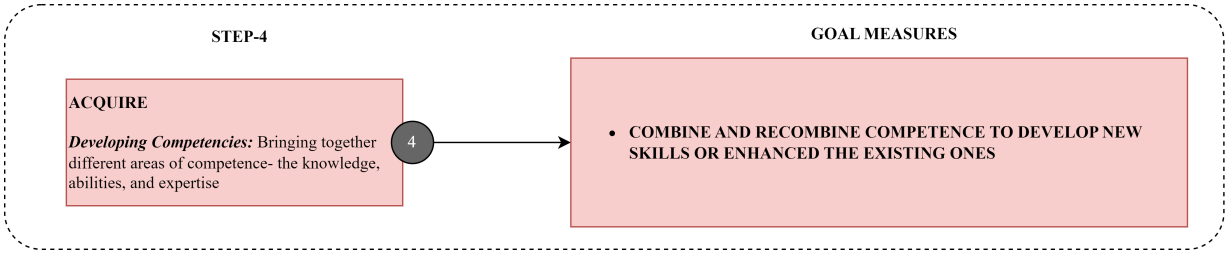


Figure 6.8: Proposed Framework-strategy 4

6.4 Skills developed

Table 6.1 outline the relevant skills development with the application of 4A's. Some of the high-rated skills are also mentioned by many interviewees which are highlighted in bold.

Developed skills	**Developed skills**
Openness to change	Contingency planning
Judgement and Decision making	Adaptability quotient
Emotional intelligence	Cognitive flexibility
Creativity and Innovation	Conflict management
Shared Leadership	**Empathy**
Better risk management	Negotiation
Ambidexterity	**Coordination and communication**
Self-Regulation	**People management**
Collaborative Problem-Solving	Proactiveness

Table 6.1: Skills developed from 4A's Framework

6.5 Example explanation of the 4A's Framework

Let's take an example from the interview, where one of the interviewees shared an uncertainty through a quotation. We can analyze this uncertainty using the 4A's framework and identify the skills we are

cultivating to address it effectively.

"Regarding the appeal, it concerns the neighbors of the land station. They understand why TenneT is building this type of substation; although they are in favor of renewable energy, they are worried that the converter station will produce more noise than they can tolerate. Thats the reason they made an appeal and, of course, we are taking that very seriously. We will do everything we can to reduce the impact on those neighbors. We have explained a lot to the neighbors and held information evenings where they could verify what we were presenting. We even took a group of them to an existing substation. We have already implemented measures to reduce sound levels, and while they were impressed, they remain unconvinced. TenneT is taking all possible measures, but they are still not convinced that our land station will achieve the same results". [PM9]

Uncertainty: The neighbors are concerned that the noise produced by the new converter station will exceed their tolerance levels. Despite giving them all the necessary assurance, the neighbors aren't convinced.

Impact of the uncertainty on the project: This uncertainty has led to an appeal from neighbors, which could cause delays, increased scrutiny, and necessary modifications to the project. It may also lead to permit delays as authorities require additional time for assessment. Furthermore, this situation could affect community relations and support for the project, ultimately affecting its success and implementation.

Let's apply this uncertainty to the proposed 4A's framework:

Address

- Recognize that this is a legitimate uncertainty, not just a risk.
- Engage with team members to discuss the neighbors' concerns openly.
- Acknowledge that despite assurances, the neighbors remain unconvinced.
- Encourage open dialogue about potential impacts on the project.

Accomplish

- Conduct social learning sessions to share knowledge about noise levels from similar projects.
- Engage in story-telling, perhaps sharing experiences from other projects where similar concerns were successfully addressed.
- Collaborate with technical experts to gather more detailed information about expected noise levels.
- Discuss potential mitigation strategies and their effectiveness.

Adapt/Adjust

- Based on the knowledge gained, adapt the approach to addressing neighbors' concerns.
- Consider adjusting the project design or implementing additional noise reduction measures.
- Develop new strategies for community engagement and information sharing.
- Prepare contingency plans for potential project delays or modifications.

Acquire

- Identify new skills needed to address this type of uncertainty, such as community relations, technical communication with non-experts, or noise mitigation techniques.

- Develop competencies in negotiation and conflict resolution.
- Acquire knowledge about local regulations and appeal processes.
- Enhance the team's ability to balance technical solutions with community needs.

By applying this framework, the project team can move from simply reacting to the neighbors' concerns to proactively managing the uncertainty, potentially turning it into an opportunity for better community relations and project improvement. Additionally, the team has gained knowledge about regulations, technical requirements, and relationships.

6.6 Conclusion

The main aim of this section is to answer Sub-question 4

SQ4- How can a framework be developed to assist the development of key skills for managing uncertainties?

Answering this question helps fulfill the research's main objective: to create a framework for developing key skills to manage uncertainties in the Landstation project. Chapter 6 details the process of developing this framework. Initially, measures identified from the case study were organized into a structured framework called the Four A's: Address, Accomplish, Adapt/Adjust, and Acquire. Although these strategies were not strictly derived from existing theories, they were inspired by various management approaches like perception-based management, interactive management, and adaptive management. These approaches are crucial for a large and complex project like Landstation, where a dynamic and flexible strategy is needed, rather than a one-size-fits-all method. The core concepts of each 'A' frequently also emerged during interviews, highlighting the importance of understanding different perspectives on uncertainty, fostering learning, sharing knowledge, and developing competencies.

To enhance the management of uncertainty and simplify the complexity of the project, the effects of these strategies, drawn from both literature and interviews, are aligned with the measures outlined for each strategy. The framework was further refined through logical analysis and insights from literature and interviews, establishing the order in which each strategy and its measures should be implemented.

The Four A's framework operates sequentially, similar to a waterfall model, facilitating a step-by-step development or enhancement of skills. It bridges the knowledge gap by moving from building awareness to learning, then to adaptation, and finally to skill development or enhancement. Specifically, 'Address' focuses on understanding uncertainty, 'Accomplish' emphasizes social learning and knowledge sharing, 'Adapt/Adjust' allows for reflection and modification based on insights gained, and 'Acquire' consolidates this knowledge to identify and enhance the necessary skills. This structured methodology ensures that the team acquires the competencies needed to manage uncertainties within the project effectively, as illustrated by an example.

Uncertainty varies in different phases of a project, making it ideal to apply the 4A's framework in each phase. This involves consulting a larger group of project stakeholders, including the Dura Vermeer project team, other contractors, subcontractors, and a project manager from the client side. It is also important to include project managers from other cross-functional disciplines. For example, during the early phases, a diverse team can effectively identify uncertainties related to scope definition, budget estimates, and stakeholder expectations. In later phases, uncertainties can arise during construction and delivery, such as supply chain delays, weather impacts, and labor shortages. This approach ensures a comprehensive understanding of risks at each stage, facilitating the relevant application of competencies such as risk management, communication, technical expertise, problem-solving, adaptability, and stakeholder engagement. The team addresses different uncertainties at vari-

ous phases of the project life cycle. Therefore, the framework should be applied multiple times throughout the different stages of the project.

Benefits of 4A's framework:

1. Focuses on managing communications and expectations.
2. Help to embrace the uncertainties rather than looking at them as a negative influence on the project and facilitate change, initiate a flexible approach.
3. This tool will not iron out the differences but build various perspectives present in the team.
4. Trust is typically built along the way with each applied strategy- Address, Accomplish, Adapt/-Adjust, and Acquire.
5. To create readiness to adapt to a project's environment dynamics.
6. Constructive interaction can help projects to accept new, and often external, changes or delivery methodology.
7. It will shift the project team's perspective from an explorative to an adaptive approach (i.e., being ready to face new challenges with a focus on adjusting to changing environments). These adaptive skills add business value by offering the agility needed to navigate turbulent project conditions.

Chapter 7

Discussion

This chapter offers a comprehensive analysis of the research findings, comparing them with the insights gained from the existing body of literature on uncertainty management. The purpose of this chapter is to assess how these findings align with the initial research assumptions and to critically examine the limitations encountered throughout the study. Additionally, the discussion explores the practical application of uncertainty management strategies in the 2GW Landstation project, highlighting expected and unexpected outcomes.

- Evaluation of the research: A detailed reflection on the scope, methods, and contributions of the research, examining the role of uncertainty management in large infrastructure projects.
- Comparison with Literature: The findings from the empirical study are compared with established theories to identify any gaps or alignment with theoretical frameworks.
- Limitations: A review of the research limitations, including methodology challenges and the generalizability of the findings.

7.1 Evaluation of the research

7.1.1 Scope

The research gap this thesis aims to address is the insufficiency of traditional risk management strategies in effectively managing the uncertainties inherent in large energy infrastructure projects. Specifically, there is a need to develop relevant skills and competencies that go beyond risk mitigation, allowing project teams to better anticipate, understand, and manage these uncertainties. To explore this gap, the scope of this research is centered on large infrastructure projects, with a particular focus on the Landstation project located in the Netherlands, which serves as the primary case study. Given the complexity of such projects, it was assumed, in accordance with (M Rodr Williams (2021), that the Landstation project would encounter new and significant uncertainties that existing risk management strategies might not fully address. Empirical research confirmed this assumption, identifying various uncertainties related to complex stakeholder environments.

From the literature review, it could be concluded that uncertainty does not quite have an unambiguous definition. For that reason, during the scope demarcation, an uncertainty definition was established based on the literature review, which served as a leading definition throughout the research. Especially for the empirical study phase of the thesis, the formulated definition was intended to give clarity on the concept of uncertainty. However, it appeared that peoples perception of the uncertainty definition was the one they resisted when answering questions throughout the interviews. In hindsight, it should therefore be concluded that it was virtually impossible to stick to one unambiguous definition throughout the interviews.

7.1.2 Methods

Literature Review

Several elements, such as sharing learning, storytelling, and building contingencies, were not identified in the literature review as strategies to manage uncertainty. However, these elements could or perhaps should have been encountered during the literature review phase.

Similarly, in the interviews, the competence component did not emerge as clearly as expected based on the literature and the questions asked to manage uncertainty. The goal was to identify the sources of uncertainty in the project, which would help determine the knowledge gaps and the competencies needed to address them. While these connections were identified in the literature review, the link between competence and specific uncertainties was often not recognized in the interviews. As a result, the focus frequently shifted towards risk and its associated strategies for uncertainty management.

Empirical Study

The empirical study included both interviews and an expert discussion, with the plan of interviewing fifteen participants. However, during the last interview, it became difficult to maintain control as the interviewer. Although the interviewee had much to share, the lack of opportunity to ask questions made it difficult to follow the interview guide. Additionally, the conversation often drifted in multiple directions, which, while not irrelevant, made it more time consuming to analyze later.

The conceptual framework served as the foundation for the empirical study. Although some elements of this framework were reflected in the interviews, others were not mentioned. This could suggest that these elements are either still relevant but have gone unmentioned or that they may not be applicable in this particular context and could be excluded from the framework.

7.1.3 Contribution to the research

The research provides information on the desired goals and strategies identified from the literature for uncertainty management versus a few goals added later after the interview as desired goals for

uncertainty management. It also finds the core challenges and enablers of the current state of Dura Vermeer for effective uncertainty management. Another part of the research deals with the measures for each goal to manage uncertainty. Combining these five aspects of the research facilitates the analysis of how key skills can be developed to manage uncertainty well. The empirical results largely resonate with the literature on the topic of uncertainty. The overlap between the interview responses and the conceptual framework showed that many of the theoretical uncertainty management models also apply in practice. In addition to that, many uncertainty identification methods were found in the interviews, such as lessons learned, early warning signs, and application of contingencies.

Discussion on desired goals for Dura Vermeer

The goals established for the uncertainty management process were not standalone or isolated; instead, they were interconnected in various aspects of development. For instance, achieving the goal of "understanding the subjective perspective of uncertainty" often required "knowledge sharing" and inducing a "supportive and shared mindset among stakeholders," demonstrating the interdependence of these goals. Similarly, measures such as "redesigning processes" were suggested to help shift the organizational culture and establish uncertainty as a common language, further emphasizing the interconnected nature of these objectives.

All goals were specifically aimed at increasing knowledge about uncertainty to develop relevant skills and shift mindset from risk to uncertainty by highlighting the added value of uncertainty management for relationship building and project success. While these goals are generally applicable to uncertainty management, some, like improving information flow, are particularly relevant to the Landstation project, while others may be more specific to different project teams within other organizations. Despite their context-specific nature, these generic goals remain significant and relevant to effectively manage uncertainties.

Establish best practices in knowledge sharing and monitoring and 'Understanding stakeholder environment for information flow emerged as some of the goals, most frequently mentioned during interviews. This highlights that a lack of practical experience, along with differing interests and perspectives, is a major challenge that needs to be addressed within organizations.

Broader perspective of research findings for Dura Vermeer

Interviews were conducted not only with the Dura Vermeer core project team but also with partners from various organizations who collaborate as a team toward the common goal of designing and executing the 2GW Landstation project. However, the case study in this research primarily focused on interviews with tactical level employees, who had less experience, as well as those at the managerial level within the organization. Among the interviewees, a common issue was their differing perceptions of uncertainty and their limited understanding of the concept. Many were unaware of any specific methods their organizations were using to manage uncertainty, highlighting a significant challenge. One of the interviewees pointed out that in the conventional industry, the focus is almost entirely on certainty and mitigating risks. Shifting this mindset to embrace uncertainties is a complex task. While employees are generally willing to make extra effort to understand and manage risks, the same level of commitment and understanding is typically not extended to dealing with uncertainties. This is a lack of awareness about the positives of uncertainty.

Another major challenge identified was the stakeholder environment, particularly the lack of information flow from Hitachi, which has a separate contract with TenneT and operates differently. The interviewees noted that these different contracts often create a binary mindset, where each party focuses narrowly on their contractual obligations rather than the overall goals of the project. Additionally, Hitachi's cultural background, which differs significantly from that of Dutch organizations, often leads to a focus on contracts and individual milestones over the collective project goal. Interviews with Hitachi project members could not be conducted within the time frame of this study to under-

stand their perspective on uncertainty and behavior toward other stakeholders. Additionally, it was also highlighted that the current collaboration among stakeholders is largely superficial, with little serious action or monitoring. Furthermore, TenneT's lack of concern in encouraging true collaboration among stakeholders contributes to a lax attitude toward achieving the project's ultimate goals. These issues underscore the importance of aligning stakeholders to ensure that they feel connected and committed to the project's success. Lack of clarity on project scope and requirements contributes to creating uncertainties for all parties involved.

The final challenge identified in the project was the lack of knowledge sharing, which hinders the understanding of which skills are needed to manage uncertainties and how to develop relevant skills based on different sources of uncertainty. During the interviews, it became clear that there is no comprehensive training program in place to educate people about these concepts from a broader perspective, further exacerbating the problem.

- The interviewees emphasized that sharing experiences is a crucial process for identifying, classifying, and managing uncertainties, serving as a learning platform to highlight the skills that need to be prioritized. This can be achieved through organized sessions or by maintaining a clear and user-friendly database, which can raise awareness among the team about the potential benefits of uncertainty. By doing so, it would help address the lack of familiarity and individual experience, both of which directly contribute to uncertainty.
- There was a high urge among all participants to have intimate and trustful collaboration to promote a cross-team (client, design, and contractor) conversation about risk, uncertainty, and ambiguity so that wider perspectives are accessed.
- The interviewees also mentioned that one of the issues, as noted by the TenneT project manager, is that the importance of getting "everything right the first time" has slightly shifted due to the novelty of the Landstation project. This shift is likely linked to the fact that this is the first project designed to meet 2GW standards, currently being developed to standardize and scale up for future Landstations. The newness of this standard project means that regulatory frameworks are still being continuously developed. As a result, TenneT is uncertain about the exact boundaries within which they need to operate, including laws, regulations, product requirements, and more, which introduces significant uncertainty to the project. This exhibits that knowing the stakeholder environment is crucial to staying well informed about the broader aspects of the project.

Additionally, to ensure commitment from the team, they must stay informed about the project's ongoing developments and challenges. The findings and framework of this study can serve as a valuable foundation for engaging team members in discussions and brainstorming, thus increasing their awareness and knowledge of uncertainty, and showing motivation to develop skills to manage them. Often, project managers marginalize uncertainty management goals in favor of prioritizing risk mitigation. For example, a strong focus on financial risk can sometimes take precedence over maintaining relationships. The Dura Vermeer board and TenneT, as the client, play a critical role in this process, as redesigning workflows to incorporate uncertainty management relies heavily on the acceptance and adaptability of both organizations. When they recognize the value of uncertainty management as a business case, they are more likely to embrace this change and demonstrate confidence in making it a standard practice. Finally, the pursuit of Market Leadership and Long-Term Sustainability could strongly motivate Dura Vermeer to take decisive action in managing uncertainties to ensure project success. As the company strives to build a robust foundation for its energy division and secure its future over the next 15 years, effective uncertainty management becomes essential. The success and continuity of the Landstation project will serve as a key example of realizing these strategic goals and establishing Dura Vermeer as a leader in the industry.

7.2 Limitations

The limitations of the conducted research lie within the case study. Although the study was conducted using the best methods, it is essential to acknowledge its limitations, as discussed below.

1. First of all, with Dura Vermeer providing the case of 2GW Landstation, the empirical research was limited to one company and a single project. Considering only one (company) perspective limits the research in the sense that it may not be representative of either other energy infrastructure or other large infrastructure projects. However, Dura Vermeer is a large company with experience in many complex and large infrastructure projects in different sectors. In both, Dura Vermeer has a lot of projects and thus ensures sufficient comparison material within the defined scope of this research. At the same time, considering only one project with less history as it is an ongoing project at the design phase comes with the potential limitations of not being able to have many existing uncertainties.

2. Many of the participants in the interviews were employees or partners of Dura Vermeer, predominantly from Dutch organizations, each with specialized expertise in their respective fields. Given that these participants share a similar cultural and organizational background, conducting similar interviews and workshops with practitioners from non-Dutch organizations could potentially yield different findings, as their perspectives might vary. Therefore, the results of this research may require further consideration and adaptation if applied to different organizational contexts, particularly if new gaps are identified that were not accounted for in the current framework.

3. The empirical data for this graduation project was gathered exclusively from the Dura Vermeer project team, with the intent of generating findings that could apply to other departments. However, it's important to recognize that other departments may operate differently from the project team. This suggests that the proposed framework might require additional considerations and adjustments to ensure its effective application across different departments within the organization.

4. The interview guide was designed to focus on risk and uncertainty, relating these concepts to the knowledge and skills previously identified in the literature review. Professionals were encouraged to mention any uncertainties they believed were missing, based on their real-world experience working on the Land Station project. However, none of the participants identified additional uncertainties or could recall any relevant discussions on the topic. As a result, it was challenging to gain practical insights into these two concepts during the interviews.

5. The proposed framework was not tested for industry-specific relevance. It was initially developed based on suggestions from the professionals interviewed and insights from relevant literature, followed by discussions with an expert panel. However, in the interviews, several but not all elements from the literature were mentioned. For those that were not mentioned, their relevance remains unclear. Therefore, it cannot be conclusively argued that the framework will be effectively implemented in practical scenarios.

Chapter 8

Conclusions & Recommendations

8.1 Conclusion

This chapter presents a summary and conclusions of the research study. It discusses the findings from each phase by answering the sub-research questions. Subsequently, it answers the main research question. The chapter also includes recommendations for both practice and further scientific inquiry.

This research was driven by interest in how uncertainties can be managed in situations of low expertise and limited skill availability. The main research question answered in this thesis is the following:

How can the project members of a large infrastructure project like the 2GW Landstation develop their key skills to manage uncertainties?

To find an answer to this question, four sub-questions were defined. Through a literature study, followed by an empirical study with a focus on the 2GW Land Station project, information was gathered on the concept of uncertainty and its management. Before coming to answer the final research question, the sub-questions are answered one by one.

SQ1- What is the current state of the art in large infrastructure projects?

First, we need to understand the nature of uncertainties in infrastructure projects. Much has been written on this topic, emphasizing that uncertainty is an inevitable and unavoidable aspect of project management. It is a lack of knowledge about something, where its probability of occurrence and potential outcome are usually unquantifiable and immeasurable. Categorized into internal and external uncertainties, uncertainty can originate from a great variety of sources. It can potentially have both positive and negative outcomes that can be influenced through the chosen uncertainty management approach. Uncertainty is often said to have its root cause in the lack of available information, available knowledge, or competence. Uncertainty, which arises from this incomplete information, is often also described as ambiguity. It refers to situations where a project manager must make decisions without having all the necessary information, increasing the difficulty and unpredictability of the decision-making process. In addition, when uncertainty arises from a lack of knowledge or competence, it is often treated as risk, leading to the implementation of risk management strategies. However, these strategies may be inadequate for managing uncertainty, as they are typically designed to handle known risks rather than the unknowns inherent in uncertain situations. The more information is available, it reduces the knowledge gap, which in turn aids in the development of skills. The primary source of uncertainty often arises from the size, environment, and involvement of multiple actors, each with different assumptions about the concept of uncertainty. Therefore, to shift mindset to understand the concept and its sources, it needs both technical and soft skills. Infrastructure project actors understand that risk focuses on iron law as the project's success, however, actors' satisfaction is also something that must be considered.

Uncertainty is a dynamic concept in which the magnitude decreases over time as more information becomes available and can be influenced by many different variables. Generally, the more variables are present, the higher the uncertainty. Although practitioners often use the terms "risk" and "uncertainty" interchangeably, it is important to distinguish between the two. Uncertainty is a source of risks (positive and negative); negative is risk and positive is opportunity. Hence, to identify opportunities from complexity in infrastructure projects, one should find the beneficial uncertainties that result from the complexities. An adaptive and flexible approach from the project manager and his team is needed to allow some changes to the initial plans and try to exploit possible opportunities along the course of the project through uncertainty management.

Despite that, researchers argue that uncertainty management is still not implemented by practitioners as there is no holistic approach to it. Some barriers to this reluctance are found in the literature, such as awareness, 'ignorance', 'language', 'culture', 'psychology' 'inertia', 'lack of the right positive mindset towards uncertainty' and relevant skills. Thus, researchers continue to stress the importance of uncertainty management and consider it one of the factors that can contribute to the project's success through the better achievement of the project objectives. There is strong advocacy for the shift from traditional risk management to uncertainty management in projects, thus expanding the scope of management practices. This is a paradigm shift from a technical and intellectual mindset or people skills to the ability to adapt to change. As uncertainty is inevitable in a complex project environ-

ment, the adaptability quotient becomes a prerequisite pressing need for project success. The project manager plays a crucial role, where he/she should focus on maximizing project performance by balancing the operational side with the human side. A key responsibility for future project managers is to inspire and guide their teams toward collective learning and developing collective intelligence. It is the art of doing something extraordinary with ordinary people. Although it requires courage to prioritize the human element in project management, doing so is highly rewarding and can make the work more enjoyable, fostering lifelong friendships. It also opens up incredible new opportunities and possibilities.

Embracing uncertainties with a 'prepare and commit' approach is the most effective way to enhance adaptability. The literature also suggests that an organizational culture that emphasizes the exploration and exploitation of knowledge and skills can better prepare individuals to handle uncertainty. There is no one-size-fits-all solution; instead, managing uncertainty requires a dynamic approach.

SQ2- What is the current state of uncertainty and its management practices in a large infrastructure project, like the Landstation, and how do the project teams handle them?

The identified challenges were the following: emphasis on risk management over uncertainty management, risk averse mindset, lack of a systematic approach, different perceptions of uncertainty, and systematic training on uncertainty management. There is strong evidence that the uncertainty management process is currently not implemented effectively or even is not implemented at all. Often no distinction is made between risk and uncertainty and therefore both are included in one risk management process. Combined with the fact that in practice, the focus tends to be placed on mitigating risks, potentially interesting uncertainties may be overlooked. However, despite not actively managing uncertainties, some elements of the uncertainty management process are executed or applied as part of the risk management processes. Relatics, Monte Carlo analysis, Risk Metrics, Probability, and Impact matrix are a few of the methods that are already applied to manage uncertainties. In addition, the design of contract strategies is not aligned among different stakeholders, due to which the overlapping of interfaces creates conflict.

Furthermore, in the Landstation project, efforts are being made to assign uncertainty management to parties already responsible for the risks. Since this project is a new concept, even TenneT has limited knowledge about its design and implementation, leading them to shift the responsibility for uncertainties to the contractor. In response, Dura Vermeer is working to allocate these responsibilities to the most suitable parties. Furthermore, greater flexibility is being built into project management, recognizing and accepting the higher level of uncertainty involved. Finally, although not specific to the Landstation project, a common practice in general is the inclusion of cost and schedule contingencies to manage uncertainties.

There is increased pressure to complete the detailed design on time; however, the lack of information presents a significant uncertainty for the project. To meet the milestones, execution has begun, but this multitasking is exacerbating the uncertainty. As a result, important aspects of project success, such as stakeholder satisfaction and relationship building, are being overlooked. There is significant uncertainty due to the lack of established processes, routines, and experience with this type of work. The absence of clear procedures means that more personnel are needed to manage and oversee work effectively. However, there is uncertainty regarding the availability of time and resources for proper oversight, as there is no opportunity to review past work or assess whether the current approach remains the best course of action. A key insight from an interviewee revealed a critical shortcoming in the project team's risk assessment skills and knowledge. This gap results in excessive dependence on the risk manager, potentially overburdening them. The interviewee stressed that in complex projects like the 2GW Landstation, widespread risk ownership is crucial for preventing delays and cost overruns. This observation highlights the need to develop risk management competencies across the entire team, rather than relying solely on a single risk manager.

Dura Vermeer as an organization has an open culture for sub-contractors and critical uncertainty lies in the involvement of subcontractors, referred to as partners. There is a lack of technical expertise to deal with uncertainty arising due to a plethora of technical installations. The project lacks innovative ideas and skilled engineers who can both optimize complex tasks and effectively communicate their ideas. Subsequently, the people involved in the project form their agenda, creating delays and inefficiencies. All the uncertainties mentioned, like people problems, will not be managed by risk strategies. Thus it is important to have the right mindset with the right skill balance to manage uncertainty, which Dura Vermeer is currently lacking. The Project can achieve better performance by improving their ability to navigate uncertainty and achieve positive outcomes.

SQ3- What measures are identified from practice to develop the framework?

This sub-question was addressed in Section 5.3 of the study. The empirical portion of the research, which included case study interviews, focused on exploring how the desired goals identified in the previous sub-question could be practically achieved. The 2GW Landstation project was selected as a case study for this purpose. Similar to other energy infrastructure projects, this project is large and complex, with many interfaces to manage. Interviewees, drawing on their experience with large infrastructure projects, were asked how each goal could be achieved by developing relevant skills. Despite recognizing the goals mentioned in section 5.1, participants struggled to articulate what relevant skills are necessary to achieve the goals for uncertainty management because there is a lack of knowledge to see uncertainty differently but not as a risk. Thus, it was evident that interviewees may be more interested in understanding how they could develop new skills or improve existing ones to handle uncertain situations, particularly those skills that would make it easier to predict upcoming challenges. As a researcher, it is evident to focus on the fact that, if there is a way that skills could be developed by understanding the current scenario of the project which will help predict future uncertainties. This can also be viewed in the sense that by predicting and managing a few smaller, immediate steps today, teams can effectively position themselves to handle larger uncertainties that may arise in the future. Achieving this requires a thorough understanding of the current project, as well as insights drawn from past similar experiences, a mindset to develop or improve the current skill set, and redesigning the current risk management process to include uncertainty management as a common task for the team. As a result, key observations from all interviews were consolidated and later aligned with the respective goals. These measures are summarized in tables at the end of the discussion for each aspect in Section 5.3. Additionally, a brief study was conducted to identify the main barriers seen as core challenges for Dura Vermeer, and drivers for change, providing a deeper understanding of uncertainty management.

SQ4- How can a framework be developed to assist the development of key skills for managing uncertainties?

By answering this sub-question, the main objective of the research, to develop a key skill framework to manage uncertainties for the Landstation project, is achieved. Chapter 6 elaborates on how this framework was developed. After identifying measures from the case study, an initial framework was created by organizing these measures into steps referred to as the Four A's: Address, Accomplish, Adapt/Adjust, and Acquire. While these strategies were not directly derived from established theories, they were influenced by different management approaches, including perception based management, interactive management, and adaptive management. These methods are vital for a complex project such as Landstation, where a dynamic and flexible strategy is necessary instead of a one-size-fits-all approach. The last strategy Acquire is the own logic and intelligence.

The concepts behind each 'A' frequently surfaced during the literature review and interviews. These concepts include understanding different perspectives of uncertainty, social learning, knowledge sharing, the importance of flexibility, and competency development. To improve uncertainty management and reduce the project's complexity, the effects of these strategies were derived from both the liter-

ature and interviews, each aligning with the specific objectives of each strategy. The framework was further refined using logical analysis and insights from interviews, determining the sequence in which each step and its associated measures should be addressed.

The Four As framework follows a sequential, waterfall like model, facilitating the gradual development or enhancement of skills. It closes the knowledge gap by progressing from awareness building to learning, then to adaptation and ultimately to skill enhancement. The Four A's framework provides a logical progression:

1. *Address* focuses on building an understanding and awareness of uncertainty and acknowledging diverse perspectives, aligning with the literature on perception-based management.
2. *Accomplish* emphasizes social learning and knowledge sharing, drawing from the theory of interactive management and empirical findings on the importance of collaboration.
3. *Adapt/Adjust* allows for reflection and adjustment based on learning, incorporating concepts of adaptive management focus on flexibility and responsiveness from project management literature.
4. *Acquire* stage consolidates the knowledge gained, identifying and emphasizing the skills needed. This aligns with the literature on continuous improvement and incorporates interview insights on essential skills.

This structured approach ensures that the team develops the necessary competencies to effectively manage uncertainties within the project. The framework's development was an iterative process, continuously refined based on the analysis of literature and interview data. The 4A's framework, while rooted in both theoretical concepts from literature and practical insights from interviews, represents a novel approach to developing key skills for uncertainty management. Its uniqueness lies in its holistic integration of understanding, learning, adapting, and skill acquisition, specifically tailored to the complex environment of large infrastructure projects like the Landstation.

The proposed framework has not yet been validated for its practical applicability. However, the information is derived partly from the literature and partly from interviews, providing a solid foundation for its potential effectiveness. This framework acts as a guiding tool for the Dura Vermeer project team to proceed from their current state to the desired state through structured and achievable steps. While the framework awaits practical validation, its grounding in both theory and empirical findings suggests its potential as a valuable tool for project teams facing similar uncertainties. Future research could focus on implementing and refining this framework in various project contexts, potentially leading to a more robust and widely applicable model for the development of uncertainty management skills in complex projects. This validation process could involve longitudinal studies of project teams using the framework, allowing for assessment of its long-term impact on uncertainty management capabilities.

Main Research Question:

How can the project members of a large infrastructure project like the 2GW Landstation develop their key skills to manage uncertainties?

The overarching objective of this research was to develop measures aimed at shifting the mindset of project members from a focus on risk to a broader understanding of uncertainty. This shift is critical for addressing the complex challenges faced by construction companies like Dura Vermeer and for integrating the key competencies needed to manage uncertainties in their infrastructure projects, especially the 2GW Landstation project. By employing a logical and structured set of sub-research questions, this study effectively addressed the main research question.

Lack of knowledge and competence, multiple involvement of stakeholders with different percep-

tions, lack of collaboration, lack of expertise, and unclear scope and requirements are identified as the primary sources of uncertainties in the Landstation project. Additionally, the overlap design and execution phase adds fuel to the uncertainties. Consistently, it has been acknowledged that these uncertainties are vital and can have a significant impact on project outcomes. To effectively manage these uncertainties, a comprehensive uncertainty management strategy could be helpful. This led to the solution of proposing a 4A's framework tool to understand the sources of uncertainties better and develop of improve skills to manage them. The proposed change framework (Figure 6.4) outlines the sequential strategies necessary to develop the skills required to manage strategic, operational, and contextual uncertainties within a large construction organization like Dura Vermeer. This process involves consulting a wide range of stakeholders, including the Dura Vermeer project and cross-discipline teams, other contractors, subcontractors, and a project manager from the client's side. By focusing on the 4A's strategies of awareness, knowledge sharing, lessons learned, and adaptive approaches, the framework facilitates comprehensive discussions that can lead to effective solutions. For example, strategic uncertainties can be addressed through feasibility studies and scenario planning, operational uncertainties through detailed risk assessments and contingency plans, and contextual uncertainties, such as market conditions, by selecting the right contract strategy and incorporating stakeholder perspectives.

This framework addresses a critical gap in the current approach of technically-focused organizations. While these companies often excel in technical expertise, they may underestimate the importance of people skills in managing uncertainties. The framework helps bridge this gap by demonstrating how people skills, such as effective communication, empathy, and adaptability, are crucial for navigating the unpredictable aspects of large infrastructure projects. These skills are essential for aligning diverse stakeholder perspectives, fostering collaboration, and managing the often intangible aspects of uncertainty that technical approaches alone cannot address. By integrating both technical and people skills, the framework provides a more comprehensive approach to uncertainty management, which is particularly valuable in projects involving numerous stakeholders with varying perceptions of uncertainty, all working toward a common goal. Another interesting observation was the differences between the uncertainties in the design phase and those in the construction phase. Most of the uncertainties during the construction phase were neither expected nor identified in the early phase. This highlights the dynamic and ever-changing environment of the Landstation project, emphasizing the need to focus on opportunities and to maintain this focus throughout the construction phase. Since uncertainty varies across different project phases, it is ideal to apply the 4As framework at each stage.

Since the results were partially derived from empirical research, these measures can be considered both practical and attainable for organizations. However, the validation process, which has not yet been conducted, is crucial for ensuring that the proposed framework is both effective and feasible. It is important to note that the framework is a tool that requires regular attention, similar to risk management methods. Until uncertainty management becomes a routine part of business operations with clear accountability, achieving a flexible mindset to view project risk and uncertainty differently will remain challenging. The goal is to establish a unified process of uncertainty management, which will enable this tool to be more effectively implemented. Once validated, the proposed framework will serve as a valuable tool for project members involved in large infrastructure projects. It offers a structured approach to developing the necessary skills for managing uncertainties, which could lead to better project outcomes and more effective stakeholder management in complex and uncertain environments.

8.2 Recommendation

As a closing part of this research, building upon the conclusions from the previous chapter, recommendations are developed. First, the practice recommendations are laid out, followed by recommend-

ations for future research.

8.2.1 Recommendations for Dura Vermeer

- **Increase awareness of Uncertainty**
  It has been observed that while Dura Vermeer has a robust risk management system, the team lacks awareness about managing uncertainties specifically. The first step is to ensure the team understands what uncertainty is, how it differs from risk, and why it needs to be handled differently.

- **Incorporate Uncertainty into Risk Management**
  Although uncertainties and risks are distinct, it's recommended to incorporate uncertainty management into the existing risk management framework to make it a standard practice. The starting point for that is to introduce the concept of uncertainty and ensure everyone involved is familiar with the rough definition to establish a shared understanding. This approach enables Dura Vermeer to build on its established processes while adding the needed emphasis on addressing uncertainties. By doing so, the team can approach uncertainty with the same level of seriousness as risk, treating it as a routine part of their work rather than an additional task.

- **Extend ways of working**
  Dura Vermeer's Ways of working should be expanded to include uncertainty management practices. The empirical study revealed that many components of uncertainty management are already being applied subconsciously in practice. These should be formalized and made common knowledge for all employees, ensuring consistency across the organization. In addition, a flexible approach should be implemented to respond to changing project environments.

- **Appoint an Uncertainty Manager**
  To effectively manage uncertainties, it is recommended that Dura Vermeer appoint a dedicated 'Uncertainty Manager'. This individual would be responsible for raising awareness, ensuring that uncertainties are addressed throughout the project life cycle, and guiding the team to approach uncertainty distinctly. By having a specific person responsible for managing uncertainties, the company can ensure that these issues are proactively handled rather than being absorbed into the risk management process or dismissed as uncontrollable unknowns. As a result, the team will gain knowledge through exposure to more uncertain situations, becoming more confident and serious about handling uncertainties alongside risks. Over time, this will induce accountability within each team member, reducing the dependency on managers. However, until that level of accountability is fully developed, it is essential to have someone solely focused on managing both risks and uncertainties. Instead of relying on the manager to handle every issue directly, team members should take initiative, keep the manager in the loop, and collaborate to find solutions.

- **Implement 4A's framework**
  The proposed 4A framework (Address, Accomplish, Adapt/Adjust, Acquire) should be implemented to provide a structured approach to uncertainty management. Traditionally, Dura Vermeer and its partners have focused on technical solutions to address issues, given the technical nature of their work. However, further technical advances in the management of uncertainties are already possible beyond what is currently being implemented at Dura Vermeer. Thus, more emphasis should be placed on trustful collaboration strategies to overcome human barriers to uncertainty management. This plan and these procedures should accommodate the desired features as described in the answer to the main research question of this thesis. The proposed framework supports this necessary shift in focus. At the project level, the proposed framework will provide a structured platform for collaboration, sharing of knowledge, learning, and developing or improving skills that are relevant to managing uncertainties. Over time, this approach

can help shift people from a risk-focused mindset to one that actively considers uncertainties.

- **Develop a Lessons Learned Database**
  The next step would involve gathering data on what uncertainty entails, allowing the team to learn and improve their approach. It is recommended that Dura Vermeer establish a comprehensive database to record lessons learned from past projects, with a specific focus on managing uncertainties. This database should document both positive and negative outcomes, categorize uncertainties by type, and include a detailed context for each project. It should outline the strategies used to manage uncertainties, linking them to specific technical and soft skills that were crucial in the process. The database should capture diverse stakeholder perspectives and be regularly updated to remain relevant. By making this resource easily accessible to all project teams, Dura Vermeer can enhance its ability to predict and address uncertainties in future projects. This approach will not only improve uncertainty management practices by helping identify more varied sources of uncertainty, but will also help to recognize the balance needed between technical expertise and soft skills to effectively manage these challenges.

8.2.2 Recommendations for Future

- **Psychological Factors in Skill Development**
  Skill development is highly subjective and greatly influenced by personal traits, making it a complex area that requires in-depth research, particularly from a practical and experiential perspective. Changing someone's mindset is significantly more challenging than teaching a mathematical equation. Therefore, future research should focus on understanding the cognitive and behavioral factors at play in understanding and managing uncertainty, which lacks an unambiguous definition in project contexts. It is recommended to collaborate with highly experienced project managers and industry veterans who have successfully navigated uncertainty in large infrastructure projects. These experts can provide invaluable information on thought processes, decision-making strategies, and adaptive behaviors that contribute to effective uncertainty management. Their practical wisdom can help bridge the gap between theoretical frameworks and real-world applications. This approach would help develop strategies that induce a fresh, more flexible mindset toward uncertainties in large infrastructure projects, ensuring that new methods or frameworks are more successfully integrated and embraced. By combining academic research with the knowledge of experienced professionals, we can create models that are robust and practically applicable to develop skills for uncertainty management.

- **Pilot Study Implementation**
  Establish a pilot team with an uncertainty manager dedicated to managing uncertainty, utilizing the 4A's framework. This pilot should be conducted over 180 days to monitor progress and assess effectiveness. If team members demonstrate skill development and improvement, the pilot can be deemed successful. If not, adjustments can be made and the process can be restarted. This approach should be implemented in collaboration with management and experienced project managers from different disciplines, as they will be instrumental in laying the foundation for the pilot's success. Specific metrics should be developed to measure success, such as: - Improvement in team members' ability to identify and address uncertainties - Reduction in unforeseen project disruptions - Increase in proactive uncertainty management actions - Improved stakeholder satisfaction and project outcomes

- **Broader Application of the Framework** Further research is necessary to evaluate how well the developed framework can be applied to private construction organizations beyond Dura Vermeer. The framework could be adapted for use in organizations like TenneT, Hitachi, WSP, De Kok, Spie, BAM, etc. It should also be assessed whether the framework can be adapted for use beyond the infrastructure sector. A comparative study across different types of organization and sector would provide valuable insight into the framework's versatility and potential limitations.

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Appendix A

Interview Protocol and Guide

Interview Protocol

1. Background

   This interview protocol is intended for the interviews in the context of the graduation research of Reshma Khanam, a Master's student of Construction Management and Engineering at the Faculty of Civil Engineering Technology at TU Delft. The graduation research focuses on uncertainty in stakeholder management within infrastructure projects. This protocol is suitable for gaining insight into how key role individuals deal with unpredictable events within projects. All interviews are conducted by the graduating student. Interviewees are selected in advance based on several criteria. This includes experience as a project manager assumed level of knowledge, and current position in the field.

2. Purpose of the interview

   The primary objective of the interview is to collect empirical data that contributes to the full answer to the research questions posed in the context of the graduation research. These research questions focus on how key skills can be developed and implemented in key roles to manage uncertainty in stakeholder management within their projects. The how question is central. By answering the research questions, the interviews can contribute to the long-term increasing the general level of knowledge about managing uncertainty in infrastructure projects.

3. Result of the interview

   The interviews are processed as part of the graduation research. The most important results will be found in the main text of the report.

4. Procedure for interview

   - The individuals to be interviewed are approached, through a colleague from Dura Vermeer to see if they are willing to cooperate with the interview. This invitation also includes an explanation of the context of the interview. If the person approached is positive about the interview an appointment will be made.
   - The description of the context for the interview is sent in advance. During the appointment, several important characteristics of the interview are communicated:
   - It involves an inventory of personal views and considerations, not formal positions of an organization.
   - It involves obtaining information about undertaken activities and considerations that people in key roles make in a specific project context and experience as well.

- The interview will be recorded, provided the interviewee has no objections, to reporting in the context of the graduation research. Recordings and notes will not be used in any other context.
- An interview draft will be sent to the interviewee, allowing them to make corrections.
- After completing the research, the interviewee will receive a management summary with the main results.
- The interview is expected to take 1 hour.

  The interview itself consists of four parts:

  - Introduction of the interviewer (+/- 5 minutes)
  - Introduction of the interviewee and project (+/- 5 minutes)
  - General view on complexity and uncertainty (+/- 10 minutes)
  - Discussing specific uncertainties concerning internal stakeholders in the project and, the impact of developing knowledge on uncertainty to key skills to be discussed (+/- 35 minutes)
  - Closing the interview (+/- 5 minutes)

5. Introduction to the Interview An important part of the interview is a good introduction with mutual acquaintance between the interviewer and the interviewee, for which a total of 10 minutes is taken. A checklist of aspects that should be addressed during the introduction is:

   - Expressing appreciation for participation and indicating why it is important for the completion of my research.
   - Explaining the background of the interview, checking if the information has been received during the appointment, and verifying if the context is clear.
   - Explaining the procedure during the interview. No substantive information will be provided yet, due to the open nature of the interview.
   - Checking if the location is suitable for the interview (quiet / time frame).
   - Explaining how the interview will be reported.
   - Explaining the audio recording, checking for permission.
   - Emphasizing confidentiality

   Introduction by the interviewer

Interview Guide In this appendix, the interview guide is developed for conducting the 15 interviews with Project Managers, Project Leads, Project Control Managers, Risk Managers, Purchasing Managers, Grip Managers, Design Managers, Contract Managers, and Head of Work Preparation. First, the interview started by asking the interviewee about his profile. Then, the main questions formulated to guide the discussion were asked.

Basic Profile Questions.

1. What is your background, education, and recent work experience?
2. How many years of experience do you have with large infrastructure projects?
3. Can you briefly overview the Land Station project you're currently working on?

4. What is your role and how long are you in the Land Station project?

Main Questions:

1. Do you think this Land Station project is unique from other energy infrastructure projects? If so, how does it differ?
2. Its a hypothetical question, but as per your interpretation, how do you see uncertainty?
3. What are the main uncertainties in the Land Station project? What causes the explained uncertainties? What uncertainties come due to stakeholders?
4. In which phases of the Land Station project, uncertainty is most prevalent? What techniques or strategies do you use to manage them?
5. How do you perceive risk and uncertainty in the Land Station project? Do you view them as different aspects of the same side of the coin?
6. How do you handle risks in the Land Station project? What risk management do you use to mitigate them?
7. Do you think project managers focus too much on risks and ignore uncertainty (threats and opportunities) and why?
8. Who do you think and consider stakeholders are? How do you identify key stakeholders?
9. How many key stakeholders you are working with on the Land Station project? Who is key for what goal? What are your expectations from them?
10. Do you think, stakeholders' perception is a problem to the project? What problems do you encounter with this topic?
11. What do you think about stakeholder perceptions and why it is important to understand them?
12. What is your perception of this project?
13. What uncertainties arise from key stakeholders perceptions? To what extent does it affect the project outcome?
14. How these perceptions can be dealt and do you think dealing with perception can reduce uncertainties?
15. What are the barriers to dealing with these perception uncertainties by stakeholders?
16. What are the drivers for effectively managing the stakeholder's perceptions of the project?
17. Based on your experience, what do we know currently about stakeholder perception? And, what skills are lacking to understand the perception?
18. Does individual experience act as knowledge? If yes, how can this knowledge be transferred to the team to develop a skill?
19. What skills are needed to effectively cope with the uncertainties that arise due to stakeholder perception?
20. How can these skills be developed and implemented? In what way, do these skills help in coping with the uncertainties that arise due to stakeholder's perceptions?

Appendix B

Landstation building component

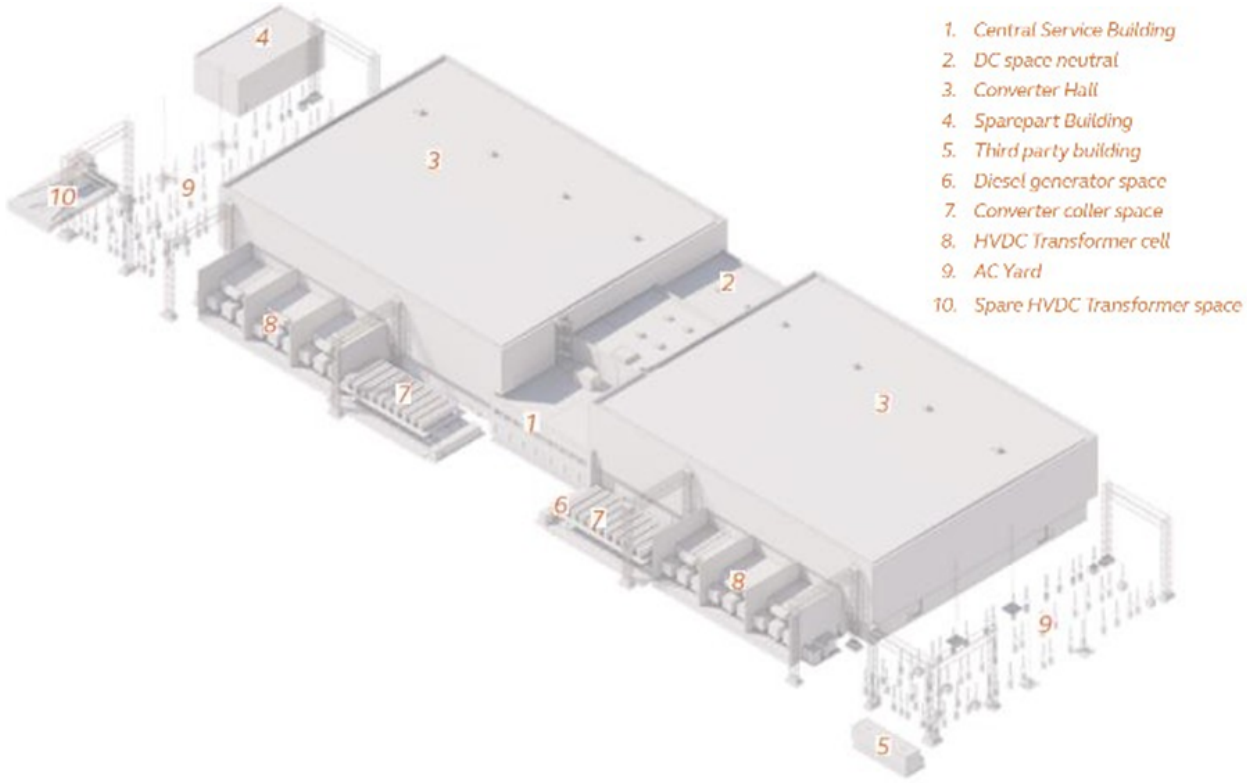

Figure B.1: Landstation building components, (Dura Vermeer internal presentation)

Appendix C

Interview Results

List of uncertainties from the interviewees

- Information flow is unstable and whether it is coming on time - client and Hitachi-
- Different mindsets towards the project outcome and each other
- Different contracts and contractual milestones misalignment between parties
- Roles are responsibilities are not defined well
- Communication is just namesake or not clear
- Trust issue
- Unclear about many technical aspects of the project
- Only TenneT is a priority
- Lack of specialists who can make the right choice at the right moment with the right people who can foresee what's going to happen
- Lack of soft skills, managers think the team is technically sound and are more into technical alignment of the project
- With experience, few managers are rigid in coming out of the traditional ways of working
- Technical feasibility
- A lot of interfaces to manage, involve people management, lack of expertise
- Relevant skill sets are missing
- Involvement of a lot of interdisciplinary departments and Interdisciplinary understanding - collaboration, alignment
- Managing different parties coming from different organizational backgrounds having different value and idea systems towards handling project
- Different interest and expectation management
- Low-cost sustainability
- Dependency with Hitachi
- Lack of knowledge, ideas, and competent engineers
- The pressure of on-time delivery of the project - one Landstaion TenneT has to spend 3 billion

euros

- Multitasking during the design phase- design and parallel execution
- Making sub-contractors partners, and partnerships with those parties could create uncertainty
- A competitor buying one of the partners creates a huge uncertainty to the project (satisfaction matters) Item No.of tasks associated and they're interdependent needs a lot of people to work, however, there is no time for monitoring, what was done yesterday and whatever we did last is still the best thing today to do

Definition of Uncertainty from different interviewees

Interviewees	Quotations
PM1	Uncertainty is identified by analyzing all received data, hence not every risk is in the uncertainty, but every uncertainty is a risk
PM2	Uncertainty involve unexpected events and unknowns. Also includes, foreseen, unforeseen, and boundary risks.
PM3	Uncertainty a factor that cannot be defined at present but needs future consideration
PM4	Risk and uncertainty are recognized as different but are managed together without distinct strategies for each
PM5	Uncertainty a known event with uncertain timing or manner, or completely unknown events with unpredictable outcomes
PM6	Risk is something visible and manageable, whereas uncertainties are unseen and cannot be managed in the same way
PM7	Uncertainty involves knowing that something needs to happen but not knowing how it will unfold
PM8	Not very familiar with the definition but it appears to be in the same context
PM9	Uncertainty a factor that initially increases the range of control needed, but this range decreases as the project progresses
PM10	uncertainties are less predictable and often result from unforeseen interactions and perceptions among project participants
PM11	Uncertainty refers to an event that cannot be predicted or foreseen, making it difficult to manage with standard risk management strategies.
PM12	Uncertainty is identified by analyzing all received data, and efforts are made to manage it.
PM13	Uncertainty is risk and an opportunity
PM14	Uncertainty is when you know something will happen, but the extent or impact is unknown. It differs from risk

Table C.1: Different uncertainty definition by Interviewees

Appendix D

Codes and Code Groups in ATLAS.ti

This appendix shows the codes assigned to every code group in ATLAS.ti. These codes were generated in the following way:

- The 15 interviews were transcribed and uploaded to ATLAS.ti.
- Quotations (highlighted segments of the material that are important and relevant to the interview aim and questions) were created.
- Codes (labels or descriptions of the quotations) were assigned to each quotation.
- Codes that are related to each other with then assigned to a code group.

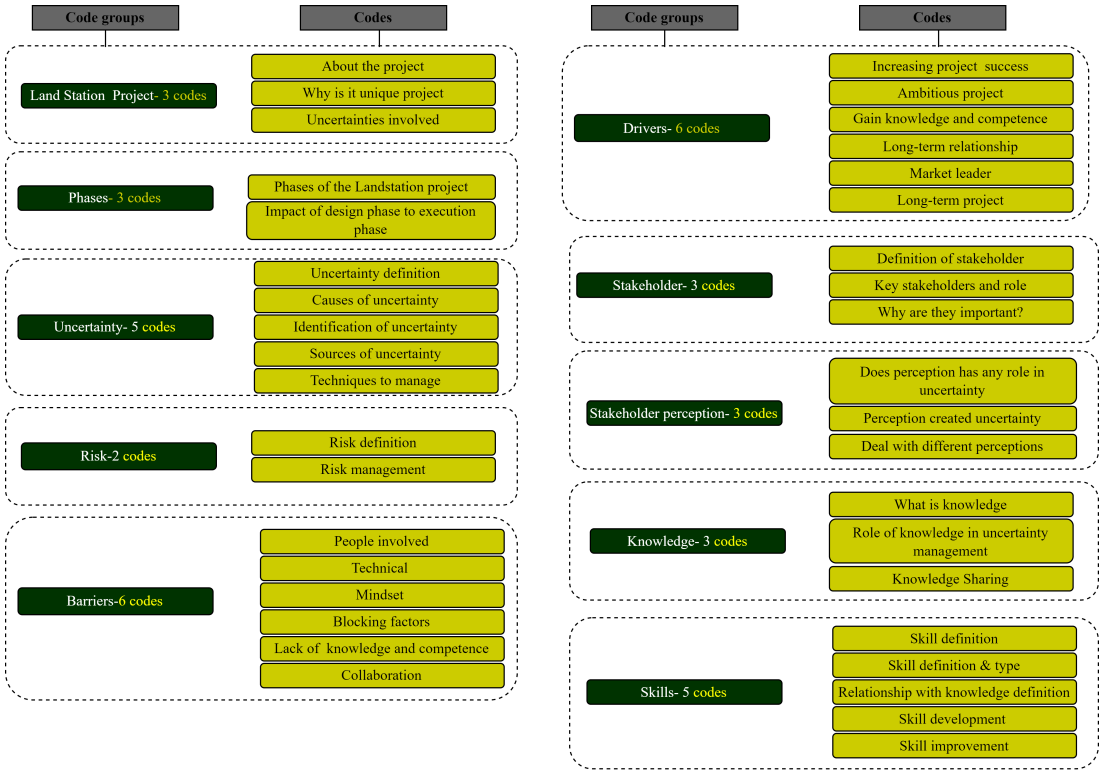

Figure D.1: Code groups and Codes in ATLAS.ti

Appendix E

Skills derived from Interviews

Openness *"For me, listening is always very important. It's crucial to listen to the other party to understand their perspective"* [PM1]

Listening *"Always stay open to communication and listen. Understand their needs and challenges. What do they find important?"* [PM5]

Communication *" you must understand the client. So that's really when you talk about perspective, that you don't only consider your perspective, but especially consider the perspective of the client. So if you understand the decision-making of the client, that will help you get things done"*

Replace yourself in the place of another one *If you can put yourself in the user's shoes, you can understand what they will face during operation, for example, which gives you insight into their needs and interests. Consider what it means for them to maintain a substation: Can it be done safely, or will they have to visit the substation every week to do additional work? Try to put yourself in their position and then act accordingly."*

Get into their shoes *"You need to ask why something is important to them to understand that it might not be the data itself, but something else that matters. This way, you can find another way to help them, ensuring that even if you can't provide the data, you can still offer valuable assistance"*

Knowing how to lead and knowing how to follow *"Dura Vermeer has been the main contractor, used to manage the perceptions and needs of others. However, in this new scenario, we are not the leading contractor"*

Proactive *"you have to be proactive"*

Empathy *"Knowing each other well helps a lot"*

Try to be calm *"you can sometimes fight with the client but don't be reactive"*

Build relationships *"those parties because then they can provide all the work for us and if that works well then we don't have to do a lot"*

Looking through someone else's eyes *"cannot find connection"*

Flexibility *"I think one of the skills you need*