Actualizing Sustainability Opportunities

Enhancing Management of Sustainability Opportunities during Front-End Development in Infrastructure Projects

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Witteveen + Bos

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Enhancing Management of Sustainability Opportunities during Front-End Development in Infrastructure Projects

by

Wilfred Wong

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PREFACE

Completing this Master's thesis signifies the end of my academic journey at Delft University of Technology. Over the past two years, I have had the privilege of deepening my knowledge in construction management and engineering, building upon my background in civil engineering while also experiencing significant personal growth.

My passion for sustainability in the infrastructure sector has been the driving force behind this research. During my time at Witteveen+Bos last year, where I explored sustainability in risk management, I came to recognize that risk should not merely about threats. It also encompasses opportunities. This realization led me to investigate why sustainability opportunities in infrastructure projects often remain underutilized. While many engineers approach this issue from a technical standpoint, I became convinced that management practices play an equally critical role in the actualization of sustainability opportunities. Thus, this thesis was born.

My research benefited from the support of a number of organizations and individuals whom I express my appreciation. I am grateful that Witteveen+Bos shared a same vision and supported my research. Collaborating with Colin Reit and Mehmet Uzun has been an inspiring experience, and I look forward to further developing our findings into practical applications that advance sustainability in the industry.

I would also like to extend my gratitude to the industry practitioners and professionals from Rijkswaterstaat, Heijmans, and Witteveen+Bos for sharing their valuable knowledge, experience, and encouragement throughout this research.

I extend my deepest gratitude to Marcel Hertogh, who chaired this research, for his valuable guidance, expertise, and support. My sincere thanks also go to my first supervisor, Martijn Leijten, for his unwavering support and for once again guiding me in exploring sustainability related challenges. Additionally, I highly appreciate Erik Jan Houwing for his enthusiasm and constructive feedback, which continually pushed me to improve my work.

Beyond academia, my family and friends have been my pillars of strength. Moving to a new country brought both excitement and challenges, but their love and encouragement made this journey possible and more rewarding. I am thankful for their presence in my life and for support me to adapt to my new home in the Netherlands.

Finally, to you, readers, I hope this thesis provides you with both insight and inspiration. May it contribute to a future where sustainability opportunities in infrastructure are not just recognized but actively actualized.

Enjoy the read!

Wilfred Wong
Delft, May 2025

Abstract

This is a thesis about enhancing the management of sustainability opportunities during front-end development in infrastructure projects from the perspective of engineering consultancy firms. This thesis provides insights and guidance for project stakeholders to manage sustainability-related ambitions and ideas. Through empirical research within the Dutch infrastructure sector, this thesis has successfully identified the current landscape, key enablers and barriers to sustainability opportunity actualization. Combining these findings with theoretical analysis, the research develops the Sustainability Human-Centered Implementation Framework for Transition (SHIFT), a structured approach to improve the management and actualization of sustainability opportunities. The framework includes operational guidelines, validated through focus groups with highly experienced industry experts in the Netherlands. The implications of this research are to work towards a more sustainable construction environment and enhance the successful actualization of sustainability opportunities.

Executive Summary

The construction industry stands at a critical junction, confronted with challenges in translating sustainability ambitions and ideas into outcomes. Many ongoing projects set ambitious sustainability objectives and successfully identified sustainability ideas, yet a common issue arises where numerous identified sustainability opportunities remain unactualized in projects. While solutions have been put forth by previous researchers to address sustainability ambition erosion, a notable gap persists in the realm of transforming ambitions to ideas and actualizing sustainability ideas. The front-end development (FED) phase plays a pivotal role in shaping sustainability outcomes. This research addresses the following key question,

> **How can the actualization of sustainability ambitions and ideas be enhanced through the effective management of opportunities during the front-end development process of infrastructure projects?**

To explore this question, the study adopts a semi-grounded theory approach, beginning with theoretical background research and empirical research to investigate the subject in depth in the field. Given the limited prior research on the actualization of sustainability opportunities, this methodology allows for a neutral, receptive and unbiased standpoint. The research draws on insights from 10 exploratory interviews with industry practitioners in the Netherlands. Key findings from these interviews not only inform the design of the framework but also guide the subsequent literature review. Empirical and theoretical insights are synthesized to develop a practical framework, Sustainability Human-Centered Implementation Framework for Transition (SHIFT), aimed at improving the actualization of sustainability opportunities during the FED phase. This framework is then validated through two focus groups comprising highly experienced industry professionals.

Key findings highlight the key enablers and barriers to sustainability actualization in infrastructure projects, as identified through the exploratory interviews.

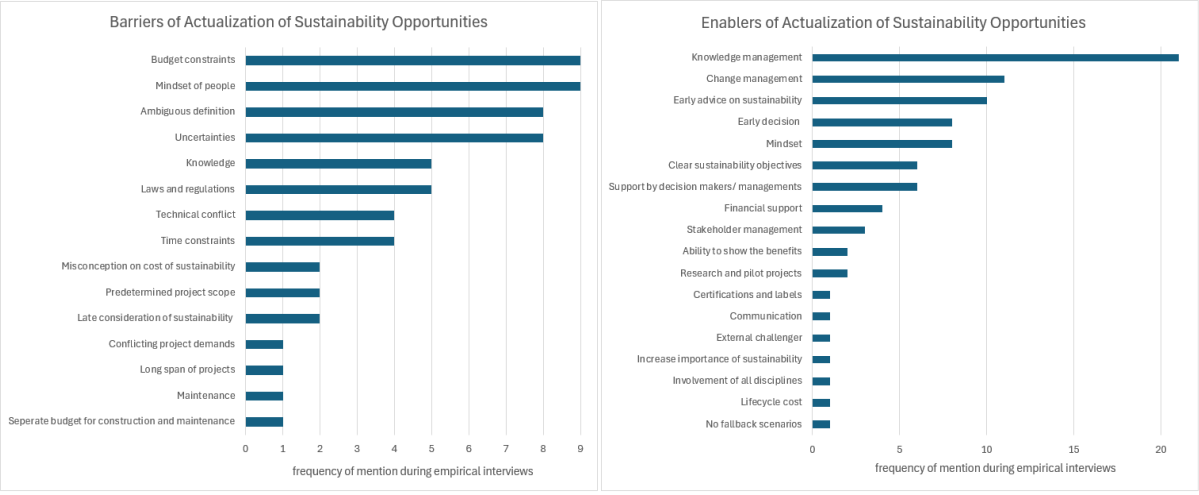

Figure 0.1: Key enablers and barriers (author)

The study uncovered several compelling insights into sustainability opportunities actualization. Most interestingly, organizations exhibit a persistent sustainability ambition execution gap. While organizational sustainability commitments are often in place, their translation into concrete project implementations remains disproportionately weak. Contrary to common perception, sustainability opportunities in practice prove to be more than just chance, its actualization is highly influenced by

decision-making by project teams and policy-makers. Field evidence reveals the prevalent cost misconception, revealing how stakeholders falsely assume the financial burden of considering sustainability opportunities. The research further identifies early-stage rigidity as a critical barrier, where inflexible project scoping decisions made during initiation phases constrain later sustainability actualization. Two key enablers emerged from interviews, the need of knowledge management and change management. Ultimately, the findings underscore integrated thinking as the foundational mindset for successful sustainability actualization.

Building on the key findings, key enablers and barriers, alongside current industry landscape and theoretical findings, 18 action items are introduced from the defined six pillars that facilitates social and technical transition in organizations.

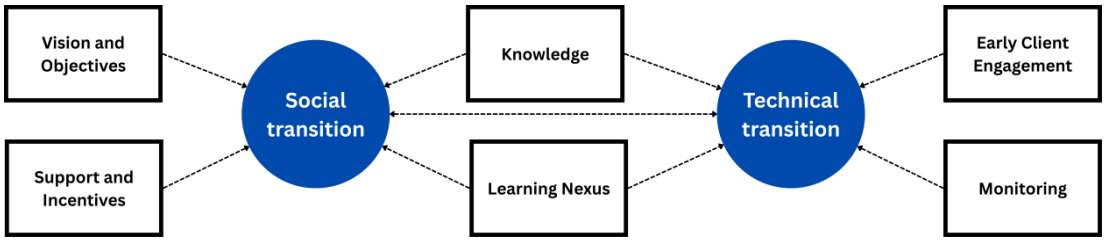

Figure 0.2:The six pillars for action items (author)

The validated Sustainability Human-Centered Implementation Framework for Transition (SHIFT) organizes sustainability action items along a conventional infrastructure project timeline, while systematically categorizing then across three organizational levels, as illustrated in Figure 0.3.

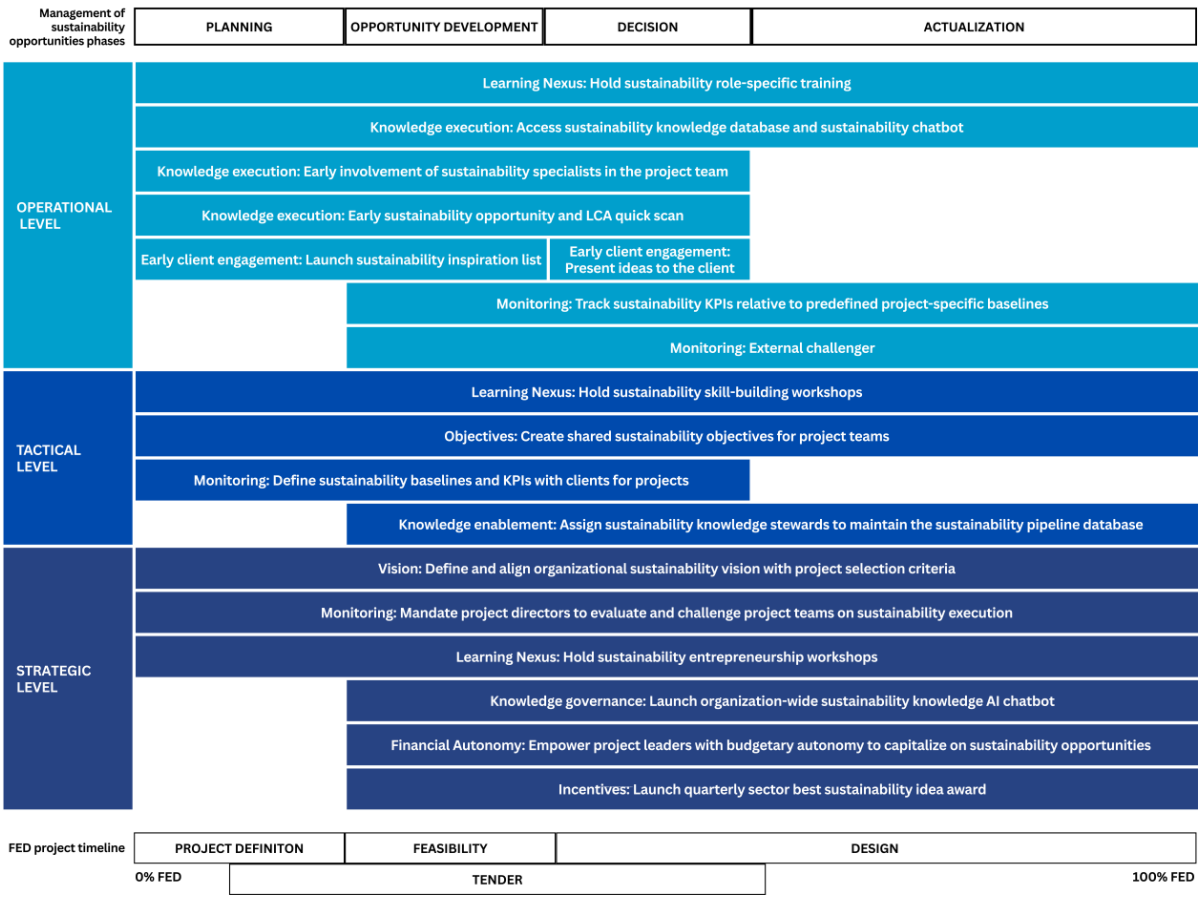

Figure 0.3: SHIFT (author)

The SHIFT provides a systematic approach to improve the actualization of sustainability in infrastructure projects by bridging strategic, tactical, and operational gaps during the FED phase. Unlike prior research focused mainly on policies or individual behaviors, SHIFT enhances the management of sustainability opportunities by addressing the challenge in translating sustainability ambitions and ideas into action. Grounded in change theory, it combines social and technical transformation through organizational level specific action items. Validated by industry experts, the refined SHIFT offers a practical and implementation ready solution for consultancy engineering firms. By integrating empirical insights with actionable steps, the framework advances both sustainability theory and practice.

The SHIFT was developed based on empirical research involving clients, contractors, and consultancies. While its current validation has been specifically conducted with consultancy engineering firms as the primary focus, the core principles of the framework is most likely to remain applicable to client and contractor organizations. Implementation across these different stakeholder groups would require contextual adaptations, but the fundamental methodology retains its validity and transferability.

The method to use this framework depends highly on the context of organizations. To meaningfully improve the actualization of sustainability opportunities, consultancy engineering firms are recommended to implement the SHIFT as their foundational approach. However, successful implementation requires more than simple adoption. Organizations are suggested to first conduct an organizational readiness assessment to evaluate their current sustainability integration capabilities and identify which of the 18 action items in the framework are most contextually relevant and feasible given their specific operational realities. This contextual adaptation is crucial because blindly applying all action items in the framework may prove counterproductive without proper organizational alignment. Fundamentally, effective implementation demands establishing clear governance structures, coupled with cultivating an organizational culture that actively embraces and rewards sustainability innovation and actualization.

Future research should explore the practical implementation of the framework through in-depth case studies to further validate its effectiveness and feasibility in real-world settings. Additionally, expanding the scope of the framework to incorporate perspectives from other key stakeholders, particularly clients and contractors, would enhance its comprehensiveness and applicability. Further investigation could also examine how the principles of the framework might be adapted or extended to project phases beyond FED, potentially creating a more integrated approach to sustainability opportunities actualization throughout the entire project lifecycle.

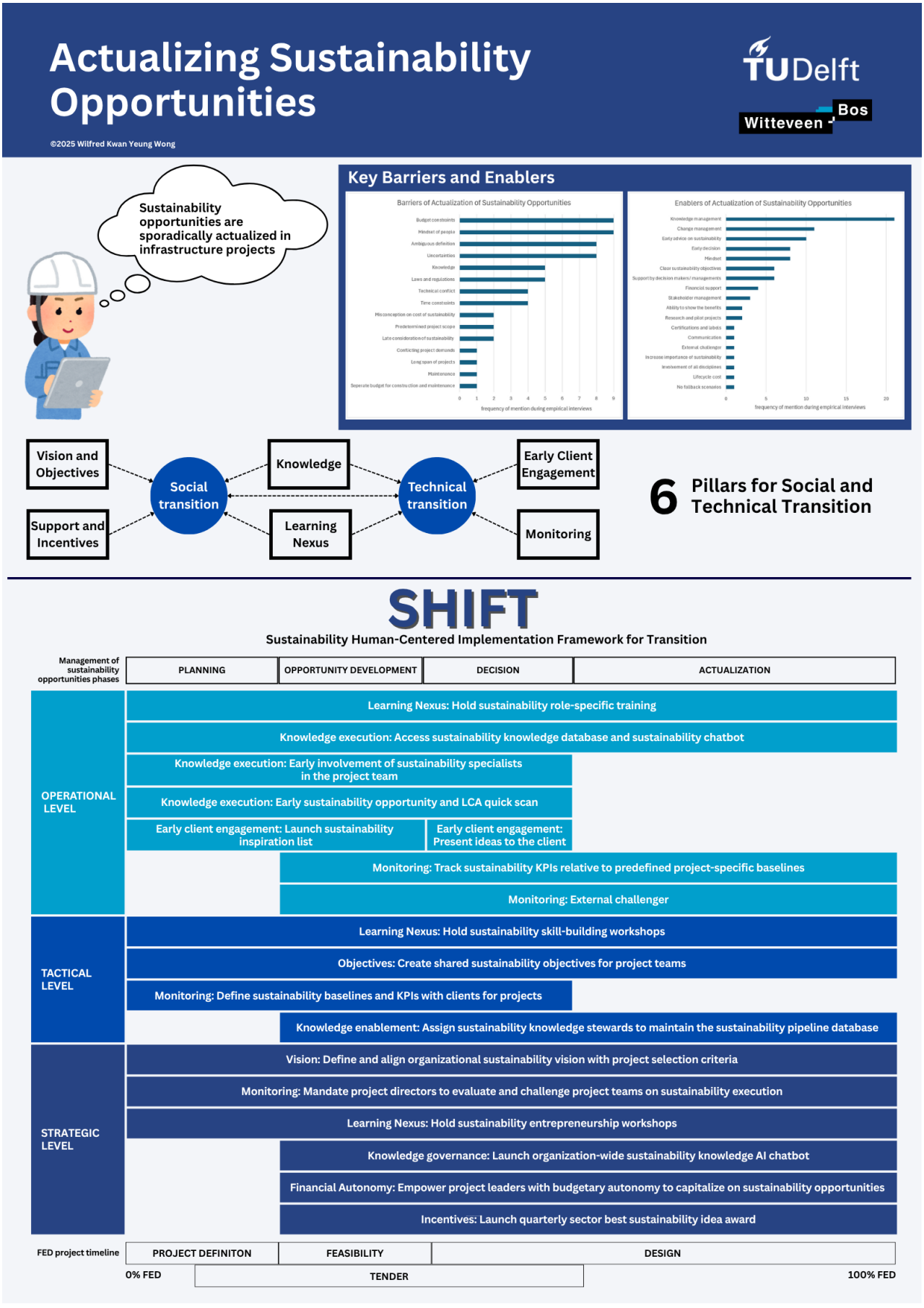

Figure 0.4: Poster (author)

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1. INTRODUCTION

Sustainability is increasingly acknowledged within the construction industry (Spassova, 2022). A widely embraced definition proposed that sustainable development entails meeting present needs without compromising the ability of future generations to meet their own needs (WCED, 1987). Broadly speaking, sustainability involves the consideration of environmental, social, and governance factors to ensure the well-being of current and future generations (Ortiz, Castells & Sonnemann, 2009).

The construction industry stands at a pivotal junction, confronted with challenges arising from unsustainable decision-making practices. In contrast to other industries where sustainability is embraced as an opportunity, the construction realm often shies away from opportunities due to perceived uncertainties and potential cost escalations (Davies et al., 2014). Clients and contractors frequently opt for proven technologies and established routine practices to minimize risks, thereby missing out on valuable opportunities for sustainability progress (Davies et al., 2014).

Many ongoing projects set ambitious sustainability objectives and identify sustainability ideas, yet a common issue arises where numerous identified sustainability opportunities remain unactualized in infrastructure projects. This underscores the critical need for aligning management practices to effectively actualize sustainability ambitions and ideas.

1.1. Motivation

Construction projects are often known to be unsustainable, concerning both the design and construction process. For instance, the construction industry alone accounts for more than 40% of global greenhouse gas emissions, 30% of natural resource extraction, and 25% of solid waste generation (Rodriguez Trejo et al., 2024). While sustainability encompasses more than solely environmental considerations, it is evident that the industry has substantial potential for enhancing its sustainability practices.

One of the key factors for successfully integrating sustainability into construction projects lies in how the project management team manages sustainability opportunities. Sustainability opportunity is a potential avenue within the project that, if effectively utilized, can enhance the achievement of sustainability ambitions. These opportunities typically arise from identifying sustainability ideas. This becomes particularly vital as construction projects grow in scale and complexity but, at the same time, require more emphasis on sustainability. Although sustainability advisory sessions are commonly conducted in projects to identify sustainability ambitions and opportunities, the prevalent problem lies in sustainability ambition erosion and challenges to actualize sustainability opportunities.

Extensive research on addressing the erosion of sustainability ambition has been conducted by a previous researcher, Veen (2023), in her master's thesis at the Technical University of Delft. The previous researcher concentrated on recognizing barriers that contribute to the erosion of sustainability ambitions in the exploratory stages of infrastructure projects, leading to the development of a framework to mitigate this erosion. The barriers identified encompass four aspects, namely capacity building, motivation, collaboration, and process barriers. Veen (2023) also pinpointed two limitations in her research: the lack of focus on the design phase and the absence of solutions for actualizing these ambitions.

While solutions have been put forth to address sustainability ambition erosion, a notable gap persists in the realm of transforming ambitions to ideas and actualizing sustainability ideas. This gap exists because of limited understanding and solutions for managing opportunities tailored to sustainability ambitions and ideas within the construction sector, resulting in unactualized ambitions and ideas. This research endeavors to narrow the gap between the actualization of sustainability ambitions and ideas in practice and the management of opportunities both in academia and in practical application. This gap is visually depicted in Figure 1.1.

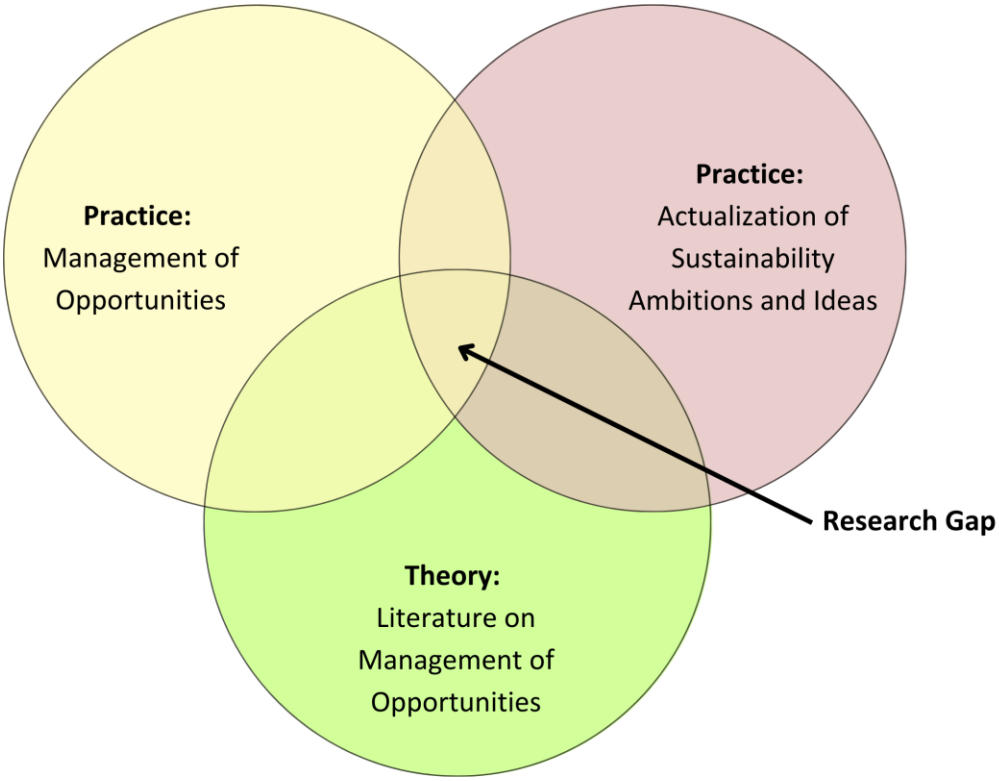

Figure 1.1: Visualization of the research gap (author)

In order to effectively embed sustainability into construction projects, it is crucial to integrate sustainability into project management processes at the earliest stages (McPhee & Dias, 2020). The front-end development (FED) phase, which is the early stage of the project, plays a pivotal role in shaping the sustainability outcomes of a project (Cidik et al., 2014). Encompassing exploratory, preliminary design, and detailed design stages, the FED phase is where crucial decisions are made that not only impact the sustainability of the project but also have

significant implications on its overall costs (Cidik et al., 2014; Dewulf, 2013). Therefore, addressing sustainability considerations at the FED phase is crucial for setting the project on a sustainable trajectory. This underscores the significant role of consultancy engineering firms in this context, given that they are predominantly engaged during the FED phase. Recognizing the substantial impact consultancy engineering firms have on sustainability outcomes, this research primarily centers on examining the actualization of sustainability opportunities through the lens of these firms and draws upon research insights rooted in consultancy engineering practices.

Therefore, to effectively address these challenges, the scope of this study, depicted in Figure 1.2, revolves around investigating the synergy between the management of opportunities and sustainability ambitions and ideas during the FED phase within infrastructure projects.

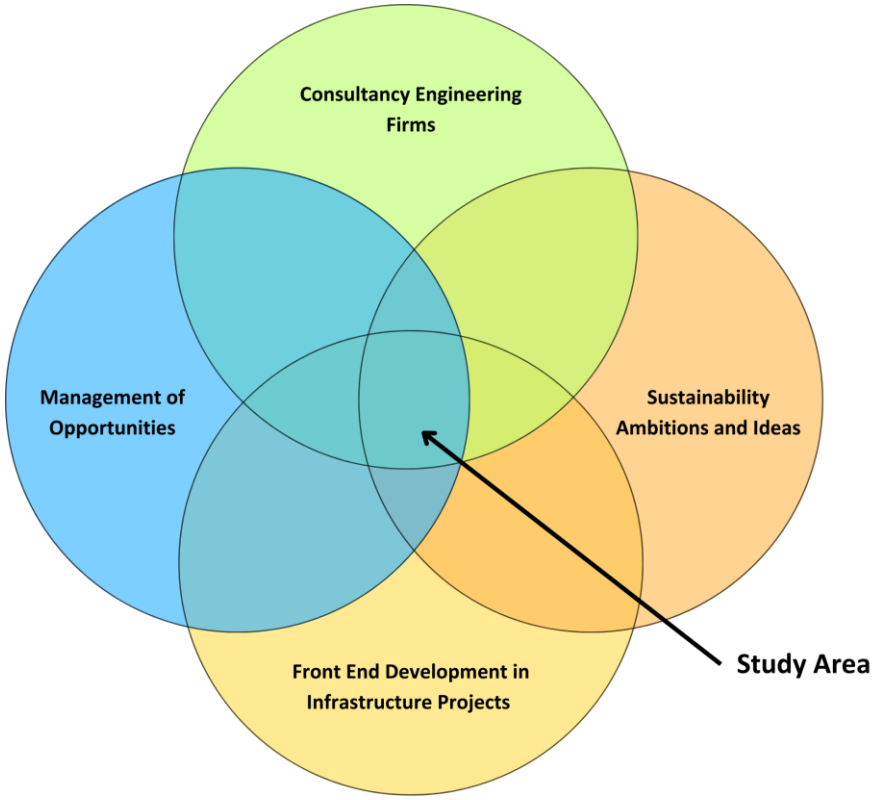

Figure 1.2: Visualization of the study area (author)

1.2. Research Problem

Building upon prior mentions, the construction industry faces challenges in actualizing sustainability ambitions and ideas. A substantial number of opportunities to actualize sustainability ambitions and ideas tend to slip through the cracks as the project advances through its various stages, revealing a gap between the process of managing opportunities and the actualization of sustainability ambitions and ideas.

While existing research predominantly delves into the factors contributing to ambition erosion within projects, there remains a scarcity of scientific exploration into sustainability during the FED phase coupled with the phenomenon of sporadically actualization of sustainability opportunities in infrastructure projects (Storacker et al., 2013). The question of how to actualize sustainability opportunities in projects is still endeavored to be discovered. Within

this context lies the core research challenge of how to effectively manage opportunities to actualize sustainability ambitions and ideas.

1.3. Research Objectives and Implications

The primary objective of this research is to investigate the phenomenon of the sporadically actualization of identified sustainability ambitions and ideas, as well as to explore management solutions that can be implemented during the FED phase to improve the actualization of sustainability opportunities in subsequent stages. This overarching objective can be divided into three key research aims, which are outlined below:

i. To identify key barriers and enablers associated with actualizing sustainability-related project ambitions and ideas.
ii. To assess the current landscape of theories and practices related to the management of opportunities in construction projects.
iii. To develop a management framework and operational guidelines for effectively actualizing sustainability ambitions and ideas.

The first objective seeks to uncover the practical challenges that construction projects face when attempting to actualize sustainability ambitions and ideas into projects from the lens of consultancy engineering firms. Concurrently, it seeks to identify enablers for enhancing the management of sustainability-related opportunities in projects in the FED phase from the perspective of consultancy engineering firms. By understanding both the barriers and the enablers, project controllers can better strategize and prioritize their efforts toward actualizing sustainability-related ambitions and ideas during the FED phase.

The second objective seeks to provide a comprehensive understanding of the management of sustainability opportunities, including innovations, designs, and processes within the construction sector. It involves evaluating the existing theories and methodologies that lie in the identified study area, as well as the practices that practitioners use to manage sustainability opportunities. By mapping out the current landscape, this objective aims to highlight best practices and establish a foundation for further exploration and development.

The third objective focuses on creating a structured approach so that project stakeholders can effectively actualize sustainability ambitions and ideas. The development of a framework will provide clear principles for actualizing sustainability opportunities in the project lifecycle. Additionally, creating operational guidelines will empower teams to practically manage and actualize sustainability-related opportunities that contribute to sustainability outcomes. This objective ultimately aims to facilitate a more systematic and effective approach to actualizing sustainability opportunities in infrastructure projects, ensuring that opportunities are not overlooked or diluted without justification.

1.3.1. Scientific Implication

The findings of this research have significant scientific implications for the fields of sustainability and project management within the construction industry. The research seeks to make contributions to fill the scientific gap in the management of sustainability-related opportunities in the FED phase. By elucidating the factors contributing to the non-actualization of sustainability ambitions and ideas, this study provides a deeper understanding of the

dynamics that impede the effective actualization of sustainable opportunities in infrastructure projects. Furthermore, the proposed framework and guidelines for the FED phase can serve as a foundation for future research, encouraging further exploration into how early-stage decision-making influences sustainability outcomes.

1.3.2. Practical Applications

This research not only contributes to the theoretical discourse on the management of sustainability opportunities but also offers practical insights that can enhance the actualization of sustainability opportunities in infrastructure projects. By highlighting effective management strategies during the FED phase, the study equips project stakeholders with a framework and actionable guidelines to manage sustainability ambitions and ideas early in the project lifecycle and enhance the successful actualization of sustainability opportunities in projects. These insights ensure that sustainability opportunities remain considered rather than becoming diluted over time. Additionally, implementing the proposed framework and guidelines can result in more resilient and environmentally responsible infrastructure outcomes.

1.4. Research Question

As outlined in the previous section, there is considerable research potential in developing a framework with practical operational guidelines that can be utilized during the FED phase to effectively actualize sustainability opportunities in construction projects. By integrating rigorous scientific inquiry with practical insights from industry professionals, it is believed that the scientific gap introduced in Section 1.1 can be reduced. Based on the aforementioned research objectives, the central research question of this paper emerges:

How can the actualization of sustainability ambitions and ideas be enhanced through the effective management of opportunities during the front-end development process of infrastructure projects?

To provide additional support for the answering of the primary research question, three research sub-questions have been identified,

- SQ1: Why are sustainability ambitions and ideas sporadically actualized in infrastructure projects?
- SQ2: How have scientific and practical methodologies for the management of opportunities been shaped?
- SQ3: How can insights gained from barriers hindering the actualization of sustainability opportunities and the enablers in managing project opportunities be leveraged to improve the actualization of sustainability ambitions and ideas?

1.5. Research Design

In the research design, the objectives are tightly connected to the research sub-questions. By addressing the sub-questions derived from the overarching objectives, the research output is produced, which in turn facilitates the answering of the primary research question. This section will provide a detailed explanation of the research design process.

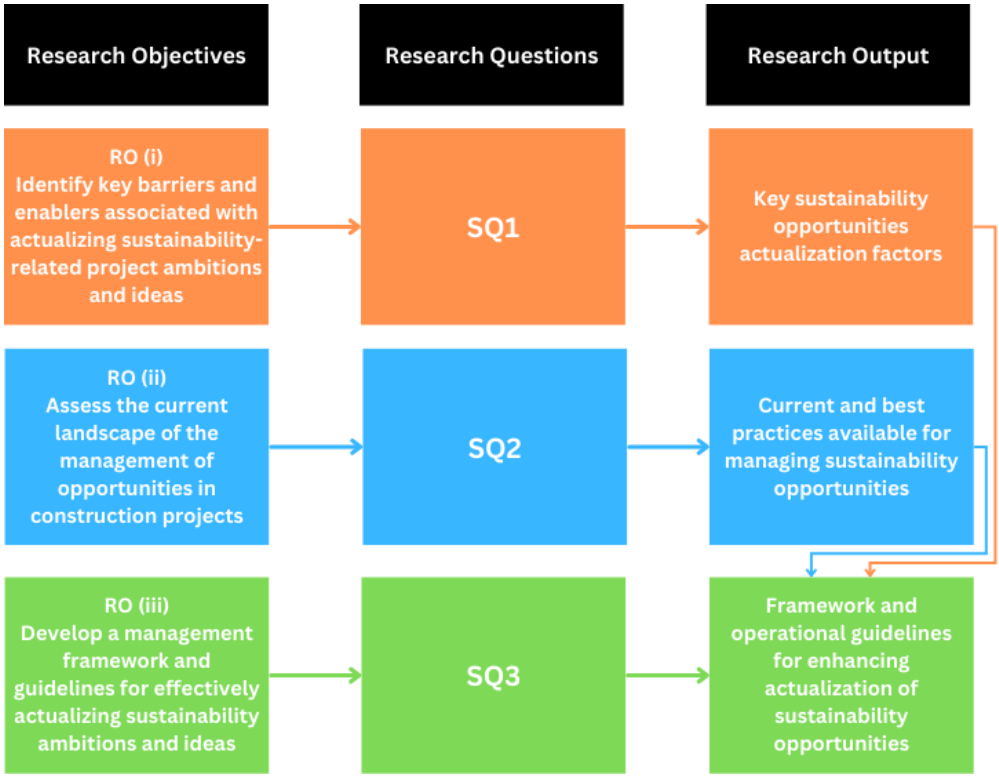

Figure 1.3: Research design (author)

Figure 1.3 illustrates the research design with a cohesive structure linking the research objectives, questions, and outputs. The first research objective (RO i) aims to identify barriers and enablers for actualizing project ambitions and ideas, leading to the research question (SQ1): Why are sustainability ambitions and ideas sporadically actualized in infrastructure projects? This inquiry seeks to uncover key factors contributing to the non-actualization of sustainability opportunities and enablers to the actualization of sustainability opportunities, ultimately providing insights to inform strategies for managing sustainability opportunities throughout project development. The second research objective (RO ii) involves assessing the current landscape of the management of opportunities in construction projects, which corresponds to the question (SQ2): How have scientific and practical methodologies for the management of opportunities been shaped? This question maps the evolution of scientific and practical approaches, highlighting existing theories and best practices that have emerged in the management of opportunities. Finally, the third objective (RO iii) focuses on developing a management framework and guidelines, addressing the question (SQ3): How can insights gained from barriers hindering the actualization of sustainability opportunities and the enablers in managing project opportunities be leveraged to improve the actualization of sustainability ambitions and ideas? This inquiry aims to formulate a scientific framework with practical strategies and guidelines for project managers to ensure the actualization of sustainability opportunities.

Overall, the research is designed to produce valuable insights into enhancing sustainability outcomes in infrastructure projects, emphasizing the interconnectedness of understanding practical challenges, evolving theories, and developing practical applications.

1.6. Scope

The scope of this research focuses on understanding how sustainability ambitions and ideas can be effectively actualized through the management of opportunity during the FED phase of infrastructure projects by consultancy engineering firms. This study is scoped within the areas highlighted in Figure 1.2, concentrating on the actualization of sustainability ambitions and ideas, management of opportunities, and the FED phase in infrastructure projects from a consultancy engineering firm point of view. In this research, FED is scoped as encompassing the exploratory and design stages of a project.

1.7. Thesis Outline

This section presents an overview of the thesis structure, illustrating the connections between individual chapters and the research question and sub-questions, as visualized in Figure 1.4.

The study adopts a semi-grounded theory approach, building on the foundational principles of grounded theory pioneered by Glaser and Strauss (1967) while adding an initial theoretical background exploration to guide the empirical research. Grounded theory approach focuses on deriving results grounded in data from the field (Khan, 2014). Unlike a pure grounded theory approach, this modified methodology begins with a review on theoretical background of the research subject before engaging in empirical research. The empirical findings then inform and shape the theoretical research, allowing for a dynamic interplay between theory and empirical data. The insights derived from this process will ultimately contribute to the development of a structured framework and practical guidelines.

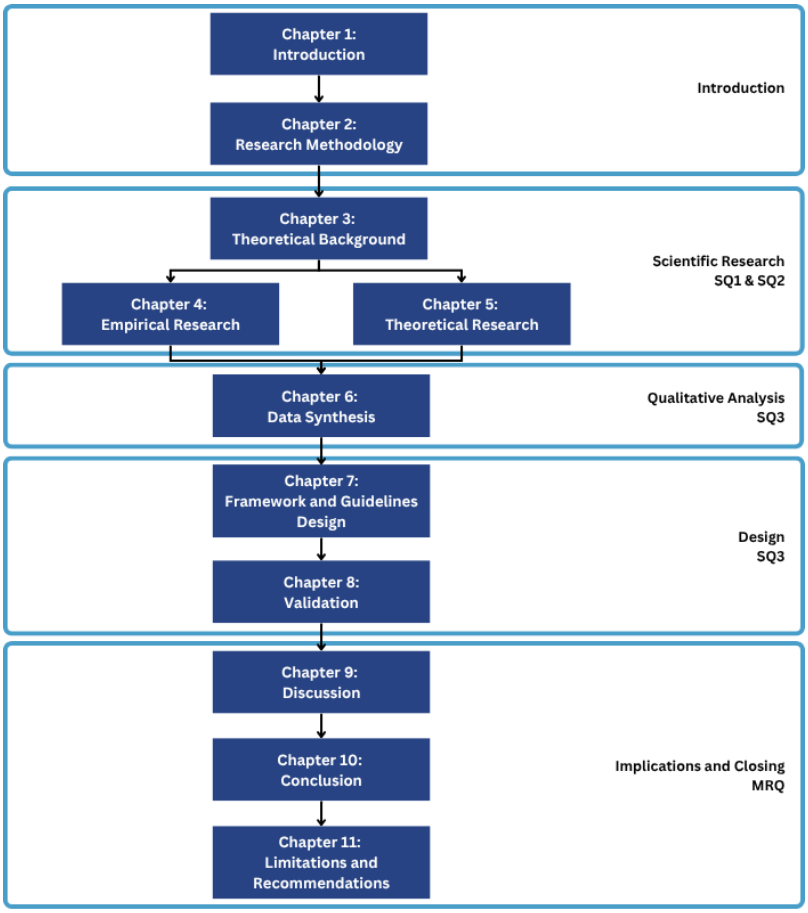

Figure 1.4: Thesis outline (author)

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2. RESEARCH METHODOLOGY

This Chapter outlines the research methodology employed in this study, describing the approaches and techniques used to collect, analyze, and utilize research data to generate findings and achieve the research objectives.

2.1. Methodological Approach

The study employs a semi-grounded theory approach, an adaption of the classic grounded theory approach developed by Glaser and Strauss (1967). While traditional grounded theory approach emphasizes starting with empirical data gathering, this research modifies the approach by first engaging with theoretical backgrounds of the research subject before proceeding to empirical research. This adjustment is particularly valuable given the complexity of the research topic, as it ensures a shared understanding of key definitions prior to empirical investigations. Importantly, the initial theoretical background exploration focuses specifically on fundamental concepts and definitions related to the research subject, providing essential context without predetermining empirical outcomes.

The decision to adopt this approach stems from the limited in-depth scientific research into the actualization of sustainability ambitions and ideas. While some existing research has delved into the management of sustainability opportunities and the obstacles hindering their actualization, practical implementation often falls short of expectations. By beginning with a structured theoretical background review, the study establishes a conceptual baseline while remaining open to emergent insights from the field. This ensures that the research is neither overly constrained by pre-existing literature nor entirely detached from academia. Thus, the empirical research maintains a neutral, receptive and unbiased standpoint, free from external and historical research influences. This approach enables an open-minded and comprehensive examination of the subject matter directly obtaining insights from industry insiders. This methodology welcomes an inclusive analysis that includes a wide array of viewpoints and experiences from the field.

The collection of firsthand information provides a broad and unbiased understanding of the practices in managing sustainability opportunities as well as the enablers and barriers surrounding sustainability implementation. After the completion of empirical research, the study explores the existing literature related to the subject. The study integrates insights gained from empirical interviews with published literature, synthesizing knowledge from both sources. By combining empirical observations with established literature, this methodology empowers the research to construct a theoretical framework grounded in practical experience and complemented by scholarly discourse.

A core component of this methodology is theoretical sampling, an iterative process where data collection and analysis inform subsequent research directions (Khan, 2014). As empirical findings emerge, they dynamically shape the theoretical research framework, ensuring that conclusions remain deeply rooted in empirical evidence. This approach enables an inclusive examination of diverse stakeholder perspectives while critically engaging with existing literature.

Together with the aforementioned semi-grounded theory approach, the double diamond methodology is employed as the foundational framework for guiding the research. Developed by the British Design Council in 2005, the double diamond process model is renowned for its structured approach to problem-solving and innovation (Design Council, 2005). This methodology is particularly chosen because it offers a systematic approach for exploring and addressing sustainability-opportunity-related actualization challenges in infrastructure projects, as well as developing the framework and guidelines for improving the management of sustainability opportunities. The double diamond methodology that is used in this research is visually represented in Figure 2.1.

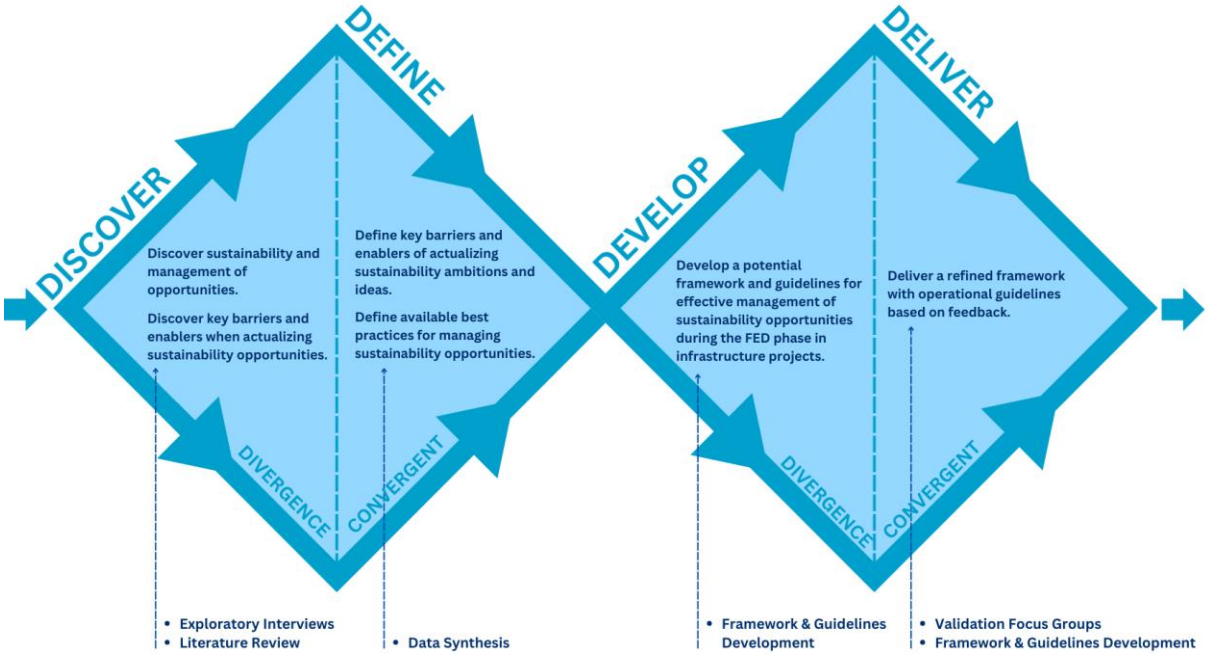

Figure 2.1: Double diamond Research Methodology (Design Council, 2005; author)

This methodology commences with the discovery phase, during which insights will be gathered through exploratory interviews with industry practitioners and a comprehensive review of existing literature. This phase is designed to first delve into the domain of the actualization of sustainability opportunities through theoretical background research and empirical research. Subsequently, guided by the empirical data findings, the research progresses to theoretical research on managing sustainability opportunities. The discovery phase will conclude upon the attainment of necessary data and the point of theoretical saturation, a concept elaborated on in the subsequent section. Following this, the define phase will focus on synthesizing these insights into clear barriers and enablers that articulate the non-actualization of sustainability opportunities and define best practices for the management of sustainability opportunities. In the development phase, the research will engage in

brainstorming and prototyping potential frameworks and guidelines for effective management of sustainability-related opportunities during the FED phase to enhance its actualization based on the defined factors and best practices. Finally, the delivery phase will involve refining these solutions based on the validation round, ensuring their practicality and applicability for practice. Overall, the double diamond methodology will provide a structured yet adaptable research approach to discover, define, develop, and deliver.

2.2. Methodology

This study adopts a qualitative approach to explore the challenges and opportunities associated with actualizing sustainability opportunities in infrastructure projects. To ensure credibility, enhance validity, and mitigate bias, the concept of triangulation, as proposed by Patton (1999), is utilized. In qualitative research, triangulation involves utilizing various methods and data sources to attain a holistic comprehension of a phenomenon (Patton, 1999).

Data for this study are mainly gathered through practitioner engagements and literature reviews, utilizing multiple data sources from both scientific and practical sides. The sample size and data collection method are further discussed accordingly in the subsections. The findings will be utilized to develop a framework that includes actionable guidelines for the FED phase in enhancing the actualization of sustainability opportunities in infrastructure projects. The research methodology is outlined as follows.

2.2.1. Exploratory Interviews

To initiate the grounded theory approach research in the discovery phase of the double diamond methodology, empirical data is collected to understand the context of the sporadic actualization of sustainability opportunities in practical settings and to discover the current practices in managing such opportunities. Exploratory interviews are being conducted to gather qualitative empirical data to expand the knowledge for this study.

These exploratory interviews are structured in a semi-structured manner and engage with relevant practitioners. The interviews with practitioners aim to acquire practical insights and perspectives on the subject. The interview findings will be analyzed and synthesized with the outcomes of the literature review in the define phase of the double diamond methodology. These results will serve to guide the development of a framework and a set of guidelines for effectively managing sustainability opportunities. Noteworthy, in order to ensure the diversity of the sample for analysis, stakeholders for these interviews include diverse roles, such as project managers, risk managers, sustainability specialists, cost estimators, and technical designers. The sample overview for empirical research is detailed in Chapter 4.

The determination of the number of exploratory interviews is based on the concept of theoretical saturation. The notion of theoretical saturation is rooted in grounded theory by Glaser and Strauss (1967) and is commonly utilized to determine sample sizes for qualitative research interviews (Rowlands, Waddell & McKenna, 2016). The theoretical saturation point is the point where further data collection and analysis cease to provide additional value to the developing theory (Saunders et al., 2018). In this study, an iterative approach to data collection and analysis involving continuous engagement with the data and comparing new data with existing findings is employed. The expectation is that theoretical saturation will likely be reached within 8 to 10 interviews.

2.2.2. Literature Review

Literature review is utilized in two phases within the discovery phase of the double diamond methodology, theoretical background research and theoretical research. The theoretical background chapter reviews literature focuses on exploring and defining sustainability and opportunity within the construction sector. The primary objective of this review is to acquire scientific knowledge on sustainability and opportunity.

The subsequent theoretical research uses literature review to build upon insights gained from the empirical research. The literature review initially examines established best practices and theoretical frameworks concerning sustainability and management of opportunities, particularly during the FED phase, within the academic community. Additionally, the review scrutinizes selected key findings from the empirical research. The primary objective of this review is to acquire scientific knowledge on the actualization of sustainability opportunities while also delving into specific topics derived from the empirical research findings.

A systematic literature search is utilized to pinpoint existing relevant literature, with a focused categorization based on distinct themes. This theme-based approach ensures a comprehensive exploration of the literature landscape related to these aspects, enabling a comprehensive understanding of the subject.

2.2.3. Data Synthesis

A comprehensive data synthesis will be undertaken to examine the findings from both empirical and theoretical research. The findings from empirical research and theoretical research are compared, analyzed, and combined. This process occurs during the define phase of the double diamond approach, diverging wealth of findings from empirical and theoretical research to defining key barriers and enablers in actualizing sustainability opportunities as well as available best practices for managing sustainability opportunities. This step ensures that the development of the framework is rooted in the key findings from both empirical evidence and existing theories.

2.2.4. Framework and Guidelines Development

The development of a comprehensive framework, informed by the knowledge acquired from the empirical research, theoretical research and data synthesis, is a pivotal step in enhancing the actualization of sustainability opportunities. This framework provides a solid foundation for incorporating effective management of sustainability opportunities in the FED phase of infrastructure projects. The framework aims to serve as both a theoretical contribution and a source of practical guidance. To heighten its practical utility, actionable guidelines are developed alongside the framework to assist project controllers in effectively managing sustainability ambitions and ideas.

The framework and guidelines development process are structured into two distinct phases, namely the preliminary design phase and the detailed design phase. During the preliminary design phase, the initial groundwork for the potential directions and key components of the framework is established. This phase will involve translating the findings from the empirical research, theoretical research and data synthesis into a conceptual framework. The conceptual framework acts as a foundational blueprint, outlining essential concepts and guiding principles for managing sustainability opportunities.

The conceptual framework will undergo adjustments and improvements based on the feedback gathered during the validation workshops. These valuable inputs will shape the detailed framework, outlining specific criteria and actionable guidelines for integrating the proposed changes seamlessly into routine project management processes. The goal is to align the framework with practical requirements while ensuring its concordance with scientific research. By incorporating practitioner input and leveraging the latest scientific research insights, the framework will be capable of effectively tackling real-world challenges and providing practical solutions.

2.2.5. Validation Focus Groups

To ensure the robustness and practical applicability of the proposed management framework and guidelines for sustainability, a feedback process is implemented, involving validation focus groups with practitioners. These focus groups will serve as an invaluable opportunity for potential users to review and provide valuable input on the framework and guidelines.

The validation focus groups are conducted in small-group settings to facilitate active participation from all attendees. Each session comprises a minimum of two practitioners representing different roles within infrastructure projects. Prior to the sessions, participants receive a one-page introductory overview of the framework. During the discussions, participants evaluate the framework based on their professional expertise and working experiences. The primary objective of these focus groups is to identify potential areas for improvement, address gaps, and refine both the framework and its accompanying guidelines. The number of validation focus groups is determined by the design of the framework, with a total of three sessions conducted: one for strategic-level validation, one for tactical and operational-level validation, and one for validation from the client perspective.

2.3. Research Methodology and Research Design

In Figure 2.2, the relationship between the research methodology and research design is visually depicted, illustrating how the chosen research methodologies align with the research design. This visualization provides a clear representation of how the methodological approach adopted in the study shapes the design of the research process.

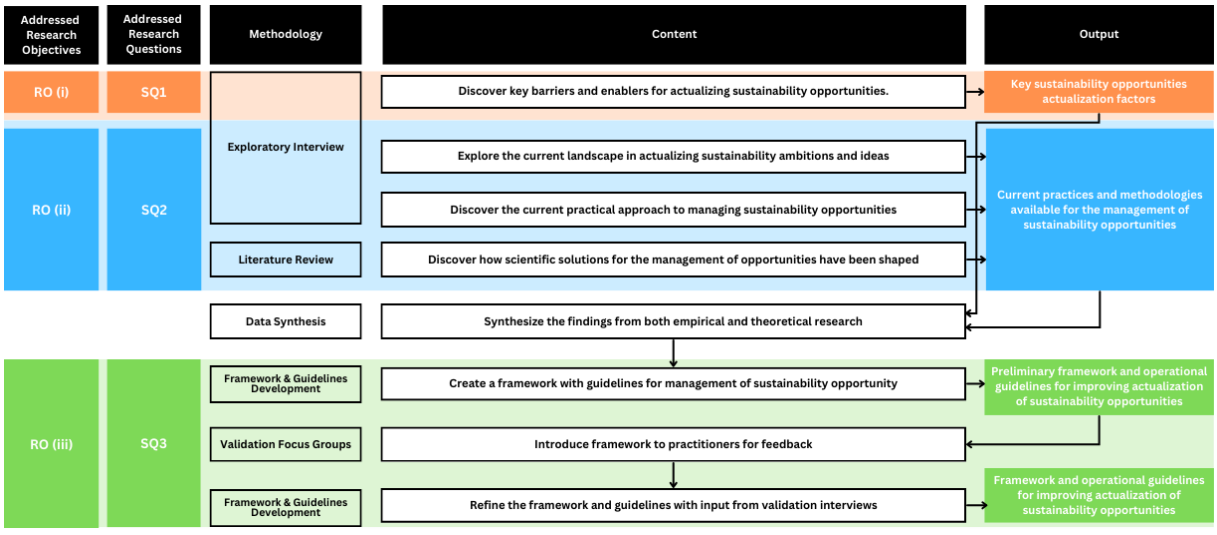

Figure 2.2: Research Methodology and Research Design (author)

3

3. THEORETICAL BACKGROUND

The research begins by establishing a theoretical foundation through a comprehensive review of key concepts, specifically examining how opportunity and sustainability are defined within the construction industry and project management domains in academia. This initial theoretical exploration serves as a crucial first step in the semi-grounded theory approach, providing the foundation necessary to guide subsequent empirical investigation while maintaining openness to emergent insights from field data.

A systematic literature search method employing targeted keywords is used to identify relevant existing literature. Scopus, a scholarly article database, is utilized for the theme-based search. This theme-based strategy involves refining the pool of relevant readings by inputting multiple keyword searches and time period. After obtaining a manageable number of papers, they are manually screened based on their abstracts and conclusions. Subsequently, the chosen relevant and frequently cited literatures are reviewed in detail and incorporated into this chapter as needed. Figure 3.1 provides the literature selection overview.

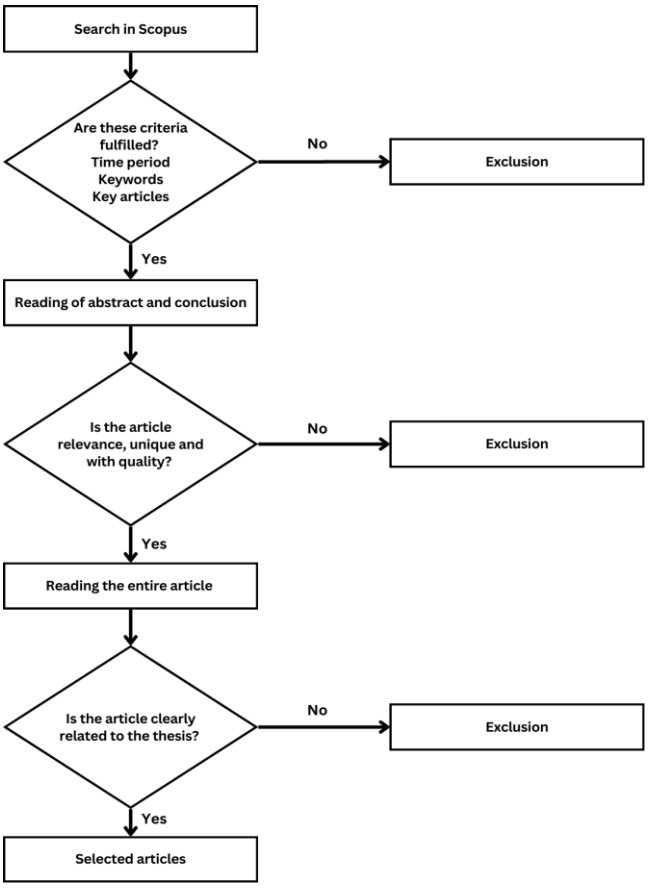

Figure 3.1: Literature selection overview (author)

3.1. Opportunity

The term 'opportunity' has been used over the past 150 years (Gartner et al., 2017). The origin of the English word 'opportunity' traces back to its Latin and Greek roots. It embodies more than a mere chance; it symbolizes a gateway to potential growth and success. In Latin, '*opportunus*' originated from '*ob*' meaning 'to', and '*portus*' meaning 'harbor' (Gartner et al., 2017; Hillman, 1987). Similarly, the Greek concept of '*kairos*' signifies a penetrable opening, suggesting a window of opportunity that opens briefly and then closes (Gartner et al., 2017).

Turning towards more recent scholarship on opportunity, the idea of opportunity has been focused both conceptually and empirically in the strategic and project management area. In the area of strategic management literature, the idea of opportunity has been found mainly in SWOT (Gartner et al., 2017). The acronym SWOT, which refers to strengths, weaknesses, opportunities, and threats, was published by the Stanford Research Institute in 1966. While the idea of opportunity was in use through the SWOT framework as practice from the 1980s, there was limited theoretical research on how opportunities were conceptualized by other scholars (Whittington, 1996).

The theoretical exploration of the idea of opportunity became apparent in the 'strategic issue identification' area in the 1990s (Gartner et al., 2017). Studies in this realm pointed out that the characteristics of opportunities are situations with high positive gain and high controllability (Thomas & McDaniel, 1990). However, it has been proven that individuals perceive opportunities and threats differently based on interpretations. When options are presented as losses, risk-taking choices are viewed as opportunities, whereas when framed as gains, the same risk-taking choices are seen as threats (Highhouse & Yüce, 1996). This shows that losses and gains serve as status quo reference points that influence perspectives, while threats and opportunities are subjective interpretations of the situation at hand.

Opportunity within the context of project management generally refers to a potential condition that has a positive effect on project objectives. The concept of opportunity, often categorized as positive risks, emerges as a significant component under the overarching umbrella of uncertainty (Marsov et al., 2022). Theoretical perspectives on risk commonly depict it as a potential deviation, whether positive or negative, from an expected value. Notably, within project management practice, there exists a prevalent tendency among practitioners to predominantly view risks as threats, thus potentially neglecting the advantageous effects they might offer (Marsov et al., 2022). This one-sided perspective has sparked considerable debate within the community of risk scientists and practitioners, particularly regarding whether the term 'risk' should encompass both opportunities and threats (Hillson, 2002). According to Hillson (2002), two distinct definitions emerge in academia: one posits risk as an overarching concept encompassing both opportunities and threats, while the other defines risk exclusively in terms of threats, with opportunity framed as a positive uncertainty. This contrast is illustrated in Figure 3.2.

The question arises as to whether these variations in definitions hold significance. It particularly affects how opportunities are perceived. In this study, it is believed that the definition of risk encompasses both opportunities and threats is a clear statement recognizing both opportunities and threats are equally important influences over project success, and both need to be managed proactively. This perspective aligns with the definition put forth by the Project Management Institution (2021) in the PMBOK, which defines risk as an uncertain

future event or condition capable of influencing project objectives either positively or negatively. It is emphasized that opportunities and threats share a common ground, both involving uncertainty that can influence project outcomes (Hillson, 2002). Therefore, in this research, the definition of opportunity within the term risk is employed, acknowledging the intertwined nature of opportunities and risks in project management.

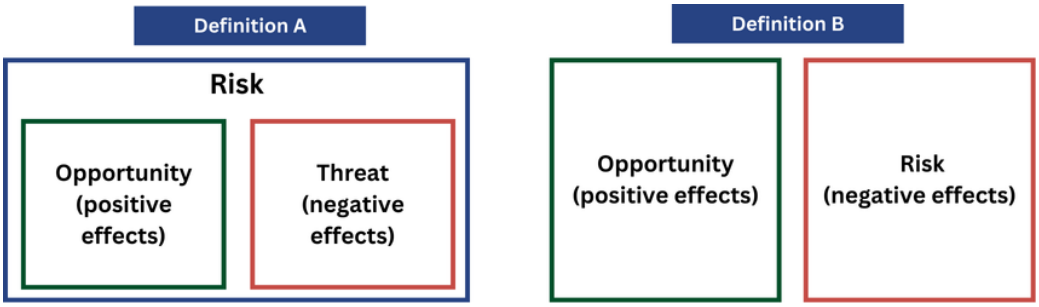

Figure 3.2: Distinct definitions for 'risk' (Hillson, 2002; author)

3.2. Sustainability

Sustainability is the goal of sustainable development (International Organization for Standardization [ISO], 2014). The concept of sustainability can be broadly defined as the consideration of environmental, social, and governance (ESG) factors to ensure the well-being of current and future generations (Ortiz, Castells & Sonnemann, 2009). It is a multifaceted notion that is often approached from a standpoint of integrating ethical standards, rules, and guidelines to guide decision-making within projects and organizations (Marcelino-Sádaba et al., 2015).

In practice, sustainability is frequently approached through the 17 Sustainable Development Goals set forth by the United Nations Department of Economic and Social Affairs in 2015, which are part of the 2030 agenda for sustainable development (United Nations Department of Economic and Social Affairs, 2016). Both concepts for sustainability can be aligned. The alignment of ESG factors with the SDGs can be illustrated, as depicted in Figure 3.3.

Figure 3.3: Illustration of SDGs and ESG (United Nations Department of Economic and Social Affairs, 2016; author)

In addition to the concepts of ESG and SDGs, the notion of the triple bottom line approach, first introduced in 1994, suggested that attaining sustainability in construction requires a thorough evaluation of social, environmental, and economic performance, assigning equal

significance to all dimensions of sustainability (ISO, 2014; Kiani Mavi et al., 2021). Regardless of the specific concept chosen, all these definitions address similar components and underscore the equal importance of all aspects of sustainability. The primary distinction lies in how they categorize sustainability factors differently.

Sustainability has emerged as a powerful driving in the field of civil engineering, despite continuing to be a significant contributor to global greenhouse gas emissions and resource extraction (Rodriguez Trejo et al., 2024). The research landscape surrounding sustainability in civil engineering has expanded, focusing on key areas like waste management, material selection, and environmental assessment methodologies (Lima et al., 2021). Certification programs such as LEED and BREEAM have established benchmarks for sustainable practices. Initiatives like the EU Taxonomy and the Sustainable Finance Action Plan are encouraging investments in truly sustainable projects, addressing concerns of greenwashing. In the Netherlands, initiatives like the Corporate Sustainability Reporting Directive and the forthcoming legislation on Responsible and Sustainable International Business Conduct are reinforcing commitments to sustainability, exerting pressure on businesses to prioritize sustainable practices.

Despite the growing recognition of sustainability, there is still a lack of clarity regarding the implications of sustainability in the future. The lack of operational clarity hindered the progress of sustainability practices within the construction industry (Robinson, 2004). This absence of operational concepts and actions based on sustainability principles can lead to inconsistent practices and missed opportunities for positive impact.

3.3. Conclusion

This chapter delved into the theoretical background of the research subject, with an examination of definitions of opportunities and sustainability. In project management literature, opportunities are usually characterized as positive risks, though scholarly debate persists regarding whether opportunities should be conceptually separated from risks. While existing risk management frameworks, such as RISMAN, PMBOK and ISO 31000, theoretically accommodate opportunities, empirical studies consistently demonstrate their predominant application for threat mitigation rather than opportunity realization. The literature review revealed sustainability to be a multidimensional concept, including ESG, SDGs, and the triple bottom line approach. These definitions share fundamental principles while emphasizing different aspects of sustainability performance.

4

4. EMPIRICAL RESEARCH

The empirical research is conducted to explore the sporadic actualization of sustainability opportunities within practical contexts and to understand prevailing strategies in managing sustainability opportunities. This chapter addresses research sub-questions 1 and 2 through qualitative inquiry, using semi-structured exploratory interviews with industry practitioners. The chapter first outlines the process of collecting and analyzing qualitative empirical data, then details the key findings. The empirical evidence not only reveals current landscape in sustainable practice but also laying groundwork for theoretical development.

4.1. Introduction to Empirical Research

This empirical research focuses on unraveling the landscape of sustainability opportunities actualization within real-world scenarios. By engaging with practitioners through semi-structured interviews, the empirical research has three main objectives,

i. Explore the current landscape in actualizing sustainability ambitions and ideas in infrastructure projects.
ii. Discover key barriers and enablers for actualizing sustainability opportunities.
iii. Discover the current practical approach to managing sustainability opportunities.

The empirical research aims to extract firsthand experiences, perspectives, and strategies employed in the actualization and management of sustainability opportunities. Through this approach, a holistic view of the challenges, successes, and evolving practices in the management of sustainability opportunities can be comprehensively examined. The results of the empirical investigation undergo thematic analysis, shaping the trajectory of the theoretical research.

The choice to employ semi-structured interviews as the data collection method in the empirical study stems from the need to capture the valuable insights of practitioners actively engaged in overseeing and managing sustainability opportunities within infrastructure projects, alongside the lack of theoretical research and findings in the field of sustainability opportunities actualization (Bryman, 2016). Interviews play a pivotal role in this research as they serve as the primary means of gathering qualitative empirical data directly from experienced practitioners actively involved in managing infrastructure projects. Through semi-structured exploratory interviews, diverse insights and practical experiences can be elicited, providing a deeper understanding of the contextual factors influencing the actualization and management of sustainability ambitions and ideas (Bryman, 2016). This approach allows for the exploration of the complexities and practical implications surrounding the management of sustainability opportunities and the generation of context-specific data for developing a grounded theory framework.

4.2. Sampling Strategy

The principal sampling strategy employed for the exploratory interviews is purposive sampling. This method entails the selection of participants based on specific characteristics or criteria that are relevant to the research objectives (Suri, 2011; Tongco, 2007). It enables the deliberate selection of individuals who can provide valuable insights and information on actualizing and managing sustainability opportunities in infrastructure projects during the FED phase.

Criteria for participant selection is tailor designed based on the principles on theoretical sampling by Corbin & Strauss (2014):

i. Practitioners who have been involved in infrastructure projects.
ii. Practitioners who have engaged with sustainability opportunities.
iii. Diversity in terms of role and organizational levels in infrastructure projects.
iv. Practitioners with at least 3 years of experience in the construction industry.

By employing purposive sampling based on these criteria, the selected participants are ensured to have the relevant knowledge and experiences to provide meaningful insights into sustainable practices and management of opportunities in the construction industry. This approach helps obtain rich and diverse data that can contribute significantly to the research findings.

Following these criteria, interviewees are chosen from Witteveen+Bos, a Dutch consultancy engineering firm; Rijkswaterstaat, the largest client for infrastructure projects in the Netherlands; and Heijmans, a Dutch engineering contractor. These individuals offer perspectives on the actualization of sustainability ambitions and ideas, as well as the management of opportunities in practice.

The distribution of interviewees across organization types is determined through a dual consideration of stakeholder influence during the FED phase of infrastructure projects and the alignment with the scope of the study. Consultancy engineering firms and clients are identified as primary participants because of their substantial involvement in decision-making during the FED phase, while engineering contractors typically play a more limited role during a typical FED phase of infrastructure projects. Hence, most interviewees are selected from the consultancy engineering firm and client. While both consultancy engineering firms and clients play an important role in the FED phase, the majority of interviews are conducted with practitioners from consultancy engineering firms. This emphasis reflects the ultimate research objective of developing a framework with guidelines for consultancy engineering firms to improve the process of managing sustainability opportunities. Furthermore, to uphold criterion (iii) regarding diversity in infrastructure project roles, stakeholders from the contractor side are also included in the empirical research to provide comprehensive perspectives. Hence, the participant distribution is designed to be 70% consultants, 20% clients, and 10% contractors. This weighting ensures the data relevance while maintaining comprehensive viewpoints.

In order to guarantee, criterion (iii), a diverse range of perspectives while ensuring, criterion (ii), that the interviewees possess engagement in sustainability opportunities, the study targeted specific roles within infrastructure projects that are most relevant to the research

objectives. Given the scope of the research, only key roles with significant influence on sustainability were selected for interviews. The following roles within an infrastructure project have been chosen for the interviews:

i. Project managers: project and strategic oversight
ii. Process managers: strategic oversight
iii. BIM managers: digital and operational integration
iv. Sustainability advisors: specialized sustainability input
v. Technical managers: operational engineering solutions
vi. Cost managers: financial perspective

Additionally, to align with the criterion of organizational level diversity, interviewees are selected across hierarchical levels.

4.3. Interview Protocol

The interview protocol serves as a roadmap for the interviewer, ensuring adherence to the interview process and guidelines. A detailed outline of the interview protocol can be found in Appendix A. The semi-structured interviews are designed based on research sub-questions 1 and 2, and the objectives of this empirical research.

The interview structure entails commencing with general inquiries, transitioning to specific questions related to practical experiences, followed by inquiries soliciting recommendations for future actions, and ending with reflective questions concluding the interview. Each interview session is tailored for a duration of 60 minutes.

While the primary focus of these interviews is to capture practical insights, they also strive to uncover unanticipated information. By employing semi-structured interviews, flexibility is afforded, facilitating the exploration of novel viewpoints. The subsequent topics were considered during the formulation of the interview protocol:

i. Definition of sustainability
ii. The current situation in actualizing sustainability ambitions and ideas
iii. Barriers and enablers in actualizing sustainability ambitions and ideas
iv. Management of opportunities
v. Practical examples of actualizing sustainability opportunities

The data derived from these subjects plays a crucial role in translating obtained practical expertise into the exploration of scientific theoretical frameworks and concepts using the grounded theory methodology. The insights garnered from these areas will shape the direction of the theoretical research.

4.4. Ethical Considerations

In conducting interviews for empirical research, paramount emphasis is placed on upholding ethical considerations throughout the research process. The ethical considerations of these interviews are anchored in principles of respect, confidentiality, and informed consent.

Before the commencement of interviews, informed consent is obtained from each participant, detailing the purpose of the research, the nature of their involvement, and the measures in place to protect their identities and information according to the data management plan in Appendix B. The privacy and autonomy of each participant are safeguarded, ensuring that their voluntary participation is based on a comprehensive and conscious understanding of the research objectives and procedures. Confidentiality protocols are strictly adhered to, with anonymization practices employed during data transcription and analysis to ensure the anonymity of interviewees. This commitment to ethical standards underscores the foundation of trust and integrity upon which this research is conducted.

4.5. Data Collection Procedures

Interviews are designed in alignment with the sampling strategy and interview protocol, taking into account ethical considerations. The interviews are conducted both online and in-person to accommodate participant preferences and logistical constraints.

The selection of interviewees is based on the established sampling strategy, with invitations sent via email, outlining the research objectives and the empirical research design. Upon the agreement to participate by interviewees, an informed consent document and a research background information summary are provided, detailing the data management procedures and the background of the research. This data management plan, endorsed by the TU Delft Data Management Support Staff, governs the handling of data, including storage methods and measures for safeguarding sensitive information, as outlined in detail in Appendix B.

Before the interview commences, explicit permission is granted from each interviewee to record the session, utilizing a voice recorder and storing the recording securely on the TU Delft OneDrive platform. Subsequently, the interview is transcribed, ensuring anonymization and inclusion of contextual comments for clarity. The anonymized transcript is shared with the interviewee for verification. Upon approval, these transcripts are utilized for empirical data analysis during the later phases of the research. Appendix B provides a comprehensive overview of data usage and storage protocols for reference.

4.6. Data Analysis

In this section, the data analysis process is detailed. The interviews are analyzed through qualitative thematic analysis, aligning with the objectives outlined in Section 4.1.

Following each interview, immediate transcription of the recording takes place. Upon completion, all personal details are filtered out. The anonymized transcripts are analyzed and coded through ATLAS.ti, leading to initial data insights. These codes are then categorized into groups that correspond to the empirical research objectives, thereby structuring the data effectively. These grouped insights from the codes shed light on the predominant discussion topics among interviewees within each theme, subsequently shaping the direction of theoretical exploration in Chapter 5.

4.7. Overview of Interviews

In **Error! Reference source not found.**, an overview of all conducted interviews is presented. The table includes details such as the roles, experience, types of projects primarily engaged in, and the organization of the interviewees. Such information serves to showcase the

connection between the backgrounds of interviewees and their responses in the interview. The selection process of the interviewees was detailed in Section 4.2.

Table 4.1: Overview of interviews (author)

#	Role	Professional Experience Duration (Years)	Types of Infrastructure Projects Primarily Involved In	Organization	Abbreviation Reference
1	BIM Director	18	Highways, Tunnels, Power stations	Consultancy Engineering Firm - Witteveen+Bos	BD.CEF
2	Cost Manager	25	Highways, Bridges, Waterways	Consultancy Engineering Firm - Witteveen+Bos	CM.CEF
3	Process Manager	42	Tunnels, Railway, Airports	Consultancy Engineering Firm - Witteveen+Bos	PM.CEF_1
4	Project Manager	30	Multi-disciplinary projects	Consultancy Engineering Firm - Witteveen+Bos	PM.CEF_2
5	Project Manager	11	Highways, Transportations, Energy	Consultancy Engineering Firm - Witteveen+Bos	PM.CEF_3
6	Project Manager	23	Bridges, Waterways	Consultancy Engineering Firm - Witteveen+Bos	PM.CEF_4
7	Sustainability Advisor	13	Water, Waterways, Bridges	Consultancy Engineering Firm - Witteveen+Bos	SA.CEF
8	Technical Advisor	14	Tunnels, Hydraulic structures	Client - Rijkswaterstaat	TA.C_1
9	Technical Advisor	3	Highways	Client - Rijkswaterstaat	TA.C_2
10	Project Manager	18	Highways, Tunnels	Contractor - Heijmans	PM.CO

4.8. Findings

In the data analysis process, the collected data has been analyzed through the lens of six primary themes. These themes encompass the current landscape regarding the actualization of sustainability opportunities, the nature of sustainability opportunities, factors influencing the actualization of sustainability opportunities, barriers of actualization of sustainability opportunities, enablers of actualization of sustainability opportunities, and current approaches to manage sustainability opportunities. These thematic categories have been derived from the set research objectives of this empirical study. By delving into these six themes, the study aims to fulfill the three defined empirical research objectives, as depicted in Figure 4.1.

Figure 4.1: Empirical research objectives and analyzed themes (author)

This section delves into the noteworthy findings within each of the six themes as outlined. In the following sections, in some instances, the role of the interviewee is mentioned along with quotes extracted from the interviews to provide substantiation. A comprehensive overview of

the participants, including their roles, can be referenced in **Error! Reference source not found.** for a more detailed understanding of the context in which these findings have been derived.

4.8.1. Current Landscape of Actualization of Sustainability Opportunities

In the current landscape of actualizing sustainability opportunities within the infrastructure industry, insights gained from the interviews underscore a significant emphasis on sustainability at higher organizational level. A quote from a cost manager [CM.CEF] from Witteveen+Bos sheds lights on this emphasis, stating,

> *'According to our company goal, every project should have focus on sustainability.'*

This organizational level sustainability commitment extends beyond consultancy engineering firms to clients as well. Reflecting this emphasis, a technical manager [TM.C_1] at Rijkswaterstaat affirms,

> *'Currently, at an organizational level within Rijkswaterstaat, there is a very high emphasis on sustainability.'*

However, a prevailing trend emerges wherein despite this pronounced emphasis from the top level, the implementation of sustainability measures remains predominantly confined to minor and small solutions. As highlighted by a project manager [PM.CEF_3] at Witteveen+Bos,

> *'Currently, sustainability opportunities in infrastructure projects are usually something relatively small compared to the project size. Typical examples are adding some type of green, planting trees, seeding plants that can be good for biodiversity, and adding beehives.'*

Another project manager [PM.CEF_2] further elaborates,

> *'Often, the initial focus lies on engineering the design, with sustainability considerations tacked on as an afterthought. This approach is flawed as it results in merely incorporating minor sustainability elements onto a pre-determined design.'*

This pattern suggests that while sustainability is considered at the project level, it is frequently an afterthought, resulting in the implementation of mainly minor sustainability solutions rather than significant major changes in projects. The current disparity between the overarching sustainability focuses on the organizational level and the limited scope of actualized sustainability opportunities being put into practice reflects a critical area for exploration and advancement within infrastructure projects. This pattern has provided insights for subsequent chapters, which will focus on exploring methods for improving the actualization of substantial sustainability opportunities at the project level.

4.8.2. Nature of Sustainability Opportunities

The discussion has long centered around the definitions of opportunities and risks, particularly within the realm of project management. The Project Management Institution (2021) in the

PMBOK, which defines risk as an uncertain future event or condition capable of influencing project objectives either positively or negatively. It is emphasized that opportunities and threats share a common ground, both involving uncertainty that can influence project outcomes (Hillson, 2002). The interviews have delved into whether practitioners perceive the actualization of sustainability opportunities in projects as inherently chances or contingent on decisions made by the project team. The overall results in illustrated in Figure 4.2.

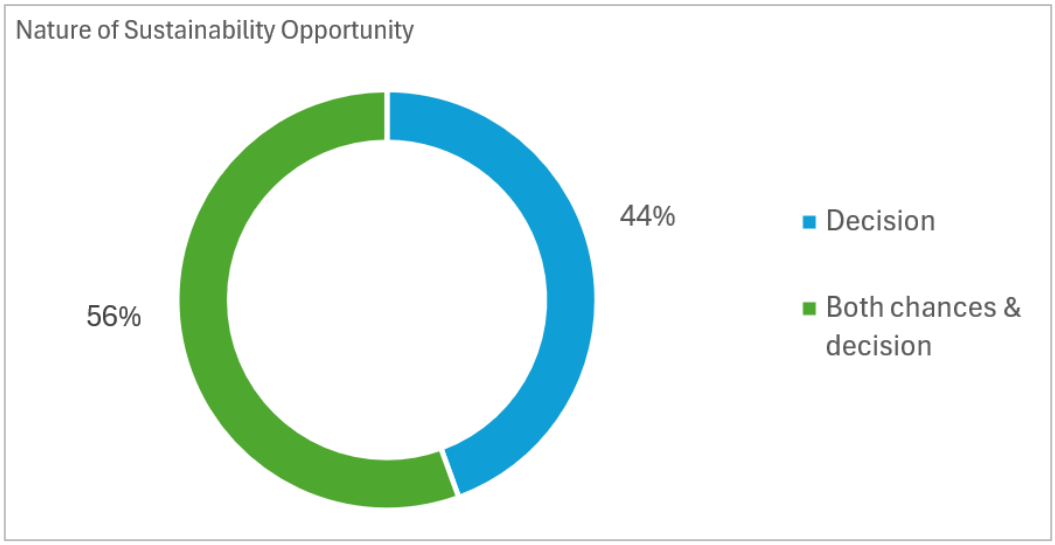

Figure 4.2: Results of nature of sustainability opportunities (author)

Analysis of participant responses regarding the perceived nature of sustainability opportunities revealed that 56% of participants believed that actualization of sustainability opportunities is a combination of chances and decision-making, while 44% viewed decision-making as the determinant of actualization of sustainability opportunities. Notably, no participant, 0%, considered the actualization of sustainability opportunities is driven purely by chances.

The consensus among the majority of interviewees is that the actualization of sustainability opportunities embodies elements of both chances and decisions. As articulated by a process manager [PM.CEF_1],

> *'The realization of sustainability in projects involves both chances and decisions, shaped by the specific circumstances at hand.'*

Process manager [PM.CEF_1] explained that chances refer to both internal and external situational and contextual factors present at the given moment, while decision refer to the strategic judgements made by project stakeholders or even politicians. Expanding on this, a BIM director [BD.CEF] elaborated on the distinction between sustainability opportunities as chances and decisions, stating,

> *'It is an opportunity when sustainability ambitions and ideas are identified, and then somebody needs to make the decision if you are going to use it or not. The decision is mainly driven by contractual aspects, sustainability scores*

> *requirements, financial consequences, potential benefits, and mindset. There can be a lot of reasons why you do it or not do it.'*

Contrary voices in the interviews believe that the actualization of sustainability ideas primarily depends on decisions rather than chance at the project level. Project manager [PM.CEF_3] explained,

> *'The actualization of sustainability opportunities depends on the decision made. When looking into the word "opportunity" in the framework of risk management, indeed the actualization of sustainability opportunities is a throw of dice. However, it is not the scope of an infrastructure project to predict the chances of a new sustainable solution to appear in the future.'*

This perspective suggests that implementing a known sustainable solution is a deliberate decision on whether to incorporate it rather than a gamble of chance due to uncertainties. The primary elements of chance predominantly reside beyond the scope of the infrastructure project itself, largely within the field of research and development aimed at pioneering new solutions. The uncertainty of actualizing a sustainability opportunity can also be seen on a strategic level, as highlighted by project manager [PM.CEF_3], who remarked,

> *'On a strategic level for a company, sustainability can be seen as an opportunity for companies to expand into new markets and enhance their corporate image.'*

This underscores that the uncertainty and chances of sustainability opportunities lies in the future outcomes of implementing sustainable ideas, such as being a frontrunner in a new market or improving corporate image post-implementation of sustainability solutions.

On a macro point of view, technical manager [TM.C_1] from Rijkswaterstaat explains that sustainability actualization in infrastructure projects often hinges on political determinations.

> *'It is the government who decides the budget for infrastructures. The level of emphasis on sustainability within projects depends on the government policies at that moment, which determines the priority given to sustainability initiatives and the budget for actualizing sustainability ideas.'*

Additionally, technical manager [TM.C_1] notes that the realization of sustainability opportunities is subject to the focus of different government institutions,

> *'The actualization of sustainability opportunities is influenced by the different priorities and agendas of different government institutions. The interest of the specific institutions determines the budget to a specific sustainability proposal.'*

Overall, the nature of sustainability opportunities within infrastructure projects from the perspective of industry practitioners underscores a balance between chance occurrences and deliberate decisions. While some view these opportunities as a blend of both, others emphasize the important role of decision-making in the human process of actualizing sustainability ideas. The interplay between political determinations, corporate strategies, and

governmental priorities further influences the actualization of sustainability opportunities, highlighting the complex and dynamic landscape of sustainability opportunities.

4.8.3. Factors Influencing the Actualization of Sustainability Opportunities

This empirical study further explored the factors perceived by practitioners to influence the actualization of sustainability opportunities. The data underwent analysis through coding of transcripts based on factors highlighted during the interviews. Figure 4.3 showcases the list of factors discussed and the frequency of their mention across all interviews. Commonly mentioned factors point to a consensus among practitioners regarding their significant influence in actualizing sustainability opportunities. Therefore, this section will first delve into a detailed discussion of the top three most frequently mentioned factors, followed by a discussion of additional factors that, while less frequently cited, remain important to enhancing the management of sustainability opportunities.

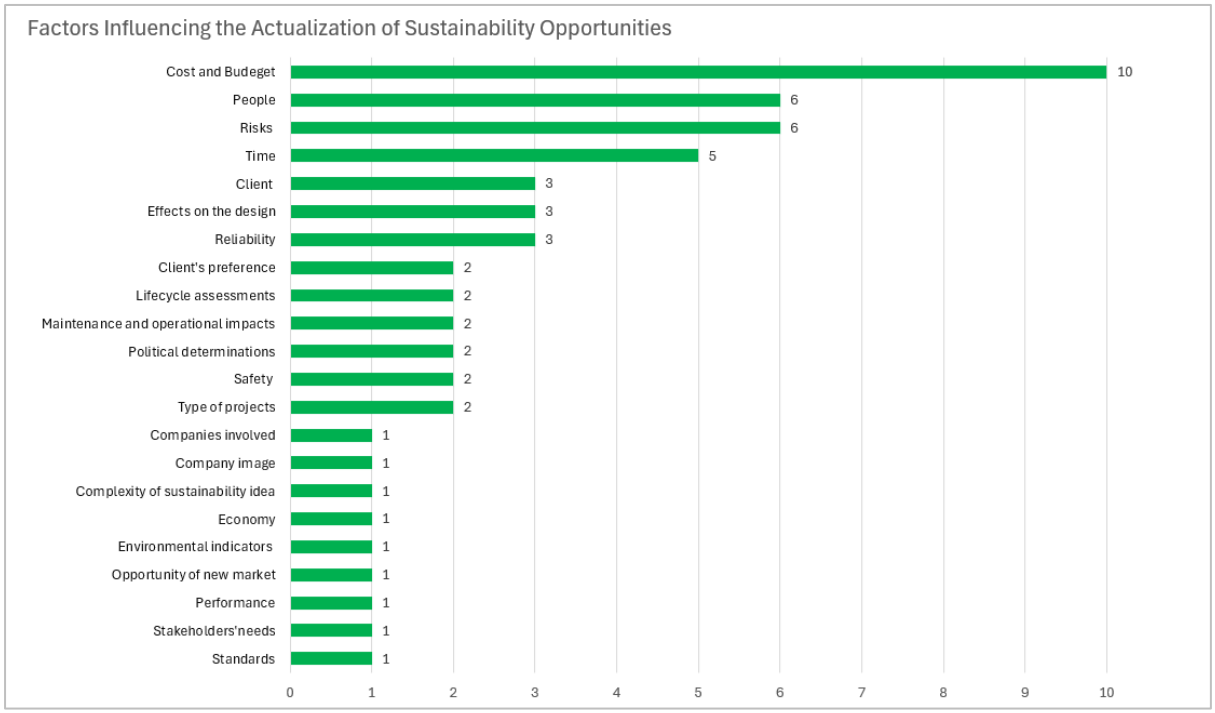

Figure 4.3: Code distribution of factors influencing the actualization of sustainability opportunities (author)

Cost and budget

It is evident that cost and budget are the most frequently mentioned factors, amplifying the importance of project finance when considering the actualization of sustainability ideas. A project manager [PM.CEF_4] highlighted this relationship, stating that

> *'Within the project, the actualization of sustainability opportunities is dependent on whether the cost estimates align with these ideas.'*

This factor proves particularly crucial during feasibility studies of sustainable alternatives, where practitioners usually have to carefully balance the required investments against anticipated benefits. Multiple industry experts emphasize that budget constraints, being a decisive factor in infrastructure projects, significantly influence project decision-making, including determinations about whether to actualize sustainability opportunities.

People

The aspect of people has also drawn substantial attention, particularly focusing on the mindset of the project team. Multiple practitioners have emphasized the significant influence of perspectives of individuals on sustainability within the project team on the actualization of sustainability ideas. A sustainability advisor [SA.CEF] elaborated on this,

> *'The level of emphasis on sustainability depends on the people working on the project, both from the client and the consultancy engineering firm. If the team wants the sustainability goals to be reach and contribute to sustainability, then the project will have high emphasis on sustainability. If not, there can be many reasons or excuses not to do sustainability in a project, resulting in low emphasis on sustainability.'*

Supporting this perspective, a process manager [PM.CEF_1] emphasized the impact of people within the project team, noting that,

> *'The actualization of sustainability also depends on the people in the project team. Project controllers with no sustainability ambition are more likely to opt for non-sustainable solutions.'*

Risks and Time

Risks and time are the third most mentioned aspects, with risks primarily linked to uncertainties surrounding the new sustainable solutions. A project manager [PM.CO] from Heijmans expressed the importance of risks, stating,

> *'We must assess the associated risks. This involves evaluating how a sustainability concept impacts the structure and ensuring its future safety and integrity.'*

Risk emerges as a critical factor in the actualization of sustainability ideas in infrastructure development, mainly due to the typical risk averse nature of infrastructure projects stem for the essential public function and scale. The adoption of innovative sustainability solutions introduces inherent uncertainties, as limited prior experience with new approaches potentially increases perceived risk levels. This risk-innovation relation significantly influences decision-making processes, often creating barriers to the implementation of sustainable alternatives.

Time is another pivotal factor from the interview findings, specifically concerning the additional hours required to integrate sustainable solutions within existing project timelines. This time factor is observed in two different phases: the FED phase, where extended manhours may be required to explore and design sustainable alternatives, and the construction phase, where execution of these solutions may prolong execution schedules. Ultimately, these time implications directly relate to cost, as increased project durations typically escalate labor and operational costs.

Stakeholders needs

Although stakeholder needs were not frequently mentioned explicitly in the interviews, the thematic analysis indicates that this factor was indirectly referenced in related points raised

by multiple participants. This suggests that while not frequently cited as a standalone concept, stakeholder influence plays a critical role in actualizing sustainability opportunities in infrastructure projects.

Clients emerged as a prominently cited stakeholder group, with interviewees highlighting how client organizations and preferences significantly influence project outcomes. This observation aligns with broader findings about how participating parties, including not just clients but also consultancy engineering firms and contractors, shape the actualization of sustainability opportunities. As noted by Project Manager [PM.CEF_4], stakeholders often have different requirements, objectives, and expectations. These different requirements, objectives and expectations may sometimes conflict with sustainable solutions. In such cases, consultancy engineering firms can play a pivotal mediating role by advocating for sustainable alternatives.

This factor underscores the strategic role of consultancy engineering firms in mediating stakeholder interests. By proactively addressing conflicting requirements and advocating for sustainable alternatives, consultancy engineering firms can steer design processes toward sustainability actualization.

Standards

Standards emerged as an infrequently mentioned yet influential factor affecting the actualization of sustainability opportunities. This primarily stems from regulatory constraints that fail to accommodate innovative sustainable solutions. Notably, this factor intersects with other key factors, such as reliability and safety. Even when alternative solutions are scientifically validated, existing building standards may prevent their adoption. These findings explain why laws and regulations were frequently cited as barriers in the interviews. Beyond legally binding standards, similar constraints arise from internal organizational standards and client preferences. Certain clients maintain rigid project specifications that are risk averse, which discourages novel sustainable alternatives from consideration despite their technical viability.

These findings underscore the need for broader reforms in infrastructure industry standards. While such changes fall beyond the direct scope of consultancy engineering firms, such organizations can still play a valuable advisory role. For instance, providing expert assessments of sustainable alternatives, and demonstrating the technical reliability and safety of new sustainable solutions to clients and regulators.

As shown in Figure 4.3, 22 factors were identified by practitioners, with a detailed focus on the top three factors and some other selected factors in this section. It is important to note that each factor exhibits different extent of influence on the actualization of sustainability opportunities. However, given the comprehensiveness of these findings, not all factors can be detailly examined here. For further insights, specific quotes from the interviews related to each factor can be provided upon request. These factors, as identified by the practitioners, are considered when shaping the framework aimed at enhancing the realization of sustainability opportunities within projects in Chapter 7.

4.8.4. Barriers of Actualization of Sustainability Opportunities

This empirical study further explored the barriers of actualizing sustainability opportunities. The data was analyzed by coding transcripts to identify the barriers outlined during the interviews. Figure 4.4 presents a list of barriers discussed, along with the frequency of their mention across all interviews.

Barriers that are frequently referenced indicate a consensus among practitioners regarding their significance in impeding sustainability initiatives. Hence, this section will explore the top four most commonly referenced barriers in detail. Additionally, some lesser-mentioned barriers that are related to the top four will also be discussed for a more comprehensive perspective.

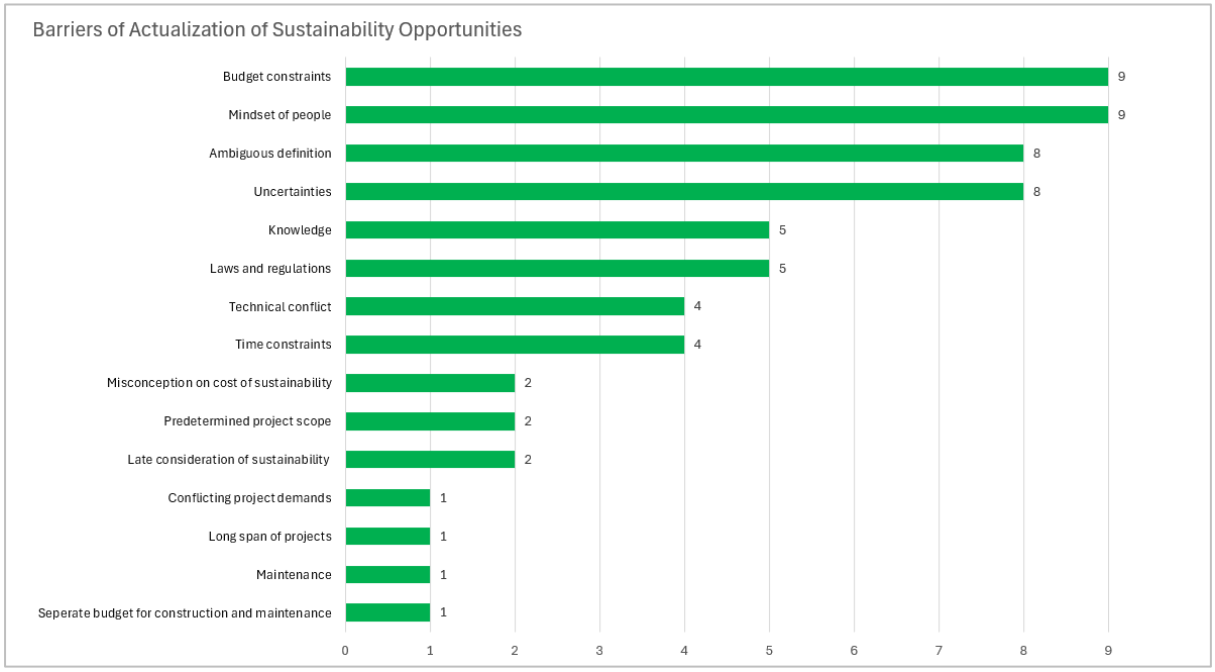

Figure 4.4: Code distribution of barriers of the actualization of sustainability opportunities (author)

Budget

Echoing the significant influence of cost and budget on the realization of sustainability opportunities, budget constraints is one of the most frequently mentioned barriers in the interview process. Project manager [PM.CEF_2] captures this emphasis by stating,

> *'There are always a lot of ideas and ambitions on sustainability in a project. However, it stops when there is no money.'*

Similarly, project manager [PM.CEF_4] notes that,

> *'The biggest barriers to actualize sustainability ideas into projects are usually financial barriers. We had projects that have big sustainable ambition, but the budget is not sufficient to realize the ideas.'*

Project manager [PM.CEF_3] further explains the instances where sustainability goals could not be realized due to budget constraints by stating,

> *'Typically, when a project faces budget constraints, sustainability objectives are often the first to be compromised.'*

It is important to highlight that, in addition to budget constraints, another significant barrier related to financial constraints involves the separated budgets and limited integration within governmental units in the Netherlands. This observation was underscored by a senior project manager [PM.CEF_2],

> *'In general, public organizations maintain separate budgets for construction and maintenance, creating a challenge for project managers seeking additional public funding during the initial investment phase for sustainability initiatives. This is problematic as investing in sustainability upfront can lead to cost savings during the operational stage, but the division of budgets hinders the ability to allocate resources effectively. On the other hand, a private client will not have this problem as they will consider the lifecycle cost in the budgeting.'*

Misconception on cost for sustainability

Interestingly, while project managers underscore budget constraints as a primary barrier, cost managers highlight a different challenge—the misconception surrounding the costs of sustainability. A cost manager [CM.CEF] elaborates this misconception, stating,

> *'There is a common perception that sustainability always translates to increased costs, which is not necessarily true. We frequently face inquiries about the higher costs associated with choosing alternative materials for sustainability. The crucial question, however, should revolve around the potential benefits of constructing less, which can enhance sustainability while also reducing expenses. Take, for example, pavement construction; while sustainable tiles may be pricier than traditional ones, building fewer pavements and incorporating more green spaces can be both cheaper and more sustainable.'*

This viewpoint is echoed by a process manager [PM.CEF_1],

> *'There is a common misconception that sustainable solutions are inherently more costly, which impedes the implementation of sustainable practices.'*

It is a valid observation that some sustainable solutions are more costly and are limited by budget constraints, but some sustainable solutions are cost-comparable or even more economical than traditional designs. Nonetheless, the prevalent industry misconception that sustainability equates to higher costs has inadvertently led project teams to overlook certain sustainable options unconsciously.

Furthermore, industry experts, including cost managers [CM.CEF] and sustainability advisors [SA.CEF], emphasize that while certain sustainable alternatives may require higher initial investments, they often yield long-term cost savings. This perspective on lifecycle cost

provides a convincing value proposition for clients considering sustainable options. However, this potential must be carefully weighed against the barrier identified earlier, particularly the challenge of separated budgeting systems for construction and maintenance common in government organizations. These budgetary divisions may affect investment choices, even when lifecycle cost analyses demonstrate clear long-term benefits.

This finding reveals a significant knowledge gap regarding the cost implications of sustainable solutions. The misunderstanding of the cost of sustainability fundamentally leads to inaccurate and ineffective decision-making in infrastructure projects.

Late consideration of sustainability and predetermined project scope

The divergence perspectives between cost managers, who do not view cost as a significant barrier, and project managers, who perceive budget constraints as a major barrier, can be attributed to the timing of sustainability considerations within projects. As highlighted by project manager [PM.CEF_2],

> *'Project teams frequently encounter budgetary constraints when attempting to integrate sustainability later in the project lifecycle, as sustainability was not factored into the cost estimation during the earlier design stages. As a result, retrofitting sustainability features becomes financially unfeasible within the allocated budget.'*

This delayed integration of sustainability and the initial focus on engineering design without early sustainability considerations explain why project managers often identify budget constraints as the primary barriers to actualizing sustainability opportunities. This issue was reflected in Section 4.8.1, where the delayed consideration of sustainability results in the implementation of primarily minor sustainability solutions in infrastructure projects.

The late consideration of sustainability is also interrelated with and partially contributes to another obstacle, the predetermined scope of projects. This relationship is explained by industry practitioners that when sustainability is considered and integrated too late in the project lifecycle, it limits the flexibility to modify the scope of projects, thereby constraining the implementation of some sustainable solutions.

During the FED phase, a main task is defining the project scope. Practitioners identify that when project scope is predetermined without early sustainability consideration, it becomes a barrier to incorporating sustainability ideas later. This is because projects are often already defined or set in motion by the time sustainability is considered, leaving little room for impactful modifications. However, if sustainability is prioritized earlier in the process, the scope may remain more adaptable, allowing for adjustments that align with sustainability goals.

It must be acknowledged, however, that certain projects, particularly those subject to inflexible technical or contractual constraints, may exhibit limited scope changes even with early sustainability considerations. This is explained by BIM director [BD.CEF] with an example,

> *'For example, if the initial scope specifies four lanes, downsizing to two lanes may not be an option. As consultants, our primary objective is to enhance sustainability within the given scope.'*

Consequently, while early sustainability consideration enhances the potential for scope adaptability, its effectiveness remains dependent upon project-specific constraints.

The barriers of budget constraints, misconception on cost for sustainability, and late consideration of sustainability will be comprehensively addressed in the forthcoming framework outlined in Chapter 7. This framework aims to provide strategies and tools for overcoming these challenges.

Mindset of people

Another main barrier being identified in the study is the mindset of people involved in infrastructure projects. As mentioned in Section 4.8.3., people are a significant influence over the actualization of sustainability in projects. Notably, project manager [PM.CEF_4] underscores that the construction industry remains traditional. Echoing this statement, sustainability advisor [SA.CEF] underscores that it is not uncommon to have project stakeholders resisting incorporating sustainability into projects. This resistance is observed across both client and consulting engineering firms. Project manager [PM.CEF_2] highlights,

> *'Many clients focus solely on present needs without considering the adaptability and long-term viability of infrastructure, potentially overlooking opportunities for sustainability.'*

[PM.CEF_2] further elaborates that misalignments in sustainability priorities between client project teams and consultants can pose challenges in actualizing sustainability in projects. Similarly, resistance towards integrating sustainability early in the design process is encountered within consultancy engineering firms, as noted by [PM.CEF_2], who explains that some designers prioritize initial design aspects over sustainability considerations. This point of view is agreed by [PM.CEF_1] and further explained by [CM.CEF],

> *'There is a common expectation for building new things in construction projects, prompting a reflection on the necessity for constant newness.'*

The inherent tendency of individuals to gravitate towards familiar practices and areas of expertise, inadvertently creates an obstacle to the actualization of sustainability opportunities within projects. This mindset impedes the integration of sustainable practices, underscoring the need to address and shift these perspectives in order to improve the actualization of sustainability opportunities.

This mindset of people is also shaped by the current evaluation practices, where project teams are assessed primarily against contractual requirements such as time and cost performance, while sustainability considerations are frequently excluded from performance metrics. Such evaluation practice creates a behavioral pattern within the industry where project teams prioritize fulfilling traditional performance indicators rather than sustainability.

This oversight of sustainability partly stems from the inherent ambiguity in the definition of sustainability which subsequently creates challenges in quantifying sustainability progresses. As sustainability requirements typically lack formal and clear evaluation mechanisms and accountability measures, they are often perceived as gimmick or value-add components rather than essential project deliverables. This behavioral pattern persists despite the growing recognition of the long-term benefits of sustainability, as immediate project evaluation frameworks still emphasize mostly on traditional success criteria. Therefore, project teams tend to have a behavioral pattern of prioritizing contractual deliverables that are formally evaluated, while putting sustainability objectives to secondary status.

Uncertainties

The presence of uncertainties surrounding sustainable solutions has been identified as a significant barrier within project environments. Project manager [PM.CO] articulates this point,

> *'The uncertainties surrounding the outcomes of new sustainability solutions presents a considerable barrier, especially when presenting it to the clients.'*

This perspective is echoed from the standpoint of the client by technical advisor [TA.C_1],

> *'The main barriers when actualizing sustainability ideas are lack of knowledge on the solutions and uncertainty about the performance.'*

The root cause of this uncertainty surrounding new solutions often lies in a deficiency of knowledge. BIM director [BD.CEF] underscores this by explaining that challenges are compounded by a lack of familiarity with available options and their practicality.

The resulting uncertainty stemming from a knowledge gap often leads design teams to opt for conventional approaches. This inclination is elaborated by sustainability advisor [SA.CEF], who notes that sustainability ideas inherently entail relatively higher risks, pushing design teams to opt for conventional design practices due to their familiarity and comfort with them.

Expanding on the topic, Technical Advisor [TA.C_2] explains that the uncertainties surrounding innovative sustainability solutions often entail specialized maintenance requirements once the structure is built. This aspect creates hesitancy among asset operators, as the implementation of innovative designs necessitates additional maintenance efforts from them. Consequently, operators tend to favor conventional standard designs to alleviate the complexities associated with maintenance obligations.

These factors underscore the importance to address the knowledge gap and uncertainties to enhance the actualization of sustainability ideas. Addressing these challenges will be one of the core points in the forthcoming framework outlined in Chapter 7.

Ambiguous definition of sustainability

Multiple practitioners have underscored that a main barrier to actualizing sustainability lies in the unclear definition of sustainability. According to sustainability advisor [SA.CEF],

> *'The definition of sustainability is fussy, as it holds different meanings for different individuals.'*

Sustainability advisor [SA.CEF] further elaborates the problems of an ambiguous definition by stating,

> *'Having different definitions on sustainability is a problem. The difference in definition of sustainability results in different designs. Consequently, differences in the understanding of sustainability allow individuals to say that their projects are sustainable based on subjective criteria.'*

This underscores how the vague and broad definition of sustainability complicates its integration into projects. This perspective is echoed by project manager [PM.CEF_4], who remarks,

> *'Unlike technical aspects that are more binary in nature, sustainability lacks clear-cut boundaries, making it challenging to implement definitively.'*

This highlights the necessity to consolidate the definition of sustainability effectively. The definition of sustainability will undergo further exploration in the theoretical research in Chapter 5.

Overall, it is observed that the differing perspectives on key barriers to actualizing sustainability opportunities can be attributed to the specific roles and responsibilities of participants. The diversity of roles within an infrastructure project influences the range of concerns encountered, leading to variations in the frequency of mention of certain barriers. This underscores the importance of considering the roles of participants when interpreting the importance of different barriers and developing methods to address them effectively.

As shown in Figure 4.4, 15 barriers were identified by practitioners. For further insights, specific quotes from the interviews related to each barrier can be provided upon request. These barriers, as identified by the practitioners, are considered when shaping the framework in Chapter 7.

4.8.5. Enablers of Actualization of Sustainability Opportunities

This empirical study further explored the enablers of actualizing sustainability opportunities. The data is analyzed by coding transcripts to identify the enablers outlined during the interviews. Figure 4.5 presents a list of enablers discussed, along with the frequency of their mention across all interviews.

Enablers that are frequently referenced indicate a consensus among practitioners regarding their significance in improving sustainability initiatives. Hence, this section will explore the top five most commonly referenced enablers in detail. Additionally, some lesser-mentioned enablers that are related to the top five will also be discussed for a more comprehensive perspective.

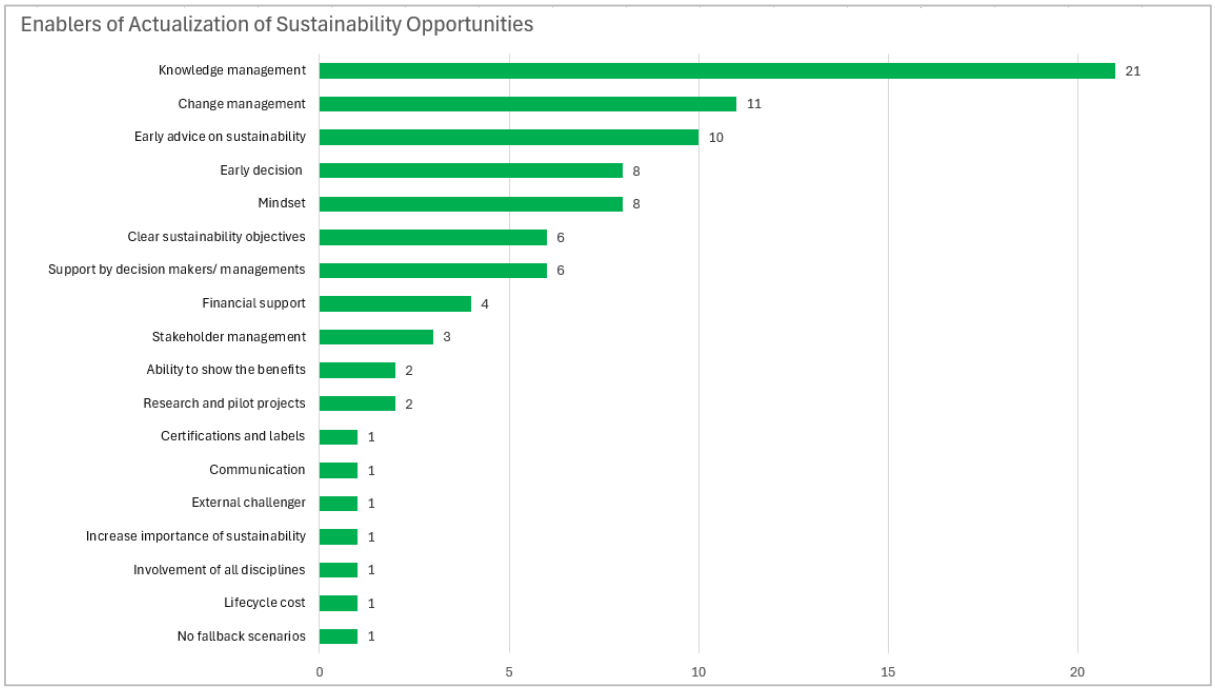

Figure 4.5: Code distribution of enablers of the actualization of sustainability opportunities (author)

Knowledge management

One of the most frequently discussed enablers is knowledge management, as highlighted by process manager [PM.CEF_1].

> *'Effective knowledge management plays an important role. Determining actionable steps for sustainability can be challenging, but having a database of proven technological solutions for sustainability can significantly assist in this process.'*

The prevalence of discussions around knowledge management by practitioners is primarily due to the recognized knowledge gap in sustainable solutions. Currently, existing sustainable solutions are not systematically organized, as reflected in Section 4.8.4. where uncertainties and price misconceptions pose significant barriers to actualizing sustainability opportunities. This knowledge gap among practitioners can be addressed through knowledge management practices.

Project manager [PM.CEF_3] further elaborates that the issue lies not in a lack of knowledge per se, but in the accessibility and awareness of existing knowledge within the company. This is echoed by technical advisor [TA.C_2] from Rijkswaterstaat,

> *'Within the industry, I think a lot of people are not aware of what is possible.'*

Numerous sustainability ideas and solutions may already exist, yet the challenge lies in understanding and effectively sharing this knowledge across teams due to the size of organizations and industry.

A well-structured knowledge management database can facilitate knowledge exchange, offering a comprehensive list of sustainable options for designers and clients to consider from

the outset. For instance, suggest by project manager [PM.CO] and project manager [PM.CEF_4], this approach allows for the presentation of a menu of well-defined options that include associated costs, anticipated outcomes, advantages and disadvantages, similar to a restaurant menu. By streamlining the decision-making process, clients and designers are empowered to make informed decisions. BIM director [BD.CEF] further explained the importance of knowledge management practices for actualizing sustainability opportunities,

> *'Currently, the common practice involves reaching out to a sustainability specialist for guidance. However, this process may involve scheduling meetings, potentially leading to time constraints for project managers. In this scenario, offering a menu of sustainability options could streamline the decision- making process. This approach provides valuable insights and practical guidelines, aligning with the principles of knowledge management.'*

Furthermore, introducing an innovation manager to oversee innovations and establish an opportunity menu, as suggested by [PM.CEF_3], could enable strategic investment decisions by the management based on a comprehensive overview of available solutions. Complementing this approach, [BD.CEF] suggests enhancing sustainability in decision-making processes by advocating for the integration of artificial intelligence in conjunction with BIM can further improve sustainability in decision-making processes. By integrating data from various sources, these tools provide new insights and visualizations.

An additional advantage of having knowledge management practices for sustainability is the ability to incorporate sustainability ideas that may have faced challenges in previous projects into the database. These ideas, despite encountering setbacks, can serve as valuable resources for future projects. This concept is elaborated by technical advisor [TA.C_1],

> *'Not all sustainability solutions that encounter setbacks are unsuccessful; rather, they may not be feasible or suitable for certain projects. These solutions could find applicability in other projects or different project elements.'*

Project manager [PM.CEF_4] echoes on this point, stating,

> *'Sustainability is not something just to implement in one project. Valuable sustainable ideas can be retained, shared, and potentially integrated into future projects. While a particular sustainable idea may not align with the current project, it could be more suitable for upcoming projects.'*

This underscores the important role of knowledge management practices in enabling the actualization of sustainability opportunities. Given its critical importance, further research is imperative to delve into why knowledge management is crucial for actualizing sustainability opportunities. Exploring the methodologies and tools derived from the scientific community that can aid in enhancing knowledge management practices is crucial and will be integrated into the framework. This domain will be extensively investigated in the upcoming theoretical research phase.

Change management and Mindset

The second most frequently mentioned enabler is change management at an organizational level, which is closely linked to another prevalent enabler, mindset. As highlighted by BIM director [BD.CEF],

> *'The integration of sustainability primarily revolves around a cultural and mindset shift. Exploring change management strategies can be instrumental in this regard.'*

For instance, project manager [PM.CEF_1] emphasized,

> *'Integrating sustainability into projects requires a lot of changes, and it is not easy to initiate it in the industry. Change of mindset is needed. Many professionals in the infrastructure sector focus only on short-term goals, which can make sustainability less of a priority. If we start considering the long-term future, sustainability will become more significant for projects.'*

[PM.CEF_1] further elaborated that engineers may struggle to grasp the significance of looking beyond their immediate projects and considering the broader context. This shift can be achieved through a bottom-up approach, by raising awareness and fostering a mindset change. As noted by [CM.CEF], [PM.CEF_2], and [SA.CEF], instigating these changes is a gradual process. Change of mindset within the company, maintaining an open mindset and fostering a culture of continuous learning can lead to valuable insights and improvements. Employees should feel welcomed to voice their suggestions on sustainability without hesitation. Project manager [PM.CEF_4] reinforced this by stating,

> *'Internally, it is important to foster a culture that encourages change, particularly among highly skilled engineers. It is challenging to do things different. Embracing the need for innovative approaches, especially in sustainable solutions, is essential.'*

[PM.CEF_1] underscored that such transformations take time. Social transitions typically require more time than technical transitions, with technical transitions often dependent on social transitions. To implement change management strategies for such social transitions, [CM.CEF] suggested that companies can go beyond client requests for standard designs by offering additional value by presenting optimal designs with cost estimations for promoting sustainability at no extra charge. Additionally, [CM.CEF] recommended fostering an open and innovative culture within the company by introducing a monthly award to recognize the best sustainability idea. Additionally, [CM.CEF_2] emphasized the significance of awareness from bottom up and support by decision makers from top down in driving this change,

> *'Awareness is the important element for the actualization of sustainability ideas. Consistently advocating for sustainability among both clients and colleagues is important in our collective efforts to preserve our planet. Understanding the impact of our actions is fundamental; without this awareness, progress towards sustainability remains insignificant. This awareness must originate from bottom up, with support and resources provided from the top down.'*

This highlights the critical role of change management practices and mindset shifts at organizational level in enabling the actualization of sustainability opportunities. Given their importance, further research is essential to explore methods and tools from the scientific world that can enhance these practices and mindsets. This research will integrate these enablers into the framework and will be one of the main focuses in the upcoming theoretical research phase.

Early advice on sustainability and Early decision

The third and fourth most discussed enablers are early advice on sustainability and early decision-making, both closely intertwined and stemming from the barrier of late consideration of sustainability mentioned in Section 4.8.4. The significance of early decisions is elaborated by project manager [PM.CEF_4], who emphasized,

> *'We prioritize making decisions early in the process because the greatest impact on sustainability occurs during the initial design phase. As the design process progresses, the room for maneuvering diminishes, making it challenging to introduce new ideas as we advance further along the project timeline.'*

This is echoed by technical advisor [TA.C_1] from the client perspective, who stated,

> *'If there are sustainability ideas to be actualized, it is ideal to propose them early in the project lifecycle.'*

Early decisions regarding sustainability necessitate early advice on sustainability. Sustainability advisor [SA.CEF] underscored the importance of involving sustainability experts at the early stage of a project. Project teams that engage sustainability specialists in the early stages can receive guidance on sustainability and enable the ability to influence the design towards a more sustainable trajectory. Moreover, the early engagement of sustainability specialists can assist in establishing clear sustainability objectives for the project team, another significant enabler highlighted by several industry practitioners.

Process manager [PM.CEF_1] agrees that integrating sustainability specialists into the team and involving them in design decisions is crucial. However, as detailed in Section 4.8.1, not all projects prioritize sustainability from the outset, leading to challenges in actualizing sustainability opportunities. Additionally, [PM.CEF_1] highlighted that the earlier proposed shared sustainability knowledge database facilitates effective and persuasive discussions within the project team and with the client during the initial phases. This database serves as a form of early sustainability advice, aiding in early decision-making processes.

It is evident that engaging sustainability advisors early for consultations and using knowledge management practices can encourage early decision-making on sustainability, thereby enhancing the realization of sustainability opportunities.

Overall, the findings regarding enablers reveal a shared consensus among stakeholders regarding the significance of knowledge and change management. Additionally, factors such as early advice and early decision-making have been recurrently highlighted, aligning with the barriers related to delayed considerations of sustainability. As shown in Figure 4.5, 18 enablers

were identified by practitioners. For further insights, specific quotes from the interviews related to each enabler can be provided upon request. These enablers, as identified by the practitioners, are considered when shaping the framework aimed at enhancing the actualization of sustainability opportunities within projects in Chapter 7.

4.8.6. Current Approaches to Manage Sustainability Opportunities

This empirical study delves into the current approaches for managing sustainability opportunities to understand the methodologies commonly employed by practitioners, with the aim of informing the development of a suitable framework. It reveals a lack of standardized approaches in current sustainability opportunity management. Project strategies for managing sustainability opportunities appear to be primarily influenced by the level of sustainability ambitions of the project team. To have a better understanding of the current status quo, the exploration encompasses the approaches and steps utilized to manage sustainability across the project lifecycle, focusing on the most frequently cited strategies by industry professionals.

Two primary pathways for incorporating sustainability into projects are highlighted. As articulated by BIM director [BD.CEF],

> *'You either start with very high ambitions regarding sustainability, or you just begin and consider sustainability towards the end.'*

In projects emphasizing high sustainability standards, the initial phase involves understanding the sustainability ambitions of the client. For example, sustainability advisor [SA.CEF] described the process,

> *'Typically, when we start the project, we go sit with the client and ask about their ambitions and thoughts on different themes in sustainability. We get an understanding what sustainability aspects are prioritized.'*

Subsequently, most projects formulate sustainability objectives based the understanding of the sustainability ambitions. Project manager [PM.CEF_3] stressed the main role of project managers in steering the project team toward achieving project objectives, underscoring its significance to translate sustainability ambitions to clear objectives. Project manager [PM.CEF_4] elaborated,

> *'We create a list of requirements based on each ambition and engineer our designs accordingly.'*

During this phase, as noted by sustainability advisor [SA.CEF], some projects engage in brainstorming sessions while larger projects may conduct environmental advisory sessions. However, these practices are not universal across all infrastructure projects.

Once sustainability ideas are identified, feasibility studies, cost estimations, and cost-benefit analysis are conducted. This approach is applied to all identified alternatives within projects. Elaborating on this, project manager [PM.CEF_3] outlined,

> *'We estimate the associated hours required. Then, we assess the potential benefits and conduct a cost-benefit analysis. By adding up the investment and evaluating the achievable outcomes, we then present a proposal to the client.'*

Following the proposal to the client and decisions on actualizing sustainability opportunities, there are regular reviews of sustainability progress. As explained by project manager [PM.CEF_4],

> *'Throughout each stage, we assess whether our solution aligns with the specified requirements and verify that these requirements are in line with the overarching goals.'*

[PM.CEF_4] cited a successful case of sustainability idea actualization, emphasizing the importance of ensuring meeting sustainability objectives at each project stages. It is also important for the project manager to sustain support from decision-makers by regularly engaging with them to ensure alignment and support. For sustainability progress reviews, [PM.CEF_4] also highlighted the addition of an external challenger in a project that facilitated the actualization of sustainability opportunities.

As [BD.CEF] described, the aforementioned approach is typically adopted in projects with ambitious sustainability goals. Conversely, in projects with moderate or low sustainability ambitions, teams typically follow traditional methods until the later stages in the project, where sustainability considerations are integrated. At this point of time, minor adjustments or additions may be made related to sustainability.

Figure 4.6 presents a list of current approaches discussed, along with the frequency of their mention across all interviews.

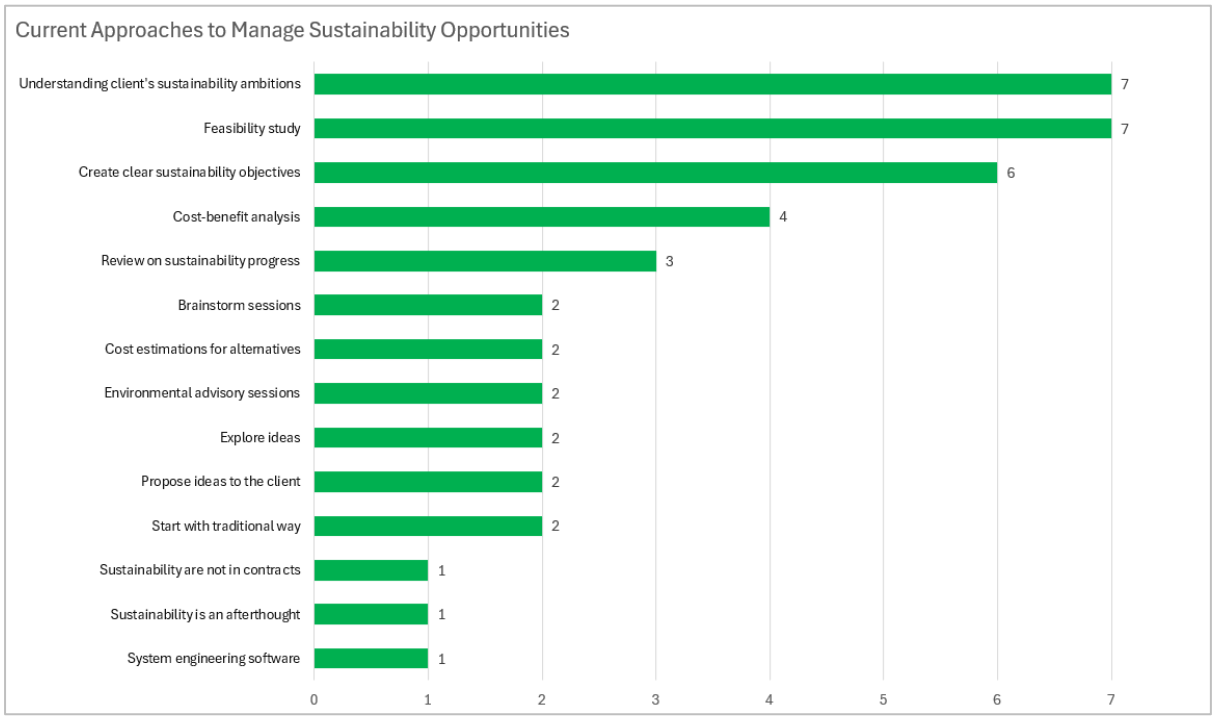

Figure 4.6: Code distribution of current approaches to manage sustainability opportunities (author)

This section sheds light on current sustainability opportunity management practices, offering valuable insights for further scientific exploration into the methodologies the scientific community can provide in this domain.

Overall, it is observed that consultancy engineering firms predominantly adopt a rather passive approach to managing sustainability opportunities, often limiting their actions to client-driven demands. This finding is considered in the development of the framework in Chapter 6, which proposes proactive action items that consultancy engineering firms can take for improving the actualization of sustainability opportunities during the FED phase.

4.9. Limitations

This empirical research is subject to certain limitations. Primarily, due to the scope of the study, interviews were conducted with a selection of the most relevant roles within infrastructure projects, thereby some roles were being excluded. Furthermore, certain roles were represented by only one participant during the interviews, potentially introducing bias based on individual experiences. It is also crucial to note that this study is conducted based on the infrastructure sector in the Netherlands, thus it may restrict the generalizability of the empirical findings to a local context. Moreover, the interviews conducted from the perspective of the consultancy engineering firm were limited to a single company, which may limit the diversity of viewpoints presented.

4.10. Empirically Informed Theoretical Research Formulation

As explained in this chapter, certain findings of the empirical research will be directly integrated into the framework in Chapter 7, while other research findings will be further scrutinized in the theoretical exploration in Chapter 5. The linkage between empirical research findings and the theoretical research structure is shown in Figure 4.7.

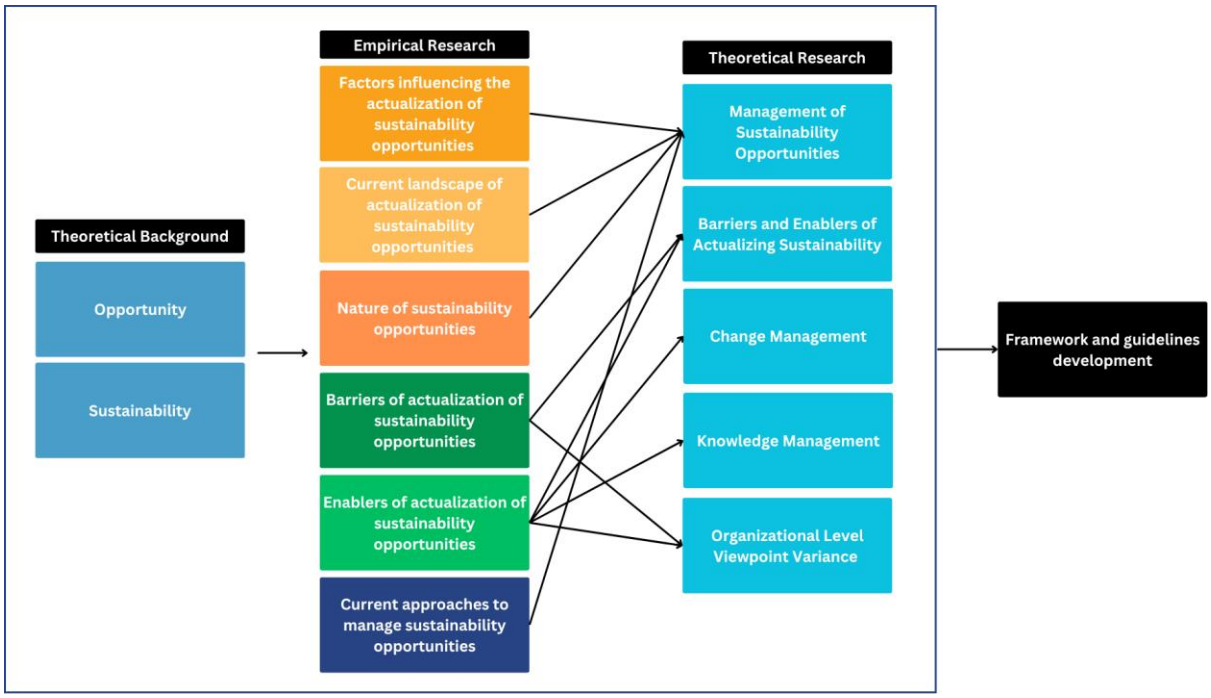

Figure 4.7: Linkage between empirical researching findings and theoretical research structure (author)

The research demonstrates a dual pathway for incorporating empirical findings. First, themes requiring deeper theoretical grounding informed the subsequent literature review, driving targeted investigation into relevant concepts. Second, empirical results that are more robust and clearer are directly incorporated into the framework and guidelines. The relationship between empirical findings and theoretical findings are elaborated in greater depth during the data synthesis presented in Chapter 6, which will systematically analyze these interconnected knowledge streams.

4.11. Conclusion

The empirical research serves as the foundational element of the grounded theory approach in this thesis, focusing on collecting and analyzing practical insights regarding the actualization of sustainability opportunities. These findings are crucial for informing the subsequent theoretical research direction. The empirical research has extensively delved into various aspects, including the current landscape of sustainability opportunities actualization, the nature of these opportunities, factors influencing their realization, barriers, enablers, and existing approaches to managing them. The summary of the key empirical research findings is visually represented in Figure 4.8.

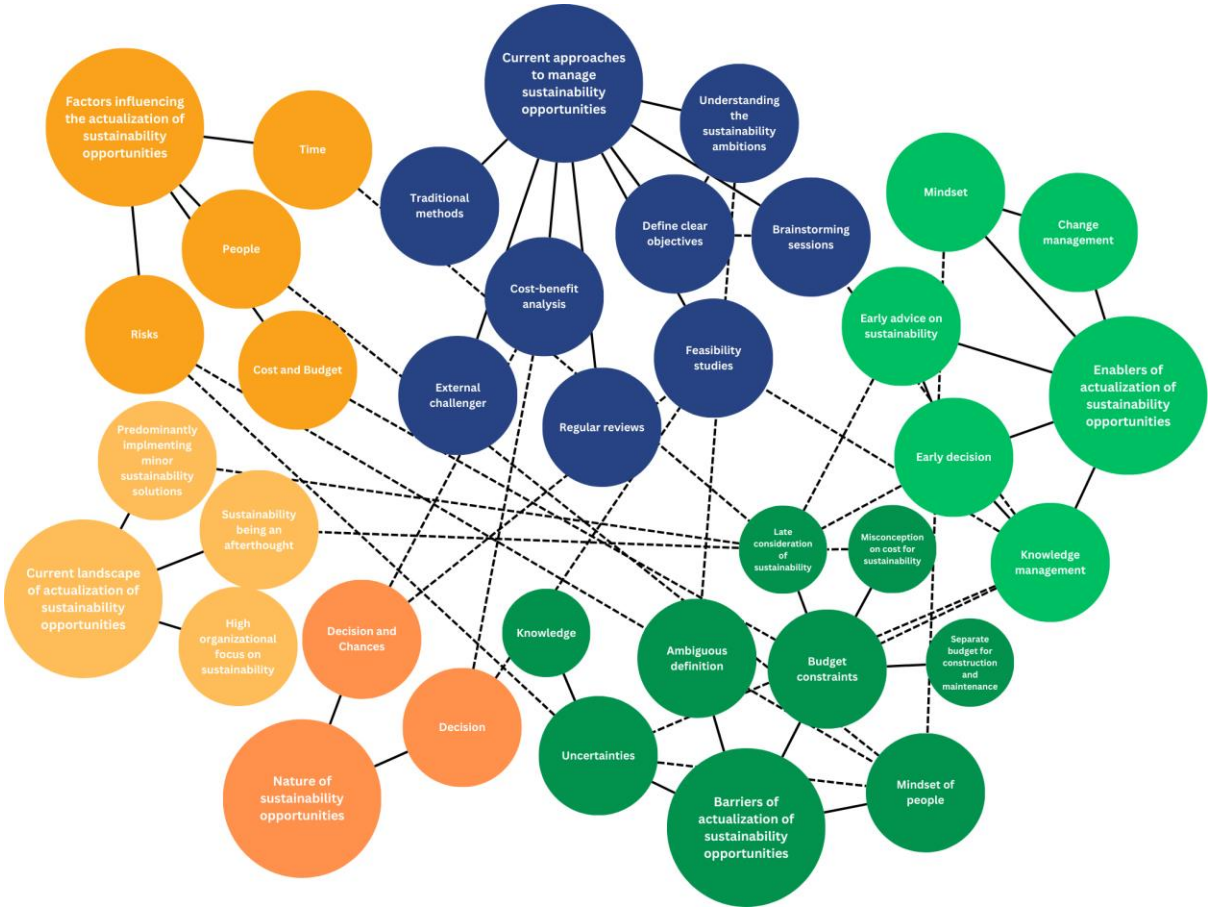

Figure 4.8: Summary of key empirical research findings (author)

The illustration visually summarizes key findings through a color-coded system. Each major theme is represented by a large circular shape, with corresponding smaller circles in matching colors depicting the individual findings. The solid lines connect elements in the same theme,

while the dotted lines between these elements serve as connectors, mapping the conceptual relationships between related findings across themes.

An intriguing pattern observed from overviewing the data is the varying perspectives among practitioners with different roles in an infrastructure project concerning the realization of sustainability opportunities Individuals with similar roles often share common perspectives, while those with different roles tend to offer varied viewpoints. This pattern in viewpoints is logical as distinct roles within a project come with different objectives and focuses, leading individuals to perceive different perspectives of the project. This phenomenon also explains why similar themes are frequently echoed by participants with akin roles and work experiences.

Moreover, disparities in viewpoints are observed among practitioners at different levels within a company. Typically, management-level professionals provide strategic insights from an organizational standpoint, while operational-level practitioners offer perspectives rooted in their daily operational experiences within specific project domains. This observation presents an interesting avenue for theoretical exploration into how individuals at varying organizational levels possess distinct perspectives on the same subject.

Despite practitioners holding diverse opinions on the themes explored, their responses often complement each other, indicating a cohesive narrative within the industry. This shows that it is difficult for individuals within the industry to understand the full picture of the topic and this empirical research aligns opinions across different roles which provides a holistic view of the topic. This highlights the challenge faced by industry individuals in grasping the complete picture of the topic. The empirical research aligned opinions across different roles, offering a comprehensive and holistic perspective on the subject matter.

5

5. THEORETICAL RESEARCH

This theoretical exploration will add on to the findings grounded in the empirical research for developing a framework for improving the actualization of sustainability opportunities. The primary objective of this chapter is to address SQ2, which includes acquiring scientific knowledge on the actualization of sustainability opportunities and gaining deeper understandings in specific topics derived from the empirical research findings.

The literature review framework has been structured to align with key findings from the empirical research. Figure 4.7 demonstrated the conceptual linkage between empirical findings and theoretical research directions, while Figure 5.1 presents the structure of the literature review itself. The literature review consists of two parts: theoretical background research and theoretical research. Chapter 3 established the theoretical foundation by examining existing knowledge and definitions concerning opportunities and sustainability. This literature review will specifically explore methodologies for managing sustainability opportunities, and key barriers and enablers affecting their actualization. The subsequent section will center on reviewing the subjects derived from the empirical research, exploring selected topics from its key findings. These theoretical findings will be synthesized with empirical research results to form the basis for framework development.

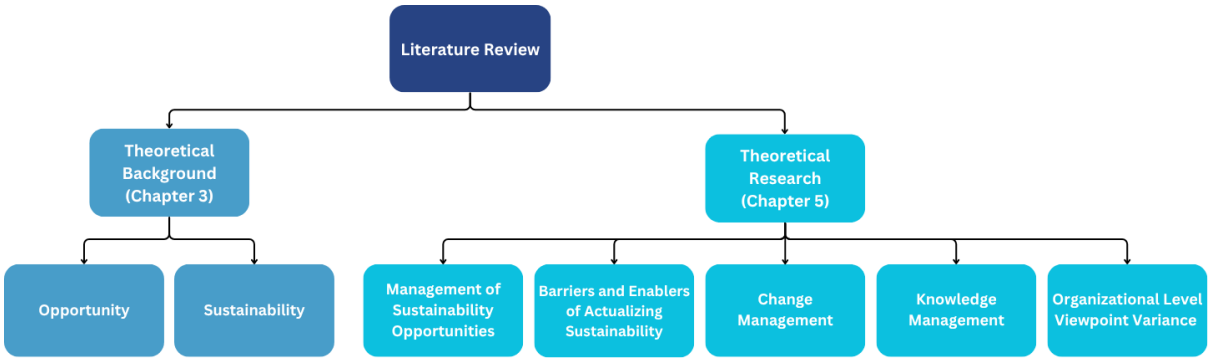

Figure 5.1: Background research structure (author)

This chapter employs the same literature search methodology as implemented in Chapter 3. For a detailed discussion of the approach, please refer to Chapter 3.

5.1. Management of Sustainability Opportunities

Upon grasping the definitions of opportunities and sustainability, it becomes imperative to delve into the existing management practices and theories related to the management of sustainability opportunities within academia. Following the theme-based research approach, it is apparent that there is a scarcity of articles specifically addressing the management of sustainability opportunities. However, a substantial number of articles are available on the

management of sustainability and management of opportunities separately, which will be utilized instead. By exploring how sustainability opportunities can be effectively managed and actualized from a scientific point of view, valuable insights can be obtained to compare with the data from empirical research and inform the development of the framework aimed at improving the management of sustainability opportunities.

5.1.1. Management of Opportunities

In connection with the discussion about the definitions of risk, supporters of an exclusively negative interpretation of risk and a distinct conceptualization of opportunity would logically advocate separate processes for the management of risk and opportunity. On the other hand, supporters of a perspective that considers risk to encompass both opportunities and threats acknowledge the feasibility of addressing both within an integrated framework through a common process (Hillson, 2002). Having established the preference for the latter definition as justified in the preceding section, it becomes apparent that the current risk management process can accommodate the management of opportunities alongside threats, although necessitating certain adjustments to the standard risk management approach. In accordance with the Project Management Institution (2021) in PMBOK, risk management is defined as the systematic process of identifying, analyzing, and responding to project risk, which involves maximizing the probability and consequences of positive events and minimizing the probability and consequences of negative events to project objectives.

Focus of threats and opportunities

Despite the clear scope defined in PMBOK by the Project Management Institution, the risk management process still tends to focus on the management of threats. Scholars have not paid much attention to the processes and practices of managing opportunities (Hietajärvi et al., 2017). In practice, project managers rather focus on preventing threats than exploiting opportunities. In a Norwegian study conducted by Krane et al. (2014), 12 construction projects were studied to assess how effectively they capitalize on opportunities. By tracking the number of identified opportunities and threats across the project lifecycle, the study unveiled a phenomenon termed the "blind spot of risk management", as depicted in Figure 5.2.

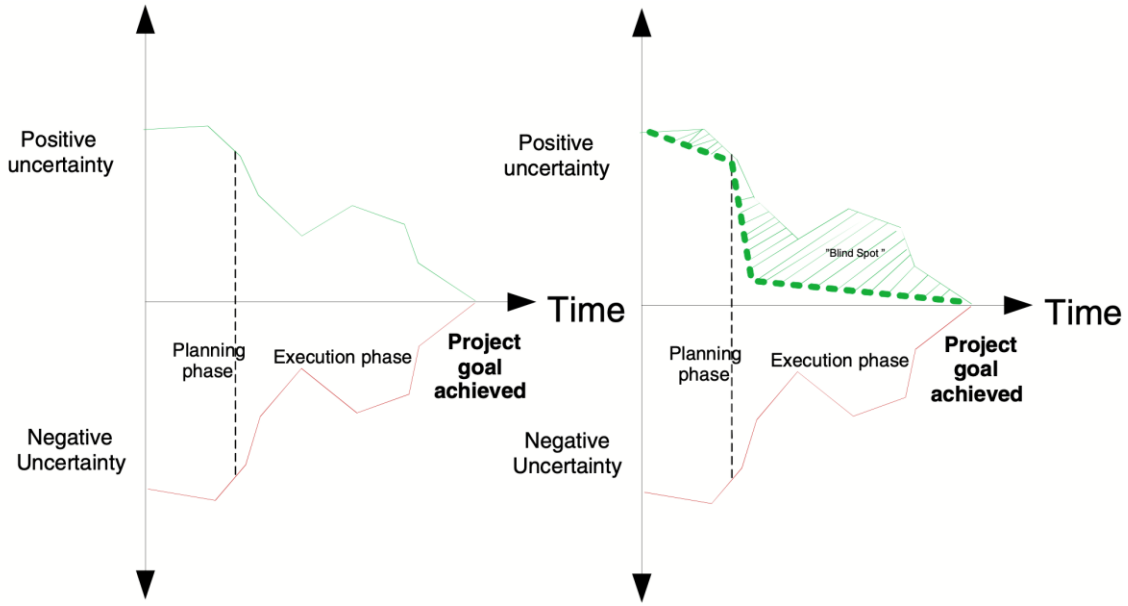

Figure 5.2: Number of opportunities and threats during project phases (Krane et al., 2014)

The findings indicate that projects typically begin with a significant number of identified opportunities, which diminishes in later stages (Krane et al., 2014). To ensure precise terminology, Krane et al. (2014) defines the planning phase as concept development, the initial part of the execution phase as the design phase, and the subsequent part of the execution phase as the detailed design and construction phase. This result underscores the notion that projects tend to prioritize addressing threats and neglecting opportunities within risk management, yet threats and opportunities should carry equal importance.

This phenomenon stems from the common experience of risk practitioners who find it easier to identify potential pitfalls and problems than to look for hidden advantages or upsides. Furthermore, currently, the guidelines and tools for how to manage opportunities in practice are deficient (Lehtiranta, 2014). Therefore, this section will further delve into risk management processes and the required modifications tailored for effective opportunity management.

Risk management process

In academia, an array of risk management processes is available and recognized. Among these, the RISMAN method, developed collaboratively by the Dutch Ministry of Transport, Twijnstra Gudde Management Consultants BV, NS Railinfrabeheer BV, and Delft University of Technology (de Rijke et al., 1997), is one of the most prominent approaches. This methodology provides a systematic process for analyzing, quantifying, and managing risks in large-scale infrastructure projects, achieving widespread adoption in the Netherlands.

The RISMAN method begins with uncertainty identification to pinpoint potential risk sources, followed by steps focused on risk quantification and project risk assessment. As depicted in Figure 5.3, the process comprises six major steps.

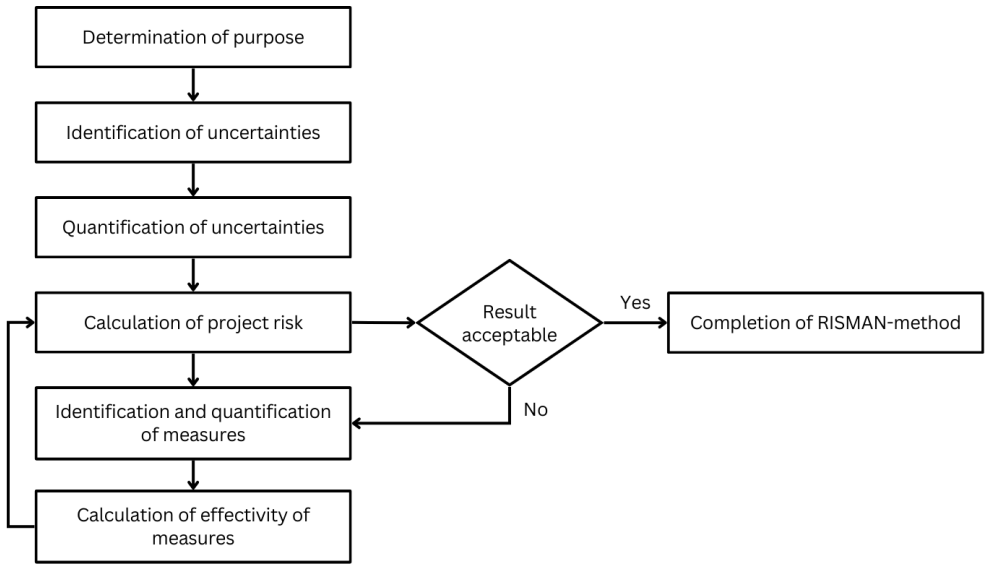

Figure 5.3: RISMAN method (de Rijke et al., 1997)

The six-step RISMAN framework has high emphasizes on its iterative process. The iterative process comprises of five main steps that systematically perform risk analysis, choose control measures, implement control measures, evaluate control measure, and update risk analysis.

Through its recursive application, project teams can uncover previously overlooked risks and reevaluate identified risks. The iterative process steps are presented in Figure 5.4.

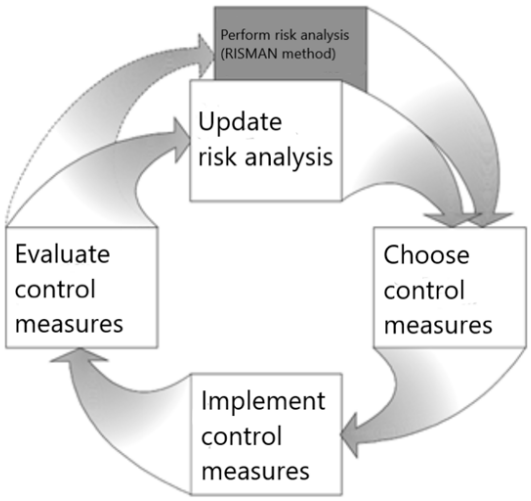

Figure 5.4: RISMAN iterative process steps (RISKID, 2023)

This study also examines the risk management methodologies outlined in PMBOK by the Project Management Institute (2021) and ISO 31000:2018, with the integration of insights from multiple scholars (Ettouney & Alampalli, 2016; Faber & Stewart, 2003; MacAskill & Guthrie, 2013; Purdy, 2010; Schieg, 2006; Taghipour, 2015). As per PMBOK and ISO 31000, project risk management entails a methodical procedure for recognizing, assessing, and responding to project risks. While these two standards vary in their structured processes, the fundamental concept remains consistent, as depicted in Figure 5.5.

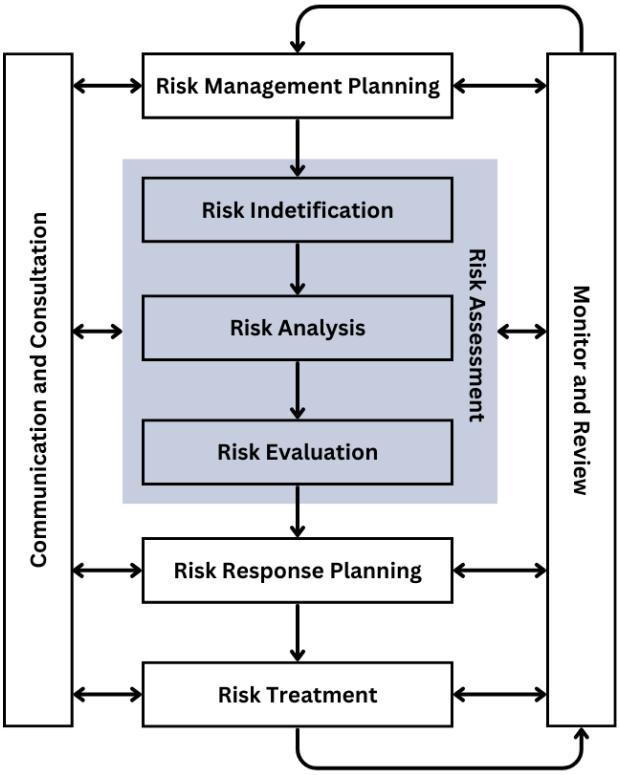

Figure 5.5: Typical risk management process (ISO 31000:2018; Project Management Institution, 2021; author)

The diagram depicts a standard risk management process that initiates with risk management planning to set the context. Subsequently, it progresses to risk assessment involving risk identification, analysis, and evaluation. The next step involves risk response planning, which maps out strategies for risk mitigation or exploitation. Following this, the risk treatment phase addresses the risks accordingly. Moreover, the illustration highlights that risk management is not a one-off process but an ongoing process demanding continuous communication, consultation, monitoring, and review.

Given the escalating emphasis on and importance of sustainability, Wong (2024) attempted to integrate sustainability considerations into conventional risk management processes. The development of the framework initially grounded in theoretical foundations, followed by empirical refinement through pilot testing across five projects within an engineering consultancy firm. The resulting framework, named as the Sustainability Risk Management Framework 2.0, is presented in Figure 5.6.

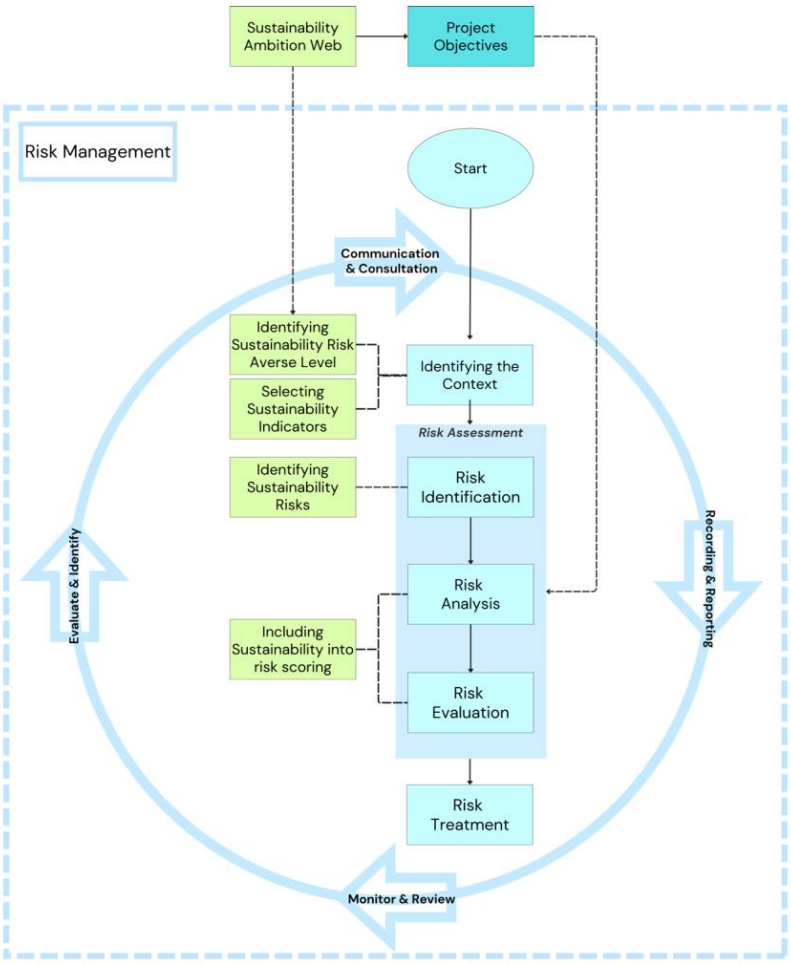

Figure 5.6: Sustainability Risk Management Framework 2.0 (Wong, 2024)

Wong (2024) explicitly recognized that the development and pilot testing of the framework were rooted in existing risk management paradigms which predominantly focused on threat management. This limitation mirrors the constraints identified in preceding mentioned frameworks, underscoring a gap in current risk management approaches regarding their capacity to manage sustainability-related opportunities. Consequently, the framework requires targeted modifications to align with the management of opportunities.

Risk management process for managing opportunities

This risk management process is structured to address both threats and opportunities. Nevertheless, current practice predominantly focuses on managing threats rather than seizing opportunities (Hietajärvi et al., 2017). Given the limited emphasis on utilizing the risk management process for managing opportunities, each stage of the risk management process is considered and explored to identify whether changes are required in order to include opportunities explicitly from the academic perspective.

Risk management planning is the initial stage of the risk process that identifies the context, including ensuring that project objectives are clearly stated and understood. This phase is deemed sufficiently robust to cope with managing opportunities without necessitating major alterations (Hillson, 2002). To effectively manage opportunities in subsequent stages, it is recommended to outline the specific opportunity-focused techniques to be utilized later within this initial phase (Hillson, 2002; Košmrlj et al., 2015). Moreover, it is beneficial to emphasize the dual focus of risk management at the outset of the project, given the atypical prioritization of threat management over opportunity exploitation (Denney, 2020). This emphasis enables stakeholders to better align with the intended risk management approach.

Numerous methodologies available in academia and the market for risk identification, encompassing techniques, such as brainstorming, workshops, and checklists (Swanepoel & Pretorius, 2015). No singular method proves supreme for risk identification, as each approach holds the potential to effectively uncover both opportunities and threats. Yet, expecting risk managers in the construction sector to alter their ingrained habits of using traditional risk identification practices primarily focused on negative risks is overly optimistic (Hillson, 2002). Therefore, supplementing these methods with alternative approaches can be beneficial.

Risk analysis involves the examination of risks, including their probability and potential consequences. The primary technique is the probability-impact matrix (Dumbravă & Iacob, 2013). To incorporate opportunities, a dual probability-impact matrix has been suggested (Hillson, 2002; Hopkinson, 2021), as depicted in Figure 5.7.

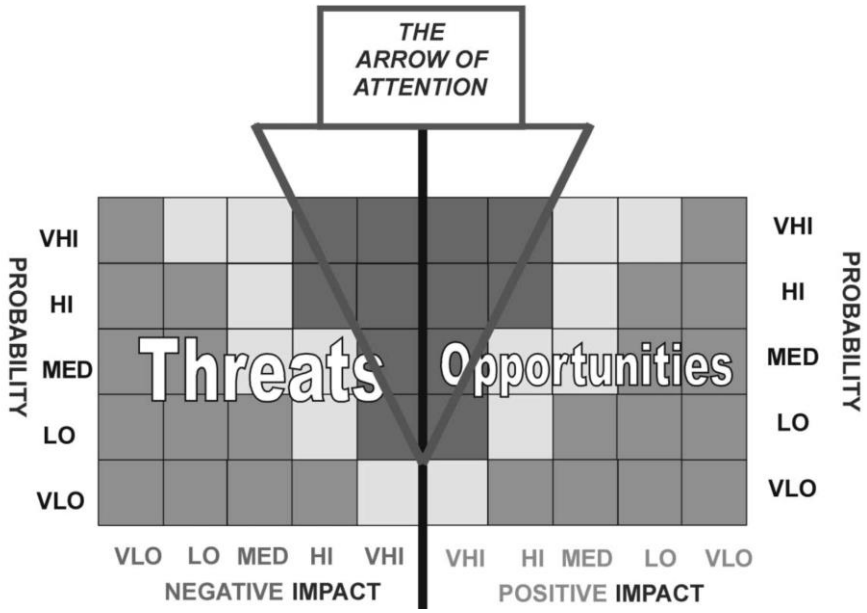

Figure 5.7: Double probability-impact matrix (Hillson, 2002)

Risk evaluation involves pinpointing key risks to inform decisions regarding risk responses. This phase can likewise make use of the dual probability-impact matrix (Hopkinson, 2021). For instance, the risks and opportunities situated within the 'arrow of attention' in Figure 5.7 should either be mitigated or exploited.

The risk response planning phase formulates responses to the identified risks, encompassing distinct strategies for managing threats and opportunities. While threats often prompt the use of the four common risk strategies, namely avoid, transfer, mitigate, and accept, responding to opportunities with these same strategies is typically inadequate. Hillson (2002) introduced an alternative set of four strategies that are now widely adopted for opportunities: exploit, share, enhance, and ignore.

This section has shown that a unified risk management process, with adjusted steps and approaches, is capable of addressing both threats and opportunities from a scientific point of view. In the next chapter, this approach to the management of opportunities will be integrated with the subsequent exploration of management of sustainability to draw comparisons with the empirical research findings.

Opportunity framing

The concept of opportunity framing, described by Hertogh (2014), represents a structured approach for understanding and defining opportunities. This process aligns project objectives and stakeholder priorities. It serves as the starting point of the decision-making process for the actualization of opportunities. The objective of opportunity framing is value creation, which can be achieved through redefining project concept, integrating new technologies, and expanding project scope. While Hertogh (2014) suggests that the FED phase represents the ideal stage for initiating opportunity framing, he underscores the importance of maintaining flexibility throughout the planning, realization, and operational phase.

Hertogh (2014) suggests five crucial at opportunity framing,

- To define the project scope
- To involve stakeholders
- To define when the project will be successful
- To create value drivers
- To identify risks

Opportunity framing holds particular relevance for this study, which focuses on improving decision-making processes during the FED phase of infrastructure projects. The five crucial at opportunity framing will be integrated into the development of the proposed framework in Chapter 6. By adopting these principles, the framework aims to enhance the identification and evaluation of sustainability opportunities.

5.1.2. Management of Sustainability

While sustainability has increasingly asserted its importance in the construction industry, the integration of sustainability principles into project management practices lags (Banihashemi et al., 2017). A survey conducted by McKinsey & Company indicated that even though organizations recognize the importance of sustainability, most of them do not practically

engage in its management (Nawaz & Koç, 2018). This section explores selected prevailing guidelines and management models for management of sustainability, chosen for their academic significance and direct relevance to the research objectives. The selection criteria prioritize guidelines and models that are theoretically sound and practically applicable.

Standardized guidelines for management of sustainability

The ISO standard includes a guideline offering instructions on integrating sustainability into management practices. As per the guideline, the process involves determining responsibilities, choosing approaches to sustainability, identifying principles related to sustainability, identifying sustainability issues, and finally, addressing sustainability issues (International Organization for Standardization [ISO], 2019). This process is depicted in Figure 5.8.

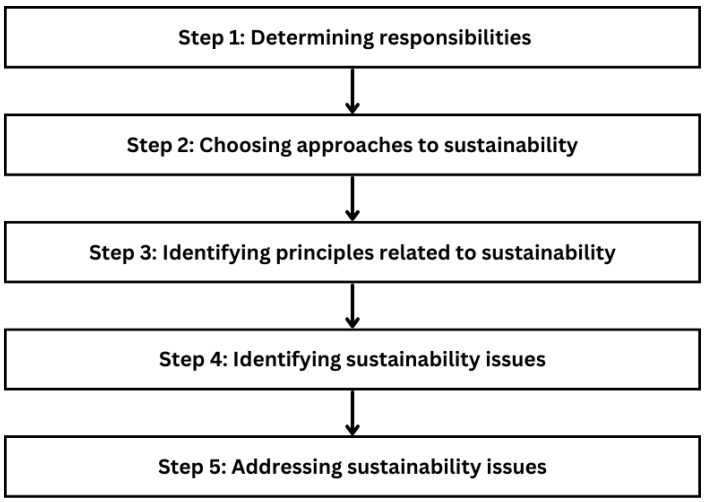

Figure 5.8: Illustration of sustainability management process suggested in ISO Guide82:2019(E)

The suggested sustainability management process commences by allocating responsibilities by establishing agreements and contextualizing sustainability within project operations through the project committee (ISO, 2019). Subsequently, in the selection of sustainability approaches, ISO Guide 82 presents a range of methodologies, namely the systematic approach, life-cycle approach, precautionary approach, risk-based approach, and stakeholder approach (ISO, 2019). Furthermore, alongside these approaches, ISO Guide 82 outlines several sustainability principles to consider, including transparency, stakeholder interests, and ethical considerations. Following the establishment of sustainability approaches and principles, the next phase involves identifying sustainability issues. According to Guide 82, project managers can identify sustainability concerns by aligning them with core sustainability topics using established or recognized sustainability frameworks like the triple bottom line approach, ESG, or SDGs. This stage entails identifying relevant and significant sustainability issues (ISO, 2019). Finally, sustainability issues can be addressed through one of the three standards, namely process standards, management system standards, or product standards (ISO, 2019).

Sustainability management model - Sus5

Maas and Reniers (2014) have contributed to sustainability management by introducing the Sus5 framework. It is a conceptual framework that offers a structured approach to addressing sustainability issues in project management from strategic level to operational level. The framework is divided into soft and hard axes and is illustrated in Figure 5.9.

Within this framework, the significance of knowledge management is emphasized, encompassing the dissemination of information within an organization, the effective management of stakeholder knowledge, and facilitating communication both vertically and horizontally within a business unit (Maas & Reniers, 2014).

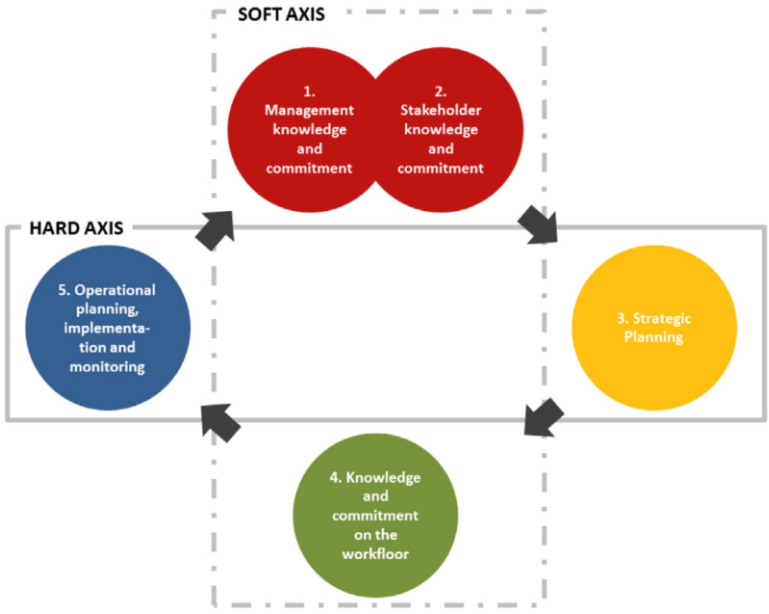

Figure 5.9: Sustainability management system framework Sus5 (Maas & Reniers, 2014)

Sustainability management methodology - Perrott's strategic sustainability management process

Perrott (2015) presents a strategic methodology for sustainability management within organizations. This holistic approach follows a top-down design, as depicted in Figure 5.10.

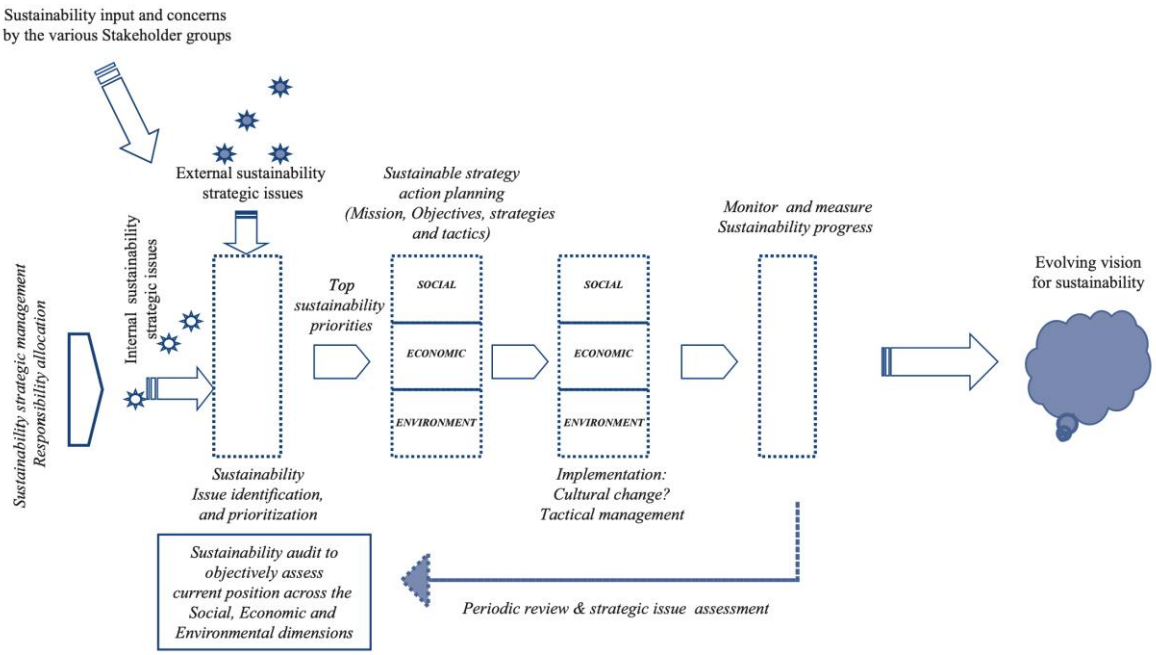

Figure 5.10: Perrott's strategic sustainability management process (Perrott, 2015)

The process presents the essential components of sustainability management. The visual representation of the process is inherently descriptive, commencing from the left-hand side of Figure 5.10. Key elements within this process encompass the allocation of responsibilities, prioritization of sustainability concerns, action planning, change and tactical management, as well as monitoring and measurement.

5.2. Barriers and Enablers of Actualizing Sustainability

Understanding the barriers and enablers that impact the actualization of sustainability is crucial for understanding the sustainability landscape within the construction industry. This foundational knowledge is instrumental in developing the framework that effectively addresses barriers and leverages enablers. The empirical research has also delved into this inquiry. This section primarily concentrates on the academic viewpoint regarding the barriers and enablers. A comprehensive synthesis of theoretical and empirical insights on this subject will be conducted in Chapter 6.

5.2.1. Barriers of Actualizing Sustainability

Actualizing sustainability opportunities in projects presents several barriers. This section of the literature review explores the common barriers mentioned in articles. Given the saturation of research papers on barriers to realizing sustainability, the papers highlighted in this section have been chosen based on their relevance, frequency of citations, and the uniqueness of their findings.

Siew, Sepasgozar, and Akbarnezhad (2015) identified four key barriers in actualizing sustainability in construction projects, including multiple definitions of sustainability, ineffectiveness of sustainability reporting tools, negligence of human resource management to promote sustainability, and slow adoption of sustainable technologies. Ohiomah et al. (2019) identified through their research that key barriers to actualizing sustainability opportunities include perception that sustainable project is expensive, lack of expertise and trainings, lack of awareness, and lack of government support. Rincón et al. (2021) explored key barriers for actualizing sustainability, including late inclusion of sustainability concerns in projects, functional units have separate budgets and low integrations, narrow vision of sustainability, lack standardizations in criteria for sustainability, and permissive actor-led sustainability exclusion. Kineber, Kissi, and Hamed (2022) pointed out several key barriers, including societal limitations, economic, mindset, lack of knowledge, and lack of sustainability experts.

The diverse range of key barriers identified across these studies underscores the complexity of the sustainability landscape. Ahmed et al. (2023) attributed variations in barriers to the actualization of sustainability to regional differences. Their research revealed that the top five barriers to realizing sustainability in construction projects in different countries is different. This underscores the importance of considering the regional context when examining the barriers. These barriers will be integrated with empirical research findings from practitioner interviews to provide a comprehensive understanding of the barriers faced in actualizing sustainability opportunities.

5.2.2. Enablers of Actualizing Sustainability

While barriers exist in the path to actualizing sustainability, there are enablers for actualizing sustainability opportunities. This section of the literature review explores the common enablers mentioned in articles. Given the saturation of research on enablers to realizing sustainability, the literatures highlighted in this section have been chosen based on their relevance, frequency of citations, and the uniqueness of their findings.

Ohiomah et al. (2019) identified through their research that key enablers to actualizing sustainability opportunities include financial support, knowledge management, public demand, create awareness, and professional trainings. Kar and Jha (2021) mentioned that the key enablers include corporate social responsibility initiatives, commitment of stakeholders, and government directives. Rincón et al. (2021) identified a list of enablers for sustainability actualization, including knowledge source and generation strategies, clear objectives, flexible project procedures, and inclusion of sustainability concern as criteria.

Similar to barriers, the diverse array of key enablers identified across these studies highlights the complex nature of sustainability in construction industry. These enablers will be synthesized with empirical research findings from practitioner interviews to offer a comprehensive understanding of the factors that facilitate the actualization of sustainability opportunities.

5.3. Knowledge Management

Based on findings analyzed from the empirical research, knowledge management emerged as a prevalent enabler in interviews, showcasing its potential to enhance the realization of sustainability opportunities. This section of the literature review will initially explore knowledge management itself, followed by an examination of the correlation between knowledge management and the actualization of sustainability opportunities. Subsequently, it will delve into the methodologies by the scientific community for implementing knowledge management in engineering firms.

5.3.1. Definition of Knowledge Management

Knowledge stands as an important resource within any organization (Dave & Koskela, 2009), with some studies suggesting that the success of an organization hinges on its management of both internal and external knowledge (Dave & Koskela, 2009; Lam et al., 2021; Switzer, 2008).

In organizational contexts, there are two distinct forms of knowledge: tacit knowledge and explicit knowledge. Explicit knowledge is readily documented and stored, encompassing resources such as procedure manuals, best practices guides, and work breakdown structures within the construction industry (Carrillo & Chinowsky, 2006). Notably, the construction sector has made significant steps in developing and implementing systems for managing the capture, storage, and retrieval of explicit project-related knowledge (Dave & Koskela, 2009).

Conversely, tacit knowledge has yet to receive ample attention within the construction industry. Tacit knowledge, rooted in experiences of individuals and stored in their minds, proves challenging to manage (Yepes & López, 2021; Zhang & He, 2016). Within construction, tacit knowledge holds particular significance due to the unique nature of each project, which

generates a wealth of knowledge throughout the project life cycle. Regrettably, this valuable knowledge predominantly remains confined to the minds of the team members and often fails to be shared across the organization for future project applications (Dave & Koskela, 2009).

The concept of knowledge management has existed since the 1980s (Nonaka, 2009). Within an organization, the essence of knowledge creation resides in the dynamic exchange between tacit and explicit knowledge among individuals through continuous interactions, promoting innovation and improvements (Dave & Koskela, 2009). Despite its long presence, there exists no formal consensus on the exact scope of knowledge management. However, a widely acknowledged definition put forth by Webb (1998) defined knowledge management as the process of identifying, optimizing, and actively managing intellectual assets to improve company performance. The dimensions of knowledge management are illustrated in Figure 5.11 by Jashapara (2004).

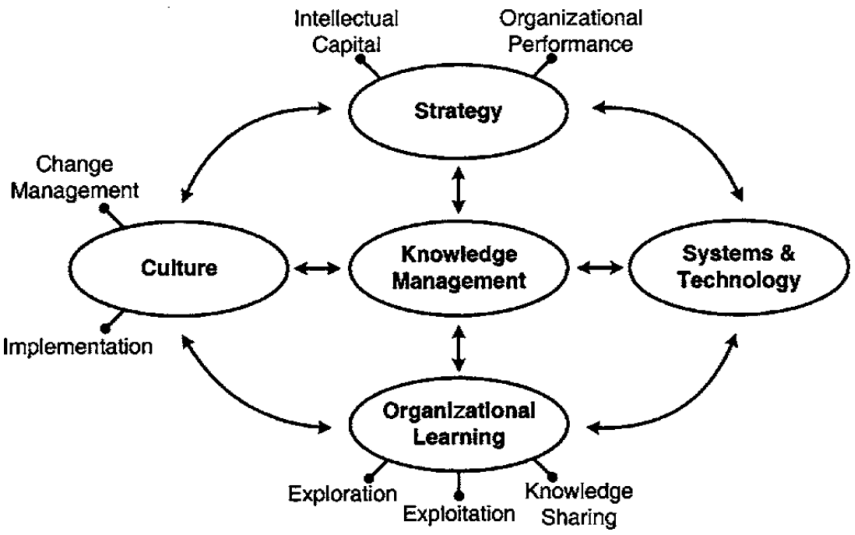

Figure 5.11: Dimensions of knowledge management (Jashapara, 2004)

Figure 5.11 highlights the multifaceted nature of knowledge management, showcasing its connections with various interdisciplinary factors such as culture, strategy, systems and technology, and organizational learning.

5.3.2. Knowledge Management and Sustainability

In the construction industry, knowledge management is being seen as an important part of the actualization of sustainability practices (Kivits and Furneaux, 2013; Leblanc & Thomson, 2012). There is a need for allowing project stakeholders to acquire, transfer, and exchange knowledge about sustainability in construction projects to enable better selection and actualization of sustainability in construction projects (Zhang & El-Gohary, 2013). The relationship between BIM, knowledge management and sustainability, as explained by Kivits and Furneaux (2013), is illustrated in Figure 4.15. BIM enables knowledge management, which, in turn, facilitates sustainability efforts by enabling the reuse of knowledge.

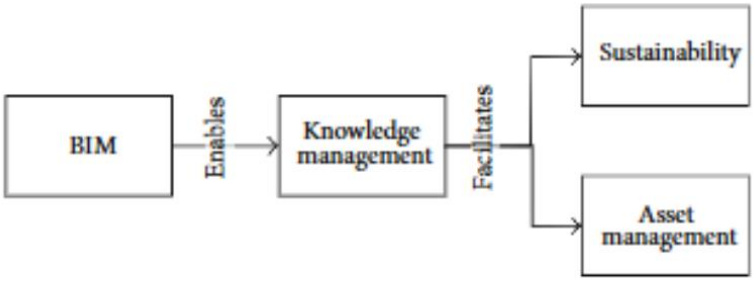

Figure 5.12: Relationship between BIM, knowledge management and sustainability (Kivits and Furneaux, 2013)

Kivits and Furneaux (2013) further explains that because the knowledge, once being created, can be reused, resulting in less errors, greater consistency, clarity, accuracy, and clear responsibility of authorship. This approach ensures that knowledge generated through sustainability initiatives can be stored and applied in future projects, which addresses some of the uncertainties when exploring sustainability alternatives.

The construction industry is a knowledge drive industry. An effective management of sustainability-related knowledge is a fundamental component in achieving sustainability in projects (Pietrosemoli & Monroy, 2013). Robinson et al. (2006) described knowledge assets as the roots of corporate sustainability, emphasizing that the understanding of sustainability represents the unseen foundation of an organization, much like roots that must be nurtured to yield fruits. In this analogy, knowledge management serves as the practice of nurturing and strengthening these foundational roots to foster sustainable growth and development within organizations. This support process enables the development of capabilities and innovation, assists cultural transformations, facilitates knowledge transfer, and promotes the sharing of lessons learned across project phases and between different projects (Pietrosemoli & Monroy, 2013).

These literatures underscore a positive correlation between knowledge management and sustainability, underscoring how proper knowledge management practices can enhance the actualization of sustainability opportunities within the construction industry.

5.3.3. Knowledge Management in Construction

The construction industry operates on a project-based model, where each project is unique and involves numerous stakeholders collaborating at various stages throughout its lifecycle. Each construction project is similar to a temporary multidisciplinary organization, with team members coming together for the duration of the project and often dispersing once the project concludes (Kamara et al., 2002). Notably, the construction sector is fiercely competitive, characterized by narrow profit margins, while clients increasingly demand superior and sustainable outcomes within shorter timeframes (Carrillo & Chinowsky, 2006; Dave & Koskela, 2009). Given these inherent characteristics and challenges, knowledge management emerges as a particularly attractive strategy within the industry.

The challenge in the construction sector lies not in generating knowledge but in the waste of valuable information that could be useful for upcoming projects (Yepes & López, 2021). The dynamic and distinctive nature of construction projects presents great potential of opportunities for knowledge acquisition. By effectively capturing and reusing this knowledge, the industry can prevent “reinventing the wheel” and foster innovation (Dave & Koskela, 2009).

Implementing knowledge management in the construction sector facilitates smoother knowledge transfer across project phases and between different projects. This approach not only captures and recycles valuable insights but also lays the foundation for a database of best practices. Such a database is particularly beneficial in the realm of sustainability knowledge. Given the ambiguous and uncertainties surrounding sustainability, timely knowledge exchange regarding proven technological solutions can bridge knowledge disparities among practitioners. By facilitating access to the latest advancements, this exchange prevents redundant efforts and time wastage, minimizes uncertainties, and encourages practitioners to innovate and implement new sustainable solutions with less hesitation.

5.3.4. Knowledge Management Strategy and Implementation

There are two primary strategies for implementing knowledge management effectively. The first is the information technology (IT) centric strategy, which emphasizes using IT or BIM tools to streamline the capture, access, and reuse of information and knowledge (Holtshouse, 2013). On the other hand, the people-centric strategy focuses on fostering an environment where employees are encouraged and empowered to develop, enhance, exchange, and utilize their knowledge to achieve project and organizational objectives (Syed, 2024).

Carrillo & Chinowsky (2006) have examined knowledge management practices in six engineering firms within the construction industry to identify best practices. From their research, four relevant key points have been selected and summarized.

Choosing the Right Strategy

For engineering firms in the construction sector, which rely on both tacit knowledge from employees and explicit knowledge in documentation, a holistic approach that combines people-centric and IT-centric strategies is deemed most effective.

Learning from Others

Internal knowledge sharing between business units facilitates the discovery of individuals or projects with relevant experience or examples, while external learning from projects outside the organization can provide valuable insights from the market.

Appointing Dedicated Individuals

Appointing individuals responsible for knowledge management is crucial. These individuals must have the time and resources to plan and execute knowledge management initiatives, addressing the time constraints often faced by construction firms.

Ensuring Visibility and Value

To embed knowledge management within the organization, it is essential to start by recognizing and celebrating successful knowledge management steps. Progressively, move towards establishing tangible metrics that showcase the value added by knowledge management initiatives to senior management.

These strategies and insights can serve as a starting point for engineering firms in the construction industry seeking to optimize their knowledge management practices. These findings will be incorporated into the framework development in Chapter 6.

5.4. Change Management

Based on findings analyzed from the empirical research, change management at organizational level is another crucial enabler in interviews, showcasing its potential to enhance the actualization of sustainability opportunities. This section of the literature review will initially explore change management itself, followed by an examination of the correlation between change management and the actualization of sustainability opportunities. Subsequently, it will delve into the methodologies by the scientific community for implementing change management in engineering firms.

5.4.1. Definition of Change Management

Change, as defined by Erdogan et al. (2005), is the process of making or becoming different, including alterations or modifications. In the construction industry, change management typically occurs on two distinct levels: organizational and project levels (Erdogan et al., 2005). Within construction projects, organizations encounter many changes, predominantly design changes. On the other hand, organizational change management also includes the implementation of changes at the organizational level, often involving management, technology, personnel, and cultural aspects. The primary objective at the organizational level is effectively introducing changes to the organization, whereas at the project level, the emphasis lies in adapting to changes arising within the project due to internal or external factors (Erdogan et al., 2005). In this section, the review focuses on organizational change management, in line with the results of the empirical research findings.

Organizational change management links closely with the management of organizational processes, strategies, changes in values, and changes in human behavior. The main reason for implementing effective organizational change management is to enable organizations to adapt to a rapidly changing environment (Abu Orabi et al., 2024). Notably, there is no one best way of structuring an organization as it depends on the circumstances (Erdogan et al., 2014). Given the changing nature of circumstances in businesses, organizations also need to be adaptable. This echoes the significance of change management underscored by industry practitioners in the Chapter 4 interviews, particularly in terms of making changes to daily operational processes to enhance sustainability.

5.4.2. Change Management and Sustainability

Sustainable transformations necessitate a comprehensive approach that extend beyond technical changes. It requires the engagement with the softer aspects of organizational changes, encompassing values, visions, policies, and the practices of change management (Lozano et al., 2016). Initiatives for sustainability in an organization usually refers to transitioning from the current state to a more desirable one (Ragsdell, 2000). Organizations that resist sustainability-driven changes risk marginalization due to external factors like changes in government regulations on sustainability, emerging sustainable technologies, workforce dynamics, and competitive landscapes.

Within the domain of internal organizational change for sustainability, the two primary methodologies often employed are the top-down and inside-out approaches (Lozano et al., 2016). The top-down strategy emphasizes hierarchical management, performance measurement, and control mechanisms, whereas the inside-out approach focuses on

encouraging internal innovation and change initiatives. Illustrated in Figure 5.13 is the transformative journey towards corporate sustainability suggested by Lozano (2012).

According to Lozano et al. (2016), the model elucidates that implementing sustainability-oriented changes can disrupt the established equilibrium, guiding the organization towards a more sustainability orientated state. Given the iterative nature of change processes, fostering change drivers and implementing effective strategies to overcome barriers to change are pivotal. The institutional framework provides stability during the transitional phase. Once the new structure and objectives are achieved, the more sustainability orientated state becomes the new status quo.

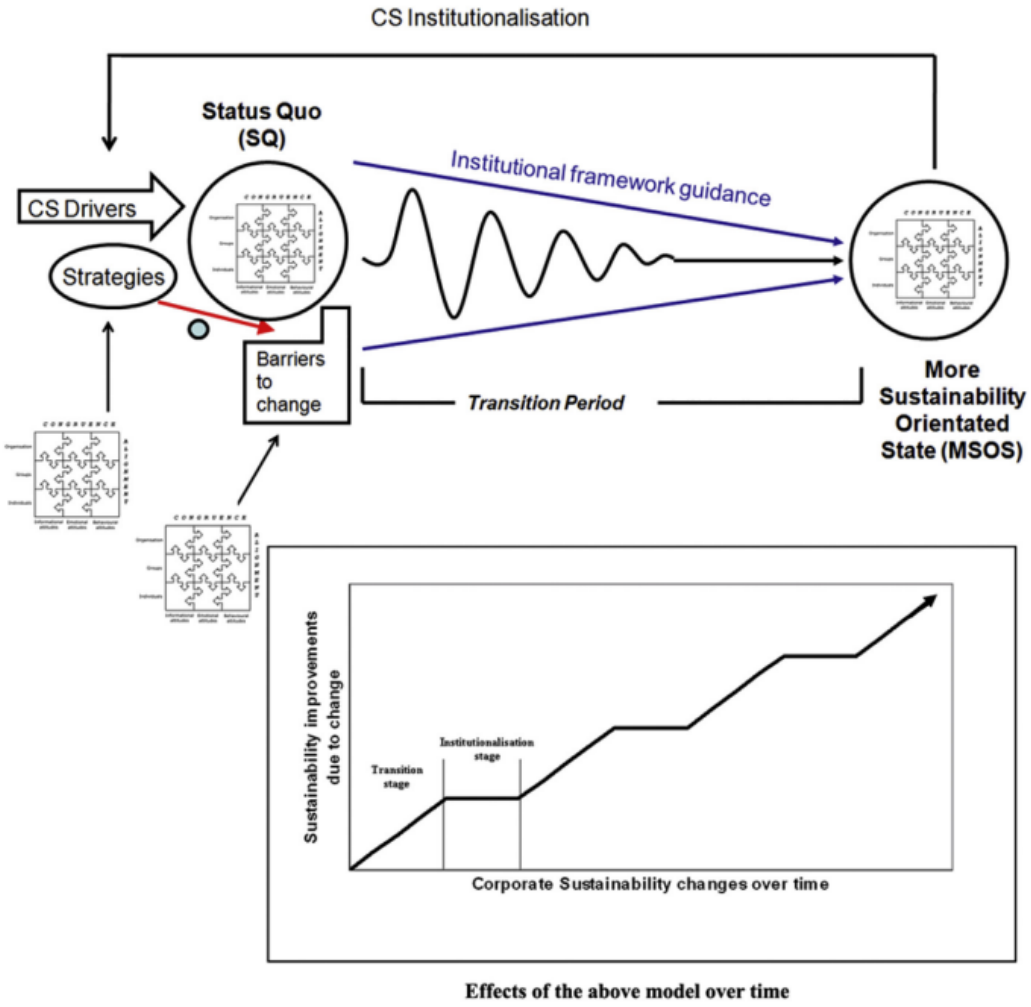

Figure 5.13: Illustration of the dynamics of changes for corporate sustainability (Lozano, 2012)

5.4.3. Change Management Strategy and Implementation

Lewin (1947) introduced the three-step model of change, which is widely regarded as the foundational framework for change management (Errida & Lotfi, 2021). These three steps include unfreezing, transition, and refreezing. The initial phase, unfreezing, involves destabilizing the existing status quo by creating the necessity for change and securing buy-in for change, thus preparing the groundwork for forthcoming changes. Subsequently, the transition phase entails the progression towards the envisioned future state. Finally, refreezing

occurs post-implementation, resulting in the establishment of a new organizational culture, behaviors, and practices.

Although various alternative models exist, most of them are extensions of Lewin's model, expanding its three steps into more detailed steps. For instance, Mento et al. (2002) proposed a comprehensive 12-step methodology for change management implementation. This approach includes determining the idea and its context, defining the change initiative, evaluating the climate for change, developing a change plan, identifying a sponsor, preparing the recipients of change, creating cultural fit, developing and choosing a change leader team, creating small wins for motivation, constantly and strategically communicating the change, measuring progress of the change effort, and integrating lessons learned.

The parallel between the change management steps outlined by Lewin (1947) and Mento et al. (2002) is visually represented in Table 5.1.

Table 5.1: Change management steps according to Lewin (1947) and Mento et al. (2002)

Lewin (1947)	Mento et al. (2002)
Unfreezing	Step 1: determine the idea and its context Step 2: define the change initiative Step 3: evaluate the climate for change
Transition	Step 4: develop a change plan Step 5: identify a sponsor Step 6: prepare the recipients of change Step 7: create cultural fit Step 8: develop and choose a change leader team Step 9: create small wins for motivation Step 10: constantly and strategically communicate the change Step 11: measure progress of the change effort
Refreezing	Step 12: integrate lessons learned

Having examined the methodologies for implementing change management in organizations, it is also important to consider the success factors for the effective implementation of change management. Errida & Lotfi (2021) unveiled 12 key success factors after analyzing 37 change management models. The key success factors include,

- Clear and shared vision and strategy of change
- Change readiness and capacity for change
- Change team performance
- Activities for managing change management
- Resistance management
- Effective communication
- Motivation of employees and change agents
- Stakeholder engagement
- Leadership and sponsorship

- Reinforcement and sustainment of change
- Approach and planning for change
- Monitoring and measurement

These steps and success factors can serve as a starting point for engineering firms in the construction industry seeking to optimize their change management practices for improving actualization of sustainability opportunities. These findings will be incorporated into the framework development in Chapter 7.

5.5. Organizational Level Viewpoint Variance

In academia, organizational decisions and processes are typically categorized into three levels by their time span and value: strategic, tactical, and operational (Harrington & Ottenbacher, 2009). Strategic decisions shape the long-term direction of the entire company, aligning with its mission, goals, and objectives (Kuruppuge & Gregar, 2020). Tactical decisions focus on the implementation of strategies to achieve goals, often appears as action plans, policies, and procedures on a sectional, departmental or individual level. Operational decisions impact daily functional operations within the organization. The three levels are illustrated in Figure 5.14.

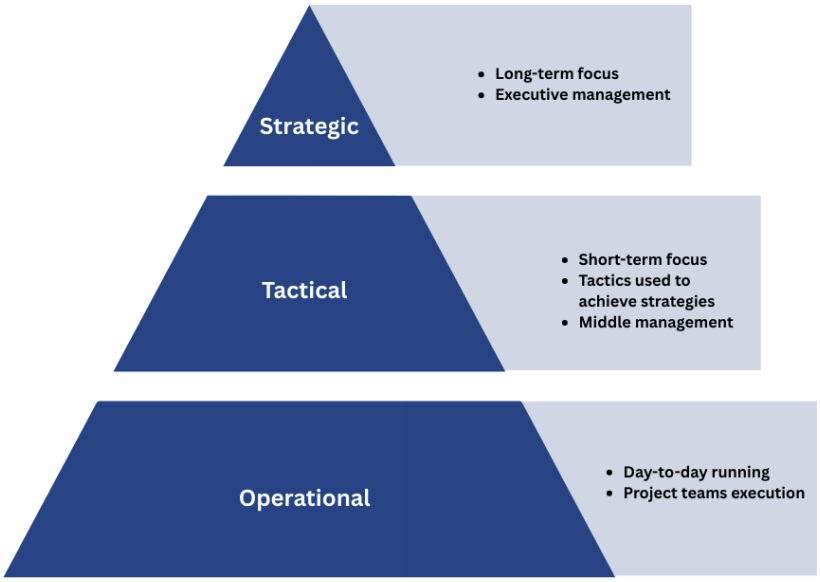

Figure 5.14: The three organizational levels (author)

The variance in viewpoints across organizational levels becomes evident in empirical research, where practitioners at different levels within an organization offer distinct perspectives on the same subject. This discrepancy can be attributed to the varying decision-making responsibilities, strategic, tactical and operational, inherent in their daily roles.

Weldy & Gills (2010) explored the diverse viewpoints at different organizational levels during change implementation. The study investigated the viewpoints of managers who primarily tasked with strategic decisions, supervisors overseeing tactical decisions, and employees responsible for operational decisions. Findings revealed that managers exhibited the highest perception in overall satisfaction during the introduction of new ideas, followed by supervisors and employees. This hierarchy of perception was attributed to the relatively limited

information and awareness regarding changes by lower-level employees, primarily due to their focus on operational aspects relevant to their roles. Managers, overseeing the strategic landscape, have a broader perspective. This information gap is often a result of limited information access and decision-making authority for lower-level employees, as well as inadequate communication systems connecting different organizational levels. It highlights the necessity for enhanced communication between managers and subordinates to encourage greater participation across organizational levels and mitigate the disparities in perspectives among business levels.

This section presented scientific findings and explained the varying perceptions observed across organizational levels, which sheds light on the variations of perspectives observed in the empirical research. It clarifies that beyond the influence of distinct roles on viewpoints, organizational levels themselves play a significant role in shaping perspectives. Understanding these dynamics is pivotal for designing a framework that effectively incorporates input from practitioners at various levels. Consequently, the guidelines within the framework should be structured to cater to the strategic, tactical, and operational dimensions, ensuring comprehensive coverage and alignment with the diverse viewpoints present in different organizational strata.

5.6. Conclusion

Building upon these conceptual foundations, the chapter synthesized opportunity management methodologies, such as RISMAN, and sustainability management frameworks, such as Sus5 model and Perrott's strategic sustainability management process. The use of such dual research method is because of the lack of academic articles that simultaneously address both dimensions. The literature review further explored documented enablers and barriers to sustainability opportunities actualization, creating a foundation for comparative analysis with empirical findings in Chapter 6.

The latter part of the theoretical research focused on key themes derived from the empirical findings, notably knowledge management and change management practices. These practices emerged prominently in interviews and are thoroughly investigated in this chapter to inform the framework development based on existing literature. This exploration informs the structuring of the framework and guidelines to accommodate these disparities in organizational user levels effectively.

6

6. DATA SYNTHESIS

In this chapter, data synthesis will be done to collectively examine the key findings from both empirical research and theoretical research. The findings from empirical and theoretical research will be compared, analyzed, and combined. The section will synthesize the findings in four selected themes.

6.1. Empirical and Theoretical Understanding of Sustainability

One of the primary barriers identified in the empirical research is the ambiguous definition of sustainability. This section will first synthesize the different interpretations of sustainability from empirical data and academic articles. Subsequently, this section explores how such different interpretations influence the actualization of sustainability opportunities.

In the interview process, participants were asked to provide their definitions of sustainability. The responses are analyzed and sorted into 17 distinct topics. These topics are created based on how participants described sustainability. The distribution of these coded responses is illustrated in Figure 6.1.

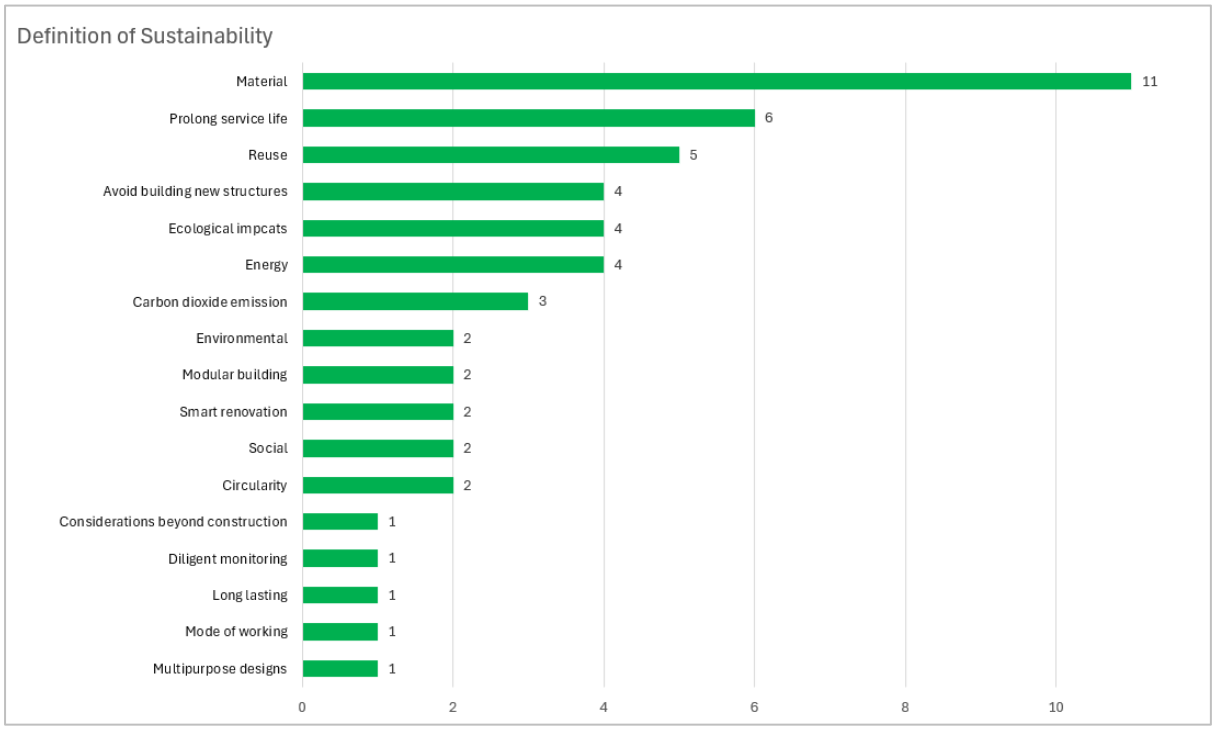

Figure 6.1: Code distribution of definition of sustainability (author)

When comparing the outcomes of empirical research with the theoretical understanding of sustainability, both sets of findings align in recognizing the broad scope of sustainability. It is apparent that each individual, whether a practitioner or a scholar, interprets sustainability in their unique way.

Nevertheless, the empirical data highlights a notable lack of comprehensive understanding of sustainability among construction industry practitioners. While academia commonly acknowledges a broad definition of sustainability, which typically encompass environmental, social, and governance aspects, the interview data revealed a significant contrast, indicating that practitioners tend to hold a more limited perspective on sustainability. Over 92% of responses centered on environmental aspects, with only about 6% touching on social aspect and 2% mentioning the domain of governance. Within the environmental realm, almost half of responses concentrated on material-related topics. This shows the limited and imbalanced viewpoints held by practitioners in contrast to the academic perspectives on sustainability. Particularly, the triple bottom line approach from academia underscores the equal importance of all sustainability dimensions, a principle not consistently reflected in practical applications. While academia allows for diverse interpretations of sustainability, it uniformly recognizes sustainability as multidimensional, with each dimension having equal emphasis.

Project manager [PM.CEF_2] and sustainability advisor [SA.CEF] have observed this disparity from their daily work, noting a prevalent misunderstanding of sustainability within the industry, where individuals often limit their perception of sustainability to only carbon emission. These observations are mirrored in the empirical data. In practice, sustainability advisor [SA.CEF] and technical advisor [TA.C_2] encounter challenges due to varying interpretations, as individuals tend to focus on select aspects of sustainability while overlooking others. This potentially leads to claims of sustainability without a comprehensive consideration of its complete definition.

Addressing and emphasizing this issue within the framework is crucial for enhancing the understanding of sustainability itself, a pivotal step towards actualizing sustainable practices effectively.

6.2. Sustainability Opportunities Nature in Theory versus Practice

Understanding the nature of sustainability opportunities is crucial as it influences the approach to enhancing the management of such opportunities. According to the literature review in Chapter 5, in academic contexts, opportunities represent favorable conditions that positively impact project objectives and fall under the umbrella of risk. This academic definition partially aligns with practical perspectives on sustainability opportunities.

Based on empirical research outcomes showcased in Chapter 4, 56% of participants perceive sustainability opportunities as a combination of chances and decisions. Here, chances refer to project conditions, while decisions are recognized as another key element in realizing sustainability opportunities, a factor not explicitly highlighted in academic opportunity definitions. This underscores the significance of decision-making in relation to opportunities, with 44% of respondents indicating that the actualization of sustainability opportunities primarily depends on decisions undertaken by the project team.

These findings underline the necessity for the development of the framework to consider not just the conditions but also the factors and individuals involved in the decision-making process.

6.3. Synthesizing Barriers and Enablers in Sustainability Actualization

Research on the barriers and enablers influencing the actualization of sustainability opportunities in infrastructure projects has been done empirically and theoretically. This section aims to have an overview of the factors surrounding actualizing sustainability from both empirical and theoretical research.

Through the analysis of existing literature and empirical investigations, it is apparent that the landscape of barriers and enablers to realizing sustainability opportunities is vast and complex, encompassing a multitude of factors. Given the depth of this domain, it is unfeasible for this research to address and incorporate every single aspect. Therefore, Table 6.1 and Table 6.2 provide a summary of the most relevant barriers and enablers selected in the empirical and theoretical findings, offering a comprehensive outlook on the key factors influencing the actualization of sustainability opportunities.

Furthermore, it has been substantiated through interviews and literature reviews that the varied perspectives on barriers and enablers are related to the specific roles individuals play, the levels within organizations, and the diverse geographical contexts. This understanding offers valuable insights into the tailored enhancement and mitigation measures required for each distinct barrier and enabler, taking into account the dynamics of roles, organization levels, and regional considerations.

Table 6.1: Overview of barriers to sustainability opportunities (author)

Barriers	Empirical Research	Theoretical Research
Budget constraints	✓	
Mindset of people	✓	✓
Ambiguous definition	✓	✓
Uncertainties	✓	
Knowledge	✓	✓
Laws and regulations	✓	
Technical conflict	✓	✓
Time constraints	✓	
Misconception on cost of sustainability	✓	✓
Predetermined project scope	✓	
Late consideration of sustainability	✓	✓
Conflicting project demands	✓	
Long span of projects	✓	
Maintenance	✓	
Separate budget for construction and maintenance	✓	✓
Ineffectiveness of reporting tools		✓
Lack of experts and trainings		✓
Lack of government support		✓

Table 6.2: Overview of enablers to sustainability opportunities (author)

Enablers	Empirical Research	Theoretical Research
Knowledge management	✓	✓
Change management	✓	✓
Early advice on sustainability	✓	
Early decision	✓	
Mindset	✓	✓
Clear sustainability objectives	✓	✓
Support by decision makers/ managements	✓	✓
Financial support	✓	✓
Stakeholder management	✓	✓
Ability to show the benefits	✓	
Research and pilot projects	✓	
Certifications and labels	✓	
Communication	✓	
External challenger	✓	
Increase importance of sustainability	✓	
Involvement of all diciplines	✓	
Lifecycle cost	✓	
No fallback scenarios	✓	
Public demand		✓
Professional trainings		✓
Flexible project procedures		✓
Inclusion of sustainability as criteria		✓

The key barriers and enablers identified through the synthesized data will be taken into account in shaping the framework discussed in Chapter 7.

6.4. Synthesizing Management of Sustainability Opportunities

The exploration of managing sustainability opportunities has been conducted by examining existing practices from interviews and recommended methodologies outlined in literature. Figure 6.2 illustrates an ideal step-by-step process of management of sustainability opportunities. The illustration stems from existing practices from practitioners, risk management frameworks from academia, and management of opportunities guidelines from academia. It integrates insights from experiences from practitioners with process frameworks derived from academic research.

This integrated approach commences with the planning phase, where the project team is tasked with understanding the sustainability ambitions of the clients and subsequently translating these ambitions into well-defined project objectives. The planning phase should happen as early as possible in the project lifespan. Establishing a strong sustainability foundation during the planning phase paves the way for progress into the opportunity development phase. Within the opportunity development phase, the process starts with sustainability advisory, followed by the identification of sustainability ideas, concluding in the evaluation of these ideas based on criteria such as cost-effectiveness, benefits, technology readiness level and feasibility. This is the phase where sustainability ideas are generated and

analyzed based on the sustainability project objectives. Following the assessment of sustainability ideas, the project team presents the ideas to the client and collectively decide on which sustainability ideas to actualize within the project. Upon reaching a consensus on the chosen sustainability ideas, the team can proceed to implement the identified sustainability opportunities into the project.

Throughout this process, it is also important to conduct regular reviews of sustainability progress to ensure alignment with the established objectives, a process also facilitated by healthy communication and consultations within the project team and with the clients.

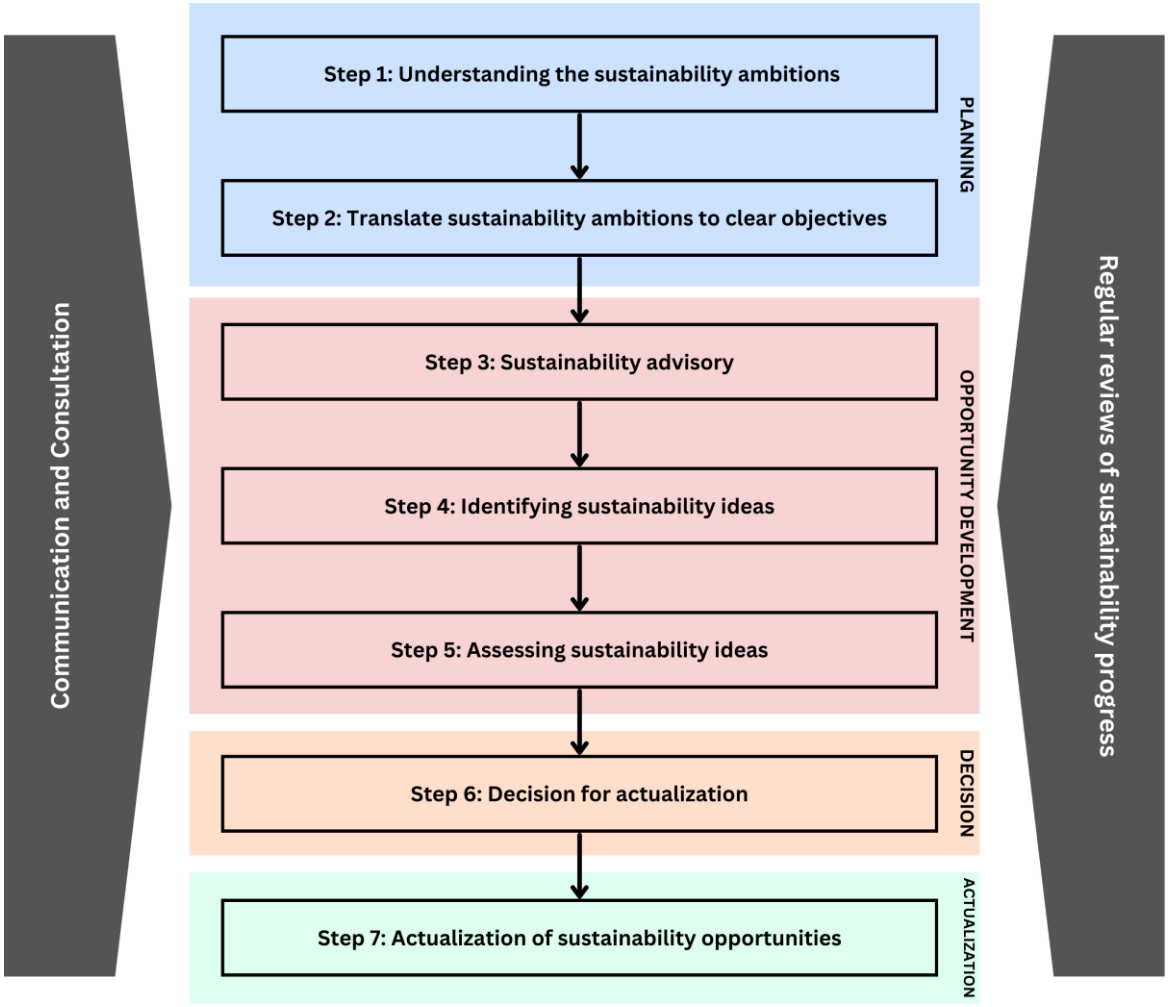

Figure 6.2: Synthesized process of management of sustainability opportunities (author)

It is important to note that the steps outlined above represent recommended guidelines for projects to follow. However, given the dynamic and unique nature of individual projects, some steps may overlap across different phases, and their sequence may vary.

This process illustration acts as a key input for the development of the framework in the subsequent chapter. A detailed explanation of the actions associated with each phase will be provided in the framework presented in Chapter 7.

6.5. Conclusion

This section has synthesized key insights from empirical research and theoretical literature. The analysis reveals several important findings that highlight both convergences and divergences between academic perspectives and practical implementations.

The definition of sustainability demonstrates significant complexity. While academic literatures show definition variations across different authors, they tend to include similar elements in the definition but with different categorization approaches. However, there is less alignment among practitioners on the definition of sustainability. This is mainly because practitioners interpret the concept of sustainability through the lens of their specific roles and responsibility. This misalignment suggests a need to in line the definition of sustainability.

The examination of the nature of sustainability opportunities reveals another important divergence. Academic research typically presents sustainability opportunities as favorable conditions. In contrast, practitioners view sustainability opportunities as both conditions and active decision-making processes by decision-makers or management. This distinction between theoretical perspective and operational reality represents a critical gap in current sustainability domain.

The identified barriers and enablers derived from both empirical research and literature are synthesized in a summary table. The comparative table reveals partial alignment among findings, with some difference attributed to regional variations in the studies and different organizational-level perspectives represented across sources. These differences underscore the contextual nature of the subject.

Finally, the research has created an integrated process framework for managing sustainability opportunities. This model combines elements from risk management frameworks, opportunity management methodologies, and current practical practices in the field.

These findings collectively inform the development of the framework presented in the following chapter, which aims to improve the actualization of sustainability opportunities through better management.

7

7. FRAMEWORK AND GUIDELINES DESIGN

This chapter presents the development of a framework with guidelines to improve the actualization of sustainability ambitions and ideas in infrastructure projects, which addresses research sub-question 3. The framework integrates three main knowledge sources, the empirical findings from Chapter 4, the theoretical findings from Chapter 5, and the data synthesis outcomes from Chapter 6.

As outlined in the methodology in Chapter 2, the framework and guidelines development process are structured into two phases, namely the preliminary design phase and the detailed design phase. This chapter focuses exclusively on the preliminary design, establishing the conceptual foundation that will undergo validation in Chapter 8. The final detailed framework and guidelines will be presented in Chapter 8. This two-phase approach ensures both theoretical robustness and practical applicability of the final framework.

7.1. Framework

The adoption of a framework-based approach is justified by its ability to provide a systematic and structured methodology for addressing the actualization of sustainability opportunities. By outlining clear and actionable steps, the framework serves as a practical guide for both researchers and practitioners seeking to enhance management processes of sustainability opportunities. Additionally, it efficiently synthesizes theoretical insights and empirical evidence into an accessible model, facilitating comprehension and implementation. This structured representation not only enhances usability but also ensures that best practices can be effectively translated into organizational actions, thereby bridging the gap between theory and practical execution.

The framework is developed through an integrative process combining the findings from the empirical research, the theoretical research, and data synthesis. This section presents the framework development process and the proposed conceptual framework in detail. The framework development follows a three steps approach,

i. Initial organization of key research findings
ii. Translation of findings into action items
iii. Structuring action items into a conceptual framework

This structured methodology ensures that each component in the framework remains grounded in both empirical evidence and theoretical foundations while being traceable.

7.1.1. Initial Organization of Key Research Findings

The framework development process begins with the organization of key research findings. These findings are categorized according to three organizational levels, namely strategic, tactical, and operational, to ensure comprehensive coverage of perspectives. The categorization of the key findings is presented in Table 7.1, which serves as the foundation for subsequent framework development stages.

Table 7.1: Categorized key findings (author)

Organizational Levels	Key Research Findings
Strategic Level	• **Barriers: Knowledge** *(5)* • **Enablers: Knowledge management** *(21)* • **Enablers: Change management** *(11)* • **Enablers: Mindset** *(8)* • **Enablers: Clear sustainability objectives** *(6)* • **Enablers: Support by decision makers/ managements** *(6)* • **Enablers: Financial support** *(4)* • **Enablers: Research and pilot projects** *(2)* • **Enablers: Increase importance of sustainability** *(1)* • **Enablers: No fallback scenarios** *(1)* • **Enablers: Inclusion of sustainability as criteria** *(0)*
Tactical Level	• **Barriers: Mindset of people** *(9)* • **Barriers: Knowledge** *(8)* • **Barriers Misconception of cost of sustainability** *(2)* • **Barriers: Ineffectiveness of reporting tools** *(0)* • **Barriers: Lack of experts and trainings** *(0)* • **Enablers: Knowledge management** *(21)* • **Enablers: Change management** *(11)* • **Enablers: Mindset** *(8)* • **Enablers: Clear sustainability objectives** *(6)* • **Enablers: Stakeholder management** *(3)* • **Enablers: Research and pilot projects** *(2)* • **Enablers: Communication** *(1)* • **Enablers: Involvement of all disciplines** *(1)* • **Enablers: Professional trainings** *(0)* • **Enablers: Flexible project procedures** *(0)* • **Enablers: Inclusion of sustainability as criteria** *(0)*
Operational Level	• **Barriers: Budget constraints** *(9)* • **Barriers: Mindset of people** *(9)* • **Barriers: Ambiguous definitions** *(8)* • **Barriers: Uncertainties** *(8)* • **Barriers: Knowledge** *(5)* • **Barriers: Technical conflict** *(4)* • **Barriers: Time constraints** *(4)* • **Barriers Misconception of cost of sustainability** *(2)* • **Barriers: Predetermined project scope** *(2)* • **Barriers: Late consideration of sustainability** *(2)* • **Barriers: Long span of projects** *(1)* • **Barriers: Ineffectiveness of reporting tools** *(0)* • **Barriers: Lack of experts and trainings** *(0)* • **Enablers: Knowledge management** *(21)* • **Enablers: Change management** *(11)* • **Enablers: Early advice on sustainability** *(10)* • **Enablers: Early decision** *(8)* • **Enablers: Mindset** *(8)* • **Enablers: Clear sustainability objectives** *(6)* • **Enablers: Ability to show the benefits** *(2)* • **Enablers: Certifications and labels** *(1)* • **Enablers: Communication** *(1)* • **Enablers: External challenger** *(1)* • **Enablers: Lifecycle cost** *(1)* • **Enablers: Professional trainings** *(0)* • **Enablers: Flexible project procedures** *(0)*

*Numerical annotations reflect their frequency of mention during empirical interviews

This hierarchical classification stems from both empirical observations and theoretical validation, which revealed distinct perspective differences among stakeholders corresponding to their decision-making responsibilities. This grouping method ensures the development of targeted solutions appropriately tailored to each organizational level based on their specific needs and decision contexts.

As presented in Table 7.1, the key findings are categorized according to the three organizational levels from the perspective of consultancy engineering firms. This firm-centric classification reflects the focus on developing action items for such organizations. While most findings align clearly with one or more of these hierarchical levels, some identified findings, particularly external factors beyond the direct control of consultancy firms, were intentionally excluded from the table. This selective approach ensures the framework remains focused on addressable and consultancy engineering firm focused factors while acknowledging the existence of broader contextual influences that may require other considerations.

Additionally, the numerical annotations accompanying the barriers and enablers reflect their frequency of mention during the empirical interview phase. Items with the number zero represent those identified through literature review but not being mentioned in interviews by industry practitioners. As established in Chapter 4, these citation frequencies serve as indicators of prevalence among practitioners rather than measures of absolute importance, with responses influenced by the professional roles and hierarchal level of individuals being interviewed.

The development of the framework prioritizes empirically derived barriers and enablers. This is because existing literatures have demonstrated the significant regional variations in the actualization of sustainability opportunities due to differing industrial contexts, regulations, and political landscape (Ahmed et al., 2023). Given the Netherlands specific focus of this research, the empirical findings from local practitioners provide the most relevant knowledge for the framework development, ensuring contextual applications for the target implementation.

7.1.2. Translation of Findings into Action Items

The hierarchical organization of key findings by organizational level enables the development of targeted action items to enhance sustainability actualization at each level. Drawing upon the categorized findings, the proposed action items are designed to leverage and optimize enablers, address and mitigate barriers, as well as taking into account for the current landscape and nature of sustainability opportunities.

The action items are systematically designed around six core thematic areas, each carefully developed in response to the key enablers and barriers identified through empirical and theoretical research. These topics serve as pillars to facilitate both social and technical transitions within organizations, addressing the multidimensional challenges of sustainability opportunities actualization. Figure 7.1 illustrates the six pillars.

The six core topics target two critical dimensions of organizational change for sustainability,

i. Social Transition: Fostering mindset shifts, knowledge-sharing, and collaborative practices to embed sustainability into workplace culture and decision-making.
ii. Technical Transition: Providing practical tools, knowledge, metrics, and processes to actualize sustainability in project delivery.

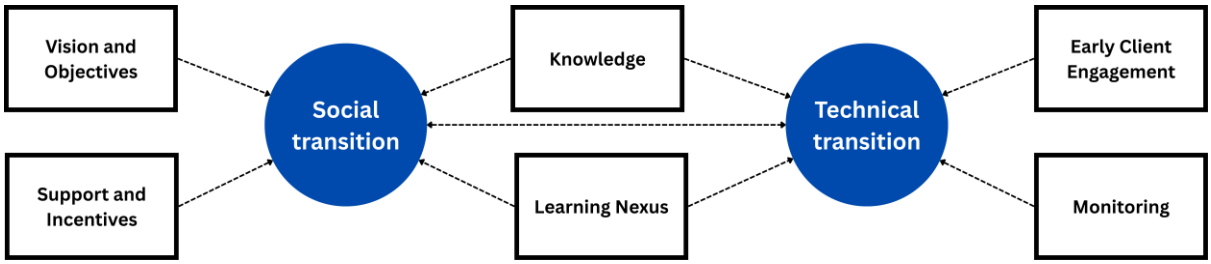

Figure 7.1: The six pillars for action items (author)

With these six pillars clearly defined surrounding social transition and technical transition within organizations for actualizing sustainability in projects, action items are designed for each pillar to facilitate the transition. The proposed action items are presented in Figure 7.2.

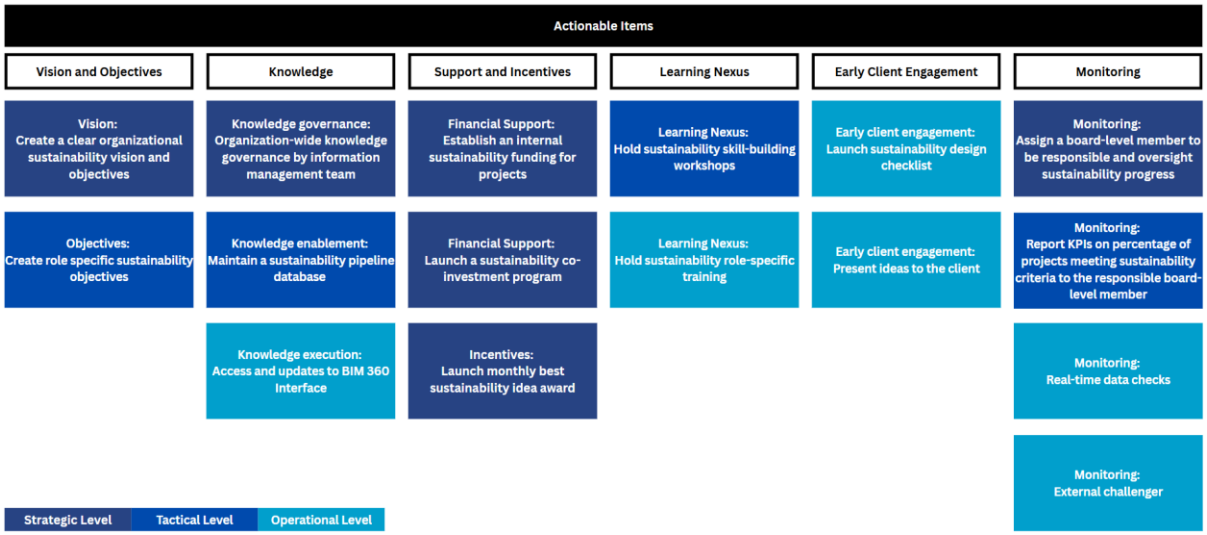

Figure 7.2: Overview of conceptual action items (author)

Table 7.2 and Table 7.3 give an overview of the proposed action items that are designed based on the key research findings. These items were designed through a balanced approach that considers both practical implementation feasibility and key findings, ensuring meaningful sustainability integration while avoiding organizational disruption. The action items are designed based on the organizational structure where strategic level items establish organizational direction on sustainability priorities, tactical level items bridge strategy and execution by translating objectives into operational support mechanisms, and operational level items directly enhance the actualization of sustainability opportunities in daily workflows on project level.

Table 7.2: Proposed action items for strategic and tactical levels (author)

Organizational Levels	Proposed Actionable Items**	Corresponding Key Research Findings
Strategic Level	Create a clear organizational sustainability vision and objectives	• Enablers: Change management *(11)* • Enablers: Mindset *(8)* • Enablers: Clear sustainability objectives *(6)* • Enablers: Support by decision maker/ managements *(6)* • Enablers: Increase importance of sustainability *(1)* • Enablers: Inclusion of sustainability as criteria *(0)*
	Assign a board-level member to be responsible and oversight sustainability progress	• Enablers: Support by decision makers/ managements *(6)* • Enablers: Increase importance of sustainability *(1)* • Enablers: Inclusion of sustainability as criteria *(0)*
	Organizational-wide knowledge governance by information management team	• Barriers: Knowledge *(5)* • Enablers: Knowledge management *(21)* • Enablers: Support by decision makers/ managements *(6)*
	Establish an internal sustainability funding for projects	• Enablers: Support by decision makers/ managements *(6)* • Enablers: Financial support *(4)* • Enablers: Research and pilot projects *(2)*
	Launch a sustainability co-investment program	• Enablers: Support by decision makers/ managements *(6)* • Enablers: Financial support *(4)* • Enablers: Research and pilot projects *(2)*
	Launch monthly best sustainability idea award	• Barriers: Mindset of people *(9)* • Barriers: Knowledge *(5)* • Enablers: Knowledge management *(21)* • Enablers: Mindset *(8)*
Tactical Level	Hold sustainability skill-building workshops	• Barriers: Mindset of people *(9)* • Barriers: Knowledge *(8)* • Barriers: Lack of experts and trainings *(0)* • Enablers: Mindset *(8)* • Enablers: Professional trainings *(0)*
	Create clear role specific sustainability objectives	• Enablers: Change management *(11)* • Enablers: Mindset *(8)* • Enablers: Clear sustainability objectives *(6)* • Enablers: Increase importance of sustainability *(1)* • Enablers: Inclusion of sustainability as criteria *(0)*
	Report KPIs on percentage of projects meeting sustainability criteria to the responsible board-level member	• Barriers: Mindset of people *(9)* • Barriers: Knowledge *(8)* • Barriers: Ineffectiveness of reporting tools *(0)* • Enablers: Change management *(11)* • Enablers: Stakeholder management *(3)* • Enablers: Communication *(1)* • Enablers: Inclusion of sustainability as criteria *(0)*
	Maintain a sustainability pipeline data base	• Barriers: Knowledge *(8)* • Barriers: Misconception of cost of sustainability *(2)* • Enablers: Knowledge management *(21)* • Enablers: Involvement of all disciplines *(1)*

*Numerical annotations reflect their frequency of mention during empirical interviews

**The action items presented in this table follow a logical demonstration sequence rather than representing a hierarchy of importance or priority.

Table 7.3: Proposed action items for operational level (author)

Organizational Levels	Proposed Actionable Items**	Corresponding Key Research Findings
Operational Level	Hold sustainability role-specific training	• Barriers: Mindset of people *(9)* • Barriers: Ambiguous definitions *(8)* • Barriers: Knowledge *(5)* • Barriers: Lack of experts and trainings *(0)* • Enablers: Change management *(11)* • Enablers: Mindset *(8)* • Enablers: Professional trainings *(0)*
	Access and updates to BIM 360 interface	• Barriers: Budget constraints *(9)* • Barriers: Uncertainties ***(8)*** • Barriers: Knowledge *(5)* • Barriers: Technical conflict *(4)* • Barriers: Time constraints *(4)* • Barriers Misconception of cost of sustainability *(2)* • Barriers: Late consideration of sustainability *(2)* • Enablers: Knowledge management *(21)* • Enablers: Change management *(11)* • Enablers: Early advice on sustainability *(10)* • Enablers: Mindset *(8)* • Enablers: Ability to show the benefits *(2)* • Enablers: Lifecycle cost *(1)*
	Launch Sustainability design checklist	• Barriers: Mindset of people *(9)* • Barriers: Ambiguous definitions *(8)* • Barriers: Predetermined project scope *(2)* • Barriers: Late consideration of sustainability *(2)* • Enablers: Change management *(11)* • Enablers: Early advice on sustainability *(10)* • Enablers: Mindset *(8)* • Enablers: Clear sustainability objectives *(6)* • Enablers: Communication *(1)*
	Present ideas to the client	• Barriers: Mindset of people *(9)* • Barriers: Knowledge *(5)* • Barriers Misconception of cost of sustainability *(2)* • Barriers: Late consideration of sustainability *(2)* • Enablers: Early decision *(8)* • Enablers: Mindset *(8)* • Enablers: Ability to show the benefits *(2)* • Enablers: Communication *(1)*
	Early involvement of sustainability specialists in the project team	• Barriers: Mindset of people *(9)* • Barriers: Ambiguous definitions *(8)* • Barriers: Knowledge *(5)* • Barriers: Technical conflict *(4)* • Barriers: Late consideration of sustainability *(2)* • Barriers: Lack of experts and trainings *(0)* • Enablers: Early advice on sustainability *(10)* • Enablers: Early decision *(8)* • Enablers: Mindset *(8)* • Enablers: Clear sustainability objectives *(6)* • Enablers: Communication *(1)*
	Real-time data checks	• Barriers: Knowledge *(5)* • Barriers: Long span of projects *(1)* • Barriers: Ineffectiveness of reporting tools *(0)* • Enablers: Knowledge management *(21)* • Enablers: Ability to show the benefits *(2)* • Enablers: Communication *(1)*
	External challenger	• Barriers: Mindset of people *(9)* • Enablers: Change management *(11)* • Enablers: Mindset *(8)* • Enablers: Communication *(1)* • Enablers: External challenger *(1)*

*Numerical annotations reflect their frequency of mention during empirical interviews
**The action items presented in this table follow a logical demonstration sequence rather than representing a hierarchy of importance or priority.

The framework emphasizes both vertical alignment and horizontal consistency. A representative example of vertical integration appears in knowledge management, beginning with strategic establishment of an information management team for organizational-wide knowledge governance, extending through tactical development and maintenance of a sustainability pipeline database, and leading to the operational implementation through BIM 360 interfaces. Horizontal consistency is achieved through complementary items at each level. For instance, at the strategic level where establishing sustainability vision and objectives is reinforced by assigning a board-level member to oversight responsibility, ensuring the sustainability vision and objectives are not merely decorative vases.

While the framework tries to include a substantial body of empirical and theoretical findings, it intentionally prioritizes the most important and actionable findings to maintain focus and scope. This selective approach is necessary because of the extensive research data collected in this study. This approach creates a focused foundation for sustainability actualization, with opportunities for future expansion to incorporate the findings that has not been incorporated yet. The prioritized action items listed in Table 7.2 and Table 7.3 will subsequently form the core of the framework.

7.1.3. Structuring Action Items into a Conceptual Framework

The conceptual Sustainability Human-Centered Implementation Framework for Transition (c-SHIFT) for consultancy engineering firms is developed integrating action items designed in the previous section into a multi-level cohesive structure. This framework organizes the proposed action items into three dimensions, namely organizational levels, phases of managing sustainability opportunities, and project timeline.

The vertical axis of the proposed framework categorizes action items hierarchically according to three organizational levels. As depicted in Figure 7.3, this division comprises strategic, tactical, and operational tiers. The framework assigns action items to their respective organizational levels according to the detail mappings provided in Table 7.2 and Table 7.3. This division in the vertical axis ensures users from different levels in the organization can take corresponding actions.

Figure 7.3: Vertical axis of c-SHIFT (author)

The framework is designed to ensure strong vertical linkages across the three organizational levels, creating a cohesive system where strategic, tactical, and operational action items mutually support and reinforce one another. The strategic level action items provide guiding principles for tactical planning, tactical level action items translate strategic objectives into actionable plans, and operational level executes concrete outcomes that feed back into strategic evaluation.

The framework incorporates dual horizontal axes of parallel significance to guide and visual sustainability integration. The first axis, the management of sustainability opportunities phases, represents the sequential phases from the synthesized methodology in Figure 6.2. The horizontal axis is visually illustrated in Figure 7.4. This axis enables mapping of action items to their most relevant implementation phases, ensuring the methodological coherence.

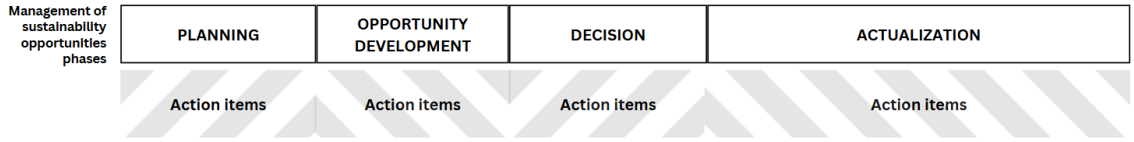

Figure 7.4: Horizontal axis 1 of c-SHIFT (author)

The second axis, the project timeline, aligns the proposed action items with typical project stages. It indicates when each action is relevant and recommended to be initiated or prioritized within a project, as visually illustrated in Figure 7.5. This project timeline is determined by considering the different stages within the FED phase in a typical infrastructure project.

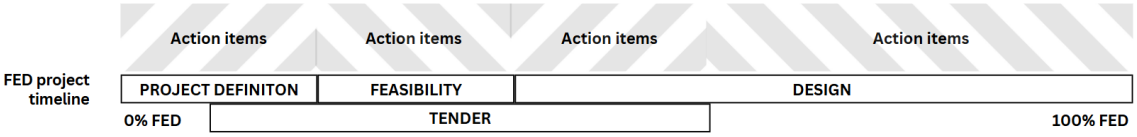

Figure 7.5: Horizontal axis 2 of c-SHIFT (author)

The FED project timeline commences with the project definition phase, wherein clients work out the core scope, ambitions, and objectives of the project, and the consultancy engineering firms analyze the scope requirements. In some projects, consultancy engineering firms may be early involved in assisting the client to define the scope. Progressing to the feasibility phase, where conceptual alternatives undergo feasibility assessment. This feasibility assessment usually involves technical and financial assessments. Advancing through the design phase, encompassing design development from conceptual design to detailed design specifications. The tender phase, representing procurement processes for consultancy services, may happen at different timeframe depending on project-specific characteristics and client preferences, as illustrated in Figure 7.5. While the framework adopts a generalized timeline to standardize action item mapping, it acknowledges the variations of timeline in different projects. Despite the scheduling differences, the action items remain applicable.

Together, these axes create an integrated framework that clarifies not only which actions to prioritize but also when it is relevant within a project progression. Figure 7.6 visualizes the conceptual Sustainability Human-Centered Implementation Framework for Transition (c-SHIFT). While most action items are self-explanatory in Figure 7.6, their practical application will be elaborated in greater detail in the next section.

This multidimensional structuring of the c-SHIFT enables stakeholders to contextualize recommendations within both hierarchical decision-making structures and project workflows. Figure 7.6 not only visualizes the interplay between organizational roles, management phases, and timing factors but also serves as a tool for translating theoretical and empirical findings into actionable sustainability practices.

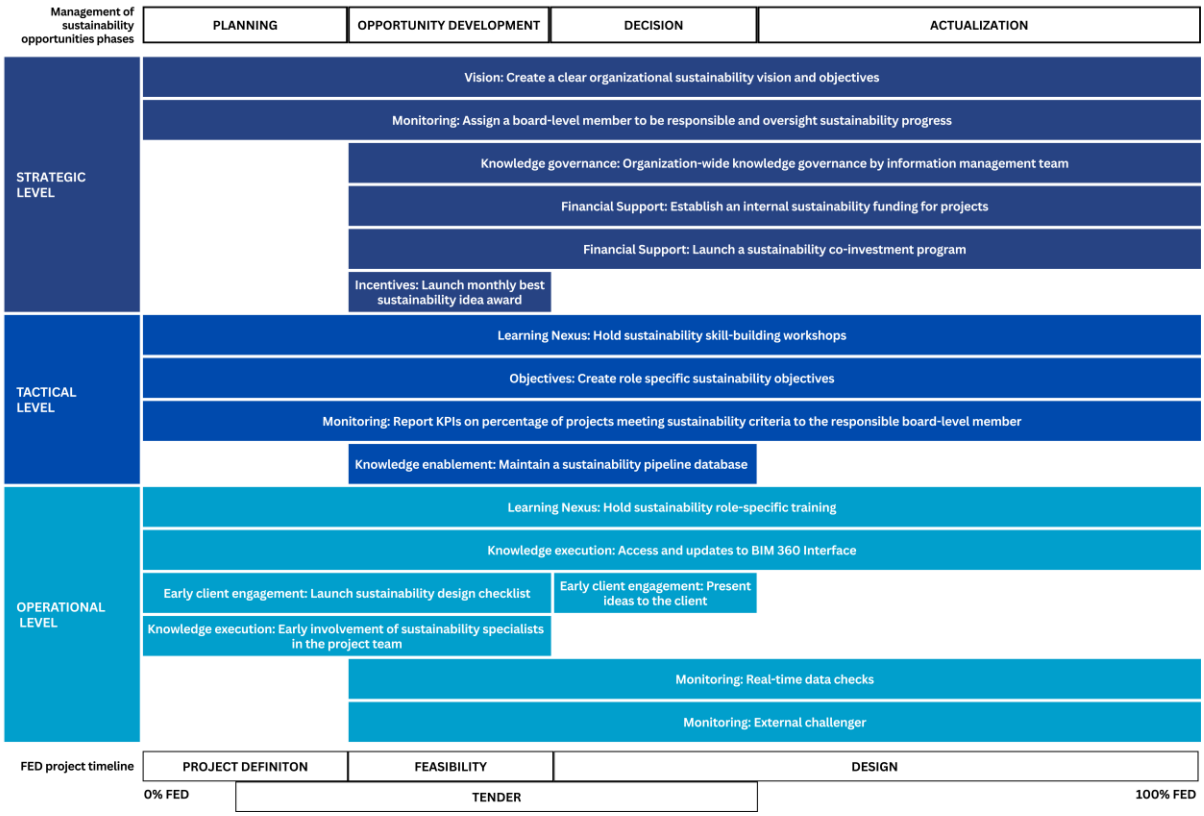

Figure 7.6: Conceptual Sustainability Human-Centered Implementation Framework for Transition, c-SHIFT (author)

7.2. Guidelines

This section provides a detailed breakdown of each proposed action item across strategic, tactical, and operational levels. Drawing upon the foundation of empirical research findings, theoretical findings, and data synthesis, this section presents a structured set of implementation guidelines accompanied by their theoretical and practical rationales. The development of these guidelines follows the methodology of integrating qualitative insights from previous chapters the ensure both academic and practical relevance.

The conceptual guidelines presented in this section represents the first phase of the guidelines development process. While these guidelines have been carefully designed based on extensive field research and literature review, they remain subject to empirical validation. Chapter 8 will detail the validation process using validation focus group methodology. Therefore, the validated and improved guidelines can be found in Chapter 8.

Appendix C outlines the action items along with corresponding implementation guidelines and their underlying motivations. The guidelines serve as actionable explanations, suggesting concrete steps to effectively realize the proposed items. Organizations may need to adjust or even expand the tasks in the guideline based on context. Meanwhile, the motivation for each action item clarifies its purpose and anticipated benefits, ensuring stakeholders understand not just what to implement but why it matters. These three tables collectively act as a structured yet flexible actionable guidelines that combines practitioner efforts and theoretical investigations.

7.3. Conclusion

Building upon the empirical evidence and theoretical insights in this study, a conceptual framework has been constructed. The framework systematically integrates 15 distinct action items, each conceptually grounded in one of six identified foundational pillars that emerged from the research synthesis. Together, these action items form the conceptual Sustainability Human-Centered Implementation Framework for Transition (c-SHIFT), which is structured across,

- Three organizational levels (strategic, tactical, operational)
- Key phases of management of sustainability opportunities
- A typical infrastructure project FED timeline

By synthesizing theory and practice, the c-SHIFT provides scalable and actionable guidance for consultancy engineering firms to translate sustainability ambitions and ideas into outcomes. Its flexible structure allows for contextual adaptation while maintaining alignment with sustainability principles.

8

8. VALIDATION

This chapter validates the conceptual Sustainability Human-Centered Implementation Framework for Transition (c-SHIFT) and guidelines proposed in Chapter 7, ensuring their robustness and practical applicability. Addressing research sub-question 3, the validation employs qualitative methods, focus group discussions with industry practitioners, to critically assess the relevance, robustness, and applicability of the framework. The chapter begins by detailing the methodology for data collection and analysis, followed by a presentation of key validation outcomes. By systematically evaluating the framework through expert feedback, this phase bridges theoretical development with actionable industry insights, reinforcing the contribution of the study.

8.1. Introduction to Validation

This validation process focuses on evaluating the relevance, robustness, and applicability of the proposed conceptual framework. By engaging with industry practitioners through validation focus groups, the validation process has three main objectives,

i. Validate the relevance of the conceptual framework and guidelines on improving sustainability actualization.
ii. Assess the implementation feasibility of the conceptual framework and guidelines.
iii. Refine and improve the framework and guidelines based on the collected feedback.

The validation process aims to assess and enhance the relevance, feasibility and effectiveness of the proposed conceptual framework and guidelines. The results from the validation not only refine the components of the proposed framework and guidelines but also strengthen its overall robustness and ensuring its alignment with practical implementation needs.

Focus group is selected as the validation methodology due to their demonstrated capacity in generating rich and interactive qualitative data effectively (Parker & Tritter, 2006). This approach aligns with the objectives of validating the framework through engagement with stakeholders (Breen, 2006). Unlike individual interviews, focus groups leverage group dynamics to stimulate critical debates, facilitate idea exchange, as well as encouraging commentary on experiences and points of views of other participants (Breen, 2006; Kitzinger, 1995). These characteristics are beneficial for the framework validation process as they enable triangulation of stakeholder viewpoints during discussions, thereby reducing individual bias and enhancing external validity (Onwuegbuzie et al., 2009). Furthermore, this approach mirrors the co-constructive nature of grounded theory approach by fostering collective industry stakeholder engagement. Consequently, this methodology ensures that the framework is not only theoretically sound but also applicable in real-world contexts.

8.2. Sampling Strategy

The selection of participants for the validation focus groups followed a purposive sampling strategy. This method involves the selection of participants based on predefined criteria aligned with the validation objectives (Tongco, 2007). This sampling approach ensures the inclusion of information-rich participants who are potential end-users of the framework, thereby enhancing the validity and applicability of the findings.

It enables the deliberate selection of individuals who are highly experienced in the industry and are potential framework users, ensuring both reliability and practical value of the validation process. Drawing from the suggestions on theoretical sampling by Corbin & Strauss (2014), the following criteria were applied for participant recruitment:

i. Practitioners who have been involved in infrastructure projects.
ii. Diversity in terms of role in infrastructure projects.
iii. Diversity in terms of organizational level.
iv. Practitioners with at least 5 years of experience in the construction industry.

Consistent with focus group methodology best practices, homogeneity within each group were maintained to foster productive dialogue, while heterogeneity across groups was ensured to mitigate biases (Breen, 2006). Specifically, each focus group comprise participants with similar organizational levels, but with different specializations to stimulate productive and multidisciplinary dialog. To align with the intended application of the framework, two distinct focus groups were structured, each targeting a specific stakeholder tier:

i. Strategic level focus group: Senior management and decision-makers
ii. Tactical and operational level focus group: Project managers, design leaders or technical managers

Participants for the two focus groups are chosen from the infrastructure and mobility business line of Witteveen+Bos, a Dutch consultancy engineering firm, as the framework is designed for the use of such organizations. This targeted sampling approach specifically addresses the validation objective of evaluating the practical relevance and implementation feasibility of the framework within consultancy engineering contexts. By limiting participation to professionals within this scope, the study maintains methodological consistency while capturing specialized insights from practitioners who would ultimately use the framework in real-world projects.

8.3. Focus Group Protocol

The focus group protocols are designed to ensure methodological rigor, maintain alignment with research objectives, and ensure consistency across all focus group sessions. Following established focus group research principles (Breen, 2006; Krueger & Casey, 2015), the protocol development incorporated best practices for structured yet flexible group discussions. A comprehensive outline of the protocol is provided in Appendix D.

Prior to each session, participants received standardized pre-session materials, including background information and session expectations, to ensure uniform baseline understanding among all participants (Breen, 2006; Krueger & Casey, 2015). This pre-session alignment helped optimize discussions and enhance data quality.

During the sessions, the researcher assumed the role of facilitator, guiding discussions according to a structured agenda with carefully formulated guiding questions. The protocol design is based on research sub-question 3 and the objectives of this chapter. Each 60-minute validation focus group session followed four distinct phases:

i. Introduction: Establishing context and ground rules
ii. Warm-up: Initiating participant engagement by trigger questions
iii. Core validation: Evaluation of the framework
iv. Closing: Synthesizing key insights and final reflections

The two validation focus groups follow an identical methodological structure but differ in their validation content. Validation Focus Group 1 consists of senior management and organizational decision-makers, representing the strategic level. Given their role in high-level decision-making, this group evaluates the strategic level action items in the conceptual framework, ensuring relevance and applicability to their context. As the primary end-users of these strategic action items, their validation is critical.

Validation Focus Group 2, consists of project managers, design leads, and technical managers responsible for tactical and operational execution. This group assesses the tactical and operational level action items, as their expertise lies in project oversight, mid-level decision-making, and day-to-day execution. Their feedback ensures that the proposed actions are feasible and effective in practical, on-the-ground applications.

While the primary objectives of the focus group sessions are centered on framework validation, the protocol intentionally allowed flexibility for discovering unanticipated perspectives, recognizing the value of new data. This balanced approach ensured both focused data collection for validation purposes and openness to novel insights that could enrich the development of the framework.

8.4. Ethical Considerations

In conducting focus groups for validation, emphasis has been placed on ethical considerations. The ethical considerations of these focus groups are anchored in principles of respect, confidentiality and informed consent. During focus group session introductions, participants were explicitly instructed to engage respectfully, withhold unnecessary judgment, and maintain openness to diverse viewpoints. It is a protocol designed to foster healthy dialogue, put participants at ease and minimize power imbalances (Breen, 2006; Kitzinger, 1995).

Prior to the commencement of the focus group sessions, informed consent is obtained from each participant, detailing the purpose of the research, the nature of their involvement, and the measures in place to protect their identities and information according to the data management plan in Appendix B. The privacy and autonomy of each participant are safeguarded, ensuring that their voluntary participation is based on comprehensive and conscious understanding of the research objective and focus group procedures. Confidentiality protocols are strictly adhered to, with anonymization practices employed during data transcription and analysis to ensure the anonymity of participants. This commitment to ethical standards underscores the foundation of trust and integrity upon which the research is conducted.

8.5. Data Collection Procedures

The focus group sessions are conducted in-person following the established sampling strategy, focus group protocol, and ethical guidelines. Participant selection is based on predefined criteria, with invitations distributed via email containing research objectives and focus group session details.

Upon the agreement to participate by industry practitioners, an informed consent document and a research background information summary are provided, detailing the data management procedures and the background of the research and the proposed framework. This data management plan, endorsed by the TU Delft Data Management Support Staff, governs the handling of data, including storage methods and measures for safeguarding sensitive information, as outlined in detail in Appendix B.

Before the focus group session commences, explicit permission is granted from each participant to record the session, utilizing a voice recorder and storing the recording securely on the TU Delft OneDrive platform. Subsequently, the session is transcribed, ensuring anonymization and inclusion of contextual comments for clarity. The anonymized transcript is shared with the participants for verification. Approved transcripts served as the primary data source for validating and refining the proposed framework and guidelines. Appendix B provides a comprehensive overview of data usage and storage protocols for reference.

8.6. Data Analysis

In this section, the data analysis process is detailed. The focus group sessions are analyzed through thematic analysis to systematically evaluate the relevance to improving sustainability actualization and practical feasibility of each proposed action item, aligning with the validation objectives outlines in Section 8.1. The approach enabled the identification of critical insights regarding each action items in the conceptual framework.

Following each validation focus group session, immediate transcription of the recording takes place. Upon completion, all personal details are filtered out. The anonymized transcripts are analyzed and coded through ATLAS.ti, leading to initial data insights. These codes are keywords from the session which are categorized into groups that correspond to the validation objectives and the components of the framework, thereby structuring the data effectively. These grouped insights from the codes shed light on the main discussion topics among participants within each component of the framework and the overall framework, subsequently shaping the direction for improvements of the proposed framework.

8.7. Overview of Validation Focus Groups

In Table 8.1, an overview of the conducted validation focus groups is presented. The table includes details such as the roles, main focus, experience, and the organization of the participants. Such information serves to showcase the connections between the backgrounds of the participants and their discussions in the focus groups. The selection process of the validation focus group was detailed in Section 8.2.

Table 8.1: Overview of Validation Focus Groups (author)

#	Group	Role	Main Focus	Professional Experience Duration (Years)	Organization	Abbreviation Reference
1	Focus Group 1 (Strategic)	Business Unit Manager	Design and engineering	27	Consultancy Engineering Firm	BUM.CEF_1
2		Business Unit Manager	Construction management	15	Consultancy Engineering Firm	BUM.CEF_2
3	Focus Group 2 (Tactical & Operational)	Business Unit Manager	Life cycle management	25	Consultancy Engineering Firm	BUM.CEF_3
4		Group Leader	Circular contracts and procurement	9	Consultancy Engineering Firm	GL.CEF_1
5		Group Leader	Design and engineering	20	Consultancy Engineering Firm	GL.CEF_2
6		Project Manager	Nature-propagating infrastructures	30	Consultancy Engineering Firm	PM.CEF_5

8.8. Validation Results

In the data analysis process, the collected data has been analyzed first through the lens of relevance and practical feasibility of each conceptual action items in the framework. This is derived from the objectives of the validation process. The analysis concludes with the validation on the completeness of the overall framework.

This section first delves into the relevance and practical feasibility of the noteworthy findings from the validation focus group sessions for each action items in the framework. Then the section delves into the overall completeness of the framework. In the following sections, in some instances, the role of the participants is mentioned along with quotes extracted from the focus groups to provide substantiation. A comprehensive overview of the participants can be referenced in Table 8.1 for a more detailed understanding of the context in which these findings have been derived.

8.8.1. Strategic Level

This section analyzes Validation Focus Group 1 results for strategic level action items, evaluating their relevance to improve the actualization of sustainability and implementation feasibility from an executive perspective.

Action item:

Vision: Crate a clear organizational sustainability vision and objectives

Relevance:

The action item, create a clear organizational sustainability vision and objectives, was validated as relevant for improving sustainability actualization in projects. A business unit manager from a consultancy engineering firm [BUM.CEF_2] emphasized its importance, stating,

> *'Having a clear sustainability vision and objectives is key. If sustainability is explicitly stated as a core objective, it gives us a tangible direction to work toward.'*

However, another business unit manager [BUM.CEF_1] contested this view, arguing that consultancy engineering firms operate within a constrained decision-making role,

> *'(As consultants) we advise, we don't make final decisions. Pushing too aggressively for sustainability by having a high organizational vision and objectives might overstate our role. We're just one of the players in a larger system, and we rely on clients to drive the agenda.'*

This reveals a critical limitation, while the action item is theoretically sound, its practical impact is limited by the role of consultancy engineering firms within projects. [BUM.CEF_2] remarked on this point that even within advisory constraints, creating a clear organizational vision ensures sustainability remains part of tradeoff discussions in projects, giving an example,

> *'For example, committing to always proposing at least one sustainable alternative, so we actively influence decisions.'*

The focus group discussion thus concluded that while this action item holds relevance, its effectiveness in improving sustainability actualization in infrastructure projects is contingent on how consultancies navigate their advisory role. Consequently, adjustments are needed to align the action item with the realities of consultancy influence. This consideration is further explored in the subsequent implementation feasibility analysis, which examines implementation strategies of this action item to maximize impact.

Implementation feasibility:
The focus group affirmed the feasibility of creating a clear organizational sustainability vision and objectives but critically examined implementation strategies tailored to the consultancy engineering context. [BUM.CEF_1] suggested a strategic leverage point, while direct project influence remains constrained by their advisory role, significant sustainability impact can be achieved through proactive project selection. This perspective was illustrated through a case example,

> *'We made an implicit tradeoff at the outset when selecting projects. We selected to do this project because of its high sustainability objectives.'*

This insight reveals that while the ability of consultancy engineering firms to influence sustainability outcomes within projects is limited by the advisory role, they can exercise significant impact through project selection. It is suggested that the created clear sustainability vision can extend beyond project application, it can translate into business decisions about which projects to undertake. Such strategic implementation allows consultancy engineering firms to maintain respect for client decision-making authority, work within their industry role, and still ensure organizational commitment to sustainability through selective engagement.

The discussion concluded that while the action item remains feasible, its potential depends on applying the sustainability vision and objectives at the project selection stage, where consultancy engineering firms retain full ability to shape their sustainability trajectory.

Action item:

Monitoring: Assign a board-level member to be responsible and oversight sustainability progress

Relevance:

The action item proposing to assign a board-level member to be responsible and oversight sustainability progress was validated as partially relevant for improving sustainability opportunity actualization in infrastructure projects. While assigning executive responsibility creates accountability, the focus group identified limitations in direct project influence at this organizational level. As business unit manager [BUM.CEF_2] noted, board-level members in a company typically do not intervene directly in projects. Project directors or tender board represent a more appropriate level for such oversight responsibilities in projects. This perspective was reinforced by [BUM.CEF_1], who explained,

> *'This is the difference of the project organization and the regular organization. You need the board level of the project organization to make an impact on projects. The board level might be too high for regular interventions, but applying similar action items at slightly lower levels could be impactful.'*

The validation focus group revealed that while the core idea of designated sustainability accountability and oversight remains valid, its relevance depends on implementation at the proper organizational tier. The consensus suggests adapting this action item to project directors or equivalent leadership positions within project governance structures, thereby maintaining the accountability ideas while ensuring relevant operational influence. This adjusted approach can preserve the intended benefits of the original conceptual action item while addressing the identified gap between corporate oversight and project execution.

Implementation feasibility:

The feasibility of implementing sustainability progress monitoring faced significant challenges during validation, as highlighted by focus group participants. Business unit manager [BUM.CEF_2] described the fundamental obstacle,

> *'Sustainability progress is always a tough one because we still do not know how to measure sustainability.'*

This observation underscores the critical industry-wide limitation on the absence of standardized metrics for measuring sustainability performance and progress in infrastructure projects. While future developments may address this gap, current practical constraints necessitate alternative approaches to monitor sustainability integration.

The focus group proposed an alternative solution to enhance implementation feasibility of this action item. Shifting from binary progress reporting to incorporating structured sustainability challenges and questionings during project reviews. Specifically, it was recommended that project directors actively question project teams about recognized and missed sustainability opportunities during quality assessments. This approach transforms sustainability monitoring from a checkbox exercise into an engaged dialogue, creating

dedicated moments for collective sustainability consideration. [BUM.CEF_2] provided a compelling case example,

> *'In one of the projects, thanks to the challenging questions in the tender board, we discussed what we can improve for the projects for our people and what we can do in terms of sustainability on this project. Ultimately, we were able to use some of our own money to do something on sustainability for that project.'*

This shows that assigning project directors or tender board to challenge project teams regularly on sustainability through open questions is impactful for the actualization of sustainability opportunities in infrastructure projects. While this validation demonstrates the effectiveness of challenge-based mechanisms, [BUM.CEF_1] noted the execution of tender board challenge is currently limited to the offering phase. Expanding such interventions throughout the project lifecycle could significantly enhance sustainability actualization.

Overall, the validation focus group has suggested that challenge-based approach by project directors offer an immediate positive effect on the actualization of sustainability opportunities. On the other hand, metrics development for sustainability remains a crucial research priority but yet to be feasible for wide implementation. Therefore, this adjusted approach maintains the purpose of the original conceptual action items while accommodating current measurement limitations and practice realities.

Action item:

Knowledge governance: Organization-wide knowledge governance by information management team

Relevance:

The validation focus group acknowledged the conceptual relevance of implementing organization-wide knowledge governance through an information management team. As [BUM.CEF_2] noted,

> *'Organizational level information management can be helpful because you have some sorts of centralized point of entrance where you start.'*

The validation focus group agreed that the fundamental challenge related to knowledge is the 'unknown unknowns' problem where practitioners do not know what sustainability knowledge they are missing. This is an obstacle to effective sustainability actualization. At an organizational level, structured knowledge management systems can mitigate this challenge by establishing centralized information access points. However, participants in the validation focus group emphasized that database solutions alone prove insufficient for effective knowledge transfer. [BUM.CEF_2] elaborated,

> *'I don't believe database solutions alone can address this. In my experience, it is rare to see a good example of a knowledge database that is actually being used in furthering knowledge of others.'*

While recognizing this limitation, [BUM.CEF_2] suggested that the AI advancements might change this dynamic. The ability to query an AI system as if consulting a knowledgeable colleague could bridge some gaps and increase the influence of having a database.

Nevertheless, the validation focus group consensus indicated that successful knowledge governance requires complementing structured databases with also organic knowledge exchange mechanisms. The validation focus group recommended coupling information management systems with informal knowledge-sharing opportunities, aligning with other proposed action items that facilitate interpersonal learning. This integrated approach addresses both the technical and social dimensions of knowledge dissemination, potentially overcoming the challenge of low engagement.

Implementation feasibility:
The validation focus group has stressed the concern of the implementation feasibility on effectively execute knowledge management within organizations. [BUM.CEF_1] elaborated,

> *'Effective knowledge management remains one of the most difficult organizational challenges because it fundamentally depends on individuals.'*

The validation focus group identified a critical challenge in capturing and recording the practical, project-specific knowledge and skills that practitioners develop through experience. As noted by [BUM.CEF_1], conventional database systems often prove inadequate for documenting tacit knowledge of professional experts. Tacit knowledge is difficult to manage through formal codification yet is an important component of effective sustainability actualization.

However, the validation focus group recognized emerging artificial intelligence technologies hold significant promise for addressing such knowledge management limitation. [BUM.CEF_2] highlighted the potential of AI technologies to transform organizational learning processes by incorporating the database with an interactive AI tool that can respond to queries about sustainability. Such AI systems could synthesize documented data with analyzed project experiences to provide context-sensitive guidance.

This perspective suggests that by enabling more dynamic knowledge interactions, an AI-enhanced system could significantly improve the implementation feasibility of the knowledge governance strategies within consultancy engineering firms.

Action item:
Financial support: Establish an internal sustainability funding for projects
Financial support: Launch a sustainability co-investment program

Relevance:
The validation focus group expressed doubts regarding the relevance of establishing organization-wide financial support mechanisms for sustainability opportunities actualization. It was explained that funding for sustainability opportunities should be inherently integrated within existing project budgets rather than treated as a separate allocation. As [BUM.CEF_2] emphasized,

> *'Project teams should have an entrepreneurial mindset, willing to allocate some project funds toward extra sustainability insights...Every project leader has the flexibility to spend a little more if they see a valuable opportunity.'*

This perspective was reinforced by [BUM.CEF_1], who clarified that,

> *'Ultimately, it's not about creating a formal funding program. It's about shifting mindsets.'*

The consensus emerging from this discussion suggests that effective sustainability actualization depends less on supplemental organizational funding and more on empowering project leaders with sufficient budgetary flexibility to capitalize on sustainability opportunities within their existing project budget, and having an entrepreneurial mindset in project teams that encourages innovative use of project resources for sustainability. This approach aligns financial decision-making more closely with project-specific opportunities while maintaining project financial responsibility at the operational level. The insights by the validation focus group highlight the importance of organizational culture and leadership autonomy over centralized funding mechanisms in enhancing sustainability opportunities actualization.

Implementation feasibility:
While the feasibility of implementing separate central financial support mechanisms was not extensively examined due to limited perceived relevance, the validation focus group proposed alternative approaches demonstrating clear practical viability.

The validation focus group emphasized that empowering project leaders with greater budgetary autonomy to pursue sustainability opportunities within existing project constraints, coupled with fostering an entrepreneurial mindset among project teams, represents a proven feasible strategy. This conclusion derives from evidence of their successful application of such approaches in current projects, with consensus about its scalability across consultancy engineering firms.

The validation process thus revealed that financial enablement for sustainability actualization proves most feasible and efficient through enhanced project-level budgetary flexibility rather than through separate central funding mechanisms, as this aligns with both practical project realities and organizational financial structures.

Action item:
Incentives: Launch monthly best sustainability idea award

Relevance:
The validation focus group affirmed that such recognition programs could effectively promote innovation and motivate behavioral change toward sustainability actualization. [BUM.CEF_1] strongly endorsed this action item, saying,

> *'Rewarding positive behavior and putting them in the spotlight helps drive change. I'm a strong advocate for incentives to shape behavior.'*

This perspective was reinforced by [BUM.CEF_2], who noted,

> *'I agree this can get attention grow. It aligns with what we discussed earlier about fostering an entrepreneurial mindset around sustainability. This approach can really influence how people think, which is positive.'*

This action item complements other validated action items by creating motivational structures that support broader sustainability actualization efforts.

Implementation feasibility:
The implementation feasibility of a best sustainability idea award program received qualified endorsement from the validation focus group. [BUM.CEF_1] expressed confidence in the action item, stating,

> *'I believe this will work well in our company. It's like raising children. You need effective reward strategies.'*

However, [BUM.CEF_2] identified practical considerations requiring refinement, noting,

> *'…from a practical standpoint, monthly recognition might be too frequent, quarterly might work better.'*

Furthermore, [BUM.CEF_2] emphasized that management buy-in is critical, explaining,

> *'If we commit to quarterly recognition, we have to follow through consistently and truly highlight people's contributions.'*

It is also suggested by the validation focus group that this program is best suit to be on a sector level. A company-level approach is too broad and less relatable, but sector-level implementation keeps it relevant, close and meaningful.

8.8.2. Tactical Level

This section analyzes Validation Focus Group 2 results for tactical level action items, evaluating their relevance to improve the actualization of sustainability and implementation feasibility from a tactical perspective.

Action item:
Learning Nexus: Hold sustainability skill-building workshops

Relevance:
The validation focus group agrees that having sustainability skill-building workshops is relevant to enhancing the actualization of sustainability opportunities. As group leader [GL.CEF_1] emphasized,

> *'Trainings and workshops are valuable.'*

This perspective was further substantiated by business unit manager [BUM.CEF_3], who provided an idea of workshop content design,

> *'We can start with having one language (for sustainability). This means to identify and understand what sustainability really means.'*

This example highlights that effective sustainability workshops requires to start with basic definitions to align understandings before addressing complex applications. Starting with fundamental concepts prevents misinterpretations of sustainability while establishing a shared foundation for subsequent skill development. The validation confirms that sustainability learning opportunities are essential for actualization of sustainability opportunities in projects.

Implementation feasibility:
While trainings and workshops are regarded as impactful for improving the actualization of sustainability opportunities by enhancing sustainability awareness and skills, the validation focus group identified challenges on the implementation of workshops regarding participation. As described by [GL.CEF_1],

> *'Trainings and workshops are valuable, but they typically attract those already committed or interested in sustainability.'*

This creates an outcome where training and workshops primarily benefits those already committed to sustainability, while those most needing development remain excluded. This participation gap undermines the purpose of the action item.

To address such problem, the focus group proposed several strategies. First, workshops should prioritize practical and immediately applicable skills. [GL.CEF_1] explained,

> *'The key is ensuring participants can immediately apply what they learn in real projects. Successful stories will organically draw others in. When people see tangible outcomes from the workshops and trainings, it sparks curiosity.'*

This suggests that workshops focusing on actionable skills and techniques with immediate project applicability can lead to tangible results, thereby increasing their appeal even among previously disengaged individuals.

Another suggestion is made by [GL.CEF_2] which relates to leadership involvement in workshops. It is suggested that it is important that management from the company also join these workshops. This shows the commitment on sustainability by management and shows that sustainability responsibilities should not just fall on project teams.

Finally, additional knowledge sharing methods can broaden the reach of sustainability knowledge. [PM.CEF_5] described an idea on top of workshops for learning,

> *'We publish bi-weekly updates on our intranet highlighting sustainability in projects, primarily focusing on biodiversity. We feature about 20 projects*

annually, with short descriptions and visuals. Long articles don't get read, so we keep it concise and engaging.'

This learning approach complements workshops by providing low-barrier, ongoing education. Together, these suggestions create a more inclusive learning ecosystem that eventually can potentially change organizational practices and culture.

Action item:
Objectives: Create role specific sustainability objectives

Relevance:
The validation focus group expressed doubts regarding the relevance of role-specific sustainability objectives in infrastructure projects, citing several substantive concerns. The primary concern centered on the risk of fragmented optimization, where individual team members might prioritize their role specific sustainability targets at the expense of the overall project sustainability outcomes. As [BUM.CEF_3] described,

'…you will have the problem where everyone just optimizes their own sustainability goal if there are role specific objectives. You will be only responsible for your own goal. This will not work.'

A concrete example illustrated this limitation. [GL.CEF_2] described a scenario,

'…we work for a producer to design prefabricated beams. We can optimize those beams in a very sustainable way. The problem is we are more sustainable but the contractor who has to pour the concrete on top of those beams needs to include twice as much reinforcement because we left all reinforcement out of our beams...we optimized our sustainability goal but created sustainability problems for others. At the end, the overall bridge is not sustainable.'

This case demonstrated how separated sustainability targets can generate unintended consequences that harm overall project environmental benefits. The focus group further emphasized that sustainability inherently requires collective action. [PM.CEF_5] emphasized this,

'Sustainability requires integrated thinking. The greatest value comes from collaborative interaction. It is better when all parties share common goals and work toward them collectively.'

This perspective aligns with the observation by [GL.CEF_1] that sustainability is multidimensional and need trade-off analysis across aspects within sustainability. Recognizing these challenges, [BUM.CEF_3] proposed an alternative approach,

'I think you can make one person responsible. He can check with everyone in the project team. Identify what the sustainability ideas are and put them together.'

The validation focus group refined this action item by preserving the benefits of clear accountability while maintaining the essential of having collective sustainability goals.

Implementation feasibility:
While the feasibility of creating role specific sustainability objectives was not extensively examined due to limited perceived relevance, the validation focus group proposed alternative approaches demonstrating clear practical viability.

The validation focus group confirmed the implementation feasibility of implementing shared sustainability objectives for project teams, coupled with the appointment of a designated responsible personnel. This approach addresses key challenges identified during discussions, particularly the need to balance collective goals with clear accountability in sustainability implementation. Additionally, the appointment of a designated responsible personnel echoes the suggestion by Validation Focus Group 1 on strategic level to have project directors to evaluate and challenge sustainability execution in projects. The validation focus group recognized that unified objectives help prevent the fragmentation risks associated with role-specific targets, while the appointed leadership ensures focused coordination and oversight throughout the project.

Action item:
Monitoring: Report KPIs on percentage of projects meeting sustainability criteria to the responsible board-level member

Relevance:
The validation focus group confirmed that implementing KPIs to track the adherence of projects to sustainability criteria represents a relevant action item for enhancing sustainability actualization. As emphasized by [PM.CEF_5],

> *'…the monitoring process itself has value. It leads to deeper conversations about sustainability, which is progress in itself.'*

The validation focus group offered specific recommendations to strengthen this action item. [PM.CEF_5] suggested incorporating KPI determination as a distinct element within the sustainability inspiration list, stating that,

> *'Having the KPIs as one of the topics in the inspiration list where we can talk with the client helps.'*

[GL.CEF_1] reinforced this view, noting that,

> *'The initial conversation with clients to determine KPIs is itself a critical step.'*

These insights have informed refinements to the original action item, particularly emphasizing the importance of early client engagement in KPI determination and the function of KPIs as conversation starters.

Implementation feasibility:
While the validation focus group confirmed the relevance of using KPIs to monitor sustainability progress, the group identified significant challenges in the practical implementation. [GL.CEF_1] highlighted a fundamental dilemma,

> *'What I think is difficult with KPIs is related to the question: what makes a project sustainable. For example, a nitrogen reduction project that we are doing now. While it is very good for water quality and biodiversity, it is bad for sustainability when you look towards CO2 emissions and material use.'*

This example illustrates the difficulty of capturing overall sustainability performance through conventional metrics. Another challenge is raised by the group regarding the dynamic nature of sustainability standards. As [BUM.CEF_3] explained,

> *'…technological advancements can rapidly alter our benchmarks. You can use KPI to monitor sustainability progress but there are so many developments in the world that changes the sustainability benchmarks.'*

To address these implementation challenges, the validation focus group proposed establishing project-specific sustainability baselines as a reference for monitoring sustainability progress. [GL.CEF_2] explained this solution,

> *'Without a reference point, neither meaningful KPIs nor effective monitoring are possible. We should establish proper sustainability baselines for projects…when there is a baseline, we can judge our sustainability progress based on that baseline. There is something for us to reference and discuss about.'*

This suggestion offers project to have project-specific constraints and enable monitoring relative to the initial conditions. This suggestion also accommodates the evolving technologies while maintain the measurement of sustainability for the project consistent.

Therefore, the validation suggests this refined approach of combining baseline establishment with KPI monitoring to better address the dynamic and broad nature of sustainability in infrastructure projects, which enhances the relevance and the feasibility of implementation.

Action item:
Knowledge enablement: Maintain a sustainability pipeline database

Relevance:
The validation focus group agreed the conceptual action item of maintaining a sustainability pipeline database as a valuable inspirational resource, particularly during early project phases. The focus group recognized this approach as instrumental for keeping pace with rapidly evolving sustainability practices and technologies if it is managed efficiently. As [GL.CEF_1] explained that sustainability evolves rapidly. The project examples in the database can help engineers to understand what the current technology level is and set progressive boundary levels for sustainability.

This tactical action item directly supports the strategic knowledge governance objectives examined in Section 7.8.1, providing a practical implementation pathway for knowledge management.

Implementation feasibility:
While the validation focus group acknowledged the relevance of maintaining a sustainability pipeline database as a knowledge inspiration resource, significant concerns were raised regarding its implementation feasibility. [BUM.CEF_3] explained,

> *'I think this is a good idea for inspiration, but the challenge is how to manage and maintain such a system effectively.'*

A concrete example from [GL.CEF_2] illustrated these implementation difficulties,

> *'I am responsible for a database for engineers and we are with 80 people. Currently, only about 5 people put information on the platform. The others are all using it but if there is no one responsible for the updates, it is the end of the database. We are not very good at documenting lessons learnt and you need it for this database.'*

This example highlights the critical challenge of sustaining user engagement and content updates in a knowledge management database. These operational concerns echo the feasibility concerns raised by the Validation Focus Group 1 regarding strategic level knowledge governance. However, participants noted that AI technologies may gradually mitigate these implementation challenges in the future.

The validation focus group consensus suggests that while the database concept remains valuable, its successful implementation requires three key elements, automated updates to reduce manual maintenance, a cultural shift in knowledge-sharing behaviors, and dedicated personnel for content updates. The validation focus group emphasized that technology alone cannot sustain such database. It demands both technical solutions and organizational commitment.

8.8.3. Operational Level

This section analyzes Validation Focus Group 2 results for operational level action items, evaluating their relevance to improve the actualization of sustainability and implementation feasibility from a tactical perspective.

Action item:
Learning Nexus: Hold sustainability role-specific training

Relevance:
Similar to the validation of the workshop on the tactical level, the validation focus group agrees that having sustainability role-specific is relevant to enhancing the actualization of sustainability opportunities. As group leader [GL.CEF_1] emphasized,

> *'Trainings and workshops are valuable.'*

The validation confirms that sustainability learning opportunities are essential for actualization of sustainability opportunities in projects.

Implementation feasibility:
The implementation feasibility validation for implementing role-specific sustainability training aligns with the findings for skill-specific workshops. A critical insight from both assessments is that while such trainings effectively enhance sustainability awareness and competencies, their impact is limited by low participation among those who would benefit most but are less engaged. To mitigate this challenge, the focus group recommended prioritizing practical and actionable skills in training design to demonstrate immediate value and encourage involvement.

Action item:
Knowledge execution: Access and updates to BIM 360 Interface
Knowledge execution: Early involvement of sustainability specialists in the project team

Relevance:
Enabling access and updates through BIM 360 interfaces was validated as fundamentally supporting the tactical action item of maintaining an effective sustainability pipeline database. This technical infrastructure provides the necessary platform for using and sharing sustainability knowledge across projects, with the validation focus group emphasizing the role of the BIM interface in ensuring data accessibility and real-time updates.

Regarding the second component of knowledge execution, the focus group strongly endorsed the early involvement of sustainability specialists in project teams as an important action item for enhancing sustainability opportunities actualization. As [GL.CEF_2] articulated,

> *'I think having early involvement of sustainability specialist is key. They equip project managers with the right insights to engage clients, challenge outdated assumptions, and explore new possibilities. Project managers take the first step, then bring in experts to drive deeper discussions.'*

This perspective highlights the complementary roles of project managers initiating sustainability discussions and sustainability specialists deepening these advice and conversations through technical expertise. Sustainability specialists can build upon this groundwork by providing technical depth and specialized sustainability knowledge, transforming preliminary discussions into actionable sustainability strategies in projects. The validation focus group confirms that this early sustainability specialist engagement can improve the impact of sustainability actualization in infrastructure projects.

Implementation feasibility:
The implementation feasibility challenges related to maintaining an up-to-date sustainability database echo those previously identified in Section 7.8.2. The validation focus group acknowledged the persistent difficulty of sustaining user-contributed updates but proposed a balanced operational solution, retaining the database as an accessible knowledge repository

while complementing it with an interactive sustainability chatbot. For database maintenance, the group recommended a tactical level solution by appointing dedicated sustainability knowledge stewards responsible for updating and managing content. This specialized role would ensure the pipeline remains current while alleviating the burden of updating lessons learnt on general project teams.

The validation focus group confirmed the practical feasibility of engaging sustainability specialists into project teams during early project stages. The action item provides clear guidance for project managers to proactively engage available in-house sustainability experts during early project phases. However, self-motivated project managers is a critical implementation factor, as observed by [PM.CEF_5],

> *'That requires self-motivated project managers. If we cultivate more project managers who genuinely care about sustainability and nature, they'll proactively seek out the right consultants.'*

This insight reveals that effective implementation of such action item extends beyond formal protocols. It requires also individual mindset and professional values. This human factor is addressed by two other action items, sustainability monitoring and sustainability learning nexus. Together, these complementary items create an ecosystem that cultivate the necessary motivation and capabilities for project teams to actively utilize the sustainability database and chatbot and proactively engage sustainability specialists during early project phases.

Action item:

Early client engagement: Launch sustainability design checklist
Early client engagement: Present ideas to the client

Relevance:

The validation focus group affirmed the critical importance of early client engagement for enhancing the actualization of sustainability opportunities in infrastructure projects. Business unit manager [BUM.CEF_3] emphasized this point, stating,

> *'Many clients put sustainability in the contract but do not think about it anymore when projects start. I think it is a good and practical measurement. It is a good idea to engage clients as early as possible on the matter of sustainability.'*

This observation highlights a common disconnect between contractual commitments and practical implementation for sustainability. Group leader [GL.CEF_2] further elaborated on this challenge that sustainability goals are often included in contracts nowadays, but they often remain vague aspirations without clear definitions, measurable outcomes, or accountability mechanisms. This usually stems from the limited understanding of what these sustainability commitments entail in practice by the clients. Group leader [GL.CEF_1] pointed out the importance of having early conversations with clients on sustainability,

> *'You need to make sustainability understandable to them so they can make decisions from it.'*

This shows the relevance of engaging clients early in the project phase to discuss about sustainability. Project manager [PM.CEF_5] further underscored the value of early engagement, explaining,

> *'Early phases are most critical, that's when we should examine fundamental questions related to the function like lifecycle impacts, whether repairing existing infrastructure is enough, or if we even need the proposed structure.'*

This perspective positions early engagement not just as beneficial but as essential for meaningful sustainability integration. This is further explained by [GL.CEF_2] and [PM.CEF_5],

> *'We need checklists that challenge assumptions at each stage. Too often, clients request specific solutions immediately. We should step back first to understand the core problem and explore all possible approaches before narrowing down options.'*

The focus group discussion concluded that structured early engagement through sustainability checklists and presenting sustainability ideas can enhance the actualization of sustainability opportunities. By initiating sustainability dialogues during the early project phase, practitioners can align client expectations with most suitable sustainable solutions.

Implementation feasibility:
The validation focus group affirmed the implementation feasibility of early client engagement through structured sustainability discussions, though with important discussions and suggestions regarding methodology. Group leader [GL.CEF_1] highlighted the inherent practicality of such engagement, stating,

> *'I think it is easy to have a conversation with the client on sustainability because every client has a goal from his organization. In cases, where the client does not ask for sustainability, project manager can always ask the questions about sustainability using the checklist. Then you can at least have a conversation with the client on sustainability.'*

However, [GL.CEF_1] identified significant limitations in using standardized checklists,

> *'The downside of having checklist is that they are not smart enough for the type of projects we have. A checklist for tunnel renovation is very different from the checklist for building a new bridge. I think if you want to go this way, you cannot have only one checklist because it will be very broad and very abstract and it will have no use.'*

Business unit manager [BUM.CEF_3] and Project manager [PM.CEF_5] proposed an alternative approach,

> *'Perhaps we should consider an inspiration list instead, something that prompts deeper thinking rather than just box-ticking exercise.'*

The focus group consensus supported this refined approach, recognizing that while structured early client engagement remains essential, the action items must be adaptive, scalable, and maintain open-ended.

This validation suggests that early engagement is feasible and impactful when it moves beyond procedural formality to facilitate dialogue about sustainability ambitions and ideas. The concept of having an inspiration list and then propose sustainability ideas to clients in early project phase is expected to enhance the actualization of sustainability opportunities by the validation focus group.

Action item:
Monitoring: Real-time data checks
Monitoring: External challenger

Relevance:
The proposed real-time data checking action item serves as the operational implementation of the tactical level KPI reporting action item. The analysis of tactical level monitoring action item confirms that while real-time KPI checks remains relevant for enhancing sustainability actualization, the validation process revealed critical limitations in standalone KPI systems. As previously explained in Section 7.8.2, meaningful sustainability assessment requires integrating KPIs with project-specific baselines to provide proper context for performance evaluation.

This insight has led to an important refinement of the original action item. The improved approach now emphasizes tracking sustainability KPIs relative to the established project-specific baselines rather than as absolute metrics.

Furthermore, the validation focus group confirmed the relevance of incorporating external challengers as an operational method to enhance sustainability opportunities actualization in projects. This approach, when applied through appropriate contractual agreements, provides valuable external perspective and accountability in driving sustainable outcomes. However, as observed by the focus group that sustainability actualization achieves its highest potential when project teams are self-motivated rather than pushed by an external challenger.

Implementation feasibility:
The refined action item for tracking KPIs relative to project-specific baselines is feasible for implementation, building upon the validation explained in Section 7.8.2. This approach gains additional implementation momentum when integrated with recognition systems that reward project teams for achieving predetermined sustainability goals.

Regarding the action item for having external challengers, implementation feasibility is proven, with existing projects successfully incorporating this approach. The key consideration lies in the formulation of contractual terms that clearly defines the role of the third party, the objectives of the evaluation, and the collaborative relationship.

8.8.4. Completeness of the Framework

The overall framework was comprehensively validated through the two validation focus group discussions, and this section presents key findings to assess the overall completeness of the framework.

Hierarchy Levels

Validation Focus Group 1 raised questions regarding the positioning of the strategic level at the top and the operational level at the bottom of the framework. As noted by [BUM.CEF_1],

> *'The strategic level shouldn't always sit at the top. We should consider inverting the traditional hierarchy between strategic and operational levels.'*

Echoing this perspective, Business Unit Manager [BUM.CEF_2] proposed,

> *'The operational column would represent the actual work execution, while the strategic column would provide the foundational support and framework. Therefore, maybe we should visualize the operation level at the top and strategic level at the bottom.'*

In response to these recommendations, the framework will be revised to better align with the proposed structure.

Early Sustainability Opportunity and Life Cycle Analysis Quick Scan

Validation Focus Group 2 emphasized the necessity of incorporating sustainability into the process. As highlighted by [PM.CEF_5],

> *'When you have sustainability in the design process, you can use it in all types of projects. When sustainability is fix in the process, it is easier to get it on the agenda.'*

Business Unit Manager [BUM.CEF_3] provided a practical suggestion of implementing sustainability opportunity quick scan in the process,

> *'In a project, we did some quick scans on sustainability to look for sustainability chances. We made some reservations on our budget to work out quick scans. If there are some positive results from the quick scan, we will advise client for more budget to work out the opportunities. This is a good way to work out opportunities when you do not know where the possibilities are.'*

Additionally, Group Leader [GL.CEF_2] proposed another method for considering sustainability early in the process,

> *'Currently, design reports we ask all engineers to include a LCA quick scan, by doing that they can see the environmental effects of the design. We do this LCA quick scan before the real detailed LCA so that we are aware of the sustainability effects early in the process.'*

[GL.CEF_1] further elaborated on the practical advantages of these approaches, noting,

> *'Important thing is that it should be fun to use, so it is interesting to everybody. Sustainability should not be an additional thing, it needs to be part of the way we are working.'*

The simplicity and user-friendly nature of these approaches significantly enhance the practical implementation. These evidence-based recommendations will be incorporated as action items in the revised framework.

Beyond Mandates

Validation Focus Group 2 acknowledged that while the action items in the framework can effectively enhance sustainability opportunity actualization in infrastructure projects, their successful implementation hinges on employee motivation rather than mandatory enforcement. As explained by [PM.CEF_5],

> *'…you need self-motivated people. You start from them. Don't try to convince who are against you because they will be more against you after the discussion. Start with people who are supporting sustainability.'*

The discussion revealed an important organizational dynamic. Most people in the industry occupy a neutral middle ground regarding sustainability, neither strongly opposed nor actively supportive. These individuals typically require demonstration of tangible benefits and peer leadership rather than persuasion or mandatory enforcement. The validation group observed that when sustainability-minded colleagues use new practices and share successes, this neutral majority gradually follows through social learning and proven results.

This strategy suggests a phased approach to implementation of the framework. First empowering willing participants to demonstrate feasibility, then creating conditions for organic spread through visible achievements, while consciously avoiding too many efforts to convince resistant minorities. The framework accordingly recognizes that cultural change is more crucial than procedural compliance.

8.9. Validation Limitations

While the framework underwent rigorous validation through validation focus groups with industry practitioners, several limitations should be acknowledged. Firstly, although the sample size of six participants may appear slim, all participant of the validation focus groups were business unit managers or group leaders. They are senior professionals in the industry who serve as the strategic, tactical and operational backbone of the organization, ensuring their perspectives are highly representative of core decision-makers.

Secondly, the validation process did not include client representatives, an intentional choice given the focus of the framework is on consultancy engineering firms. While several action items involve client engagement, the scope of this research prioritized internal organizational processes in consultancy engineering firms. This exclusion means that the client-facing action items remain partially validated and may require supplemental evaluation in further research or implementation.

Thirdly, participant perspectives were drawn exclusively from a single Dutch consultancy engineering firm, which may limit the transferability of findings to other regional or organizational contexts. This limitation is partially mitigated by the extensive national presence and diversified project portfolio of the firm. As one of the market leaders in the infrastructure industry in the Netherlands, the participating organization provides fruitful experience for the framework validation. However, the cultural and regional specificities of the Netherlands may still influence certain implementation aspects of the framework. It is suggested that the framework would benefit from future testing in other national contexts to validate broader applications.

Fourthly, the dynamic nature of sustainability introduces a contextual limitation. Best practices today may be outdated tomorrow. This suggests that the framework serves a good starting point for now, while continuous improvements are needed.

8.10. Validation Implementation

The conceptual Sustainability Human-Centered Implementation Framework for Transition (c-SHIFT) has been revised based on the validation results and comprehensive analysis presented in Section 8.8. This section first introduces the improved SHIFT, followed by detailed explanations of the revised implementation guidelines incorporating insights and suggestions from the validation focus groups. The complete validated SHIFT is visually presented in Figure 8.1.

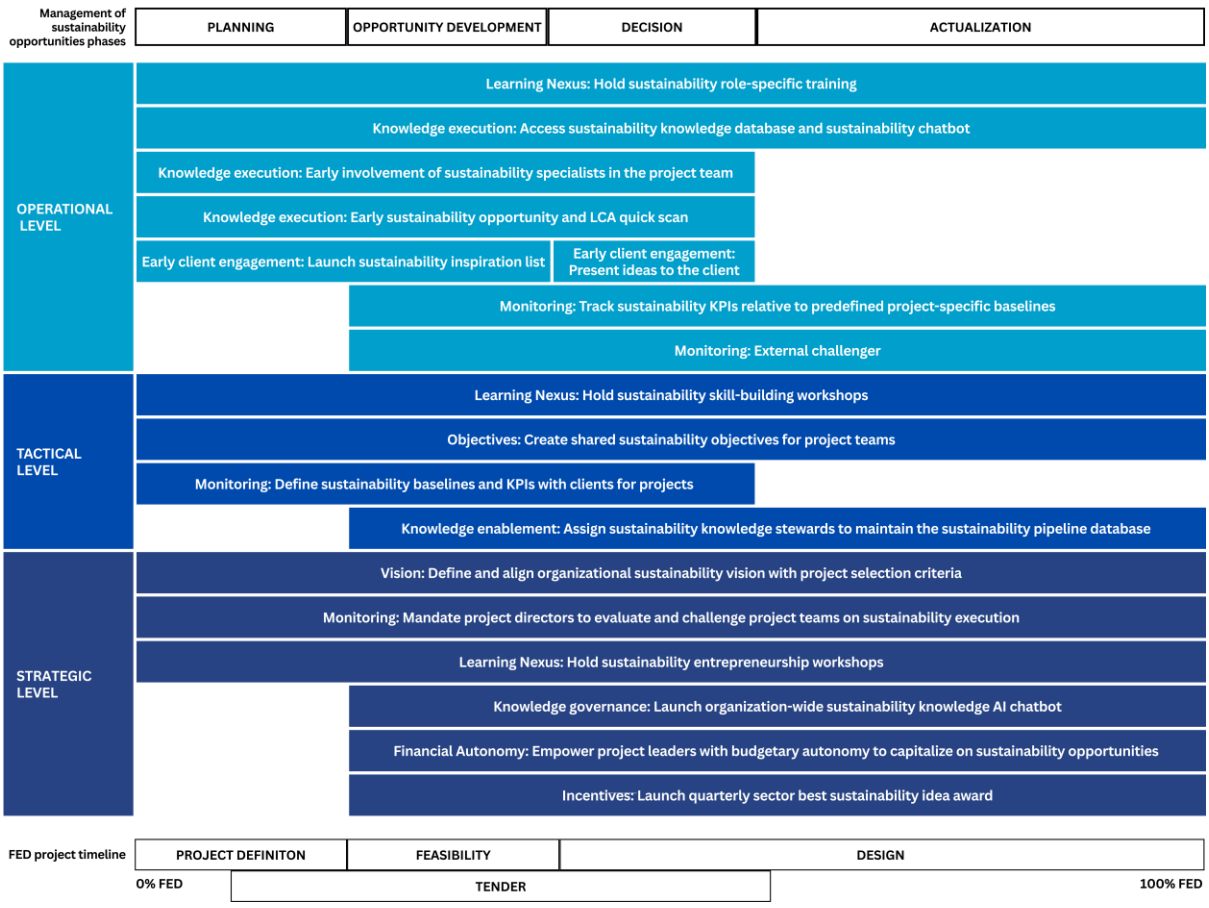

Figure 8.1: Sustainability Human-Centered Implementation Framework for Transition SHIFT (author)

Figure 8.1 presents the enhanced Sustainability Human-Centered Implementation Framework for Transition, SHIFT, which incorporates improvements derived from the validation process, prioritizing relevance and implementation feasibility. A comparative analysis with the initial c-SHIFT, shown in Figure 7.6, reveals several key modifications,

Structural adjustments to the hierarchical organization of levels:

- Operational level to the top of the framework
- Strategic level to the bottom of the framework

Addition of new action items identified as critical during validation:

- Early sustainability opportunity and LCA quick scan
- Empower project leaders with budgetary autonomy to capitalize on sustainability opportunities
- Hold sustainability entrepreneurship workshops

Removal of less relevant action items based on validation:

- Establish an internal sustainability funding for projects
- Launch a sustainability co-investment program

Refinement of existing action items based on validation:

- Access sustainability knowledge database and sustainability chatbot
- Launch sustainability inspiration list
- Track sustainability KPIs relative to predefined project-specific baselines
- Create shared sustainability objectives for project teams
- Define sustainability baselines and KPIs with clients for projects
- Assign sustainability knowledge stewards to maintain the sustainability pipeline database
- Define and align organizational sustainability vision with project selection criteria
- Mandate project directors to evaluate and challenge project teams on sustainability execution
- Launch organization-wide sustainability knowledge AI chatbot
- Launch quarterly sector best sustainability idea award

These revisions collectively strengthen the relevance and implementation feasibility of the framework while maintaining alignment with its theoretical foundations.

The practical guidelines have been updated to align with the validation findings and reflect the refinements incorporated in SHIFT. Consistent with the original framework development methodology described in Section 7.2, the same design format and methodological approach has been used for guideline revision to ensure continuity and comparability. The complete set of updated implementation guidelines is presented in Table 8.2, Table 8.3, and Table 8.4.

Table 8.2: Guidelines for strategic level action items (author)

Proposed Actionable Items	Guidelines
Vision: **Define and align organizational sustainability vision with project selection criteria**	1. **Determine ideas and contexts** ◦ Understand the foundation of sustainability and identify most relevant sustainability issues for the organization and the industry 2. **Align vision with core business strategy** ◦ Integrate sustainability KPIs into corporate performance metrics and utilize sustainability to create value 3. **Benchmark against industry peers** ◦ Maintain realistic yet ambitious targets by benchmarking competitors 4. **Standardize sustainability metrics** ◦ Adopt industry-aligned metrics for measuring and reporting sustainability for all targets 5. **Define clear and actionable vision** ◦ Define precisely what sustainability means for the organization 6. **Set SMART sustainability objectives** ◦ Breakdown the vision into specific, measurable, achievable, relevant, and time-bound objectives 7. **Align project selection criteria** ◦ Choose projects that demonstrate strong alignment with the organization sustainability vision and objectives
Monitoring: **Mandate project directors to evaluate and challenge project teams on sustainability execution**	1. **Formalize authority** ◦ Empower project directors to evaluate and challenge on sustainability execution in projects 2. **Set clear expectations** ◦ Assign clear objectives for project directors based on the organization sustainability vision 3. **Link to performance** ◦ Tie sustainability KPIs to the performance of the project directors 4. **Ensure transparency** ◦ Disclose the role and progress in project progress reports
Learning Nexus: **Hold sustainability entrepreneurship workshops**	1. **Needs assessment and goal alignment** ◦ Identify the knowledge gaps and align workshop topics with sustainability entrepreneurship 2. **Workshop design** ◦ Design workshops that contain theoretical foundation and hands-on exercise ◦ Include certifications to incentivize participation ◦ Ensure skills taught in workshops are immediately implementable 3. **Integration with organizational process** ◦ Link workshop completion to standard career development paths ◦ Mandatory trainings for certain positions 4. **Measurement and improvement** ◦ Pre and post workshop assessments to track improvements and behavior changes ◦ Adjust contents regularly to be up-to-date
Knowledge: **Launch organization-wide sustainability AI chatbot**	1. **Define objectives and functions** ◦ Identify clear objectives and functions for the sustainability chatbot 2. **Assemble the right management team** ◦ Assemble cross functional team, including knowledge stewards, data analysts and engineers, to develop and manage the system 3. **Develop a knowledge management framework** ◦ Deploy a comprehensive knowledge management framework that includes strategies, culture, organizational learning, and systems and technology 4. **Ensure usage rate, visibility and value** ◦ Encourage project teams to use the sustainability chatbot by showcasing values and examples ◦ Celebrate successful milestones ◦ Track usage rates
Financial Autonomy: **Empower project leader with budgetary autonomy to capitalize on sustainability opportunities**	1. **Formalize authority** ◦ Empower project leaders with budgetary autonomy for sustainability ◦ Trust and support by upper-management on investing in sustainability 2. **Incentives** ◦ Spotlight and recognize project leaders that utilizes the autonomy to explore and actualize sustainability opportunities 3. **Ensure visibility** ◦ Celebrate and share successful stories in intranet
Incentives: **Launch quarterly sector best sustainability idea award**	1. **Define award criteria and scope** ◦ Open to all disciplinary with clear predetermined assessing criteria ◦ Align criteria with organizational sustainability objectives 2. **Structure nomination and submission process** ◦ Ensure simple entry and process 3. **Selection committee** ◦ Include panel with representatives from each business unit and level ◦ Ensure transparency and fairness 4. **Incentives** ◦ Award trophy to winning team and highlight winner on social media ◦ Provide support to execute top ideas 5. **Engagement** ◦ Share reasons for wining ideas and non-winning ideas to encourage improvements ◦ Invite teams with top ideas to sharing sessions

Table 8.3: Guidelines for tactical level action items (author)

Proposed Actionable Items	Guidelines
Learning Nexus: **Hold sustainability skill-building workshops**	1. **Needs assessment and goal alignment** ◦ Identify the knowledge gaps and align workshop topics with organizational sustainability objectives 2. **Workshop design** ◦ Design workshops that contain theoretical foundation and hands-on exercise ◦ Include certifications to incentivize participation ◦ Ensure skills taught in workshops are immediately implementable 3. **Integration with organizational process** ◦ Link workshop completion to standard career development paths ◦ Mandatory trainings for certain positions 4. **Measurement and improvement** ◦ Pre and post workshop assessments to track improvements and behavior changes ◦ Adjust contents regularly to be up-to-date
Objectives: **Create shared sustainability objectives for project teams**	1. **Determine ideas and context** ◦ Brainstorm sustainability ideas and align sustainability definitions within the project team 2. **Create shared project-specific SMART objectives** ◦ Develop specific, measurable, achievable, relevant, and time-bound objectives 3. **Integrate into performance assessments** ◦ Link sustainability objective fulfillment rate with performance 4. **Create small wins for motivation** ◦ Set objectives that can deliver measurable results in shorter timeframe
Monitoring: **Define sustainability baselines and KPIs with clients for projects**	1. **Define standards and metrics** ◦ Align the KPIs that will be used in the project with the client ◦ Define what qualifies as a sustainable project with the client 2. **Define baselines** ◦ Define sustainability baselines of the project using the KPIs with the client 3. **Develop KPI Roadmap** ◦ Define KPI calculation formulation with the client ◦ Develop short term minimum compliance, targets and long term goals with the client
Knowledge enablement: **Assign sustainability knowledge stewards to maintain the sustainability pipeline database**	1. **Define roles and responsibilities** ◦ Assign roles and responsibilities of knowledge stewards for updating and maintaining the database 2. **Data collection and integration** ◦ Require project teams to submit data using a standardized template ◦ Pull data from project team archives by knowledge stewards 3. **Improvements** ◦ Track usage rate and user satisfaction regularly ◦ Survey users to improve features

Table 8.4: Guidelines for operational level action items (author)

Proposed Actionable Items	Guidelines
Learning Nexus: **Hold sustainability role-specific training**	1. **Needs assessment and goal alignment** ◦ Identify the knowledge gaps and align training topics with organizational sustainability objectives 2. **Training design** ◦ Design trainings that contain theoretical foundation and hands-on exercise ◦ Include certifications to incentivize participation ◦ Ensure skills taught in trainings are immediately implementable 3. **Integration with organizational process** ◦ Link trainings completion to standard career development paths ◦ Mandatory trainings for certain positions 4. **Measurement and improvement** ◦ Pre and post training assessments to track improvements and behavior changes ◦ Adjust contents regularly to be up-to-date
Knowledge execution: Access sustainability knowledge database and sustainability chatbot	1. **Visible and easy access** ◦ Ensure the chatbot is known and accessible across the organization ◦ Allow users click chatbot answers to see the original database entry ◦ Allow users to flag outdated/missing information for rapid updates 2. **Train teams for adoption** ◦ Demo how to query the chatbot and utilize the database ◦ Identify skilled users to mentor colleagues 3. **Embedded in process** ◦ Link chatbot to daily communication platform (e.g., MS Teams) ◦ Automate sustainability check by AI on proposals with tips
Knowledge execution: **Early involvement of sustainability specialists in the project team**	1. **Define roles and involvement points** ◦ Define the role and involvement of sustainability specialists in projects ◦ Set mandatory phase-specific involvement and recommended involvement points 2. **Embed in standard workflows** ◦ Set up mandatory checkpoints that require sign-off by sustainability specialists at certain project phases 3. **Incentives** ◦ Tie team performance to sustainability outcomes ◦ Recognize teams that collaborate closely with sustainability specialists

Knowledge execution: **Early sustainability opportunity and LCA quick scan**	1. **Assign responsibilities** ◦ Assign responsible team members to execute quick scans ◦ Provide templates and tools for quick scans 2. **Embed in standard workflows** ◦ Embed quick scans in project kickoffs ◦ Add quick scan as a standard step in projects ◦ Use sustainability chatbot to guide teams through scan steps 3. **Client engagement** ◦ Present quick scan results to clients for actions ◦ Co-create solutions with clients based on scan findings 4. **Highlight results** ◦ Showcase positive results driven by quick scans ◦ Recognize teams that made good use of quick scans
Early client engagement: **Launch sustainability inspiration list**	1. **Preparation** ◦ Create tailored sustainability question sets for each project category ◦ Align questions with organizational sustainability objectives 2. **Pre-meeting review** ◦ Adjust questions in the inspiration list based on client and project context 3. **Initial client meeting** ◦ Use customized question list to guide discussions ◦ Assess client priorities on sustainability 4. **Integrate into design** ◦ Require project team to follow all identified sustainability priorities ◦ Assign accountability for implementations 5. **Review and improvements** ◦ Compare final designs against the identified sustainability priorities ◦ Document lessons learned in the database for future projects
Early client engagement: **Present ideas to the client**	1. **Preparation** ◦ Review sustainable design checklist results and sustainability database ◦ Identify sustainability alternatives aligning with client priorities 2. **Effective presentation** ◦ Use case studies from database for storytelling ◦ Show benefits based on past experience 3. **Engagement strategies** ◦ Proactive engagement with client ◦ Create a collaborative environment 4. **Follow-up and decision support** ◦ Post-meeting follow-up ◦ Suggest small-scale trials if necessary ◦ Provide detailed data for decision support
Monitoring: **Track sustainability KPIs relative to predefined project-specific baselines**	1. **Deploy data collection tools** ◦ Utilize the database platform for project team members to upload data on sustainability progress ◦ Mandate digital reporting on all sustainability progress 2. **Centralize data** ◦ Centralize all collected data to visualize progress and targets in a shared dashboard relative to the baseline 3. **Automate alerts and actions** ◦ Enable rule-based triggers when sustainability KPIs are over the baselines ◦ Action items and insights driven by AI can be automatically suggested 4. **Accountability** ◦ Define clear responsibilities for alerts and progress ◦ Regular inspections by the Project Directors
Monitoring: **External challenger**	1. **Establishing criteria for external challenger engagement** ◦ Define the specific conditions and project context that requires the involvement of an external challenger ◦ Projects that meet the predetermined criteria are mandate to include external challenger in the contractual agreements 2. **Define the role of the external challenger** ◦ Define the purpose of having the external challenger and the scope of monitoring 3. **Integrate into projects** ◦ Require the external challenger to sign-off at key project phases ◦ Allow access rights of the external challenger to the sustainability progress dashboard 4. **Structured challenge process** ◦ Design a standard challenge process that project teams can follow ◦ Monitor the process by the Sustainability Director 5. **Measure effectiveness** ◦ Use organizational KPIs to measure the effectiveness ◦ Monitor the percentage of challenges adopted

9

9. DISCUSSION

The development and validation of the Sustainability Human-Centered Implementation Framework for Transition (SHIFT) represent a critical step toward bridging the persistent gap between sustainability visions and their practical actualization in infrastructure projects. Furthermore, the refinement of SHIFT signifies an enhanced iteration of the framework and guidelines.

Building on the empirical findings in Chapter 4, the theoretical review in Chapters 3 and 5, the data synthesis in Chapter 6, and the validation findings in Chapter 8, this chapter discusses the key essence and importance of the findings. It also interprets the significance of the framework developed in Chapter 7 and Chapter 8 within academia and industry practices. This discussion avoids merely restating results, instead, it interrogates the significance of primary elements in the key findings and framework, how they extend current knowledge and practices, and an overall reflection of the developed framework. By doing so, this chapter sets the stage for the subsequent conclusion and recommendation detailed in Chapter 10.

9.1. Key Insights

Diverging from the predominant research methodologies in this domain, this study adopted a semi-grounded theory approach to investigate the actualization of sustainability ambitions and ideas. This methodological choice was prompted by the limited comprehensive scientific investigations in this field. While some existing research has touched upon this subject, the practical application often falls short to meet anticipated outcomes. Consequently, this study took a unique course by emphasizing the extraction and analyzation of the root causes behind the sporicidal actualization of sustainability ambitions and ideas, drawing directly from the firsthand experiences of industry professionals.

This distinctive approach has successfully unveiled insights that were previously unexplored in a systematic manner, thereby expanding the existing knowledge within the academic community and the industry on this subject. The semi-grounded theory approach has proven successful in yielding a substantial body of knowledge which are extensively detailed in Chapter 4. Within this chapter, several pivotal findings derived from this study are explicitly mentioned and discussed.

Sustainability Actualization Lag

To begin with, when exploring the current landscape of the actualization of sustainability opportunities, a notable observation is the inconsistency between the lofty sustainability ambitions held at the upper levels of organizations, including clients, consulting engineering firms, and contractors, and the translation of these aspirations into concrete project implementations. As highlighted by various project managers, the actualization of

sustainability measures in projects often remains limited to relatively minor solutions. This observation is significant as it underscores that the challenge of projects failing to actualize sustainability opportunities does not stem from a lack of emphasis on sustainability at the organizational level.

Consequently, this situation prompts an inquiry into the underlying reasons why sustainability opportunities struggle to actualize, despite the emphasis on sustainability exhibited by all major organizations involved in infrastructure projects.

More than just Chance

In order to understand the underlying reason for sporadic actualization of sustainability opportunities in infrastructure projects, an examination of the nature of such opportunities has been undertaken through both empirically and theoretically. One particularly intriguing discovery pertains to the divergence in perceptions regarding sustainability opportunities between researchers and practitioners. Within academic circles, the definition of sustainability opportunities is often viewed as a form of risk which their actualization directly ties with chances that is influenced by project contexts. Conversely, practitioners, when queried about sustainability opportunities, regard their actualization is influenced by not solely on circumstances, but also on the decisions made by project teams and policy-makers.

This discovery is insightful, as it underscores the necessity of not only enhancing current practices and frameworks related to risk management to improve the actualization of sustainability ambitions and ideas, but also recognizing the pivotal role of decision-making processes. By acknowledging that decision-making profoundly influences the ultimate actualization of sustainability opportunities, the study emphasizes on establishing a framework that enhances the management of sustainability opportunities. Consequently, the research not only addresses risk management considerations but also underscores the significance of management practices in optimizing the management of sustainability opportunities.

The False Narrative of Cost

Cost and budget constraints have emerged as the most frequently cited factors influencing the actualization of sustainability opportunities in infrastructure projects. Empirical data from industry practitioners highlights budget limitations as the predominant barrier to sustainable practices. However, this prevailing belief that cost inherently obstructs sustainability has been challenged by cost management professionals, who argue that a fundamental misconception exists regarding the financial implications of sustainable solutions. Contrary to common perception, sustainability does not always entail higher costs; in many cases, sustainable alternatives can be cost-neutral or even cheaper. This cost misconception aligns with findings by Ohiomah et al. (2019), whose research substantiates the difference between perceived and actual costs of sustainability implementations.

The primary reason project managers perceive budget constraints as barrier lies in the delayed integration of sustainability considerations during infrastructure projects. When sustainability is treated as an afterthought, retrofitting sustainable features into later project stages often leads to cost inefficiencies. This working approach, rather than sustainability itself, drives financial constraints.

This finding underscores the necessity of dispelling misconceptions surrounding sustainability costs and early decision makings on sustainability. Beyond technical skills, practitioners must be equipped with an understanding of cost dynamics in projects. Effective knowledge management strategies are critical to ensuring that accurate financial insights reach decision-makers, enabling more informed and economically viable sustainability integration from the earliest project phases. Consequently, the research suggested several action items in the framework to ensure the early consideration of sustainability and knowledge sharing.

Knowledge is Key

Knowledge has consistently emerged as a critical factor in the interviews with industry practitioners, underscoring its pivotal role in the actualization of sustainability in infrastructure projects. Barriers, such as misconceptions about cost, uncertainties, and ambiguous definitions of sustainability, stem from a fundamental lack of knowledge among industry practitioners. These challenges highlight a clear knowledge gap on sustainability within the industry, reinforcing the need for knowledge management strategies. Notably, when practitioners were asked about key enablers for sustainability actualization, knowledge management was cited most frequently, further emphasizing its importance.

The empirical findings reveal that knowledge includes understanding sustainability itself, awareness of available sustainable solutions, familiarity with technical capabilities, and knowledge about cost regarding sustainability alternatives. Without this foundational knowledge, even well-intentioned sustainability initiatives risk being undermined by flawed judgements and implementation. Recognizing this critical need, the research delved deeper into scientific knowledge management approaches, synthesizing insights into actionable items within the proposed framework for knowledge management. By following the action items in the proposed framework, consultancy engineering firms can enhance their capacity to actualize sustainability opportunities effectively. This structured approach ensures that sustainability related knowledge is not just acquired and managed but also applied.

Change is Needed

The infrastructure industry remains deeply rooted in traditional practices, with practitioners tend to view sustainability as an optional add-on. The interviews conducted in this research have shown a common business-as-usual mindset, where sustainability is often sidelined and treated as an afterthought, compounded by rigidly defined project scopes that discourage changes even when new sustainability opportunities arise. Empirical findings have also revealed that the successful actualization of sustainability ideas ultimately depends on the mindset and commitment of the project team. Technical advancements alone cannot drive meaningful progress, they have to be preceded by social and cultural change within organizations.

Recognizing these, the research examined change management theories from academic literature, integrating proven strategies into the development of the framework. The resulting approach emphasizes that change must be systemic and supported at every organizational level, namely strategic, tactical, and operational. The action items in the framework are designed to reinforce one another, ensuring that leadership commitment translates into managerial practices, which then enable operational implementation. This shift also relates to

sustainability knowledge. By equipping practitioners with a clear understanding of its value, feasibility, and long-term benefits, it can in turn enhance awareness and reshapes decision-making. Ultimately, sustainability cannot be actualized through isolated efforts. It requires structured and organization-wide change.

Breaking the Status Quo

The analysis of literature review and current practices reveals a deficiency in how sustainability opportunities are managed in infrastructure projects, both in academic research and professional implementation. While existing risk management frameworks theoretically incorporate management of opportunities components, observations by industry practitioners indicate these methodologies remain under-utilized and ineffective in practice, particularly for sustainability-related opportunities. In some scenarios, projects with limited sustainability ambitions often completely overlook potential sustainability opportunities due to this structural gap.

This shortcoming highlights the critical need for a dedicated management approach specifically designed to manage sustainability opportunities throughout the project lifecycle, and in this research focusing on the FED phase. The framework developed through this research directly addresses this industry and academic need by providing a comprehensive and actionable framework that integrates with established project management processes while accommodating varying organizational levels for consultancy engineering firms and further research. By bridging this implementation and scientific gap, the proposed framework advances professional practice and theoretical methodology for management of sustainability opportunities.

Sustainability Requires Integrated Thinking

Initially, within the conceptual design of the framework, was the notion of breaking down broad sustainability objectives within projects and organizations into role-specific and responsibility-specific objectives. This concept was stemmed from the challenges encountered by practitioners in defining sustainability abstractly and assigning clear lines of responsibility in sustainability.

However, during the validation phase, it became evident that this approach was not effective. Experiences by practitioners revealed that isolated efforts often resulted in suboptimal outcomes, where sustainable efforts by individuals may conflict each other. The key to success actualization of sustainability lay in fostering collaboration and aligning on shared objectives.

This discovery holds significance not only for practical applications of the framework but also for academia, highlighting that while the theoretical breakdown of sustainability objectives may appear beneficial, its practical implementation may not yield favorable results.

Challenges and Innovations in Sustainability Knowledge Sharing

While knowledge remains an important enabler for the actualization of sustainability opportunities in infrastructure projects, effective knowledge-sharing methodologies continue to pose significant practical challenges in consultancy engineering firms. Despite extensive research on knowledge management, implementation gaps persist, particularly regarding the maintenance and usage of functional knowledge-sharing systems. Traditional approaches like

databases and checklists frequently fail due to the requirements of ongoing maintenance and updates of information that organizations struggle to sustain and the lack of cultural engagement within the organization for wide adoption.

The validation process revealed more effective approaches than solely building a database emerging through both technological and social innovations. Firstly, assigning dedicated data stewards to be responsible for updating information in the database is more effective than having collective responsibilities across the organization. Secondly, regularly publishing visually-engaging updates and short peer success stories on intranet demonstrate higher engagement potential than static databases by making knowledge relatable and easily digestible. Furthermore, AI enabled solutions, particularly a sustainability chatbot, address critical usability barriers by allowing natural language queries similar to consulting a human expert. When knowledge access becomes as simple as asking a colleague, usage increases dramatically. This shift from passive repositories to an interactive and intelligent system represents a promising evolution in organizational learning approaches.

9.2. Significance of SHIFT

The Sustainability Human-Centered Implementation Framework for Transition (SHIFT) enhances established opportunity management and sustainability management methodologies by offering a systematic and action-driven approach designed to facilitate organization-wide implementation of actualizing sustainability opportunities within infrastructure projects. The framework provides empirically grounded and theoretically justified methodologies to enhance the actualization of sustainability opportunities in infrastructure projects by improving management practices during the FED phase.

While prior research has predominantly focused on either macro-level policy influences or micro-level behavioral changes, SHIFT bridges this gap by integrating strategic, tactical, and operational findings into a cohesive framework. This research offers a novel and integrated perspective, contributing to the body of knowledge by demonstrating the significant unexplored potential within the FED phase to advance sustainability outcomes in the infrastructure field. Furthermore, the research reveals that the challenge in sustainability implementation does not stem from a lack of scientific research on sustainable solutions, but rather from gaps in managing these solutions during the FED phase to ensure their real-world application. In addition, the process of the development of the framework has identified a substantial set of enablers and barriers influencing sustainability opportunities actualization. While not all factors have been examined in depth, these findings present valuable avenues for future research, encouraging further exploration by the scientific community.

While the framework has substantial theoretical significance for the scientific community, the framework, along with its accompanying guidelines, also carries significant practical implications. The framework is grounded in change theories explored in the literature review and recognizing that social transformation is a prerequisite for technological transformation. Accordingly, the action items in the framework are designed to facilitate both social and technical changes. The guidelines adopt an incremental approach, providing structured and step-by-step guidance that facilitates the changes needed for the action items. Furthermore, by categorizing action items according to organizational hierarchies, the framework enables practitioners to concentrate on initiatives aligned with their specific roles and responsibilities.

Furthermore, the framework was subjected to validation through focus groups, where industry practitioners assessed its relevance, implementation feasibility, and overall completeness. Based on the feedback obtained, the framework was refined into SHIFT, an enhanced version that demonstrates greater relevance, feasibility, and completeness for deployment within consultancy engineering firms. The framework and guidelines have reached an implementation ready state, allowing immediate deployment in practice.

9.3. Reflections on SHIFT

The SHIFT was developed to improve the actualization of sustainability opportunities in infrastructure projects, with particular focus on consultancy engineering firms during the FED phase. Conducting reflective analysis is critical for continuous improvement of the framework. This evaluation utilizes a structured SWOT analysis approach, following the methodological guidelines established by Leigh (2009), to examine the strengths, weaknesses, opportunities, and threats associated with SHIFT. The SWOT analysis is shown in Figure 9.1.

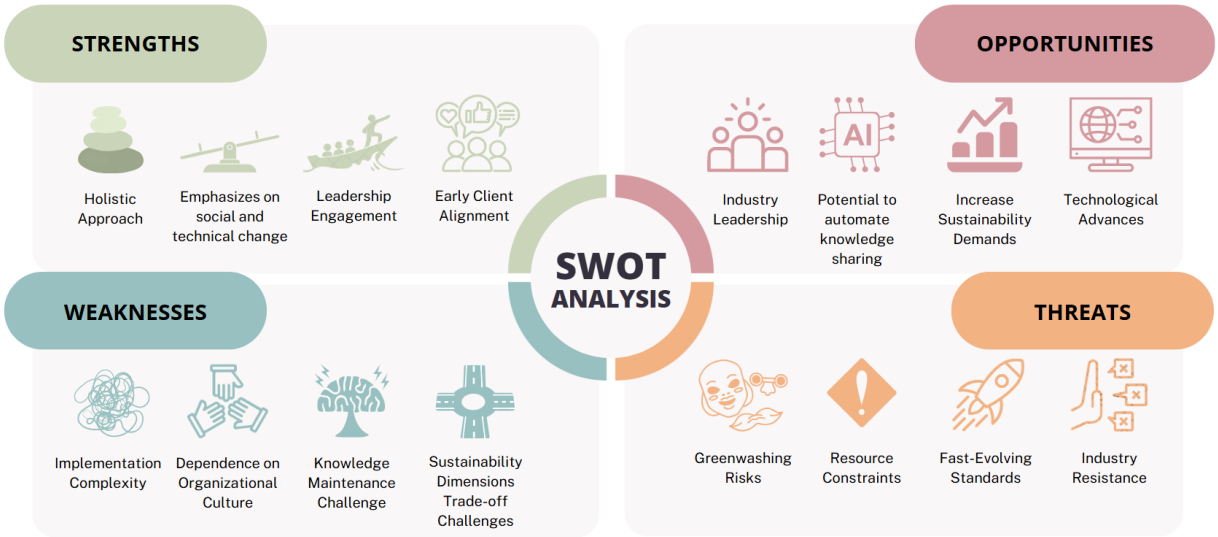

Figure 9.1: SWOT analysis of SHIFT (author)

9.4. Critical Success Factors for SHIFT Implementation

This research identifies several essential conditions required to fully realize the potential of the SHIFT in enhancing the actualization of sustainability opportunities within infrastructure projects. These include,

i. Clear governance and accountability for sustainability
ii. Integrated cross-functional collaboration
iii. Organizational culture embracing sustainability innovation
iv. Regulatory alignment
v. Stakeholders buy-in

10

10. CONCLUSION

This research delved into the phenomenon of the sporadically actualization of sustainability opportunities. The research viewed this issue through the lens of consultant engineering firm. Through this research, it was aimed to offer guidance to researchers and industry practitioners to broaden their understanding of how to improve the actualization of sustainability opportunities during the FED phase.

The main objective of this research as to answer the main research question:

> **How can the actualization of sustainability ambitions and ideas be enhanced through the effective management of opportunities during the front-end development process of infrastructure projects?**

Initially outlined in Section 1.4, this question is addressed through three specific research sub-questions. Using grounded theory approach, exploratory interviews, literature review, data synthesis, and validation focus groups are done, successfully developed a framework that helps answers the main research question.

SQ1: Why are sustainability ambitions and ideas sporadically actualized in infrastructure projects?
Exploratory interviews with practitioners confirm that sustainability ambitions and ideas in infrastructure projects exhibit sporadic actualization, particularly for larger-scale sustainability opportunities. Current practice reveals a pattern where minor sustainable solutions are frequently implemented, while sustainability considerations rarely influence core project structural decisions.

Analysis identified multiple interconnected barriers to such phenomena, including perceived budget constraints, misconception of sustainability cost, practitioner mindset, late consideration of sustainability, definitional ambiguity of sustainability itself, uncertainties, predetermined project scope, and budgetary separation between construction and maintenance (see Figure 4.4 for complete list of barriers). These factors collectively explain why sustainability ambitions and ideas are sporadically actualized in infrastructure projects.

SQ2: How have scientific and practical methodologies for the management of opportunities been shaped?
The management of sustainability opportunities in infrastructure projects lacks standardized methodologies in both scientific literature and professional practice. Exploratory interviews reveal that current approaches typically diverge into two distinct pathways. The two pathways are summarized in Table 10.1.

Table 10.1: Overview of two management approach pathways in practice (author)

	Pathway A	Pathway B
Project	Most projects	Exceptional projects with significantly high sustainability ambitions
Current Approach	Business-as-usual Sustainability considerations as an afterthought	Early alignment on sustainability ambitions and objectives with clients Feasibility assessments on sustainability alternatives Cost-benefit analyses on sustainability opportunities Reviews on sustainability progress External Challenger
Result	Limited sustainability opportunities actualization	More sustainability opportunities actualization

Most projects adopt a conventional project process where sustainability considerations are typically treated as an afterthought. Sustainability is addressed only during later project stages when opportunities for meaningful actualization have largely passed. This approach results in limited sustainability actualization. However, exceptions exist, particularly in projects with significantly high sustainability ambitions. These cases demonstrate a more structured methodology, beginning with early alignment on sustainability ambitions and objectives with clients, followed by feasibility assessments, cost-benefit analyses, and reviews. Some projects further enhance accountability by engaging third-party challengers to monitor and evaluate sustainability progress, ensuring commitments translate into outcomes.

The academic landscape of management of sustainability opportunities reveals challenges in theoretical development. Research specifically addressing the management of sustainability opportunities remains surprisingly limited, necessitating the literature review of this research examining management of opportunities and management of sustainability separately.

Existing opportunity management frameworks, including the RISMAN method, ISO 31000 risk management standards, and PMBOK project risk management framework, theoretically accommodate both threats and opportunities but in practice become disproportionately focused on threat. This persistent implementation bias remains a significant unsolved challenge in the field. Sustainability management models such as ISO sustainability guidelines, the Sus5 model, and Perrott's strategic sustainability management process offer more targeted approaches. Yet, these models lack integration with opportunity management principles, resulting in disconnected strategies that overlook the relations between management of sustainability and management of opportunities.

Moreover, existing models tend to adopt either macro-level strategic perspectives or micro-level behavioral approaches, with limited scholarly attention devoted to developing integrated methodologies that bridge these levels of analysis. The current literature reveals a significant research gap in holistic frameworks that simultaneously address strategic, tactical, and operational dimensions of sustainability opportunity actualization.

The current state of knowledge underscores the need for an integrated management methodology that simultaneously addresses sustainability and opportunity actualization. Both the empirical evidence gathered from exploratory interviews and the theoretical findings obtained from the literature review provide a foundation for advancing this line of inquiry.

SQ3: How can insights gained from barriers hindering the actualization of sustainability opportunities and the enablers in managing project opportunities be leveraged to improve the actualization of sustainability ambitions and ideas?

The sporadic actualization of sustainability opportunities in infrastructure projects stems from an array of barriers, while exploratory interviews have revealed several critical enablers that facilitate successful actualization of sustainability opportunities. Key enablers include knowledge management, change management, early sustainability advice and decision-making, organizational mindset shifts, and clearly defined sustainability objectives. These factors collectively address many of the previously identified barriers to sustainability opportunity actualization.

The literature review on sustainability opportunities actualization barriers and enablers revealed both similar and dissimilar with the empirical findings from the exploratory interviews. While some factors were consistently identified across both sources, others appeared uniquely in either literature or interview data. These differences primarily reflect regional variations in practice and organizational level effects from interviewees, highlighting the context dependent nature of sustainability actualization.

Building upon empirical findings and theoretical insights, this thesis developed the conceptual Sustainability Human-Centered Implementation Framework for Transition (c-SHIFT), a conceptual framework designed to improve the actualization of sustainability ambitions and ideas through managing sustainability opportunities. The conceptual framework consists of 15 action items designed around six foundational pillars, namely vision and objectives, knowledge, support and incentives, learning nexus, early client engagement, and monitoring. Following its initial development, the c-SHIFT underwent validation through two validation focus groups formed by experienced practitioners, which evaluated both the relevance and implementation feasibility of individual action items and the overall completeness of the framework. This validation process resulted in significant refinements, resulting in the enhanced 18 validated action items. The overview of the action items is shown in Figure 10.1.

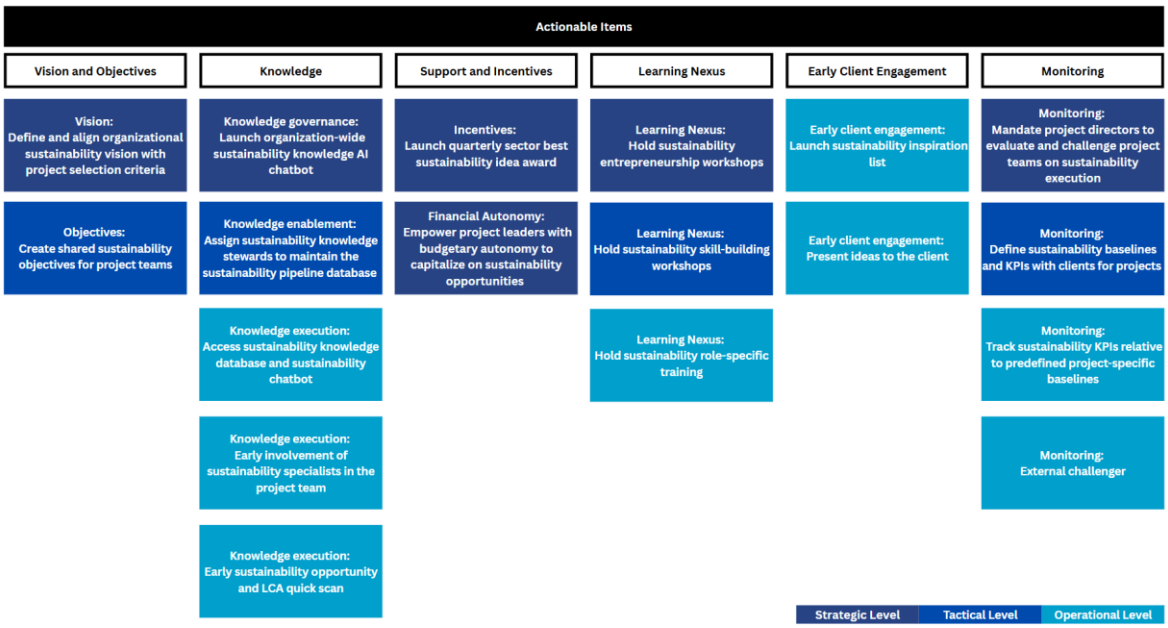

Figure 10.1: Overview of action items (author)

Building upon the above 18 action items, this research developed the SHIFT, as presented in Figure 8.1. The framework represents an evolution from its initial conceptual version (c-SHIFT), incorporating refinements from the validation processes with industry practitioners.

MRQ: How can the actualization of sustainability ambitions and ideas can be enhanced through the effective management of opportunities during the front-end development process of infrastructure projects?
The findings demonstrate that the actualization of sustainability ambitions in infrastructure projects can be enhanced through implementation of the action items outlined in the SHIFT. This framework is specifically designed to facilitate both the social transitions, such as mindset shifts and collaborative practices, and technical transitions, such as database and monitoring mechanisms. By addressing barriers at three organizational levels while leveraging key enablers, the SHIFT provides a comprehensive approach to transforming sporadic sustainability actualization into consistent improvement in sustainability opportunities actualization.

The full application of the SHIFT requires several critical conditions, including clear governance structures with defined sustainability accountability, integrated cross-functional collaboration, an organizational culture that embraces sustainability innovation, alignment with regulatory frameworks, and meaningful stakeholder buy-in in projects. These implementation conditions reflect the complex interplay of technical, organizational, and contextual factors that influence sustainability outcomes in infrastructure projects. When these conditions are met, the framework enables projects and organizations to fully systematically identify, evaluate, and actualize sustainability opportunities as integral components of project process rather than as additions.

11

11. LIMITATIONS AND RECOMMENDATIONS

The concluding chapter examines the limitations of this study and proposes recommendations for both industry practice and future research avenues. Following an analysis of the research limitations, the chapter shifts focus to recommendations for infrastructure industry professionals. The chapter culminates by identifying future research avenues to advance the theoretical and practical understanding of management of sustainability opportunities, particularly through refinement and implementation of SHIFT.

11.1. Limitations

This research acknowledges inherent limitations in its methodological design and scope, which are critical to interpreting the findings. These limitations are outlined below.

11.1.1. Methodological Limitations

While the grounded theory approach and exploratory interviews provided valuable insights, the research faced constraints in participant diversity. Although the sample size was sufficient, not all roles in infrastructure projects were equally represented. Despite a purposive sampling strategy ensuring diversity across organizations, project teams, and key roles, certain positions in infrastructure projects had minimal representation. For examples, some roles had only one interviewee. A broader sample could enhance generalizability but was infeasible due to practical constraints, such as resource limitations and time. Furthermore, as a qualitative research, the findings are contextually rich but not statistically generalizable. Future studies could adopt mixed methods to validate and quantify patterns.

11.1.2. Scope Limitations

This research primarily examines the role of consultancy engineering firms in improving sustainability opportunity actualization during the FED phase. However, these two key scope limitations should be noted. Firstly, while clients and contractors can also significantly influence sustainability outcomes, this study does not explore their contributions, as its focus is on the initiatives of consultancy engineering firms. Furthermore, this research limits its scope in the FED phase. Empirical and theoretical evidence justifies this focus, as FED critically determines sustainability opportunities actualizations. However, opportunities in later phases, such as the realization phase, are excluded, despite their potential impact.

These scope limitations shows that this research prioritize depth over breadth but imply opportunities for future research to examine such subject from other organizational perspectives and project phases.

11.1.3. Summary of Research Limitations

As a summary, Table 11.1 presents the limitations, their implications and future research mitigation.

Table 11.1: Summary of research limitations (author)

Category	Limitation	Implication	Future Research Mitigation
Methodological	Limited role representation	Findings may not fully capture all perspectives in infrastructure projects	Larger-scale studies with stratified sampling
Methodological	Qualitative nature	Rich insights but limited generalizability	Mixed-methods validation such as including surveys
Scope	Focus on consultancy firms	Partial view of sustainability opportunity actualization	Multi-stakeholder comparative studies
Scope	Focus on FED phase	Underestimates sustainability opportunities in later stages	Longitudinal studies tracking full project lifecycle

11.2. Recommendations

Building upon the key findings and limitations identified in this study, this section presents recommendations for both industry practitioners and researchers to advance the actualization of sustainability opportunities in infrastructure projects.

11.2.1. Practical Recommendations

To meaningfully improve the actualization of sustainability opportunities, consultancy engineering firms are recommended to implement the SHIFT as their foundational approach. Particular emphasis must be placed on the early project phase, where sustainability outcomes are most significantly determined. For such initiatives, a poster has been made available in Appendix E for consultancy engineering firms to introduce and promote SHIFT.

However, successful implementation requires more than simple adoption. Consultancy engineering firms are suggested to first conduct an organizational readiness assessment to evaluate their current sustainability integration capabilities and identify which of the 18 action items in the framework are most contextually relevant and feasible given their specific operational realities. This contextual adaptation is crucial because blindly applying all action items in the framework may prove counterproductive without proper organizational alignment.

Fundamentally, effective implementation demands establishing clear governance structures with defined sustainability roles and accountability mechanisms, coupled with cultivating an organizational culture that actively embraces and rewards sustainability innovation and actualization. These cultural and structural foundations enable the social and technical application of the framework to take root and deliver long-term results rather than superficial compliance. Consultancy engineering firms are advised to begin with several suitable project teams focusing on a few high-priority action items before scaling implementation across all the entire organization.

11.2.2. Future Research Recommendations

This study reveals several potential avenues for further investigation to advance the understanding and actualization of sustainability opportunities in infrastructure projects. While the current research has examined key barriers and enablers, numerous factors require more detailed exploration. Future studies can delve deeper into under-researched aspects of sustainability opportunity actualization to develop a more comprehensive understanding of such complex subject.

A critical research limitation concerns the roles of clients and contractors in sustainability actualization. For instance, given the demonstrated importance of early client engagement, future research can focus on how client organizations can effectively structure their requirements, decision-making processes, and procurement approaches to facilitate sustainability actualization. Parallel research can examine contractor-side innovations and constraints in operationalizing sustainability ambitions and ideas during project execution phase.

The SHIFT, while developed with a focus on FED phases, presents significant potential for adaptation to other project stages. Future research can explore how the principles and action items of the framework might be modified or extended to address sustainability opportunities during other project phases, such as construction, operation and maintenance phases. This includes investigating phase-specific adaptation requirements and the development of transitional methodologies to maintain sustainability focus throughout the project lifecycle.

Finally, validation studies through case studies are needed to assess real-world SHIFT implementation despite after validated by the validation focus groups in this research. Such research should document framework application across different infrastructure project types and organizational contexts, and measuring effectiveness through both qualitative and quantitative indicators. These studies would not only validate the relevance and implementation feasibility of the framework but also identify refinement opportunities based on practical experience.

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APPENDIX A- INTERVIEW PROTOCOL

Subject:	Interview Protocol
Project:	Actualizing Sustainability Opportunities: Enhancing Management of Sustainability Opportunities during Front-End Development in Infrastructure Projects
Author:	Wilfred Wong, TU Delft

1. Introduction

The purpose of this interview is to gain insight into the actualization of sustainability opportunities and the management of sustainability opportunities.

- Greetings and introduction of the purpose of the interview.
- Grant consent to audio record the interview and explain how the recording is managed.
- Explain that a validation process and subsequent follow-up will be conducted after the interview.
- Briefly explain the focus of the research project and the objectives of the empirical research. (Important definitions: Actualization means realization; FED means all phases before execution)

(estimated 5 minutes)

2. Discussion Questions

2.1. Practical background

Aim: To understand the interviewee's practical background.

- What is your primary role within infrastructure projects?
- What types of projects are you primarily involved in? (characteristics of the involved projects)
- How many years of experience do you have in the construction industry?

(estimated 5 minutes)

2.2. Definitions

Aim: To understand the interviewee's overall perspective on sustainability and sustainability-related opportunities in the construction industry.

- How would you define sustainability in the context of the construction industry?
- How would you describe the current level of emphasis on sustainability within typical infrastructure projects?
- What are sustainability opportunities in infrastructure projects?
- From your experience, do you see that sustainability opportunities in projects are in nature opportunities with chances of actualization, or do you see them more as issues that depend on the decisions that the project team chooses to implement?

(estimated 10 minutes)

2.3. Actualization of sustainability opportunities

Aim: To explore the landscape regarding the actualization of sustainability opportunities in infrastructure projects.

- How do you identify and prioritize sustainability opportunities in different project phases? Do you see variations in this process across phases?
  (Project phases: FED (Exploration, design), Execution & Operation)
- How do you actualize sustainability opportunities in the FED phase of a project?
- What are the considerations or circumstances to determine if identified sustainability ideas should be actualized?
- What barriers have you encountered when trying to actualize sustainability ideas into projects?

- What are the enablers for actualizing sustainability ideas into projects? (key factors or practices enable the successful realization of sustainability opportunities)

(estimated 15 minutes)

2.4. Management of sustainability opportunities
Aim: To explore the landscape regarding the management of sustainability opportunities in infrastructure projects.

- How does your team typically manage project ambitions and ideas throughout the FED phase in infrastructure projects? And which part of the management process do you have influence on?
- Is there a difference in managing sustainability-related ambitions and ideas?
- What management process is beneficial for the management of sustainability-related opportunities?

(estimated 10 minutes)

2.5. Practical example
Aim: To learn from practical examples.

- Can you share an example of a successful/unsuccessful actualization of sustainability opportunities in an infrastructure project? (this is asked in the interview invitation so that the interviewee can be prepared)

Guiding questions:
- What were the key strategies or initiatives that contributed to the successful realization of sustainability goals in project?
- What were the main challenges and obstacles that hindered the realization of sustainability goals in that particular project?
- How did the project team ensure that sustainability ambitions were effectively integrated into the project design and execution?
- What do you think could have been done differently to improve the realization of sustainability opportunities in infrastructure implementation projects?

(estimated 10 minutes)

2.6. Closing
Aim: To allow interviewees to input their insights and reflect on the entire interview.

- Is there anything else you would like to add about sustainability opportunities and their management in the FED phase of infrastructure projects?

(estimated 5 minutes)

The interview will be transcribed and sent to you for your verification.
There is the possibilities that you can add or delete something from the transcript.
Once the transcript is agreed upon, it will be anonymized and used as part of the empirical research.

Subject:	Interview Protocol for Cost Estimation
Project:	Actualizing Sustainability Opportunities: Enhancing Management of Sustainability Opportunities during Front-End Development in Infrastructure Projects
Author:	Wilfred Wong, TU Delft

1. Introduction

The purpose of this interview is to gain insight into the actualization of sustainability opportunities and the management of sustainability opportunities.

- Greetings and introduction of the purpose of the interview.
- Grant consent to audio record the interview and explain how the recording is managed.
- Explain that a validation process and subsequent follow-up will be conducted after the interview.
- Briefly explain the focus of the research project and the objectives of the empirical research. (Important definitions: Actualization means realization; FED means all phases before execution)

(estimated 5 minutes)

2. Discussion Questions

2.1. Practical background

Aim: To understand the interviewee's practical background.

- What is your primary role within infrastructure projects?
- What types of projects are you primarily involved in? (characteristics of the involved projects)
- How many years of experience do you have in the construction industry?

(estimated 5 minutes)

2.2. Definitions

Aim: To understand the interviewee's overall perspective on sustainability and sustainability-related opportunities in the construction industry.

- How would you define sustainability in the context of the construction industry?
- How would you describe the current level of emphasis on sustainability within typical infrastructure projects?

(estimated 5 minutes)

2.3. Cost estimation of sustainability opportunities

Aim: To explore the landscape regarding the effect of cost estimation on actualization of sustainability opportunities in infrastructure projects.

- From your experience, how does cost estimation influence the actualization of sustainability opportunities in infrastructure projects?
- Can you describe your current approach to do cost estimation for sustainability-related opportunities in infrastructure projects?
- What factors do you consider when estimating costs for sustainability ambitions and ideas?
- Is total cost of ownership also included when doing cost estimation? Will it benefit sustainability opportunities to be realized?
- Should MKI be included in cost estimation? Will it benefit sustainability opportunities to be realized?
- From your experience, are design options considering sustainability usually more expensive? Are there any examples of sustainability opportunities is less expensive than conventional design?

- Do you think that the timing of doing cost estimation plays a role in influencing the realization of sustainability initiatives? If so, how?
- Overall, what strategies can be employed to align cost estimation practices with the realization of sustainability opportunities?

(estimated 25 minutes)

2.4. Practical example
Aim: To learn from practical examples.

- Can you share examples of doing cost estimation for sustainability opportunities in infrastructure projects?

Guiding questions:

- What were the key strategies or initiatives that contributed to the successful realization of sustainability goals in project?
- What were the main challenges and obstacles that hindered the realization of sustainability goals in that particular project?
- How did the project team ensure that sustainability ambitions were effectively integrated into the project design and execution?
- What do you think could have been done differently to improve the realization of sustainability opportunities in infrastructure implementation projects?

(estimated 10 minutes)

2.5. Closing
Aim: To allow interviewees to input their insights and reflect on the entire interview.

- Is there anything else you would like to add about sustainability opportunities and their management in the FED phase of infrastructure projects?

(estimated 5 minutes)

The interview will be transcribed and sent to you for your verification.
There is the possibilities that you can add or delete something from the transcript.
Once the transcript is agreed upon, it will be anonymized and used as part of the empirical research.

APPENDIX B- DATA MANAGEMENT PLAN

Plan Overview

A Data Management Plan created using DMPonline

Title: MSc Graduation Thesis - Actualizing Sustainability Opportunities: Enhancing Management of Sustainability Opportunities during Front-End Development in Infrastructure Projects

Creator: Wilfred Wong

Principal Investigator: Wilfred Wong

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2025)

Project abstract:

This research focuses on enhancing the management of sustainability opportunities during front-end development in infrastructure projects. This thesis aims to provide insights and guidance for project controllers to manage and actualize sustainability-related ambitions and ideas. The data is gathered by exploratory interviews and validation interviews. The interviewees will be recruited through the network of supervisors.

The objectives of this research focus on developing a management framework with operational guidelines through a literature review and interviews. The implications of this project are to work towards a more sustainable construction environment and enhance the successful actualization of sustainability opportunities.

ID: 167970

Start date: 06-01-2025

End date: 30-06-2025

Last modified: 13-01-2025

MSc Graduation Thesis - Actualizing Sustainability Opportunities: Enhancing Management of Sustainability Opportunities during Front-End Development in Infrastructure Projects

0. Adminstrative questions

1. Provide the name of the data management support staff consulted during the preparation of this plan and the date of consultation. Please also mention if you consulted any other support staff.

Lora Armstrong, Data Steward at the Faculty of Civil Engineering and Geosciences, has reviewed this DMP on 13 January 2025.

2. Is TU Delft the lead institution for this project?

- Yes, leading the collaboration – please provide details of the type of collaboration and the involved parties below

In this project, TU Delft is leading the research design and developing the research. Witteveen+Bos is sharing practical experiences described in the table in question 3.

I. Data/code description and collection or re-use

3. Provide a general description of the types of data/code you will be working with, including any re-used data/code.

Type of data/code	File format(s)	How will data/code be collected/generated? *For re-used data/code: what are the sources and terms of use?*	Purpose of processing	Storage location	Who will have access to the data/code?
Interview Recordings on expert's role and experience in the industry, and opinions and experience on managing sustainability-related opportunities	MP3/ MP4	During the interview and recorded by phone recorder (in-person)/ MS Teams (online)	Capturing expert's experience in managing sustainability-related opportunities	TU Delft OneDrive	Wilfred Wong and TUD supervisors (Prof. Marcel Hertogh, Dr. Martijn Leijten, and Dr. Erik-Jan Houwing)
Interview transcript	.doc	Produced from the interview recording manually	Capturing expert's experience in managing sustainability-related opportunities in words	TU Delft OneDrive	Wilfred Wong and corresponding interview participants
Anonymized interview transcripts	.doc	Produced from the transcripts manually	Provide a privacy-preserving version of the collected data for archival	TU Delft OneDrive	Wilfred Wong, TUD supervisors (Prof. Marcel Hertogh, Dr. Martijn Leijten, and Dr. Erik-Jan Houwing), and Witteveen+Bos Supervisors (Ir. Colin Reit, Ir. Mehmet Uzun, and Ir. Erik-Jan Moll)
Informed consent forms	.pdf	Informed consent forms signed digitally.	To obtain and document informed consent.	TU Delft OneDrive and TUD supervisor store it in a dedicated folder requested on Project Data Storage	Wilfred Wong and TUD supervisors (Prof. Marcel Hertogh, Dr. Martijn Leijten, and Dr. Erik-Jan Houwing)
Contact information of interviewees	.xlsx	Before the interview	Finding experts in the domain of the management of sustainability and opportunity	TU Delft OneDrive	Wilfred Wong
Literatures	.pdf	Publicly available literature	To understand theories related to the management of sustainability-related opportunities	TU Delft OneDrive	Wilfred Wong, TUD supervisors (Prof. Marcel Hertogh, Dr. Martijn Leijten, and Dr. Erik-Jan Houwing), and Witteveen+Bos Supervisors (Ir. Colin Reit, Ir. Mehmet Uzun, and Ir. Erik-Jan Moll)
Analysis of data from interviews and literatures	.doc & .pdf	Qualitative analysis	To analyze the empirical data to understand the barriers and enablers for actualizing sustainability opportunities	TU Delft OneDrive	Wilfred Wong, TUD supervisors (Prof. Marcel Hertogh, Dr. Martijn Leijten, and Dr. Erik-Jan Houwing), and Witteveen+Bos Supervisors (Ir. Colin Reit, Ir. Mehmet Uzun, and Ir. Erik-Jan Moll)

II. Storage and backup during the research process

4. How much data/code storage will you require during the project lifetime?

- < 250 GB

5. Where will the data/code be stored and backed-up during the project lifetime? (Select all that apply.)

- TU Delft OneDrive

III. Data/code documentation

6. What documentation will accompany data/code? (Select all that apply.)

- Data – README file or other documentation explaining how data are organised
- Data – Methodology of data collection

IV. Legal and ethical requirements, code of conducts

7. Does your research involve human subjects or third-party datasets collected from human participants?

If you are working with a human subject(s), you will need to obtain the HREC approval for your research project.

- Yes – please provide details in the additional information box below

I intend to apply for ethical approval from the Human Research Ethics Committee, but have not yet done so.

8. Will you work with personal data? (This is information about an identified or identifiable natural person, either for research or project administration purposes.)

- Yes

The working field and experiences of the interviewees will be noted during the interviews.

9. Will you work with any other types of confidential or classified data or code as listed below? (Select all that apply and provide additional details below.)

If you are not sure which option to select, ask your Faculty Data Steward for advice.

- No, I will not work with any other types of confidential or classified data/code

10. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question

The intellectual property rights are framed by the UNL graduation agreement between Delft University of Technology, myself and Witteveen+Bos.

11. Which personal data or data from human participants do you work with? (Select all that apply.)

- Audio recordings
- Video materials
- Other types of personal data or other data from human participants – please provide details below
- Proof of consent (such as signed consent materials which contain name and signature)
- Telephone number, email addresses and/or other addresses as contact details for administrative purposes
- Names as contact details for administrative purposes

- Role in the company and practical experience.
- Opinions on the management of sustainability and opportunities.

12. Please list the categories of data subjects and their geographical location.

Interview participants are practitioners in the infrastructure industry in the Netherlands.

13. Will you be receiving personal data from or transferring personal data to third parties (groups of individuals or organisations)?

- No

16. What are the legal grounds for personal data processing?

- Informed consent

17. Please describe the informed consent procedure you will follow below.

The researcher will inform the potential participants about the goals and procedures of the research project. The researcher will also inform them about the personal data that are being processed and for what purpose. This information will be provided to the potential participants before the interview in a digital copy through email. All participants will be asked for their consent for taking part in the study and for data processing by signing a digital informed consent form before the start of the interview.
All participants will be asked for their consent to record the audio of the interview. Each interview will be transcribed as soon as possible. After the transcription is agreed upon with the respondent, the recording will be deleted.

18. Where will you store the physical/digital signed consent forms or other types of proof of consent (such as recording of verbal consent)?

The proof of consent (digital copy of signed document) will be preserved on the TU Delft OneDrive.

19. Does the processing of the personal data result in a high risk to the data subjects? (Select all that apply.)

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data in your research project.

If any category applies, please provide additional information in the box below. Likewise, if you collect other type of potentially sensitive data, or if you have any additional comments, include these in the box below.

If one or more options listed below apply, your project might need a DPIA. Please get in touch with the Privacy team (privacy-tud@tudelft.nl) to get advice as to whether DPIA is necessary.

- None of the above apply

23. What will happen with the personal data used in the research after the end of the research project?

- Anonymised or aggregated data will be shared with others
- Anonymous transcripts will be shared with Witteveen+Bos supervisors
- Anonymous information may be shared in the thesis and Appendix.

24. For how long will personal research data (including pseudonymised data) be stored?

- Personal data will be deleted at the end of the research project

25. How will your study participants be asked for their consent for data sharing?

- In the informed consent form: participants are informed that their personal data will be anonymised and that the anonymised dataset is shared publicly

V. Data sharing and long term preservation

27. Apart from personal data mentioned in question 23, will any other data be publicly shared?

Please provide a list of data/code you are going to share under 'Additional Information'.

- All other non-personal data/code produced in the project
- Information gathered from literature review will be shared in the thesis.

29. How will you share research data/code, including those mentioned in question 23?

- I am a Bachelor's/Master's student at TU Delft and I will share the data/code in the body and/or appendices of my thesis/report in the Education Repository

31. When will the data/code be shared?

- As soon as corresponding results (papers, theses, reports) are published

VI. Data management responsibilities and resources

33. If you leave TU Delft (or are unavailable), who is going to be responsible for the data/code resulting from this project?

My supervisor, Dr. Martijn Leijten, Assistant Professor, Faculty of TPM, with email address m.leijten@tudelft.nl

34. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

No additional resources will be required.

Dear reader,

You are being invited to participate in a research study titled Actualizing Sustainability Opportunities: Enhancing Management of Sustainability Opportunities during Front-End Development in Infrastructure Projects. This study is being done by Wilfred Wong from the TU Delft in collaboration with Witteveen+Bos.

The purpose of this research study is to explore the barriers and enablers in actualizing sustainability ambitions and ideas, and will take you approximately 60 minutes to complete. The data will be used for empirical analysis for my master's thesis. I will be asking you to participate in the interview and contribute to the research based on your experience.

As with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by not documenting any personal data and anonymizing data before use. All collected information will be stored in the TU Delft OneDrive and will be deleted after processing.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions.

Corresponding Researcher: Wilfred Wong
k.y.wong-4@student.tudelft.nl

Responsible Researcher: Dr. M. Leijten
m.leijten@tudelft.nl

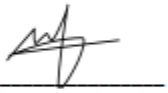
PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated [*24/02/2025*], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☒	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☒	☐
3. I understand that taking part in the study involves: • The research aims to analyse the barriers and enablers in actualizing sustainability opportunities. The data are obtained by interviews. • Interviews are recorded, the recorded interviews are stored on the TU Delft OneDrive. • The recorded interviews will be transcribed and anonymised, after which the recording files will be deleted.	☒	☐
5. I understand that the study will end 30 June 2025 and that anonymised parts of the interview may be published as part of the research.	☒	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
6. I understand that taking part in the study involves the following risks: data breach and loss of recorded files/transcriptions. I understand that these will be mitigated by using TU Delft OneDrive and deleting the processed files immediately.	☒	☐
7. I understand that taking part in the study also involves collecting associated personally identifiable research data (PIRD): name, role and years of experience with the potential risk of my identity being revealed.	☐	☐
8. I understand that some of this PIRD is considered as sensitive data within GDPR legislation.	☒	☐
9. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach: • Data is only stored on the TU Delft OneDrive • Recorded interviews are transcribed and anonymised, guidance of TU Delft and Witteveen+Bos only has access to the anonymised data. • After the transcription, recordings are deleted.	☒	☐
10. I understand that personal information collected about me that can identify me, such as name, contact details, and role, will not be shared beyond the study team.	☒	☐
11. I understand that the (identifiable) personal data I provide will be destroyed no later than 30 June 2025.	☒	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
12. I understand that after the research study the de-identified information I provide will be used for analysis for publication as master thesis or academic reports.	☒	☐
13. I agree that my responses, views or other input can be quoted anonymously in research outputs	☒	☐

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
16. I give permission for the de-identified data that I provide to be archived in TU Delft repository so it can be used for future research and learning.	☒	☐

Signatures

_____	_____	_____
Name of participant [printed]	Signature	Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Wilfred Wong		24 Feb 2025
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Researcher name [printed]	Signature	Date

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APPENDIX C- CONCEPTUAL GUIDELINES

Conceptual Guidelines for Strategic Level Action Items

Proposed Actionable Items	Guidelines	Motivation
Vision: Create a clear organizational sustainability vision and objectives	1. **Determine ideas and contexts** ◦ Understand the foundation of sustainability and identify most relevant sustainability issues for the organization and the industry 2. **Align vision with core business strategy** ◦ Integrate sustainability KPIs into corporate performance metrics and utilize sustainability to create value 3. **Benchmark against industry peers** ◦ Maintain realistic yet ambitious targets 4. **Standardize sustainability metrics** ◦ Adopt industry-aligned metrics for measuring and reporting sustainability for all targets 5. **Define clear and actionable vision** ◦ Define precisely what sustainability means for the organization 6. **Set SMART sustainability objectives** ◦ Breakdown the vision into specific, measurable, achievable, relevant, and time-bound objectives. 7. **Create small wins for motivation** ◦ Breakdown the vision into smaller objectives that can deliver measurable results in a shorter timeframe.	Despite prevalent high-level organizational commitments to sustainability, a persistent industry-wide disconnect exists where this emphasis fails to translate effectively to project-level implementation, necessitating strategic vision realignment. Interview findings reveal that current organizational visions often lack operational clarity, as exemplified by seemingly concrete targets like "net zero by 2030" which remain ambiguous in practical interpretation for engineering firms as it is undefined in terms of measurement methodologies, implementation pathways, and applicability. Furthermore, effective change management and mindset transformation require not only managerial support and elevated sustainability prioritization as key enablers, but also precise organizational sustainability visions and objectives. A well-defined collective sustainability target serves as a critical catalyst, fostering practitioner engagement by demonstrating achievability and aligning cross-hierarchical efforts toward shared goals, thereby bridging the current gap between strategic aspirations and operational execution.
Monitoring: Assign a board-level member to be responsible and oversight sustainability progress	1. **Define the role explicitly** ◦ Assign as "Sustainability Director" who reports to the board on sustainability 2. **Select the right leader** ◦ Select a board member with passion for sustainability, dare to drive changes, and understand ESG contexts 3. **Formalize authority** ◦ Empower them to challenge non-compliance within the organization 4. **Set clear expectations** ◦ Assign clear objectives based on the vision and mandate regular progress updates 5. **Link to performance** ◦ Tie sustainability KPIs to the performance of the responsible personnel 6. **Ensure transparency** ◦ Disclose the role and progress in annual reports	Sustainability success hinges on leadership commitment, especially when considering the actualization of sustainability opportunities depends on decision making and chances. Appointing a dedicated board-level on sustainability ensures strategic decisions align with sustainability goals, accelerates progress, and embeds accountability at the highest level.
Knowledge: Organizational-wide knowledge governance by information management team	1. **Define scope and objectives** ◦ Identify the clear role and objectives of the information management team and connect the scope with the sustainability vision 2. **Assemble the right team** ◦ Assemble cross functional team, including knowledge stewards, data analysts and change managers, led by a Chief Information Manager and directly reports to the Sustainability Director 3. **Develop a knowledge management framework** ◦ Deploy a comprehensive knowledge management framework that includes strategies, culture, organizational learning, and systems and technology. 4. **Ensure visibility and value** ◦ Celebrate successful knowledge management steps, track usage rates, and showcase values	Knowledge has been identified as both a barrier and enabler for sustainability actualization. While expertise exists, valuable ideas often remains in individual projects or personnel due to insufficient information sharing. To demonstrate leadership commitment, organizations can establish a dedicated knowledge management team within governance structures. This team would systematically manage sustainability knowledge across all levels, transforming scattered knowledge into centered database.
Financial support: Establish an internal sustainability funding for projects	1. **Define purpose and funding scope** ◦ Align funding goals with organizational sustainability objectives ◦ Allocate a fixed percentage of annual revenue to the fund 2. **Structure funding mechanisms** ◦ Introduce a funding committee to review proposals ◦ Develop the grant system, project selection criteria, and selection process ◦ Track results of funded projects 3. **Ensure visibility** ◦ Celebrate and share successful stories in intranet ◦ Workshops on writing sustainability fund winning proposals	One of the key enablers identified in the findings is the necessity of financial support to actualize sustainability opportunities. Crucially, this funding must be separate from the main project budget to prevent its reduction or reallocation during challenging times. Additionally, such funding would encourage project teams to work on pilot testing and additional research to advance sustainability. This enhances decision-making by enabling teams to select more sustainable options, as they can request additional funding internally. This availability of specific financial resources creates more favorable conditions for implementing sustainable solutions. This funding also shows the supportiveness and willingness to invest for sustainability actualization by the organization.
Financial support: Launch a sustainability co-investment program	1. **Align the program with objectives** ◦ Ensure the program aligns with organizational sustainability objectives 2. **Allocate initial capital** ◦ Dedicate a pilot fund and appoint a sustainability investment committee to self-sustain the program financially 3. **Identify co-investment opportunities** ◦ Project-based investment: Allocate capital to specific client projects ◦ Equity co-investment: Take a minority stake in sustainable startups 4. **Structure co-investment agreements** ◦ Construct legal templates for co-investment agreements ◦ Design green-based contracts 5. **Engage employees** ◦ Open application for internal projects ◦ Bonuses for idea generation 6. **External communication** ◦ Announce program via press release ◦ Collaborate with clients, contractors, and policymakers to identify shared ideas	The empirical research indicates that consultancy engineering firms often assume a passive and client-dependent role in sustainability actualization. To address this, the framework proposes a sustainability co-investment program where consultancy firms can invest in high-potential sustainable innovations rather than merely advising clients. This strategic shift from consultant to co-investor demonstrates management commitment while overcoming client risk aversion. By sharing financial responsibility, consultancies can increase their influence on project sustainability outcomes and transition from reactive advisors to proactive sustainability leaders, particularly within the Dutch construction industry context where this shared-risk program align with collaborative project norms.

Incentives: Launch monthly best sustainability idea award	1. **Define award criteria and scope** ◦ Open to all disciplinary with clear predetermined assessing criteria ◦ Align criteria with organizational sustainability objectives 2. **Structure nomination and submission process** ◦ Ensure simple entry and process 3. **Selection committee** ◦ Include panel with representatives from each sector and level ◦ Ensure transparency and fairness 4. **Incentives** ◦ Award trophy to winning team and highlight winner on social media ◦ Provide support to execute top ideas 5. **Engagement** ◦ Share reasons for wining ideas and non-winning ideas to encourage improvements ◦ Invite teams with top ideas to sharing sessions	To foster an environment that encourages sustainability innovation and values bottom-up input, implementing a monthly best sustainability idea award is effective. This initiative stimulates constructive competition among project teams, motivating them to integrate more sustainable practices into their work. Such recognition also demonstrates organizational commitment to rewarding sustainability efforts. Over time, it creates a culture where sustainability becomes a habitual consideration among employees. Furthermore, the competition serves as a platform for teams to share sustainable solutions, enabling peer-to-peer learning and knowledge exchange. This process naturally enhances organizational knowledge transfer while advancing sustainable practices.

Conceptual Guidelines for Tactical Level Action Items

Proposed Actionable Items	Guidelines	Motivation
Learning Nexus: Hold sustainability skill-building workshops	1. **Needs assessment and goal alignment** ◦ Identify the knowledge gaps and align workshop topics with organizational sustainability objectives 2. **Workshop design** ◦ Design workshops that contain theoretical foundation and hands-on exercise ◦ Include certifications to incentivize participation 3. **Integration with organizational process** ◦ Link workshop completion to standard career development paths ◦ Mandatory trainings for certain positions 4. **Measurement and improvement** ◦ Pre and post workshop assessments to track improvements and behavior changes ◦ Adjust contents regularly to be up-to-date	The mindset of stakeholders represents both a critical barrier and a key enabler in sustainability actualization. Empirical findings demonstrate that technical transformations toward sustainability must be started with social transformations, necessitating a fundamental shift in the understanding of the importance of sustainability by stakeholders to be self-motivated to drive its integration into projects. Another significant challenge lies in the perceived lack of sustainability knowledge, which hinders effective implementation. To address these, targeted skill-building workshops can enhance competencies of practitioners, equipping them with the necessary knowledge and tools to advance the sustainability vision of the organization.
Objectives: Create role specific sustainability objectives	1. **Decompose organizational objectives** ◦ Breakdown organizational objectives according to roles and responsibilities 2. **Co-create SMART objectives** ◦ Develop specific, measurable, achievable, relevant, and time-bound objectives with each team member 3. **Integrate into performance assessments** ◦ Link sustainability objective fulfillment rate with performance 4. **Create small wins for motivation** ◦ Set objectives that can deliver measurable results in shorter timeframe	For sustainability strategies to move beyond executive-level, organizations can systematically decompose organizational objectives into role-specific targets across all operational levels. These customized objectives help employees to overcome the common challenge of abstract sustainability definitions and visions by defining precise expected outcomes within their scope of responsibilities. It also creates clear lines of accountability by proving tangible and role-specific goals.
Monitoring: Report KPIs on percentage of projects meeting sustainability criteria to the responsible board-level member	1. **Define standards and metrics** ◦ Align the metrics with the standardized sustainability metrics outlined in the established vision and objectives ◦ Define what qualifies as a sustainable project 2. **Develop KPI Roadmap** ◦ Define KPI calculation formulation ◦ Develop short term minimum compliance, targets and long term goals 3. **Integrate in projects** ◦ Assess compliance to sustainability at key milestones in projects ◦ Require the reporting of sustainability progress for organization-wide KPI calculations 4. **Monitor and report** ◦ Visualize real-time KPI progress on intranet ◦ Monthly sector reports on compliances percentages ◦ Include the KPIs in annual reports ◦ Annually review standards and metrics 5. **Incentives** ◦ Recognize high-performing teams ◦ Celebrate short term achievements ◦ Link to bonuses	The monitoring and definition of sustainability initiatives present significant challenges due to their broad, complex and multifaceted nature. However, the implementation of KPIs for sustainability reporting serves as a critical mechanism to enhance organizational awareness and accountability. Quantifiable metrics not only facilitate clearer internal communication by providing tangible outcomes for discussion but also strengthen stakeholder engagement. Furthermore, these measurable results can be leveraged to demonstrate credibility and progress to clients when proposing sustainability strategies, thereby reinforcing organizational commitment to sustainable development.
Knowledge enablement: Maintain a sustainability pipeline database	1. **Define purpose and scope** ◦ Set clear purposes and coverage of the database 2. **Design and structure** ◦ Select suitable database software and establish its interface requirements 3. **Define roles and responsibilities** ◦ Assign roles and responsibilities within the information management team and of other project teams 4. **Data collection and integration** ◦ Require project teams to submit data using a standardized template ◦ Pull data from project team archives 5. **Enable accessibility and usability** ◦ Ensure easy access by all staff ◦ Onboard staff through workshops and demonstrations ◦ Showcase successful stories in intranet 6. **Improvements** ◦ Track usage rate and user satisfaction regularly ◦ Survey users to improve features	To transition from strategic knowledge governance to operational knowledge execution, organizational knowledge enablement must be established. A tactical level initiative to develop and maintain a sustainability knowledge database facilitates effective knowledge exchange and management. This integrated database enables cross-disciplinary contributions while mitigating potential misconceptions about sustainability.

Conceptual Guidelines for Operational Level Action Items

Proposed Actionable Items	Guidelines	Motivation
Learning Nexus: Hold sustainability role-specific training	1. **Needs assessment and goal alignment** ◦ Identify the knowledge gaps and align training topics with organizational sustainability objectives 2. **Training design** ◦ Design trainings that contain theoretical foundation and hands-on exercise ◦ Include certifications to incentivize participation 3. **Integration with organizational process** ◦ Link trainings completion to standard career development paths ◦ Mandatory trainings for certain positions 4. **Measurement and improvement** ◦ Pre and post training assessments to track improvements and behavior changes ◦ Adjust contents regularly to be up-to-date	In addition to tactical level skill-building workshops, role-specific training should be provided at the operational level. Such targeted learning opportunities enable practitioners to develop the competencies required to integrate sustainability within their specific role functions. When all roles effectively understand and incorporate sustainability principles, organizational sustainability implementation becomes significantly more achievable.
Knowledge execution: Access and updates to BIM 360 interface	1. **Define roles** ◦ Define roles within project teams for data searching and data uploading 2. **Trainings** ◦ Train individuals on reading, adding and updating data in BIM ◦ Quick guides for searching, tagging and linking reports in the database 3. **Incentives** ◦ Link sustainability funding and monthly best sustainability ideas award to the usage of BIM 360 interface 4. **Feedback and improvements** ◦ Surveys within project teams to improve workflows ◦ Regular check on data usage and data uploading	To effectively execute the knowledge management framework established through strategic knowledge governance and tactical knowledge enablement, ensuring accessible and up-to-date BIM 360 interface is important. This approach not only facilitates knowledge exchange and reduces uncertainties but also prevents delayed sustainability considerations. By providing project teams with centralized access to sustainability-related knowledge and past project examples, the database enables benchmarking and early-stage sustainability planning. Furthermore, the database of past projects offers evidence-based leverage when presenting sustainable alternatives to clients or management. As outlined at the tactical level, project teams are required to contribute their data, fostering a collaborative environment that encourages knowledge exchanging.
Early client engagement: Launch sustainability design checklist	1. **Preparation** ◦ Develop project-type standardized checklists ◦ Align checklist with organizational sustainability objectives 2. **Initial client meeting** ◦ Follow the developed checklist in the meeting ◦ Assess client priorities on sustainability 3. **Integrate into design** ◦ Mandate checklist alignment with design proposals ◦ Assign accountability for implementations 4. **Review and improvements** ◦ Compare final designs against checklist ◦ Document lessons learned in the database for future projects	It has been evident that the successful implementation of sustainability initiatives is largely determined during early project phases, with earlier consideration correlating with higher success rates. Implementing a structured sustainability checklist that contains key questions to ask clients during initial project discussions enables project teams to clearly identify client sustainability ambitions and objectives. This checklist not only facilitates early sustainability focused dialogue but also includes sustainability considerations into project planning from the start. Additionally, when supported by the sustainability database, consultancy engineering firms are more capable of providing evidence-based recommendations even in preliminary project stages during initial project discussions.
Early client engagement: Present ideas to the client	1. **Preparation** ◦ Review sustainable design checklist results and sustainability database ◦ Identify sustainability alternatives aligning with client priorities 2. **Effective presentation** ◦ Use case studies from database for storytelling ◦ Show benefits based on past experience 3. **Engagement strategies** ◦ Proactive engagement with client ◦ Create a collaborative environment 4. **Follow-up and decision support** ◦ Post-meeting follow-up ◦ Suggest small-scale trials if necessary ◦ Provide detailed data for decision support	The implementation of sustainable solutions is significantly influenced by client decisions. The role of a consultancy engineering firm involves presenting viable design alternatives to facilitate informed decisions. To enable early sustainability-related decision-making, it is critical to introduce sustainable options during initial project phases. In projects where clients do not explicitly request sustainable solutions, project teams should also proactively offer unsolicited advice and recommendations. This can be achieved through early involvement of sustainability specialists and by leveraging data from the sustainability database, which together provide evidence-based recommendations even in early-stage project discussions.
Knowledge execution: Early involvement of sustainability specialists in the project team	1. **Define roles and involvement points** ◦ Define the role and involvement of sustainability specialists in projects ◦ Set mandatory phase-specific involvement and recommended involvement points 2. **Embed in standard workflows** ◦ Set up mandatory checkpoints that require sign-off by sustainability specialists at certain project phases 3. **Incentives** ◦ Tie team performance to sustainability outcomes ◦ Recognize teams that collaborate closely with sustainability specialists	The integration of sustainability specialists within project teams at early stages is essential to provide tailored and in-depth recommendations to support decision-making processes. This proactive inclusion enables specialists to contribute technical guidance and knowledge supplement during the early project phase, thereby enhancing key enablers related to knowledge, early advice, and early sustainability decisions. Furthermore, the consistent participation of sustainability specialists fosters a sustainability focus within project teams, influencing decision making and collective perspectives.

Monitoring: **Real-time data checks**	1. **Align KPIs** ◦ Align the KPIs with project goals and organizational objectives 2. **Deploy data collection tools** ◦ Utilize the database platform for project team members to upload data daily on sustainability progress ◦ Mandate digital reporting on all sustainability progress 3. **Centralize data** ◦ Centralize all collected data to visualize progress and targets in a shared dashboard 4. **Automate alerts and actions** ◦ Enable rule-based triggers when sustainability progress is not meeting the targets ◦ Action items and insights driven by AI can be automatically suggested 5. **Accountability** ◦ Define clear responsibilities for alerts and progress ◦ Regular inspections by the Sustainability Director	Given the long-span and complexity of infrastructure projects, implementing real-time sustainability data monitoring is critical to track and demonstrate progress effectively. Such data provides tangible evidence to clients, showcasing both the current status and benefits of sustainability. This systematic approach to data collection and reporting enhances transparency, enabling more productive discussions among project teams and with clients by replacing vague sustainability claims with measurable, evidence-based concrete data.
Monitoring: **External challenger**	1. **Establishing criteria for external challenger engagement** ◦ Define the specific conditions and project context that requires the involvement of an external challenger ◦ Projects that meet the predetermined criteria are mandate to include external challenger in the contractual agreements 2. **Define the role of the external challenger** ◦ Define the purpose of having the external challenger and the scope of monitoring 3. **Integrate into projects** ◦ Require the external challenger to sign-off at key project phases ◦ Allow access rights of the external challenger to the sustainability progress dashboard 4. **Structured challenge process** ◦ Design a standard challenge process that project teams can follow ◦ Monitor the process by the Sustainability Director 5. **Measure effectiveness** ◦ Use organizational KPIs to measure the effectiveness ◦ Monitor the percentage of challenges adopted	It is acknowledged that altering mindsets and work practices presents challenges. Incorporating an external challenger has proven to be an effective approach for actualizing sustainability opportunities. This independent third-party entity monitors project team performance and provides advisory to both clients and engineering consultancies. The presence of such external oversight significantly enhances motivation to implement sustainable practices, thereby increasing the likelihood of successful sustainability actualization.

APPENDIX D- VALIDATION FOCUS GROUP PROTOCOL

Subject:	Focus Groups Protocol
Project:	Actualizing Sustainability Opportunities: Enhancing Management of Sustainability Opportunities during Front-End Development in Infrastructure Projects
Author:	Wilfred Wong, TU Delft

1. Introduction

[Establishing context and ground rules.]

- **Greetings and introduction**: Self introduction and explain the purpose of the focus group.
- **Explain ground rules**: Respect all opinions and no wrong answers.
- **Confidentiality**: Grant consent to audio record the focus group session and explain how the recording is managed.

(estimated 5 minutes)

2. Warm-up

[Initiating participant engagement by trigger questions.]
Each participant gets 1 minute to give a short answer for each question.

- **Trigger question 1**: Can you introduce yourself, your role in the company, and number of years of experience you have in the construction industry?
- **Triger question 2a**: Imagine a future where sustainability is fully integrated into infrastructure projects. What would the difference be compared to now for Witteveen+Bos? (strategic)
- **Trigger question 2b**: When I say 'sustainability in infrastructure projects', what is the first thing that comes to mind? (operational)

(estimated 5 minutes)

3. Core Validation

[Evaluation of the framework.]

- **Framework overview**: Show the visual of the framework with short explanations (5 minutes)

- **Guided Discussion**: (35 minutes)
  (Role of researcher: Facilitator)

  Focus Group 1 (Strategic Level):
  For each action item:
  - Relevance: Is it relevant/helpful to improve sustainability realization in projects?
  - Feasibility: How feasible is this action item? What steps can be taken?

  Focused Group 2 (Tactical and Operational Level):
  For each action item:
  - Relevance: Is it relevant /helpful to improve sustainability realization in projects?
  - Feasibility: How feasible is this action item? What steps can be taken?

(estimated 40 minutes)

4. Closing

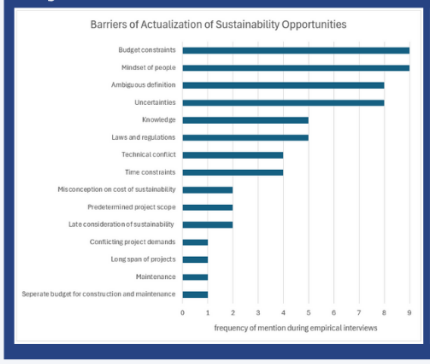
- Completeness: What is missing?
- Completeness: How can we set-up projects to facilitate sustainability implementations? (Operational)
- Completeness: What can be done on a strategic level to manage and advise on sustainability more effectively? (Strategic)
- Validation check: Overall, how confident are you that this framework would work in practice to improve sustainability actualization?
- Follow-up: A transcript of the session will be sent to each participant to validate.

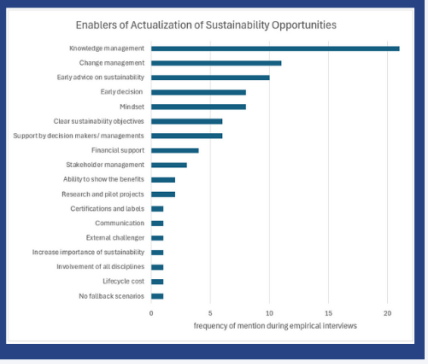
(estimated 5 minutes)

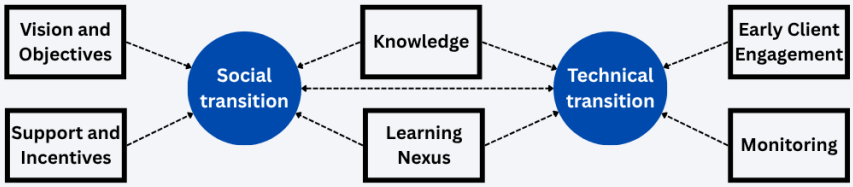
APPENDIX E- POSTER

Actualizing Sustainability Opportunities

Key Barriers and Enablers







6 Pillars for Social and Technical Transition

SHIFT

Sustainability Human-Centered Implementation Framework for Transition

Management of sustainability opportunities phases	PLANNING	OPPORTUNITY DEVELOPMENT	DECISION	ACTUALIZATION
OPERATIONAL LEVEL	Learning Nexus: Hold sustainability role-specific training			
	Knowledge execution: Access sustainability knowledge database and sustainability chatbot			
	Knowledge execution: Early involvement of sustainability specialists in the project team			
	Knowledge execution: Early sustainability opportunity and LCA quick scan			
	Early client engagement: Launch sustainability inspiration list		Early client engagement: Present ideas to the client	
		Monitoring: Track sustainability KPIs relative to predefined project-specific baselines		
		Monitoring: External challenger		
TACTICAL LEVEL	Learning Nexus: Hold sustainability skill-building workshops			
	Objectives: Create shared sustainability objectives for project teams			
	Monitoring: Define sustainability baselines and KPIs with clients for projects			
		Knowledge enablement: Assign sustainability knowledge stewards to maintain the sustainability pipeline database		
STRATEGIC LEVEL	Vision: Define and align organizational sustainability vision with project selection criteria			
	Monitoring: Mandate project directors to evaluate and challenge project teams on sustainability execution			
	Learning Nexus: Hold sustainability entrepreneurship workshops			
		Knowledge governance: Launch organization-wide sustainability knowledge AI chatbot		
		Financial Autonomy: Empower project leaders with budgetary autonomy to capitalize on sustainability opportunities		
		Incentives: Launch quarterly sector best sustainability idea award		

FED project timeline	PROJECT DEFINITON	FEASIBILITY	DESIGN
0% FED	TENDER		100% FED